NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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March 14, 2016

Genesee Valley Real Estate Co., LLC
Mr. Dante Gullace, Member
First Federal Plaza
28 East Main St., Suite 500
Rochester, NY 14614

Dear Mr. Gullace:

Subject: 690 St. Paul Street, Site #C828159
Remedial Design Work Plan: AOC #6 LNAPL;
September 2015
City of Rochester, Monroe County

The New York State Departments of Environmental Conservation and Health, collectively referred to as the Departments, have completed their review of the document entitled *Remedial Design Work Plan AOC #6 LNAPL* (the Work Plan) dated September 2015 and the associated well boring and development logs submitted on January 27, 2016 for the 690 Saint Paul Street site located in the City of Rochester. In accordance with 6 NYCRR Part 375-1.6, the Departments have determined that the Work Plan, with modifications, substantially addresses the requirements of the Brownfield Cleanup Agreement. The modifications are outlined as follows:

1. **Section 5.1:** The third paragraph is modified to indicate that LNAPL will be removed from all wells where it is present.

2. **Section 6.0:** Monitoring and LNAPL recovery method number 2 will be followed even if just a sheen is present.

3. **Section 8.0:** Results of monitoring events will also be included in the Final Engineering Report.

With the understanding that the above noted modifications are agreed to, the Work Plan is hereby approved. If you choose not to accept these modifications, you are required to notify this office within 20 days after receipt of this letter or prior to the start of field activities. In this event, I suggest a meeting be scheduled to discuss your concerns prior to the end of this 20-day period.

Prior to the start of field activities, please attach a copy of this letter to the Work Plan and distribute the approved Work Plan as follows:

- Frank Sowers (2 hardcopies, 1 with an original signature on the certification page);
- Bridget Boyd (electronic copy on CD);
- John Frazer (electronic copy on CD);
- Wade Silkworth (electronic copy on CD);
- Document repositories (1 hardcopy for each of the document repositories established for this site); and
- Copies to other interested parties upon request.

Per the approved schedule in the Work Plan, field activities are scheduled to begin by April 8, 2016. Please notify me at least 7 days in advance of the start of field activities.

We look forward to working together to bring this site back into productive use. If you have questions or concerns on this matter, please contact me at 585-226-5357.

Sincerely,

Frank Sowers

Frank Sowers, P.E.
Environmental Engineer 2

ec:
Dan Noll
Jennifer Gillen
Bridget Boyd
Justin Deming
John Frazer
Suzanne Wheatcraft
Greg Senecal
Bernette Schilling
James Mahoney
Mike Cruden

Remedial Design Work Plan
AOC #6 LNAPL
Site C828159

Location:

690 Saint Paul Street
Rochester, New York

Prepared for:

Genesee Valley Real Estate Company, LLC
First Federal Plaza
28 East Main Street, Suite 500
Rochester, New York 14614

LaBella Project No. 209280

September 2015

Remedial Design Work Plan
AOC #6 LNAPL
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Location:

690 Saint Paul Street
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28 East Main Street, Suite 500
Rochester, New York 14614

LaBella Project No. 209280

September 2015

LaBella Associates, D.P.C.
300 State Street
Rochester, New York 14614

CERTIFICATIONS

"I DANIEL NOLL *certify that I am currently a NYS registered professional engineer and that this Design Phase Investigation Plan was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10)."*

DANIEL P. NOLL
No. 081996

081996	9/16/15	
NYS Professional Engineer #	Date	Signature

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1.0 Introduction

This Remedial Design Work Plan (RDWP) is for implementation of the selected Remedial Action for AOC #6C (Light Non-Aqueous Phase Liquid (LNAPL) Area) for the property located at 690 Saint Paul Street, Rochester, Monroe County, New York, hereinafter referred to as “the Site”. The Site was entered into the New York State Department of Environmental Conservation (NYSDEC) Brownfield Cleanup Program (BCP) as Site #C828159 in 2009. A Project Locus Map is included as Figure 1.

The proposed remedial actions were identified and evaluated in the Remedial Alternatives Analysis Report (RAAR) based on the data obtained during pre-BCP activities, the Remedial Investigation (RI), and the Interim Remedial Measures (IRMs). The RAAR indicated the final remedy would be based on the results of a Design-Phase Investigation (DPI) conducted at the Site. This RDWP summarizes the findings of the previous work for the Site; however, these previous reports should be referenced for greater details on those investigation activities. A comprehensive list of the previous studies utilized in the development of this RDWP is included in the Remedial Investigation Report (RIR). The findings of the DPI conducted in February and March 2015 are summarized in this Work Plan.

2.0 Site Description & Background

The Site consists of approximately 4.73 acres of land improved with three inter-connected buildings and a fourth separate building. In total, these buildings occupy approximately 89,280 square feet of the Site (footprint area). Building 14B is currently utilized as a Charter School and by the City of Rochester School District. Building 16 is currently partially occupied by a light industrial tenant (assembly of parts), a janitorial service for storage, and the remainder is vacant. Building 14A is partially occupied by a machine shop and the remainder is vacant and Building 22 is utilized by Geva Theatre for storage and scene construction.

The Site was developed prior to 1875 and was utilized primarily for residential purposes prior to approximately the 1920s. Based on the review of historical mapping and local street directories, the Site was primarily utilized for industrial purposes by Bausch & Lomb, Inc., formerly known as Bausch & Lomb Optical Company (“B&L”) from sometime around 1920 until it was abandoned by the company in the late 1960s. The property was developed for industrial use by “B&L” to manufacture lenses and other products. From the early 1970s until 2000, the Site was used predominantly for light commercial and storage applications. Occupants and/or owners of the Site have included various individual residences, B&L, Thomas Edison Technical and Industrial High School, Geva Theater storage, and various manufacturing and industrial tenants.

In the early 1900s, B&L purchased various properties that now comprise the Project Site. In 1973, B&L conveyed the Project Site to the New York State Urban Development Corporation (“UDC”), subject to a Memorandum of Agreement and Lease extending B&L’s occupancy of certain portions of the Site. In 1982, Dante Gullace and Ralph Gullace purchased the Project Site from UDC and continued to own the Site, first as tenants-in-common and then solely by Dante Gullace until December 31, 1997, wherein all of Dante Gullace’s interests in the Site were conveyed to GVRE.

Figure 2 illustrates the Site features and boundaries.

In July 2009, the Site was entered into the NYSDEC BCP (BCP Site #C828159). Subsequent to entering the Site in the BCP, a RI and three IRMs have been completed at the Site. The RIR was submitted in January 2014 and the RAAR was submitted in May 2014.

2.1 Physical Characteristics of Site

The Site is situated in a mixed commercial, light industrial and residential area of the City of Rochester. The Site is bordered by St. Paul Street to the west with a Monroe County office building beyond, Lowell St. to the south with a City of Rochester park beyond, Martin Street to the east with a restaurant and residential properties beyond, and Hartel Alley to the north with a vacant restaurant and a light industrial (machine shop) building beyond.

2.2.1 Geology

The overburden material at the Site ranges in depth from less than two feet on the southern portion of the Site to twelve feet on the northern portion of the Site and consists of a combination of fill and native material. The fill material is up to eight feet thick and includes sand, crushed gravel and brick, construction and demolition debris, foundry sand, cinders, and ash. The native material underlies the fill material in some areas while in other areas the fill material appears to be absent. The thickness of native material ranges up to ten feet, and the material is primarily a glacial till. The till contains silt, sand, and gravel in varying amounts.

The Decew Dolomite underlies the overburden at the Site. The Decew Dolomite is the uppermost formation of the Clinton Group and consists of variably bedded, dark-gray to olive-gray, argillaceous to sandy, fine-grained dolomite that contains shaly partings and interbeds, as well as frequent pits and vugs. The thickness of this unit is generally 8 to 12 feet.

The Rochester Shale underlies the Decew Dolomite, and is a relatively uniform dark- to medium-gray, pale- and platy-weathering, highly calcareous to dolomitic mudstone. It contains abundant thin interbeds of medium gray, pale-buff weathering, laminated calcisiltites. Although the bottom of this unit was not encountered at the Site, its thickness in Western New York is generally 58 to 65 feet.

2.2.2 Hydrogeology

Apparent groundwater was generally encountered at the Site in the overburden at depths ranging from approximately four to nine feet below the ground surface. The groundwater in this interval generally flows to the west-southwest.

Underlying the overburden water-bearing zone, the shallow bedrock water-bearing interval was identified as the uppermost bedrock down to depths of approximately 20 feet below grade. This interval is the uppermost water-bearing unit within the bedrock, and no low permeability horizon separates this zone from the overburden. Groundwater flow direction is generally to the west, and water elevations in the overburden and bedrock wells suggest a downward flow direction.

3.0 Summary of Site Contamination

The RI was designed to investigate known Areas of Concern (AOCs) and this investigation also revealed additional AOCs. These AOCs are discussed in detail in the RIR. The BCP RI fieldwork conducted at the Site ultimately included advancing approximately 125 soil borings, excavating six test pits and installing 15 overburden groundwater monitoring wells (including three that were destroyed during IRM activities and four recovery wells) and 13 bedrock wells (including four bedrock-overburden interface wells) at the Site. Groundwater sampling was conducted in several rounds. The overall RI sampling program consisted of:

Sampled Media	Sample Quantities
Surface Soils	11
Test Pit Soils	7
Test Boring Soils	107
Geoprobe Groundwater	60
Monitoring Well Groundwater	47
Soil Gas	6
Standing Water	4

All samples were submitted for analysis of a combination of the following parameters:

- Volatile organic compounds (VOCs)
- Semivolatile organic compounds (SVOCs)
- Polychlorinated biphenyls (PCBs)
- Pesticides
- Metals

Contaminants of concern (COCs) at the Site were found to be primarily petroleum- and solvent-related VOCs. AOC #6C incorporates three areas of elevated concentrations of petroleum-related VOCs as summarized below. It should be noted that this RDWP specifically addresses the third area discussed below (i.e., the LNAPL Area).

SB-76 Area (2012 IRM)

During the IRM completed within AOC #6C in July and August 2012, petroleum impacted soils were excavated and disposed of off-site. Confirmation sampling data indicated that residual petroleum impacts are present along the northwestern sidewall of the IRM excavation due to the presence of a sewer line. These residual impacts appear to be related to the bedding of the underground utility encountered in the excavation. The size and purpose of this sewer line precluded its alteration or removal.

It should be noted that the confirmation sample collected from the northwestern sidewall identified all petroleum-related VOCs to be present at levels below Site RPSCOs with the exception of the compound m,p-xylene, which was detected above the Unrestricted Use and Protection of Groundwater SCOs, but below the Restricted Residential SCO. In addition, a confirmation sample was collected from the eastern sidewall of AOC #6D (located just to the northwest of AOC #6C, on the northwestern side of the sewer line), in which targeted compounds were not detected above Site RPSCOs.

The area of residual impacts above Unrestricted Use SCOs for the “SB-76” Area is estimated to be 100 square feet, as shown on Figure 3. During the backfill of the AOC #6C and AOC #6D excavations, calcium oxy-hydroxide in the form of pellets of Oxygen Release Compound

Advanced (ORC-A) manufactured by Regenesis® was added to the backfill of the bottom one to two feet of the excavation, within the saturated zone. Post-IRM groundwater sampling of MW-11 identified a lack of petroleum constituents in groundwater at concentrations above Part 703 Groundwater Standards in the vicinity of the pre-IRM SB-76 groundwater sample.

Soil Impacts Left In-Place beneath Electric Utility (2008 IRM)

An IRM in 2008 included the excavation and off-site disposal of petroleum contaminated soil, although impacted soil in the vicinity of a buried electric utility was left in place so as to leave the utility undisturbed. Confirmation samples CS-3, CS-5-R2 and CS-Elec contained VOCs at concentrations above Unrestricted Use and Protection of Groundwater SCOs. These VOCs included m,p-xylene in all three samples and ethylbenzene, toluene and o-xylene in sample CS-Elec. The area of remaining impacts is shown on Figure 3.

Non-Aqueous Phase Liquid Area

As indicated in the RI, Light Non-Aqueous Phase Liquid (LNAPL) has been periodically observed in overburden wells RW-West, RW-East and bedrock well BW-1. These wells and two additional wells (REC-B-East and REC-B-West) have been used for LNAPL monitoring and extraction events in the northern portion of AOC #6C since 2011. LNAPL has been observed periodically/sporadically since the installation of these wells.

Wells RW-West and RW-East were installed during the backfill of the 2008 IRM excavation. These wells were installed to the west and east of the buried electric utility line, respectively. These wells were installed for the purpose of LNAPL recovery and rather than a traditional slotted well screen, these wells were constructed by connecting a solid 4-in. PVC riser to a 2-feet (ft.) diameter perforated pipe, 2-ft. in length. The perforated pipe is seated on top of rock, effectively “screening” the 2-ft. of overburden soil directly above bedrock. Bedrock has been identified in this area at approximately 8.5-ft. to 9.5-ft. below ground surface (bgs). Monitoring well construction logs are included in Appendix 5. This design was intended to allow residual LNAPL to enter the wells for subsequent extraction. An initial extraction event was completed in January 2011 following the identification of 1.01-ft. and 1.22-ft. of LNAPL in RW-East and RW-West, respectively. Subsequent to this extraction event LNAPL has been sporadically identified ranging from non-measurable to up to 0.04-ft.

Subsequent to the installation of RW-West and RW-East and the acceptance of the Site into the BCP, the water table in the vicinity of these wells was found to fluctuate between 4.5-ft. and 5.5-ft. bgs. Based on the potential that LNAPL could be floating on the top of the water table above the “screened” sections of RW-West and RW-East, overburden wells REC-B-West and REC-B-East were installed immediately proximate to RW-West and RW-East, respectively in September, 2008. As depicted on the well construction logs in Appendix 5, these wells were screened between approximately 10.58-ft. and 12.58-ft. bgs., and were designed to capture the top of the fluctuating water table in this area of the Site.

BW-1 was installed in 2008 as a bedrock overburden interface well. As depicted in the well construction log in Appendix 5, well BW-1 is screened between 9.8-ft. and 17.3-ft. bgs. Bedrock was encountered in this location at approximately 8.0-ft. bgs. Immediately prior to the initial January 2011 extraction event, approximately 0.35-ft. of LNAPL was observed in this well.

Subsequent to the January 2011 extraction event, LNAPL has been sporadically measured in BW-1; however, the maximum thickness of LNAPL measured in BW-1 since January 2011 is 0.02-ft.

Analysis of a sample of LNAPL from the original recovery wells (RW-East and RW-West) identified 1,2,4-trimethylbenzene, four SVOCs, several metals (including arsenic, barium, chromium and lead), several pesticides (including 4,4'-DDE, 4,4'-DDD and 4,4'-DDT) and total PCBs at levels above NYCRR Part 703 Groundwater Standards. Analysis of a LNAPL sample from BW-1 identified aluminum, iron and sodium above NYCRR Part 703 Groundwater Standards.

Several extraction events have been completed via vacuuming or the use of absorbent socks to address LNAPL observed in monitoring wells at the Site. The table below summarizes groundwater/LNAPL extraction events completed at the Site.

Date	Targeted Wells	Description of Product Observed	Waste Generated
January 19, 2011	BW-1, RW-West and RW-East	RW-East : ~1.01' LNAPL RW-West: ~1.22' LNAPL BW-1: ~0.35' LNAPL	RW-East : ~55 gal. water/oil RW-West: ~55 gal. water/oil BW-1: ~55 gal. water/oil
February 2012	BW-05* and BW-10	Trace (<1 mm) of LNAPL in both wells	BW-05*: 5 absorbent socks BW-10: 1 absorbent sock
February 22, 2012	REC-B-East; REC-B-West; and BW-1	Less than 1cm of LNAPL in all three (3) wells	REC-B-East: ~45 gal. water REC-B-West: ~70 gal. water BW-1: ~90 gal. water/oil
April 23, 2013 to May 13, 2013	RW-East	Trace (<1 mm) of LNAPL	2 absorbent socks
July 31, 2013	BW-1 and RW-West	BW-1: ~0.08" LNAPL RW-West: Trace LNAPL	RW-West: ~80 gal. water/oil BW-1: ~60 gal. water/oil
October 10, 2013	RW-West & BW-05*	RW-West: Trace LNAPL BW-05*: ~0.8' LNAPL	RW-West: ~82 gal. water/oil BW-05*: ~45 gal. water/oil
December 2, 2013	RW-West, RW-East & BW-05*	RW-West: ~1" LNAPL RW-East: Trace LNAPL BW-05*: ~0.08" LNAPL	RW-West: ~45 gal. water/oil RW-East: ~50 gal. water/oil BW-05*: ~45 gal. water/oil

*BW-05 is located in AOC #1. Impacts identified in this well are being addressed under a separate RDWP.

It should be noted that for all extraction events the waste generated was primarily groundwater with less than 0.1% LNAPL (estimated). The approximate volume of LNAPL removed from AOC #6C since January 2011 is 0.6 gallons.

Design Phase Investigation:

A Design Phase Investigation was conducted in February and March 2015 for the northern portion of AOC #6C to further evaluate the presence of LNAPL. Three bedrock-overburden interface wells (designated BW-14, BW-15, and BW-16) were installed proximate RW-East, RW-West, and BW-1, respectively. Field activities were conducted in accordance with the *Remedial Action Work Plan Design Phase Investigation: AOC #6 NAPL* completed by LaBella and dated September 2014.

Wells were constructed of 8 to 10-ft. lengths of 0.020-slot, 4-inch diameter Schedule 40 PVC installed approximately 3-ft. to 4-ft. into bedrock. Wells in the BW-01 area (i.e., BW-01 and BW-16) are screened between 3-ft. and 17.3-ft. bgs. Wells in the RW-East area (i.e., RW-East, REC-B-East and BW-14) are screened between 1.5-ft. and 13-ft. bgs. Wells in the RW-West area (i.e., RW-West, REC-B-West and BW-15) are screened between 1.5-ft. and 13-ft. bgs. Based on the cumulative screen intervals in each area, NAPL (if present) could be observed anywhere between the indicated intervals, thus effectively accounting for water table fluctuations between these intervals.

The annulus around the screen section was sand packed with quartz sand to approximately 1-foot above the screen section. The remaining annulus was bentonite sealed to approximately 1-ft. bgs, and then grouted to the ground surface. Each well was completed with a flush mount well cover. Well construction logs are included in Appendix 5.

The three newly installed wells in addition to existing wells RW-East, RW-West, REC-B-East, REC-B-West, and BW-1 were monitored weekly for four (4) weeks for the presence of LNAPL. LNAPL was not observed in BW-14, BW-15, or BW-16 on any occasion. LNAPL was identified in BW-1, RW-East and RW-West on at least one occasion. The greatest thickness of LNAPL measured at that time was 0.04-ft in RW-West. The following table below summarizes the Design Phase Investigation monitoring results. Measurements are listed in feet bgs.

DATE:	**3/5/2015**		**3/11/2015**		**3/17/2015**		**3/27/2015**	
WELL ID	DTW	DTP	DTW	DTP	DTW	DTP	DTW	DTP
BW-1	Ice	Ice	7.28	7.27	5.25	5.24	5.08	5.06
RW-East	Ice	Ice	6.35	Trace	3.64	NA	3.73	NA
RW-West	6.81	6.79	6.52	6.48	5.08	5.06	4.67	4.66
REC-B-East	Ice	Ice	6.50	NA	3.76	NA	3.85	NA
REC-B-West	Ice	Ice	6.58	NA	5.18	NA	4.74	NA
BW-14	7.00	NA	6.70	NA	5.34	NA	4.93	NA
BW-15	6.70	NA	6.50	NA	3.75	NA	3.83	NA
BW-16	7.74	NA	7.28	NA	5.16	NA	4.90	NA

"DTW" = Depth to water (feet below ground surface)
"DTP" = Depth to product (feet below ground surface)
"Ice" = Well could not be located or accessed due to significant ice over the area surrounding the well.
"NA"= Not Applicable
"Trace" = Trace of LNAPL observed on probe/bailer, not a measureable amount.

The Design Phase Investigation Work Plan required a bail down test for assessing recoverable NAPL in the event 2-inches or more of NAPL were observed. Based on the lack of NAPL in the new wells and no wells with more than 0.48-in. (i.e., 0.04-ft.) observed, a bail down test was not completed.

Based on 1) confirmatory/documentation sampling completed as part of the AOC #6C and #6D IRM work; 2) the 2008 IRM work associated with Spill #0890771; 3) LNAPL monitoring and extraction work between 2011 and 2013; and, 4) the lack of recoverable NAPL observed during the DPI, the nature and extent of impacts in AOC #6C appear to have been adequately defined. Specifically, the following remaining contamination appears present associated with AOC #6C:

Soil:

- A total of approximately 250-square feet of VOC-impacted soil above Unrestricted Use SCOs appears present beneath the electrical utility line in AOC #6C between four and nine feet below grade, as shown in Figure 3. An additional approximately 100-square foot area of VOC-impacted soil above Unrestricted Use SCOs appears present beneath a sanitary sewer line in AOC #6C between seven and ten feet below grade in the vicinity of MW-11.
- No soil has been documented in AOC #6C (which was not removed as part of the 2008 IRM and/or is not associated with AOC #6D) which contains COCs above Restricted Residential SCOs.

Groundwater:

- Groundwater impacts (viz., VOCs present at concentrations above Part 703 Groundwater Standards) appear present in AOC #6C in the vicinity of REC-B-West.
- In addition to REC-B-West, MW-11 previously detected VOCs at concentrations above the Part 703 Groundwater Standards; however, the latest groundwater data from MW-11 indicates petroleum impacts in groundwater are no longer present in the western portion of AOC #6C.

Soil Vapor:

- Soil vapor is not a concern as it has been previously addressed through an active sub-slab depressurization system (SSDS) in Building 14B.

LNAPL:

- Limited volumes of LNAPL have been sporadically measured in wells in the northern portion of AOC #6C. Specifically, LNAPL has been previously identified in AOC #6C wells BW-1, RW-West and RW-East. The interpreted extent of LNAPL is depicted on Figure 3. Seven extraction events were completed between January 2011 and December 2013; however, a total of only approximately 0.6-gallons of LNAPL was able to be recovered during these extraction events.
- The lack of LNAPL observed in BW-14, BW-15, BW-16 REC-B-West and REC-B-East, and the continued sporadic presence of limited volumes of LNAPL in BW-1, RW-West and RW-East appears to be the result of the highly isolated location of LNAPL surrounding these wells and/or potentially the result of limited volumes of LNAPL trapped in the 2-ft. diameter perforated section of each of the original recovery wells.
- Recoverable amounts of NAPL were not identified during the Design Phase Investigation.

4.0 Standards, Criteria and Guidance Values

This section identifies the Standards, Criteria and Guidelines (SCGs) for the Site. The SCGs identified are used in order to quantify the extent of contamination at the Site that require remedial work based on the cleanup goal. The SCGs for soil and groundwater are provided below.

Soil SCGs

The SCGs for soil used in this RDWP are:

- NYCRR Subpart 375-6 Remedial Program Soil Cleanup Objectives (RPSCOs) for Unrestricted Use
- NYCRR Subpart 375-6 RPSCOs for the Protection of Groundwater
- NYCRR Subpart 375-6 RPSCOs for the Protection of Public Health – Restricted Residential Use
- NYSDEC Commissioner Policy-51 (CP-51) Supplemental Soil Cleanup Objectives (SSCOs) for Restricted Residential Use, Protection of Groundwater and/or Protection of Ecological Resources. The lower of these three SSCOs was used for comparison purposes of compounds for which Part 375 SCOs do not exist.

Groundwater SCGs

The SCGs for groundwater used in this RDWP are:

- NYSDEC Part 703 Groundwater Standards
- Technical and Operational Guidance Series (TOGS) 1.1.1 Groundwater Standards and Guidance Values

Soil Vapor SCGs

The SCGs for groundwater used in this RDWP are:

Soil Gas SCGs: Currently, no state regulatory (NYSDEC or NYSDOH) guidance values exist for soil gas.

Sub-Slab Soil Vapor and Indoor Air SCGs: The NYSDOH *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* dated October 2006 (including the USEPA Building Assessment and Survey Evaluation (BASE) Database (90th Percentile), in Appendix C) is utilized for the SCG for soil vapor and indoor air.

The SCGs selected are presented in tables included in Appendix 1 for each of the contaminants of concern identified for the Site above these SCGs.

5.0 Proposed Remedy

Based on the findings of the RI and Design Phase Investigation, it has been determined that there is not a significant volume of recoverable product present in AOC #6. A soil removal in the area of AOC #6 in 2008 did not remove soil immediately surrounding utility lines which may be the source of small volumes of LNAPL detected in nearby monitoring wells. No soil has been documented in AOC #6C (which was not removed as part of the 2008 IRM and/or is not associated with AOC #6D) which contains COCs above Restricted Residential SCOs. As such, the proposed remedy for AOC #6 is to monitor select wells periodically for the presence of LNAPL and remove any LNAPL present.

5.1 Summary of Remedial Goals

The goal of the RDWP is to remove product from monitoring wells in AOC #6, if encountered. Although previous assessments identified traces of LNAPL in overburden wells (i.e., RW-East and RW-West) and in bedrock (i.e., BW-1), extraction events have removed limited volumes of LNAPL (i.e., a total of approximately 0.6-gallons during extraction events between January 2011 and December 2013). During the Design Phase Investigation, a measurable amount of LNAPL was identified in only two (2) of the eight (8) wells in the area of AOC 6; BW-1 and RW-West. In addition, a trace amount of LNAPL was identified in RW-East on one (1) occasion. The greatest thickness of LNAPL encountered during the DPI was approximately 0.04-feet (approximately ½ inch), in RW-West. However, LNAPL has not been identified in bedrock overburden interface wells installed during the Design Phase Investigation (i.e., BW-14, BW-15, and BW-16) or in overburden wells REC-B-West and REC-B-East since their installation in February, 2015.

It should be noted that, as documented in *USEPA 510-R-96-001 Methods for Evaluating Recoverability of Free Product* (September 1996), “It has been established that the thickness of free product measured in wells usually exceeds the thickness that is present in the surrounding soil. Volume estimates based strictly on measured thickness in wells are erroneous and are often significantly greater than the volume of product that was released.” Pertinent excerpts from the USEPA document are included in Appendix 4 of this work plan.

Based on the USEPA document and the results of the RI and Design Phase Investigation, it is proposed that LNAPL will be removed from monitoring wells in which LNAPL was identified during the Design Phase Investigation and in the three (3) newly installed interface wells if and as it is encountered to achieve the remedial goals. Based on the low volumes of LNAPL historically encountered in AOC #6, the LNAPL will be removed using absorbent socks, as needed.

6.0 Design Scope

Monitoring wells in AOC #6 have been monitored for LNAPL on numerous occasions since 2011. LNAPL has been detected in three (3) of the wells (BW-1, RW-East, and RW-West) during that time. The following wells are proposed for monitoring at a frequency of semi-annually subsequent to approval of this RDWP and/or in accordance with the final SMP:

- BW-1
- RW-East
- RW-West
- REC-B-East
- REC-B-West
- BW-14
- BW-15
- BW-16

Monitoring events will be conducted for a minimum of two (2) years, and terminate following approval from the NYSDEC. Proposed monitoring and LNAPL recovery methods are as follows:

1. The thickness of LNAPL will be evaluated using a bailer as attempts to estimate LNAPL thickness using an oil/water interface probe can sometimes be hampered or misrepresented due to LNAPL coating/fouling the probe sensor. As such, a designated bailer will be lowered into each well and allowed to fill and then removed. The thickness of LNAPL in the bailer will be measured and recorded.
2. If a measurable amount of LNAPL is present in the bailer (i.e., more than a sheen), an absorbent monitoring well sock (*PIG® Monitoring Well Skimming Sock*, or similar) will be lowered into the well and placed so the oil-water interface is near the middle of the sock to account for fluctuations in the water table. Each *PIG® Monitoring Well Skimming Sock* is 1.5-inches in diameter, 18-inches in length and is capable of absorbing 0.13 gallons of product (equivalent to approximately 2.5-inches of product in a 4-inch diameter well). Note that the maximum recorded NAPL thickness during the Design Phase Investigation was 0.04-inches. Refer to Appendix 6 for technical specifications of an absorbent sock.
3. The absorbent sock(s) will be removed one (1) month prior to the next scheduled monitoring event and visual observations will be recorded. If measureable LNAPL is still present in the well, a new absorbent sock will be placed in the well. Impacted absorbent socks will be placed in plastic garbage bags (or similar) and placed in a secure, clearly labeled, 55-gallon drum in the northern (unoccupied portion) of Building 22. This drum will be properly disposed of off-site and replaced with a new drum on an as-needed basis.
4. LNAPL monitoring will continue for all wells identified above during each subsequent monitoring event. If measurable LNAPL is identified, step 2 will be repeated. Subsequent to four consecutive monitoring events without the identification of LNAPL, the NYSDEC will be petitioned to eliminate monitoring and decommission the wells. However, modifications will not be made to the monitoring plan prior to approval from the NYSDEC and NYSDOH.

The above steps will be repeated as long as LNAPL is measured in a well. If LNAPL is not identified in a well during a given monitoring event, no action will be completed regarding that given well until the subsequent monitoring event.

8.0 Schedule and Reporting (Deliverables)

Schedule

The Remedial Design field activities are anticipated to be implemented within 3 weeks of approval of this Work Plan.

Reporting

Results of monitoring events will be included in Monthly Progress Reports, as required by the BCP, until the Site receives a Certificate of Completion. Subsequent to the Certificate of Completion being issued, the monitoring events will be provided as required in the SMP.

9.0 Health and Safety and Community Air Monitoring

LaBella's Health and Safety Plan (HASP) for this project is included as Appendix 2.

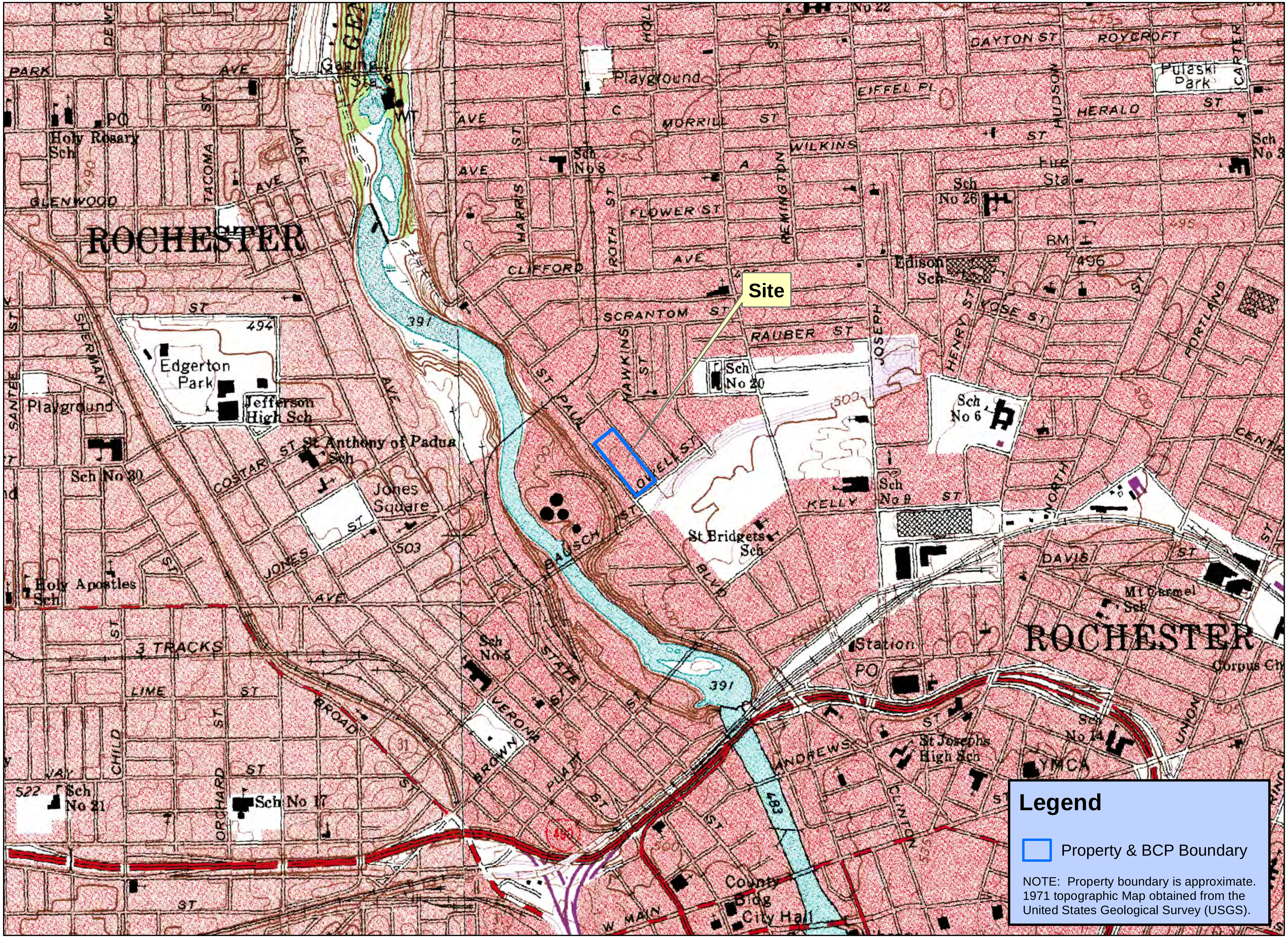
The NYSDOH Generic Community Air Monitoring Plan (CAMP) and Fugitive Dust and Particulate Monitoring is included as Appendix 3.

I:\GENESEE VALLEY REAL ESTATE CO\209280\REPORTS\RDWP AOC #6\2015.09.10 RDWP AOC #6.DOCX

LaBella Associates, D.P.C.

300 State Street
Rochester, New York 14614

Figures



Legend

Property & BCP Boundary

NOTE: Property boundary is approximate. 1971 topographic Map obtained from the United States Geological Survey (USGS).

Path: I:\Genesee Valley Real Estate Co\209280\Drawings\RDWP- AOC #6 NAPL\Figure 1 USGS.mxd

LABELLA
Associates, D.P.C.
300 STATE STREET
ROCHESTER, NY 14614
P: (585) 454-6110
F: (585)454-3066
www.labellapc.com
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PROJECT LOCUS MAP

REMEDIAL DESIGN
WORK PLAN:
AOC #6C - NAPL AREA

BROWNFIELD CLEANUP
PROGRAM

690 SAINT PAUL STREET
ROCHESTER, NEW YORK

VOLUNTEER:
GENESEE VALLEY
REAL ESTATE COMPANY

250 0 1,000

1 inch = 1,000 feet

Intended to print as 11" x 17".

209280

FIGURE 1

Legend

▨ PROPERTY & BCP BOUNDARY

NOTE: Property boundary is approximate.
2012 Aerial photograph obtained from GIS Clearinghouse.

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SITE LOCATION MAP

REMEDIAL DESIGN
WORK PLAN:
AOC #6C - NAPL AREA

BROWNFIELD CLEANUP
PROGRAM

690 SAINT PAUL STREET
ROCHESTER, NEW YORK

VOLUNTEER:
GENESEE VALLEY
REAL ESTATE COMPANY

N W E S

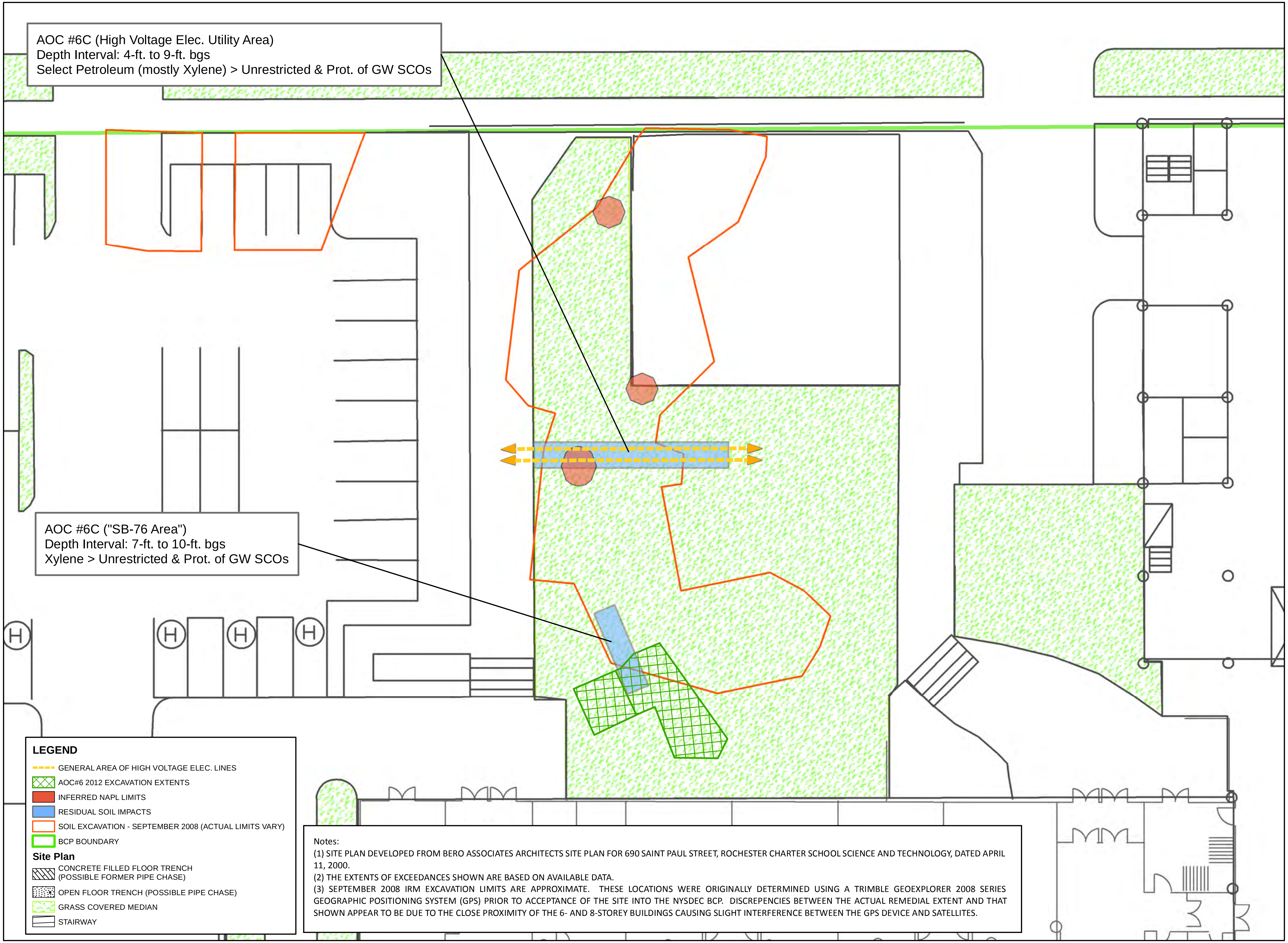
0 25 50 100 Feet

1 inch = 80 feet
Intended to Print on 11"x17"

209280

FIGURE 2

Path: I:\Genesee Valley Real Estate Co\209280\Drawings\RDWP- AOC #6 NAPL\Fig2-Aerial.mxd



AOC #6C (High Voltage Elec. Utility Area)
Depth Interval: 4-ft. to 9-ft. bgs
Select Petroleum (mostly Xylene) > Unrestricted & Prot. of GW SCOs

AOC #6C ("SB-76 Area")
Depth Interval: 7-ft. to 10-ft. bgs
Xylene > Unrestricted & Prot. of GW SCOs

LEGEND

- GENERAL AREA OF HIGH VOLTAGE ELEC. LINES
- ▨ AOC#6 2012 EXCAVATION EXTENTS
- 🟥 INFERRED NAPL LIMITS
- 🟦 RESIDUAL SOIL IMPACTS
- ☐ SOIL EXCAVATION - SEPTEMBER 2008 (ACTUAL LIMITS VARY)
- 🟩 BCP BOUNDARY

Site Plan

- ▨ CONCRETE FILLED FLOOR TRENCH (POSSIBLE FORMER PIPE CHASE)
- ▒ OPEN FLOOR TRENCH (POSSIBLE PIPE CHASE)
- ▒ GRASS COVERED MEDIAN
- ☐ STAIRWAY

Notes:
(1) SITE PLAN DEVELOPED FROM BERO ASSOCIATES ARCHITECTS SITE PLAN FOR 690 SAINT PAUL STREET, ROCHESTER CHARTER SCHOOL SCIENCE AND TECHNOLOGY, DATED APRIL 11, 2000.
(2) THE EXTENTS OF EXCEEDANCES SHOWN ARE BASED ON AVAILABLE DATA.
(3) SEPTEMBER 2008 IRM EXCAVATION LIMITS ARE APPROXIMATE. THESE LOCATIONS WERE ORIGINALLY DETERMINED USING A TRIMBLE GEOEXPLORER 2008 SERIES GEOGRAPHIC POSITIONING SYSTEM (GPS) PRIOR TO ACCEPTANCE OF THE SITE INTO THE NYSDEC BCP. DISCREPENCIES BETWEEN THE ACTUAL REMEDIAL EXTENT AND THAT SHOWN APPEAR TO BE DUE TO THE CLOSE PROXIMITY OF THE 6- AND 8-STOREY BUILDINGS CAUSING SLIGHT INTERFERENCE BETWEEN THE GPS DEVICE AND SATELLITES.

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AOC #6C FEATURES

REMEDIAL DESIGN
WORK PLAN:
AOC #6C - NAPL AREA

BROWNFIELD CLEANUP
PROGRAM

690 SAINT PAUL STREET
ROCHESTER, NEW YORK

VOLUNTEER:
GENESEE VALLEY
REAL ESTATE COMPANY

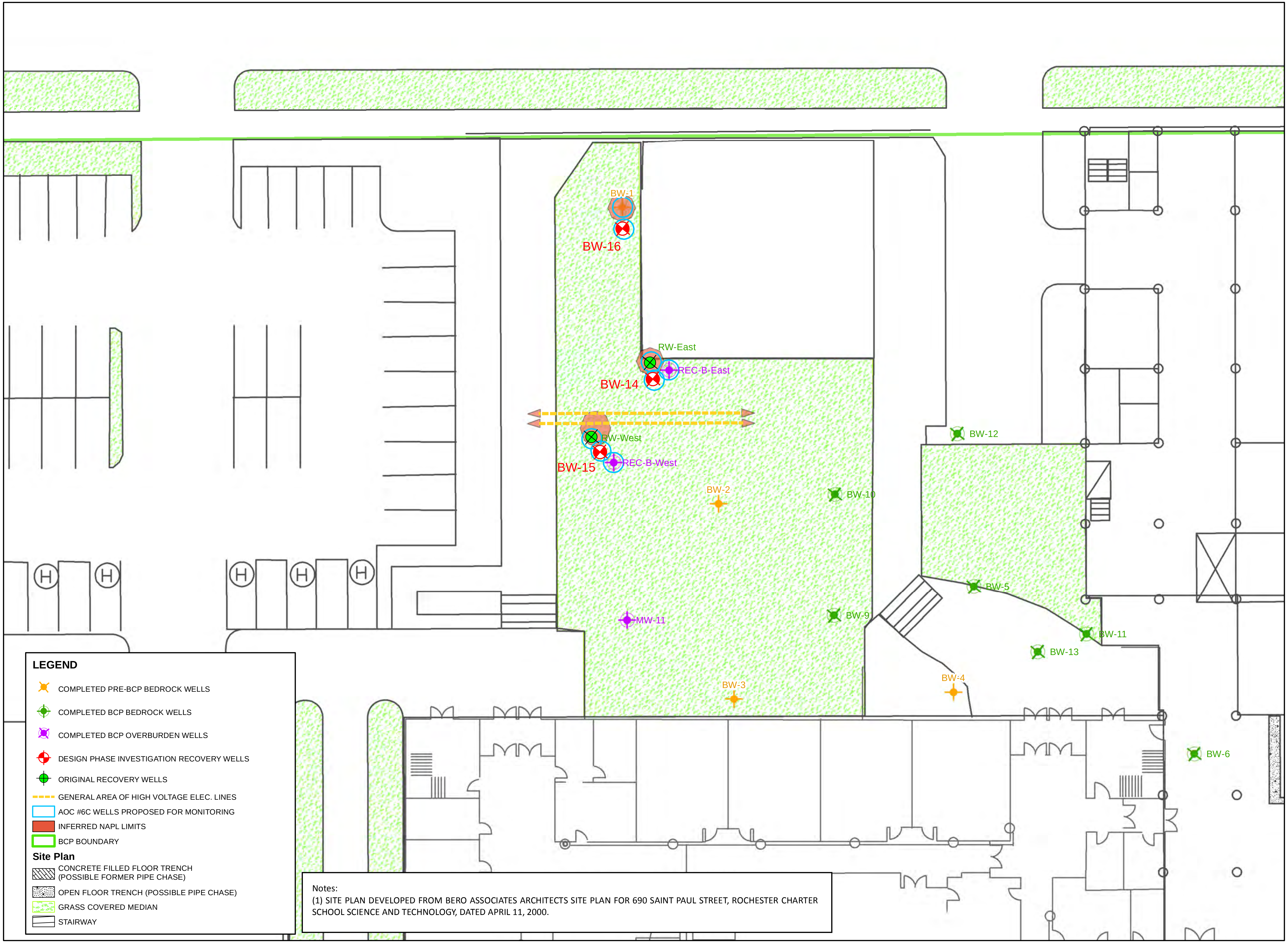
1 inch = 20 feet

Intended to print in 11" x 17" size.

209280

FIGURE 3

Path: I:\Genesee Valley Real Estate Co\209280\Drawings\RDWP- AOC #6 NAPL\Fig 3 - AOC Features.mxd



LEGEND

- COMPLETED PRE-BCP BEDROCK WELLS
- COMPLETED BCP BEDROCK WELLS
- COMPLETED BCP OVERBURDEN WELLS
- DESIGN PHASE INVESTIGATION RECOVERY WELLS
- ORIGINAL RECOVERY WELLS
- GENERAL AREA OF HIGH VOLTAGE ELEC. LINES
- AOC #6C WELLS PROPOSED FOR MONITORING
- 🟥 INFERRED NAPL LIMITS
- 🟩 BCP BOUNDARY

Site Plan

- ▨ CONCRETE FILLED FLOOR TRENCH (POSSIBLE FORMER PIPE CHASE)
- OPEN FLOOR TRENCH (POSSIBLE PIPE CHASE)
- GRASS COVERED MEDIAN
- STAIRWAY

Notes:
(1) SITE PLAN DEVELOPED FROM BERO ASSOCIATES ARCHITECTS SITE PLAN FOR 690 SAINT PAUL STREET, ROCHESTER CHARTER SCHOOL SCIENCE AND TECHNOLOGY, DATED APRIL 11, 2000.

LABELLA Associates, D.P.C.
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F: (585)454-3066
www.labellapc.com

WELL LOCATIONS

REMEDIAL DESIGN
WORK PLAN:
AOC #6C - NAPL AREA

BROWNFIELD CLEANUP
PROGRAM

690 SAINT PAUL STREET
ROCHESTER, NEW YORK

VOLUNTEER:
GENESEE VALLEY
REAL ESTATE COMPANY

N E S W

0 5 10 20 Feet

1 inch = 23 feet

Intended to print in 11" x 17" size.

209280

FIGURE 4

Path: I:\Genesee Valley Real Estate Co\209280\Drawings\RDWP- AOC #6 NAPL\Figure 4 - Well locations.mxd

LaBella Associates, D.P.C.

300 State Street
Rochester, New York 14614

Appendix 1

Standards, Criteria and Guidance Values

Table 1

Restricted Use Soil Cleanup Objectives
6 NYCRR Subpart 375-6 and CP-51 Remedial Program Soil Cleanup Objectives
(All Soil Cleanup Objectives are in mg/kg (ppm)

Contaminant	CAS No.	Restricted Residential	Protection of Groundwater
VOLATILE ORGANIC COMPOUNDS (VOCs)			
1,1,1-Trichloroethane	71-55-6	100 [a]	0.68
1,1-Dichloroethane	75-34-3	26	0.27
1,1-Dichloroethene	75-35-4	100 [a]	0.33
1,2-Dichlorobenzene	95-50-1	100 [a]	1.1
1,2-Dichloroethane	107-06-2	3.1	0.02 [f]
cis-1,2-Dichloroethene	156-59-2	0.25	0.25
trans-1,2-Dichloroethene	156-60-5	0.19	0.19
1,3-Dichlorobenzene	541-73-1	49	2.4
1,4-Dichlorobenzene	106-46-7	13	1.8
1,4-Dioxane	123-91-1	13	0.1 [e]
Acetone	67-64-1	100 [a]	0.05
Benzene	71-43-2	4.8	0.06
Butylbenzene	104-51-8	100 [a]	12
Carbon Tetrachloride	56-23-5	2.4	0.76
Chlorobenzene	108-90-7	100 [a]	1.1
Chloroform	67-66-3	49	0.37
Ethylbenzene	100-41-4	41	1
Hexachlorobenzene	118-74-1	1.2	3.2
Methyl Ethyl Ketone (MEK)	78-93-3	100 [a]	0.12
Methyl tert-Butyl Ether (MtBE)	1634-04-4	100 [a]	0.93
Methylene Chloride	75-09-2	100 [a]	0.05
n-Propylbenzene	103-65-1	100 [a]	3.9
sec-Butylbenzene	135-98-8	100 [a]	11
tert-Butylbenzene	98-06-6	100 [a]	5.9
Tetrachloroethene	127-18-4	19	1.3
Toluene	108-88-3	100 [a]	0.7
Trichloroethene	79-01-6	0.47	0.47
1,2,4-Trimethylbenzene	95-63-6	52	3.6
1,3,5-Trimethylbenzene	108-67-8	52	8.4
Vinyl Chloride	75-01-4	0.02	0.02
Xylenes (Mixed)	1330-20-7	100 [a]	1.6

Contaminant	CAS No.	Restricted Residential	Protection of Groundwater
SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs)			
Acenaphthene	83-32-9	100 [a]	98
Acenaphthylene	208-96-8	100 [a]	107
Anthracene	120-12-7	100 [a]	1,000 [c]
Benzo(a)anthracene	56-55-3	1 [f]	1 [f]
Benzo(a)pyrene	50-32-8	1 [f]	22
Benzo(b)fluoranthene	205-99-2	1 [f]	1.7
Benzo(g,h,i)perylene	191-24-2	100 [a]	1,000 [c]
Benzo(k)fluoranthene	207-08-9	3.9	1.7
Chrysene	218-01-9	3.9	1 [f]
Dibenz(a,h)anthracene	53-70-3	0.33 [e]	1,000 [c]
Fluoranthene	206-44-0	100 [a]	1,000 [c]
Fluorene	86-73-7	100 [a]	386
Indeno(1,2,3-cd)pyrene	193-39-5	0.5 [f]	8.2
m-Cresol	108-39-4	100 [a]	0.33 [e]
Naphthalene	91-20-3	100 [a]	12
o-Cresol	95-48-7	100 [a]	0.33 [e]
p-Cresol	106-44-5	100 [a]	0.33 [e]
Pentachlorophenol	87-86-5	6.7	0.8 [e]
Phenanthrene	85-01-8	100 [a]	1,000 [c]
Phenol	108-95-2	100 [a]	0.33 [e]
Pyrene	129-00-0	100 [a]	1,000 [c]

Notes:

SCO denotes Soil Cleanup Objectives.

NS denotes Not Specified.

[a] The SCOs for Restricted-Residential use were capped at a maximum of 100-mg/kg (ppm).

[d] The SCOs for metals were capped at a maximum of 10,000-mg/kg (ppm).

[e] For constituents where the calculated SCO was lower than the contract required quantitation limit (CRQL), the CRQL was used as the SCO.

[f] For constituents where the calculated SCO was lower than the rural soil background concentration, as determined by the Department and the Department of Health rural soil survey, the rural soil background concentration is used as the Track 2 SCO value for use of the site.

[h] The SCO for this specific compound (or family of compounds) is considered to be met if the analysis for the total species of this contaminant is below the specific SCO.

[i] The SCO is for the sum of Endosulfan I, Endosulfan II, and Endosulfan Sulfate.

[j] The SCO is the lower of the values for mercury (elemental) or mercury (inorganic salts).

Table 1 (Continued)

Restricted Use Soil Cleanup Objectives
6 NYCRR Subpart 375-6 and CP-51 Remedial Program Soil Cleanup Objectives
(All Soil Cleanup Objectives are in mg/kg (ppm))

Contaminant	CAS No.	Restricted Residential	Protection of Groundwater
METALS			
Arsenic	7440-38-2	16 [f]	16 [f]
Barium	7440-39-3	400	820
Beryllium	7440-41-7	72	47
Cadmium	7440-43-9	4.3	7.5
Chromium (Hexavalet)	18540-29-9	110	19
Chromium (Trivalent)	16065-83-1	180	NS
Copper	7440-50-8	270	1,720
Total Cyanide		27	40
Lead	7439-92-1	400	450
Manganese	7439-96-5	2,000 [f]	2,000 [f]
Total Mercury		0.81 [j]	0.73
Nickel	7440-02-0	310	130
Selenium	7782-49-2	180	4 [f]
Silver	7440-22-4	180	8.3
Zinc	7440-66-6	10,000 [d]	2,480

Contaminant	CAS No.	Restricted Residential	Protection of Groundwater
PCB & PESTICIDES			
2,4,5-TP Acid (Silvex)	93-72-1	100 [a]	3.8
4,4'-DDE	72-55-9	8.9	17
4,4'-DDT	50-29-3	7.9	136
4,4'-DDD	72-54-8	13	14
Aldrin	309-00-2	0.097	0.19
alpha-BHC	319-84-6	0.48	0.02
beta-BHC	319-85-7	0.36	0.09
Chlordane (alpha)	5103-71-9	4.2	2.9
delta-BHC	319-86-8	100 [a]	0.25
Dibenzofuran	132-64-9	59	210
Dieldrin	60-57-1	0.2	0.1
Endosulfan I	959-98-8	24 [i]	102
Endosulfan II	33213-65-9	24 [i]	102
Endosulfan Sulfate	1031-07-8	24 [i]	1,000 [c]
Endrin	72-20-8	11	0.06
Heptachlor	76-44-8	2.1	0.38
Lindane	58-89-9	1.3	0.1
Polychlorinated Biphenyls	1336-36-3	1	3.2

Notes:

SCO denotes Soil Cleanup Objectives.

NS denotes Not Specified.

[a] The SCOs for Restricted-Residential use were capped at a maximum of 100-mg/kg (ppm).

[d] The SCOs for metals were capped at a maximum of 10,000-mg/kg (ppm).

[e] For constituents where the calculated SCO was lower than the contract required quantitation limit (CRQL), the CRQL was used as the SCO.

[f] For constituents where the calculated SCO was lower than the rural soil background concentration, as determined by the Department and the Department of Health rural soil survey, the rural soil background concentration is used as the Track 2 SCO value for use of the site.

[h] The SCO for this specific compound (or family of compounds) is considered to be met if the analysis for the total species of this contaminant is below the specific SCO.

[i] The SCO is for the sum of Endosulfan I, Endosulfan II, and Endosulfan Sulfate.

[j] The SCO is the lower of the values for mercury (elemental) or mercury (inorganic salts).

Table 2
Groundwater Standards and Guidance Values
(All Groundwater Criteria are in ug/L (ppb)

Contaminant	CAS No.	NYSDEC Part 703 Groundwater Standards and TOGS 1.1.1 Guidance Values
VOLATILE ORGANIC COMPOUNDS (VOCs)		
Chloromethane	74-87-3	5
Vinyl chloride	75-01-4	2
1,1-Dichloroethene	75-35-4	5
Acetone	67-64-1	50
Carbon disulfide	75-15-0	60*
Methylene chloride	75-09-2	5
trans-1,2-dichloroethene	156-60-5	5
Methyl tert-butyl ether	1634-04-4	10
1,1-Dichloroethane	75-34-3	5
2-Butanone	78-93-3	50
cis-1,2-dichloroethene	156-59-2	5
Chloroform	67-66-3	7
Chloroethane	75-00-3	5
1,2-Dichloroethane	107-06-2	0.6
Benzene	71-43-2	1
Trichloroethene	79-01-6	5
Toluene	108-88-3	5
1,1,2-Trichloroethane	79-00-5	1
Tetrachloroethene	127-18-4	5
Ethylbenzene	100-41-4	5
Xylenes (mixed)	1330-20-7	5
Bromoform	75-25-2	50*
Isopropylbenzene	98-82-8	5
n-Propylbenzene	103-65-1	5
1,3,5-Trimethylbenzene	108-67-8	5
tert-Butylbenzene	98-06-6	5
1,2,4-Trimethylbenzene	95-63-6	5
sec-Butylbenzene	135-98-8	5
4-Isopropyltoluene	99-87-6	5
n-Butylbenzene	104-51-8	5
1,2-Dichlorobenzene	95-50-1	3
Naphthalene	91-20-3	10

Contaminant	CAS No.	NYSDEC Part 703 Groundwater Standards and TOGS 1.1.1 Guidance Values
SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs)		
Acenaphthene	83-32-9	20
Acenaphthylene	208-96-8	NA
Anthracene	120-12-7	50
Benzo(a)anthracene	56-55-3	0.002
Benzo(a)pyrene	50-32-8	ND
Benzo(b)fluoranthene	205-99-2	0.002
Benzo(g,h,i)perylene	191-24-2	NA
Benzo(k)fluoranthene	207-08-9	0.002
Chrysene	218-01-9	0.002
Dibenz(a,h)anthracene	53-70-3	NA
Fluoranthene	206-44-0	50
Fluorene	86-73-7	50
Indeno(1,2,3-cd)pyrene	193-39-5	0.002
Naphthalene	91-20-3	10
Phenanthrene	85-01-8	50
Pyrene	129-00-0	50

Notes:

NA denotes Not Available.

* Indicates value is from Division of Water Techinical and Operational Guidance Series (TOGS 1.1.1)

Table 2 (Continued)
Groundwater Standards and Guidance Values
(All Groundwater Criteria are in ug/L (ppb)

Contaminant	CAS No.	NYSDEC Part 703 Groundwater Standards and TOGS 1.1.1 Guidance Values
METALS		
Arsenic	7440-38-2	25
Barium	7440-39-3	1,000
Beryllium	7440-41-7	3
Cadmium	7440-43-9	5
Chromium (Trivalent)	16065-83-1	50
Copper	7440-50-8	200
Total Cyanide	57-12-5	200
Lead	7439-92-1	25
Manganese	7439-96-5	300
Total Mercury	7439-97-6	0.7
Nickel	7440-02-0	100
Selenium	7782-49-2	10
Silver	7440-22-4	50
Zinc	7440-66-6	2,000

Contaminant	CAS No.	NYSDEC Part 703 Groundwater Standards and TOGS 1.1.1 Guidance Values
PCBs & PESTICIDES		
2,4,5-TP Acid (Silvex)	93-72-1	10
4,4'-DDE	72-55-9	0.2
4,4'-DDT	50-29-3	0.2
4,4'-DDD	72-54-8	0.3
Aldrin	309-00-2	50
alpha-BHC	319-84-6	0.01
beta-BHC	319-85-7	0.04
Chlordane (alpha)	5103-71-9	0.05
delta-BHC	319-86-8	0.04
Dibenzofuran	132-64-9	NA
Dieldrin	60-57-1	0.004
Endosulfan I	959-98-8	NA
Endosulfan II	33213-65-9	50
Endosulfan Sulfate	1031-07-8	50
Endrin	72-20-8	50
Heptachlor	76-44-8	0.03
Lindane	58-89-9	0.05
Polychlorinated Biphenyls	1336-36-3	0.09

Notes:

NA denotes Not Available.

* Indicates value is from Division of Water Techinical and Operational Guidance Series (TOGS 1.1.1)

LaBella Associates, D.P.C.

300 State Street
Rochester, New York 14614

Appendix 2

Health & Safety Plan

Site Health and Safety Plan

Location:

690 Saint Paul Street
Rochester, New York 14605

Prepared For:

Genesee Valley Real Estate Company
First Federal Plaza
28 East Main Street, Suite 500
Rochester, New York 14614

LaBella Project No. 209280

August 2014

Site Health and Safety Plan

Location:

690 Saint Paul Street
Rochester, New York 14605

Prepared For:

Genesee Valley Real Estate Company
First Federal Plaza
28 East Main Street, Suite 500
Rochester, New York 14614

LaBella Project No. 209280

August 2014

LaBella Associates, D.P.C.
300 State Street
Rochester, New York 14614

Table of Contents

Page

SITE HEALTH AND SAFETY PLAN

Project Title:	690 Saint Paul Street Brownfield Cleanup Program
Project Number:	209280
Project Location (Site):	690 Saint Paul Street, Rochester, New York 14605-1742
Environmental Director:	Gregory Senecal, CHMM
Project Manager:	Dan Noll, P.E.
Plan Review Date:	______________________________
Plan Approval Date:	______________________________
Plan Approved By:	______________________________ Mr. Richard Rote, CIH
Site Safety Supervisor:	Jennifer Gillen
Site Contact:	To Be Determined
Safety Director:	Rick Rote, CIH
Proposed Date(s) of Field Activities:	To Be Determined
Site Conditions:	Slightly sloping, encompassing approximately 4.73 acres
Site Environmental Information Provided By:	Remedial Investigation Reports by LaBella Associates, D.P.C.
Air Monitoring Provided By:	LaBella Associates, D.P.C.
Site Control Provided By:	Contractor(s)

EMERGENCY CONTACTS

	Name	**Phone Number**
Ambulance:	As Per Emergency Service	911
Hospital Emergency:	Rochester General Hospital	585-922-4000
Poison Control Center:	Finger Lakes Poison Control	585-273-4621
Police (local, state):	Monroe County Sheriff	911
Fire Department:	Rochester Fire Department	911
Site Contact:	Chris Gullace	Cell: 585-330-7173
Agency Contact:	NYSDEC – Frank Sowers, P.E. NYSDOH – Bridget Boyd Finger Lakes Poison Control MCDOH – John Frazer	585-226-5357 518-402-7860 1-800-222-1222 585-753-5904
Environmental Director:	Greg Senecal, CHMM	Direct: 585-295-6243 Cell: 585-752-6480 Home: 585-323-2142
Project Manager:	Dan Noll, P.E.	Direct: 585-295-611 Cell: 585-301-8458
Site Safety Supervisor:	Jennifer Gillen	Direct: 585-295-6648
Safety Director	Rick Rote, CIH	Direct: 585-295-6241

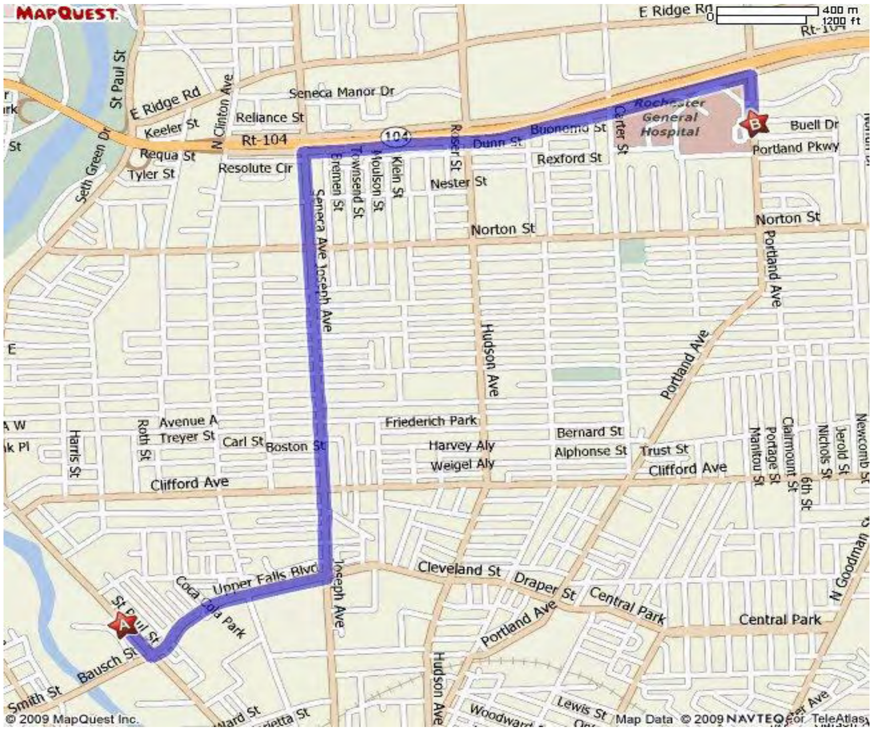
MAP AND DIRECTIONS TO THE MEDICAL FACILITY - ROCHESTER GENERAL HOSPITAL

Total Time: 8 minutes
Total Distance: 3.50 miles

Start: 690 Saint Paul St, Rochester, NY 14605-1742

START	1: Start out going SOUTHEAST on ST PAUL ST toward LOWELL ST.	0.1 mi
←	2: Turn LEFT onto UPPER FALLS BLVD.	0.6 mi
←	3: Turn LEFT onto JOSEPH AVE.	1.1 mi
↑	4: JOSEPH AVE becomes SENECA AVE.	0.3 mi
→	5: Turn RIGHT onto RT-104.	1.2 mi
→	6: Turn RIGHT onto PORTLAND AVE/CR-114.	0.2 mi
END	7: End at 1425 Portland Ave Rochester, NY 14621-3001	

End: 1425 Portland Ave, Rochester, NY 14621-3001



1.0 Introduction

The purpose of this Health and Safety Plan (HASP) it to provide guidelines for responding to potential health and safety issues that may be encountered during a Design Phase Investigation (DPI) to be performed at the Site located at 690 Saint Paul Street in the City of Rochester, Monroe County, New York. This HASP only reflects the policies of LaBella Associates D.P.C. The requirements of this HASP are applicable to all approved LaBella personnel at the work site. This document's project specifications and the Community Air Monitoring Plan (CAMP) are to be consulted for guidance in preventing and quickly abating any threat to human safety or the environment. The provisions of the HASP were developed in general accordance with 29 CFR 1910 and 29 CFR 1926 and do not replace or supersede any regulatory requirements of the USEPA, NYSDEC, OSHA or any other regulatory body.

2.0 Responsibilities

This HASP presents guidelines to minimize the risk of injury to project personnel, and to provide rapid response in the event of injury. The HASP is applicable only to activities of approved LaBella personnel and their authorized visitors. The Project Manager shall implement the provisions of this HASP for the duration of the project. It is the responsibility of each LaBella employee to follow the requirements of this HASP, and all applicable company safety procedures.

3.0 Activities Covered

The activities covered under this HASP are limited to the following:

- ☐ Management of environmental investigation and remediation activities
- ☐ Environmental monitoring
- ☐ Collection of samples
- ☐ Management of excavated soil and groundwater

4.0 Work Area Access and Site Control

The contractor(s) will have primary responsibility for work area access and site control. However, a minimum requirement for work area designation and control will consist of:

- Donning high visibility vests, hard hats, and safety glasses on-site during DPI activities; and,
- Adhering to the Site-specific Health & Safety Plan included in Appendix 1 of this IRM Work Plan.

5.0 Potential Health and Safety Hazards

This section lists some potential health and safety hazards that project personnel may encounter at the project site and some actions to be implemented by approved personnel to control and reduce the associated risk to health and safety. This is not intended to be a complete listing of any and all potential health and safety hazards. New or different hazards may be encountered as site environmental and site work conditions change. The suggested actions to be taken under this plan are not to be substituted for good judgment on the part of project personnel. At all times, the Site Safety Officer has responsibility for site safety and his or her instructions must be followed.

5.1 Hazards Due to Heavy Machinery

Potential Hazard:
Heavy machinery including trucks, drill rigs, etc will be in operation at the site. The presence of such equipment presents the danger of being struck or crushed. Use caution when working near heavy machinery.

Protective Action:
Make sure that operators are aware of your activities, and heed operator's instructions and warnings. Wear bright colored clothing and walk safe distances from heavy equipment. A hard hat, safety glasses and steel toe shoes are required.

5.2 Cuts, Punctures and Other Injuries

Potential Hazard:
In any work with heavy machinery there is the potential for the presence of sharp or jagged edges on rock, metal materials, and other sharp objects. Serious cuts and punctures can result in loss of blood and infection.

Protective Action:
The Project Manager is responsible for making First Aid supplies available at the work site to treat minor injuries. The Site Safety Officer is responsible for arranging the transportation of authorized on-site personnel to medical facilities when First Aid treatment in not sufficient. Do not move seriously injured workers. All injuries requiring treatment are to be reported to the Project Manager. Serious injuries are to be reported immediately to the Site Safety Officer.

5.3 Injury Due to Exposure of Chemical Hazards

Potential Hazards:
Volatile organic vapors from petroleum products, chlorinated solvents or other chemicals may be encountered during drilling activities at the project work site. Inhalation of high concentrations of organic vapors can cause headache, stupor, drowsiness, confusion and other health effects. Skin contact can cause irritation, chemical burn, or dermatitis.

Protective Action:
The presence of organic vapors may be detected by their odor and by monitoring instrumentation. Approved employees will not work in environments where hazardous concentrations of organic vapors are present. Air monitoring (refer to Section 9.0 and to the Site specific CAMP in Appendix 3 of the DPI Work Plan) of the work area will be performed at least every 60 minutes or more often using a Photoionization Detector (PID). Personnel are to leave the work area whenever PID measurements of ambient air exceed 25 ppm for a 5 minute average. In the event that an ambient air reading for total volatile organic compound (VOC) of 25 ppm is encountered for a 5 minute average, personnel should upgrade personal protective equipment to Level C (refer to Section 8.0) and an Exclusion Zone should be established around the work area to limit and monitor access to this area (refer to Section 6.0).

5.4 Injuries Due to Extreme Hot or Cold Weather Conditions

Potential Hazards:
Extreme hot weather conditions can cause heat exhaustion, heat stress and heat stroke or extreme cold weather conditions can cause hypothermia.

Protective Action:
Precaution measures should be taken such as dress appropriately for the weather conditions and drink plenty of fluid. If personnel should suffer from any of the above conditions, proper techniques should be taken to cool down or heat up the body and taken to the nearest hospital if needed.

5.5 Potential Exposure to Asbestos

Potential Hazards:
During ground intrusive activities (e.g., drilling) soil containing asbestos may be encountered. Asbestos is friable when dry and can be inhaled when exposed to air.

Protective Action:
The presence of asbestos can be identified through visual observation of a white magnesium silicate material. If encountered, work should be halted and a sample of the suspected asbestos should be collected and placed in a plastic sealable bag. This sample should be sent to the asbestos laboratory at LaBella Associates for analysis.

6.0 Work Zones

In the event that conditions warrant establishing various work zones (i.e., based on hazards - Section 5.4), the following work zones should be established:

Exclusion Zone (EZ):
The EZ will be established in the immediate vicinity and adjacent downwind direction of site activities that elevate breathing zone VOC concentrations to unacceptable levels based on field screening. These site activities include drilling in contaminated soil/groundwater and sampling activities. If access to the site is required to accommodate non-project related personnel then an EZ will be established by constructing a barrier around the work area (yellow caution tape and/or construction fencing). The EZ barrier shall encompass the work area and any equipment staging/soil staging areas necessary to perform the associated work. The contractor(s) will be responsible for establishing the EZ and limiting access to approved personnel. Depending on the condition for establishing the EZ, access to the EZ may require adequate PPE (e.g., Level C).

Contaminant Reduction Zone (CRZ):
The CRZ will be the area where personnel entering the EZ will don proper PPE prior to entering the EZ and the area where PPE may be removed. The CRZ will also be the area where decontamination of equipment and personnel will be conducted as necessary.

7.0 Decontamination Procedures

Upon leaving the work area, approved personnel shall decontaminate footwear as needed. Under normal work conditions, detailed personal decontamination procedures will not be necessary. Work clothing may become contaminated in the event of an unexpected splash or spill or contact with a contaminated substance. Minor splashes on clothing and footwear can be rinsed with clean water. Heavily contaminated clothing should be removed if it cannot be rinsed with water. Personnel assigned to this project should be prepared with a change of clothing whenever on site.

Personnel will use the contractor's disposal container for disposal of PPE.

8.0 Personal Protective Equipment

Generally, site conditions at this work site require level of protection of Level D or modified Level D. However, air monitoring will be conducted to determine if up-grading to Level C PPE is required (refer to Section 9.0). Descriptions of the typical safety equipment associated with Level D and Level C are provided below:

Level D:
Hard hat, safety glasses, rubber nitrile sampling gloves, steel toe construction grade boots, etc.

Level C:
Level D PPE and full or ½-face respirator and tyvek suit (if necessary). [*Note: Organic vapor cartridges are to be changed after each 8 hours of use or more frequently.*]

9.0 Air Monitoring

According to 29 CFR 1910.120(h), air monitoring shall be used to identify and quantify airborne levels of hazardous substances and health hazards in order to determine the appropriate level of employee protection required for personnel working onsite. Air monitoring will consist at a minimum of the procedures described in Appendix 2 "Site Specific CAMP". Please refer to the Site Specific CAMP for further details on air monitoring at the Site.

The Air Monitor will utilize a photoionization detector (PID) to screen the ambient air in the work areas for total Volatile Organic Compounds (VOCs) and a DustTrak tm Model 8530 aerosol monitor or equivalent for measuring particulates. Work area ambient air will generally be monitored in the work area and downwind of the work area. Air monitoring of the work areas and downwind of the work areas will be performed at least every 60 minutes or more often using a PID, and the DustTrak meter.

If ambient air PID readings of greater than 25 ppm are recorded in the breathing zone for a 5 minute average, then either personnel are to leave the work area until satisfactory readings are obtained or approved personnel may re-enter the work areas wearing at a minimum a ½ face respirator with organic vapor cartridges for an 8-hour duration (i.e., upgrade to Level C PPE). Organic vapor cartridges are to be changed after each 8 hours of use or more frequently, if necessary. If PID readings are sustained, in the work area, at levels above 25 ppm for a 5 minute average, work will be stopped immediately until safe levels of VOCs are encountered or additional PPE will be required (i.e., Level B).

If dust concentrations exceed the upwind concentration by 150 µg/m^3 (0.15 mg/m^3) consistently for a 10 minute period within the work area or at the downwind location, then LaBella personnel may not re-enter the work area until dust concentrations in the work area decrease below 150 µg/m^3 (0.15 mg/m^3), which may be accomplished by the construction manager implementing dust control or suppression measures.

10.0 Emergency Action Plan

In the event of an emergency, employees are to turn off and shut down all powered equipment and leave the work areas immediately. Employees are to walk or drive out of the Site as quickly as possible and wait at the assigned 'safe area'. Follow the instructions of the Site Safety Officer.

Employees are not authorized or trained to provide rescue and medical efforts. Rescue and medical efforts will be provided by local authorities.

11.0 Medical Surveillance

Medical surveillance will be provided to all employees who are injured due to overexposure from an emergency incident involving hazardous substances at this site.

12.0 Employee Training

Personnel who are not familiar with this site plan will receive training on its entire content and organization before working at the Site.

Individuals involved with the remedial investigation must be 40-hour OSHA HAZWOPER trained with current 8-hour refresher certification.

Table 1
Exposure Limits and Recognition Qualities

Compound	PEL-TWA (ppm)(b)(d)	TLV-TWA (ppm)(c)(d)	STEL	LEL (%)(e)	UEL (%)(f)	IDLH (ppm)(g)(d)	Odor	Odor Threshold (ppm)	Ionization Potential
Acetone	750	500	NA	2.15	13.2	20,000	Sweet	4.58	9.69
Anthracene	0.2	0.2	NA	NA	NA	NA	Faint aromatic	NA	NA
Benzene	1	0.5	5	1.3	7.9	3000	Pleasant	8.65	9.24
Benzo (a) pyrene (coal tar pitch volatiles)	0.2	0.1	NA	NA	NA	700	NA	NA	NA
Benzo (a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo (b) Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo (g,h,i)perylene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo (k) Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	NA	NA	NA	NA	NA	10.88
Carbon Disulfide	20	1	NA	1.3	50	500	Odorless or strong garlic type	0.096	10.07
Chlorobenzene	75	10	NA	1.3	9.6	2,400	Faint almond	0.741	9.07
Chloroform	50	2	NA	NA	NA	1,000	ethereal odor	11.7	11.42
Chrysene	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethylene	200	200	NA	9.7	12.8	400	Acrid	NA	9.65
1,2-Dichlorobenzene	50	25	NA	2.2	9.2		Pleasant		9.07
Ethylbenzene	100	100	NA	1	6.7	2,000	Ether	2.3	8.76
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene Chloride	500	50	NA	12	23	5,000	Chloroform-like	10.2	11.35
Naphthalene	10, Skin	10	NA	0.9	5.9	250	Moth Balls	0.3	8.12
n-propylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
p-Isopropylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethane	NA	NA	NA	NA	NA	NA	Sweet	NA	NA
Toluene	100	100	NA	0.9	9.5	2,000	Sweet	2.1	8.82
Trichloroethylene	100	50	NA	8	12.5	1,000	Chloroform	1.36	9.45
1,2,4-Trimethylbenzene	NA	25	NA	0.9	6.4	NA	Distinct	2.4	NA
1,3,5-Trimethylbenzene	NA	25	NA	NA	NA	NA	Distinct	2.4	NA
Vinyl Chloride	1	1	NA	NA	NA	NA	NA	NA	NA
Xylenes (o,m,p)	100	100	NA	1	7	1,000	Sweet	1.1	8.56
Metals									
Arsenic	0.01	0.2	NA	NA	NA	100, Ca	Almond	NA	NA
Cadmium	0.2	0.5	NA	NA	NA	NA	NA	NA	NA
Chromium	1	0.5	NA	NA	NA	NA	NA	NA	NA
Lead	0.05	0.15	NA	NA	NA	700	NA	NA	NA
Mercury	0.05	0.05	NA	NA	NA	28	Odorless	NA	NA
Selenium	0.2	0.02	NA	NA	NA	Unknown	NA	NA	NA
Other									
Asbestos	0.1 (f/cc)	NA	1.0 (f/cc)	NA	NA	NA	NA	NA	NA

(a) Skin = Skin Absorption
(b) OSHA-PEL Permissible Exposure Limit (flame weighted average, 8-hour): NIOSH Guide, June 1990
(c) ACGIH – 8 hour time weighted average from Threshold Limit Values and Biological Exposure Indices for 2003.
(d) Metal compounds in mg/m3

(e) Lower Exposure Limit (%)
(f) Upper Exposure Limit (%)
(g) Immediately Dangerous to Life or Health Level: NIOSH Guide, June 1990.

Notes:
1. All values are given in parts per million (PPM) unless otherwise indicated
2. Ca = Possible Human Carcinogen, no IDLH information

LaBella Associates, D.P.C.

300 State Street
Rochester, New York 14614

Appendix 3

Community Air Monitoring Plan

Site-Specific Community Air Monitoring Plan
NYSDEC Site #C828159

Location:

690 Saint Paul Street
Rochester, New York

Prepared For:

Genesee Valley Real Estate Company
First Federal Plaza
28 East Main Street
Rochester, New York 14614

LaBella Project No. 209280

August 2014

Site-Specific Community Air Monitoring Plan
NYSDEC Site #C828159

Location:

690 Saint Paul Street
Rochester, New York

Prepared For:

Genesse Valley Real Estate Company
First Federal Plaza
28 East Main Street
Rochester, New York 14614

LaBella Project No. 209280

August 2014

Table of Contents

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1.0 INTRODUCTION

This Site Specific Community Air Monitoring Plan (CAMP) has been prepared by LaBella Associates, P.C. (LaBella) on behalf of Genesee Valley Real Estate Company (GVRE). This CAMP addresses potential Volatile Organic Compound (VOC) vapor and particulate emissions that may occur during implementation of the Design Phase Investigation (DPI) at 690 Saint Paul Street, Rochester, New York which encompasses approximately 4.73 acres in the City of Rochester, Monroe County, New York herein after referred to as the "Site." The Site is enrolled into the New York State Department of Environmental Conservation (NYSDEC) Brownfield Cleanup Program (BCP).

2.0 PURPOSE

Various levels of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and metals (collectively refered to as "constituents of concern" (COCs)) have been detected in the soil and groundwater at the Site or are suspected to be contained in the soil and/or groundwater at the Site. The presence of these COCs through disturbance of soil and groundwater at the Site can potentially result in nuisance odors or fugitive emissions to the neighborhood in the immediate vicinity of the Site as well as to the various occupants of the Site.

This CAMP is specific to activities being conducted as part of the implementation of the DPI for AOC #6C: NAPL Area. The CAMP describes the air monitoring activities to be completed in order to provide a measure of protection for any downwind receptors including Site occupants and occupants of neighboring properties. This CAMP is not intended to provide action levels for respiratory protection of workers involved with the implementation of the DPI. Rather, a Health & Safety Plan (HASP) has been developed and is included as Appendix 2 to the DPI to cover workers directly involved with the implementation of the DPI.

This CAMP is based on the air monitoring specified in the New York State Department of Health (NYSDOH) Generic CAMP (included as Appendix 1A of the DER-10 NYSDEC Technical Guidance for Site Investigation and Remediation dated May 2010). However, this CAMP also includes more stringent (i.e., lower level) criteria for VOC monitoring as an added level of protection for Site occupants.

3.0 METHODOLOGY

This CAMP has been designed for the DPI at the Site. These activities, hereinafter referred to as "DPI activities," include, but are not limited to: soil borings via a rotary drill rig, installation of monitoring wells, soil sampling, and groundwater sampling. The CAMP is arranged in the following sections:

- Section 3.1: Background Monitoring – This section identifies the background monitoring (VOC and fugitive dust) to be completed at the beginning of each day and periodically throughout the day when DPI activities are being conducted. The background monitoring is used for comparing readings from the other monitoring locations.

- Section 3.2: Downwind Perimeter Monitoring – This section identifies the downwind perimeter work area monitoring (VOC and fugitive dust) to be completed continuously during the DPI activities. Action levels are identified in this section.

- Section 3.3: Nearest Potential Receptor Monitoring – This section identifies additional VOC monitoring that will be completed during DPI activities to provide an added measure of protection at this Site that would not normally be required by NYSDEC or NYSDOH (i.e., this is above and beyond the NYSDOH Generic CAMP). Action levels are identified in this section.

In addition to the above, this CAMP also contains a Vapor Emission to Sensitive Receptors Response Plan (Section 4.0). This includes actions to be taken in the event that sustained exceedences of the specified action levels occur.

3.1 Site Background Monitoring

At the beginning of each day of field work during the DPI activities, a wind sock or flag will be used to monitor wind direction in the work areas. Based upon daily wind conditions, a background monitoring location will be established. In the event that the wind direction changes, the background monitoring location will be moved to an appropriate upwind location. It should also be noted that previous work has shown that the wind at this Site has been erratic. As such, the two (2) background monitoring locations will need to be north or east of the soil drilling area. The background monitoring location will be at least 25 feet from the work area in an upwind location. Subsequent to establishing the initial background measurements (VOC and particulate, see below), background measurements will be collected every 60 minutes throughout the duration of the DPI activities for that day. The specific background monitoring is defined below:

> *Background VOC Monitoring:*
>
> A photoionization Detector (PID) capable of data logging will be used to screen the ambient air or VOCs in the background location (i.e., upwind). The PID will be calibrated daily (in accordance with the manufacturer's specifications) prior to collecting the background readings. The background readings will be collected by a 15-minute running average which will be used for comparison to the downwind perimeter monitoring (refer to Section 3.2) and the nearest potential receptor monitoring (refer to Section 3.3). After the initial reading, periodic background readings will be collected every 60 minutes.
>
> *Background Fugitive Dust Monitoring:*
>
> A DustTrak^{TM} Model 8530 aerosol monitor or equivalent will be used for measuring particulates. The meter must be capable of measuring matter less than 10 micrometers in size (PM-10). The dust monitor will be calibrated daily (in accordance with the manufacturer's specifications) prior to collecting the background readings. The background dust monitoring will consist of collecting measurements integrated over a 15-minute period and will be used for comparison to the downwind perimeter monitoring (refer to Section 3.2). After the initial reading, periodic background readings will be collected every 60 minutes.

3.2 Downwind Perimeter Monitoring

Subsequent to collecting the initial Background Monitoring measurements, continuous monitoring of the downwind perimeter of the work area (i.e., exclusion zone) will be conducted throughout the duration of the DPI activities that day. The downwind perimeter will vary depending on the work; however, in general this will be approximately 30 feet from the location of the work being completed. As discussed in Section 3.1, the Site contains 6-plus story buildings, and as such, upwind and downwind may be difficult to determine and/or may constantly change. As such, should conditions indicate varying wind patterns, two (2) downwind monitoring locations will be established. One (1) will be located on the northern portion of the Exclusion Zone and one (1) will be located on the eastern portion of the Exclusion Zone.

<u>Downwind Perimeter VOC Monitoring:</u>

A MiniRae Lite PID or equivalent will be used to continuously monitor for VOCs at the downwind perimeter location. The PID will be calibrated daily (in accordance with the manufacturer's specifications) at the beginning of each day. An audible alarm will be set on the PID to sound in the event that total organic vapors exceed 5 parts per million (ppm) above the background readings. For example, if the background reading is 2 ppm, then the alarm will be set for 7 ppm.

<u>Actions for Elevated VOC Readings</u>

1. In the event that the action level of 5 ppm above background is exceeded, then work activities will be temporarily halted and monitoring continued. If the total organic vapor level readily decreases (per instantaneous readings) below 5 ppm over background, work activities can resume with continued monitoring.

2. If total organic vapor levels at the downwind perimeter of the work area persist at levels in excess of 5 ppm over background but less than 25 ppm, work activities must be halted, the source of vapors identified, corrective actions taken to abate emissions (refer to Section 4.0 for engineering controls), and monitoring continued. After these steps, work activities can resume provided that the total organic vapor level 200-feet downwind of the work area or half the distance to the nearest potential receptor or residential/commercial structure, whichever is less – but in no case less than 20 feet, is below 5 ppm over background (background based on the 15-minute average).

3. If the organic vapor level is above 25 ppm at the perimeter of the work area, activities must be shutdown and the Vapor Emission to Sensitive Receptors Response Plan initiated, refer to Section 4.0.

All of the 15-minute readings will be recorded and will be available to NYSDEC and NYSDOH for viewing upon request. Instantaneous readings, if any, that are used for decision purposes will also be recorded.

<u>Downwind Perimeter Fugitive Dust Monitoring:</u>

A DustTrak^{TM} Model 8530 aerosol monitor or equivalent will be used for measuring particulates. The dust meter must be capable of measuring matter less than 10 micrometers in size (PM-10) and be equipped with an audible alarm. The dust meter will be calibrated daily (in accordance with the manufacturer's specifications) prior to collecting readings. The dust monitoring will be conducted continuously and the measurements integrated over a 15-minute period. The results will be compared to the background monitoring (refer to Section 3.1). An audible alarm will be set on the dust meter to sound in the event that particulate levels exceed 100 micrograms per cubic meter (µg/m^3) greater than background for the 15-minute period. For example, if the background reading is 100 µg/m^3, then the alarm will be set for 200 µg/m^3.

Actions for Elevated Particulate Readings

1. If the downwind PM-10 particulate level is 100 micrograms per cubic meter (µg/m^3) greater than background (upwind) for the 15-minute period or if airborne dust is observed leaving the work area, then Fugitive Dust Control Techniques must be employed (see below). Work may continue with dust suppression techniques provided that downwind PM-10 particulate levels do not exceed 150 µg/m^3 above the upwind level and provided that no visible dust is migrating from the work area.
2. If, after implementation of dust suppression techniques, downwind PM-10 particulate levels are greater than 150 µg/m^3 above the upwind level, work must be stopped and the Fugitive Dust Control Techniques identified below will be reevaluated. In this event the NYSDEC Project Manager will be contacted immediately. Work can resume provided that dust suppression measures and other controls are successful in reducing the downwind PM-10 particulate concentration to within 150 µg/m^3 of the upwind level and in preventing visible dust migration.

All of the 15-minute readings will be recorded and will be available to NYSDEC and NYSDOH for viewing upon request.

Fugitive Dust Control Techniques

One or more of the following dust control measures will be implemented in the event that the above action levels are exceeded:

- Apply water on exposed soils.
- Wetting equipment and test pit faces.
- Reducing test pit sizes.
- Immediately placing any investigation derived waste in drums and/or covering with plastic sheeting.

3.3 Nearest Potential Receptor Monitoring

A ppbRAE will be used to continuously monitor for VOCs between the nearest potential receptor and the work area. Specifically, the ppbRAE will be located half the distance between the perimeter of the work area (exclusion zone) and the nearest potential receptor, hereinafter referred to as the "Nearest Potential Receptor Monitoring Location". It should be noted that this location is not dependent on wind direction. The ppbRAE will be calibrated daily (in accordance with the manufacturer's specifications) prior to collecting readings. The ppbRAE will be operated in continuous mode and evaluate 15-minute running averages to account for any drift. An audible alarm will be set on the ppbRAE to sound in the event that total organic vapors exceed 1 ppm above the background readings. For example, if the background reading is 2 ppm, then the alarm will be set for 3 ppm.

Actions for Elevated VOC Readings

1. In the event that the action level of 1 ppm above background is exceeded, then work activities will be temporarily halted and monitoring continued. If the total organic vapor level readily decreases (per instantaneous readings) below 1 ppm over background at the Nearest Potential Receptor Monitoring Location work activities can resume with continued monitoring (assuming the downwind perimeter location is also below it's action level, refer to Section 3.2).

2. If total organic vapor levels at the Nearest Potential Receptor Monitoring Location persist at levels in excess of 1 ppm over background but less than 10 ppm, work activities must be halted, the source of vapors identified, corrective actions taken to abate emissions (refer to Section 4.0 for engineering controls), and monitoring continued. After these steps, work activities can resume provided that the total organic vapor level at the Nearest Potential Receptor Monitoring Location is below 1 ppm over background (background based on the 15-minute average).

3. If the organic vapor level is above 10 ppm at the Nearest Potential Receptor Monitoring Location, activities must be shutdown and the Vapor Emission to Sensitive Receptors Response Plan initiated, refer to Section 4.0.

All of the 15-minute readings will be recorded and will be available to NYSDEC and NYSDOH for viewing upon request. Instantaneous readings, if any, that are used for decision purposes will also be recorded.

4.0 Vapor Emission to Sensitive Receptors Response Plan

Engineering controls to abate VOC emissions source will immediately be put into effect if the action levels for VOC monitoring identified in Sections 3.2 and 3.3 are exceeded. These engineering controls may include:

- Vapor suppression utilizing foam vapor suppressants, polyethylene sheeting, or water.
- Backfilling of boreholes.
- Immediate containerization of drill spoils.

If the measures taken to abate the emission source are ineffective and the total organic vapor readings continue to be above the specified action levels for more than 15 minutes (5 ppm at the downwind perimeter monitoring location or 1 ppm at the Nearest Potential Receptor Monitoring Location), then the following actions shall be placed into effect.

- Occupants of the commercial buildings on-site will be advised to stay inside their respective structure and to close all windows.
- All personnel listed in the Emergency Contacts section of the HASP for this project will be contacted.
- The Site Safety Supervisor will immediately contact the local authorities (fire department) and advise them of the circumstances.

- Continuous air monitoring will be conducted at the Downwind Perimeter Location, the Nearest Potential Receptor Monitoring Location and within the work zone and 1 minute average measurements will be recorded every 15 minutes. Air monitoring may be halted or modified by the Site Safety Supervisor when two successive measurements are below the specified action levels.

If readings remain elevated above the specified action levels for a period of 60 minutes (5 ppm at the downwind perimeter monitoring location or 1 ppm at the Nearest Potential Receptor Monitoring Location) the Site Safety Officer will request that local authorities evacuate the occupants of the buildings.

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LaBella Associates, D.P.C.

300 State Street
Rochester, New York 14614

Appendix 4

Excerpts from *USEPA 510-R-96-001 Methods for Evaluating Recoverability of Free Product* (September 1996)

CHAPTER IV

METHODS FOR EVALUATING RECOVERABILITY OF FREE PRODUCT

CHAPTER IV

METHODS FOR EVALUATING RECOVERABILITY OF FREE PRODUCT

The primary objectives of a free product recovery system are to recover as much free product as possible, as quickly as possible, and with as little expense as possible. In order to design an effective and efficient free product recovery system, you need to answer several questions: “What is the areal and vertical extent of the free product?”, “How much free product has accumulated?”, “How much of the total volume is recoverable?”, and “How quickly can the free product be recovered?”. The answers to each of these questions relate to the recoverability of free product from the subsurface.

Intuitively, the most effective locations for free product recovery devices are those places where the accumulations are the greatest. Early tasks, therefore, include locating those areas where free product accumulations are the greatest and delineating the areal extent of the free product plume (or pools). Knowledge of the areal extent is also necessary to assess whether or not hydraulic containment is required. This information can be obtained from excavations and test pits, soil borings, and monitoring wells or well points.

The volume of free product present at a site should be estimated in order to help evaluate progress during the recovery phase. One of the ways to establish this estimate is to determine the hydrocarbon concentrations in soil and hydrocarbon thickness in wells. Methods used to estimate free product volumes are based on theoretical models, simplified correlations between hydrocarbon thickness in wells, and specific oil volumes. The reliability of volume estimates is typically low, with accuracy within an order of magnitude. Because of the uncertainty, we suggest that more than one method should be used for volume estimation.

The recoverability of free product from the subsurface environment is dependent upon several factors: The physical and chemical properties of the separate phase petroleum hydrocarbons, the transport properties of the geologic media, and the capabilities of engineered recovery systems. The physical and chemical properties of the petroleum hydrocarbons determine how the free product will primarily exist in the subsurface; whether as a vapor, a liquid, or dissolved in groundwater. These properties also affect how fast the free product will move and where in relation to the water table it will accumulate. Properties of the geologic media influence the rate and direction in which the free product will move. Engineered systems are designed for use within discrete operating ranges, and no one recovery system will be optimally suited for all hydrocarbon release sites. It is also important to realize that only a portion of the total volume of the release will be recoverable. Even under ideal conditions a significant proportion of the free product will remain in the subsurface as immobile residue.

Finally, the rate at which free product can be collected in wells or trenches will influence decisions on the types and number of wells, the type of collection equipment used, and the sizing of the treatment system and/or separators. Recovery rates can be estimated from the results of specialized pumping tests, the projection of initial recovery rates, and the use of theoretical models. As recovery progresses product thicknesses and saturation levels decrease, which affects recovery rates. Other factors, such as fluctuating water table elevations, can also affect recovery rates. As a result, the uncertainty associated with estimates of long-term recovery rates is high.

The relevant properties of petroleum hydrocarbons and geologic media that govern the behavior of free product in the subsurface have been discussed in detail in Chapter III. Engineered free product recovery systems are described in Chapter V. The remainder of this chapter presents methods for: delineating the areal and vertical extent of free product, estimating the volume of free product at a release site, and estimating free product recovery rates. Theoretical models used to estimate hydrocarbon volumes and recoverability are discussed only briefly.

Areal And Vertical Extent Of Free Product

The areal and vertical extent of free product must be delineated before a free product recovery system can be designed. First, the areal extent is defined by determining the free product thicknesses at available observation points. Second, using these data an isopach (thickness contour) map is developed. Locations where free product thicknesses are greatest are usually the best locations for installation of free product recovery equipment. There are several common methods used to identify locations and thicknesses of free product in the subsurface. Used either alone or in combination with one another, these methods include:

! Observation/measurement of free product in excavations or test pits.

- Observation/measurement or analysis of hydrocarbons in soil samples collected from borings.
- In situ measurements using a variety of geophysical and direct push techniques.
- Measurement of hydrocarbon thicknesses in wells.
- Observations of hydrocarbon seepage in springs or surface water bodies.

At a given site, not all the above methods may be applicable or cost effective, and they each have limitations. Excavations may provide information about free product thickness through measurement of either the thickness of floating product or the thickness of hydrocarbon-saturated soil. In either case, such measurements may not be indicative of the true free product thickness in the soil. For example, the water level in the excavation may not be representative of the ambient water table elevation. Measurements of the thickness of saturated soil should be conducted immediately after the excavation has been dug so that the soil does not have time to drain. Excavations are also generally limited to depths of 20 feet or less.

The process of collecting soil samples results in some degree of disturbance of the sample. For instance, the degree of compaction (which may affect saturation) can change especially if the samples are collected with a split-spoon sampler. The sample collection location relative to the water table and capillary fringe can also affect the degree of saturation and subsequent determination of free product thickness. Various *in situ* methods may be employed to overcome the problems associated with disturbed samples. However, some of the *in situ* methods are geophysical techniques that collect indirect data; that is the response of subsurface materials to an induced stress (*e.g.*, friction) or energy (*e.g.*, electricity, radiation) is measured and the resulting signal is correlated with a particular soil type or characteristic. Their applicability depends to a large degree upon site-specific conditions. The resolution of surface techniques generally diminishes with increasing depth. Borehole techniques require pre-existing wells or boreholes. Direct push techniques enable continuous subsurface data to be collected as well as provide the opportunity to collect samples of both soil and groundwater. The “Soil Borings” section of this chapter provides a limited discussion of direct push methods; a detailed discussion is beyond the scope of this manual. For additional information, please refer to OUST’s soon-to-be published manual on Expedited Site Assessment Methods and Equipment for Underground Storage Tank Sites, which is anticipated to be available in the late fall of 1996.

Although the thickness of a layer of free product in a monitor well can be measured with high accuracy and precision, the measured thickness is usually larger (sometimes by a factor of as much as 4) than the thickness that exists in the surrounding soil. The reasons behind the limitations of monitor wells in providing accurate information on the thickness of free product in the soil are discussed in greater detail later in this chapter.

In most instances where free product appears in a spring or surface water body, its presence is indicated only as a mulit-colored sheen. Rarely is it possible to measure either the thickness of the free product or the rate of flow. However, its presence may provide insight into migration pathways, which can aide in the design of the free product recovery system.

In developing an approach to free product delineation, consideration of each method should lead to the optimal strategy in terms of cost, time, and impact to existing operations at the site. Exhibit IV-1 provides a summary of the features of each of the above methods.

Strategy For Delineation Of Free Product

The strategy for delineating the extent of free product should involve the following steps:

- Estimate duration and volume of release.
- Evaluate potential to reach water table.
- Select methods for identifying locations of free product (*e.g.*, excavation, soil borings, *in situ* techniques, seepage observations, wells).
- Evaluate probable direction of groundwater flow and free product migration.
- Collect samples, make observations, and install wells/well points, moving outward until areal extent is delineated.

Estimation of the duration and volume of a release is initially based on review of inventory and other records in addition to interviews with site personnel. This information may not be credible or available for many sites.

Exhibit IV-1

Features of Methods for Delineating Extent of Free Product

Method of Data Collection	Data Analysis Method	Data Quality & Reproducibility	Correlation to Actual Free Product Thickness	Maximum Practical Depth	Minimum Free Product Thickness
Free Product Thickness in Excavations	direct measurement/ observation	highly variable, but generally low	poor-fair, qualitative (present or absent, much or little)	shallow, less than 20 feet	sheen
Soil Samples					
Chemical Analysis (lab or field methods)	indirect measurement	generally high quality, good reproducibility	good, quantitative	limited only by sample collection method	1 % of saturation of sample; depends on soil type
Direct Observation	direct measurement	highly variable	variable, depends on soil type	limited only by sample collection method	0.01 feet
In Situ Measurement					
Surface Geophysical	indirect measurement	highly variable, depends on method and conditions	variable	up to 100 feet	min. detectable thickness increases with depth
Borehole Geophysical & Direct Push	direct or indirect measurement (depends on method)	generally high, depends on method and conditions	good, quantitative	limited only by the depth of the boring	typically less than 1 foot
Free Product Thickness in Wells	direct measurement	high, very reproducible	poor, qualitative (requires extrapolation)	limited only by depth of well	0.01 feet
Seepage in springs and surface waters	direct measurement/ observation	low	poor, qualitative (present or absent, much or little)	not applicable	sheen

Initial remedial activities often provide direct observations of the depth to water and the presence (or absence) of free product at the water table. Knowledge of the depth to water table is useful in selecting the method of defining the locations of free product. For example, in areas with very shallow water tables (less than 8 feet), test pits excavated by backhoe may be the most cost effective approach to determining the extent of free product. If the geologic materials are coarse-grained sands or gravels, the test pits may also be used as temporary free product recovery trenches.

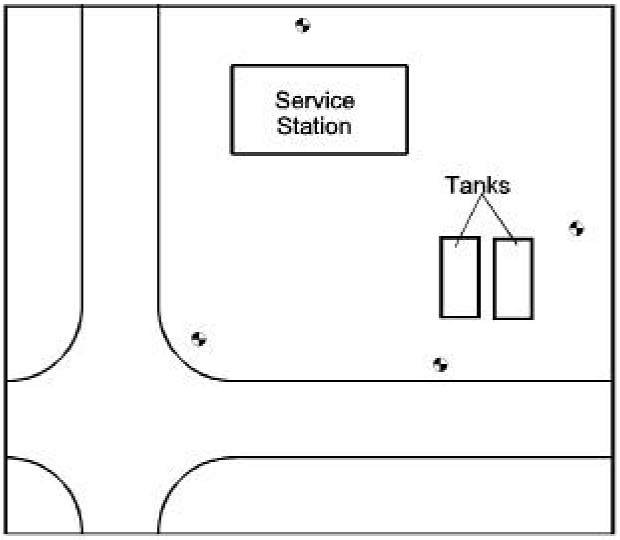
Indirect techniques to identify probable areas of free product may also be useful in focusing the free product investigation. However, these methods (*e.g.*, soil gas surveys, surface geophysical surveys) can be expensive, and the results can be difficult to equate with free product presence. One technique that holds some promise is soil gas monitoring for H_2S, which is associated with anaerobic conditions that may occur with the degradation of free or residual product in the soil (Robbins *et al.*, 1995).

The location of sampling or observation points should be focused in areas in the direction (*i.e.*, downgradient) that groundwater and free product are flowing. This direction may be inferred from the topography and location of surface water bodies (*e.g.*, streams, ponds). In shallow water table aquifers unaffected by pumping, the water table tends to be a subdued reflection of the topography (*i.e.*, groundwater flows from topographically high areas to topographically low areas). This general principle is useful in locating wells to define the direction of groundwater flow. Either traditional wells or well points may be used as locations to measure groundwater elevations. Well points, which are generally less expensive than traditional monitoring wells, can be installed with direct-push equipment during the initial site assessment phase. A minimum of three observation points (well points and/or wells) is required to define the groundwater flow direction. In addition, it is generally recommended that an additional observation point be installed upgradient of the suspected release area. These points must not all be located in the same line. If three points are used, they should be situated in an array that is approximately an equilateral triangle. If four (or more) points are used, they should be arranged in an approximately rectangular array as indicated in Exhibit IV-2. In all cases, whether monitoring wells or well points are installed, the well head or top of casing should be surveyed to establish the elevation.

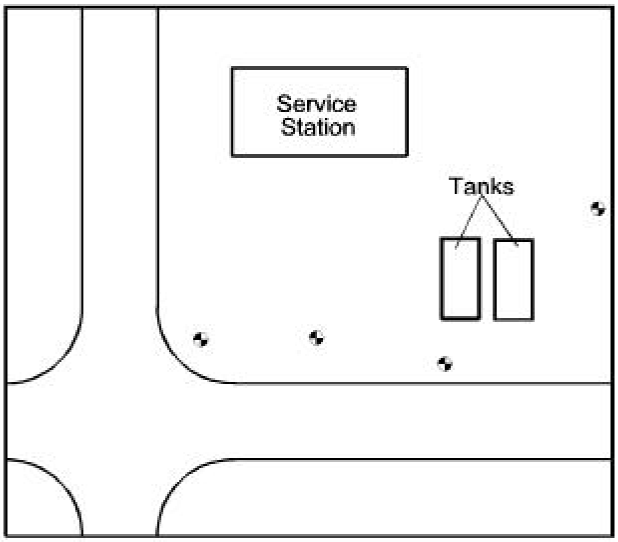
With the groundwater flow direction reliably established, additional sampling points, observation points, or wells/well points can be sited. Well installation and sampling activities generally proceed outward and downgradient from the source area. The areal extent of the plume is adequately delineated when

Exhibit IV-2

Sample Locations Of Wells/Well Points For Determining Groundwater Flow Direction



(a) Good spread, sensitive to any flow direction



(b) Poor spread, not sensitive to gradient or flow in SE-NW direction

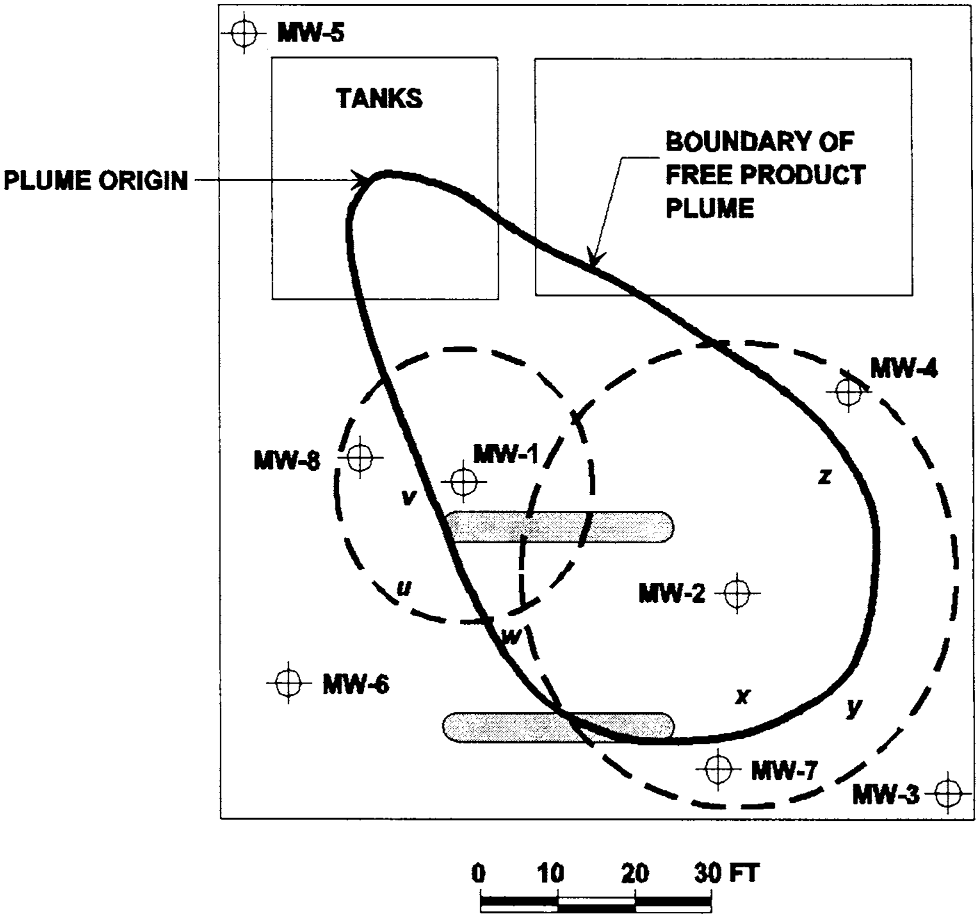
the plume is encircled by a number of observation points (and/or wells/well points) that do not indicate the presence of free product (*i.e.*, no free product is present in the well). The precision of the areal definition of the free product plume depends upon the number of observation points and distances separating the observation points both inside and outside the boundary of the plume. Although the precise number of observation points must be determined on a site-by-site basis, a sufficient number of observation points should be installed to ensure that no part of the plume is migrating in an unexpected direction. It is also important to realize how soil permeability and retention capacity affect the thickness and extent of the free product plume. For a given volume of free product released into a permeable soil (*e.g.*, sand, gravel), the plume will tend to be flat and relatively broad in extent. The same volume of free product if released into less permeable soil (*e.g*, silt, very fine sand), will form a thicker plume (especially near the point of release) and the spread will not be as broad. The decrease in plume thickness near the plume boundary is more rapid in tight formations than in permeable formations. The consequence of this is that in tight formations the distance separating inside and outside wells should be less than in permeable formations or the extent of the free product plume is likely to be overestimated.

By its nature, plume delineation is largely a trial-and-error process; the location of each additional observation point is selected based on results of the preceding ones. Because it is not practicable to install an infinite number of observation points, there needs to be a logical and systematic method which can improve plume delineation. First, we will make the assumption that the plume boundary is located half-way between two suitably positioned—one inside the plume and one outside the plume—observation points. For regular-shaped plumes (*e.g.*, circular or elliptical) the accuracy of the delineated plume area will be about ± 40 percent of the actual area. Second, we will introduce a few guidelines for suitably positioning observation points.

The well locations depicted in Exhibit IV-3 are intended to illustrate key points of the following discussion; they are not intended to be interpreted as examples of “ideal” well placement. In general, observation points that are situated within the plume boundaries can be considered to be either interior (*e.g.*, MW-2) or perimeter (*e.g.*, MW-1). For perimeter observation points, the distance between observation points located inside and outside of the free product plume should be less than 40 percent of the distance from the inside observation point to the plume origin. For example, the dashed circle around MW-1 has a radius of 16 feet, which is 40 percent of the distance (40 feet) from MW-1 to the plume origin. Well MW-8 is located within this radius and the mid-point between the two wells (marked as point “v”) is relatively close to the actual plume boundary. Error in the estimated boundary increases with distance beyond this radius. For example,

Exhibit IV-3

Placement Of Observation Points For Delineation Of Free Product Plume



well MW-6 is considerably outside the 16 foot radius and the midpoint (point “u”) significantly overestimates the plume boundary. For interior observation points, these conditions are reversed. Well MW-2 is an internal observation point, which lies 70 feet from the plume origin. The dashed circle around MW-2 has a radius of 28 feet (40 percent of 70 feet). Note that wells either on this radius (MW-4) or inside (MW-7), result in an underestimation of the plume boundary (points “x” and “z”, respectively). The midpoint (point “y”) between wells MW-1 and MW-3 (just slightly outside the 28 foot radius) is reasonably close to the actual plume boundary. If the observation point is too far outside the radius, then the extent of the plume will be overestimated. For both interior and perimeter wells, interpolation accuracy is improved if a straight line between the two observation points intersects the plume boundary at a right angle. Significant deviation from 90° results in increasing error in estimation of the plume boundary. As may be expected, there are exceptions to these guidelines. For instance, the midpoint (point “w”) between MW-2 and MW-6 is reasonably close to the actual plume boundary despite the fact that a line drawn between the two wells intersects the boundary at an angle significantly different from 90°. In spite of the uncertainty in this process, a line beginning at the plume origin drawn so that it connects points v-w-x-y-z and returning to the origin is a reasonable approximation of the actual plume boundary. The approximation could be improved by adding additional observation points to fill in the gaps: Near point “w”, between MW-3 and MW-4, and between MW-1 and MW-4.

Exhibit IV-4 shows alternative observation point spacing for free product plumes of various sizes and shapes. In reviewing a free product recovery plan, the adequacy of the delineation of the free product plume is one of the first technical factors to be checked. If the extent of the plume is not defined in all directions from the source area (plume origin), then more site characterization is required. This deficiency frequently occurs when the free product plume is not defined beyond the site property boundary.

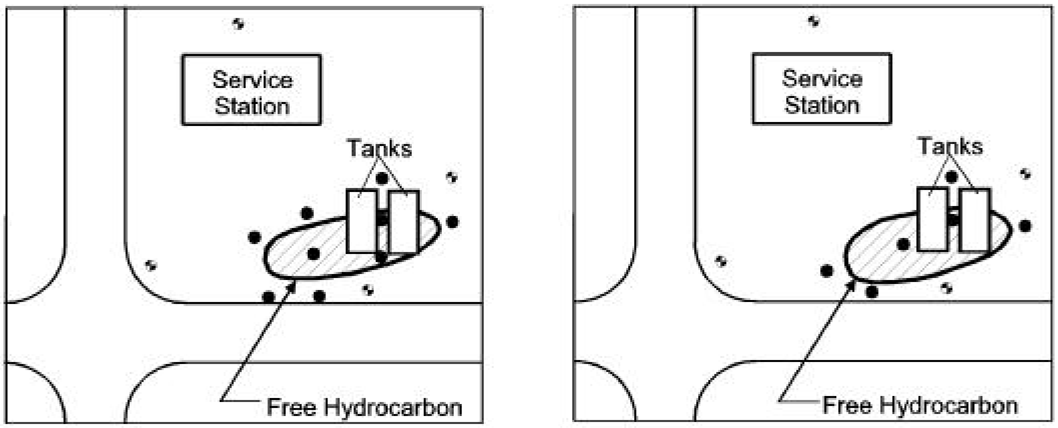
Excavations And Test Pits

Excavation of tanks or pipelines is commonly performed soon after a hydrocarbon release has been confirmed or suspected. These excavations provide for direct observation of the areal and vertical distribution of hydrocarbons. Such observations, if noted and located on a sketch map, can be used to partially identify the extent of free product. However, where the water table is below the maximum depth of the excavation equipment, the extent of lateral spreading at the water table won’t be defined.

For those sites where the water table is very shallow (*i.e.*, less than 8 feet), excavation of test pits can be a quick and cost effective approach to delineating

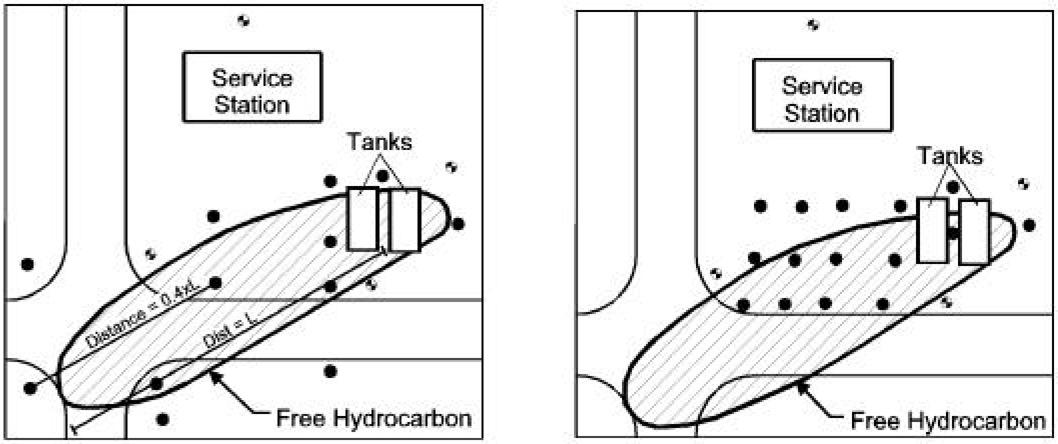
Exhibit IV-4

Delineation Of Free Hydrocarbon Plume Extent Using Soil Borings Or Probes And Monitoring Wells



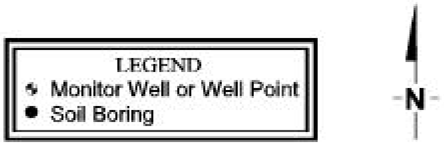
(a) Small plume, well defined in all directions, distance between soil borings about 20 feet

(b) Small plume, not delineated in NW direction



(c) Large plume, defined in all directions, with borings spread at reasonable locations

(d) Large plume, not delineated offsite-unacceptable



the extent of free product. Direct observations of the geologic media and potential preferential permeable pathways or barriers can also be obtained from test pits. The practicality of using of test pits diminishes with depth. Entry into test pits greater than 4 feet requires shoring, a trench box, or sloping of the sides of the excavation to protect workers from cave-in. Such measures although necessary, can be expensive and time consuming to construct or install. In some cases observations can be made from the surface without actually entering the excavation, but visual inspection of deep test pits from the surface is more difficult and less reliable than in shallow test pits. Also, excavated materials, if contaminated, will have to be handled appropriately (*e.g.*, treatment/disposal) which can add to the expense of the investigation.

Soil Borings

The three-dimensional distribution of liquid hydrocarbons can best be determined through a systematic program of soil sampling and free product thickness measurements. These observations may be collected through the use of traditional soil boring and sampling equipment or direct push (DP) technologies. Traditional soil boring techniques include augers (both drill rig-operated hollow-stem and solid stem as well as hand augers) and other rotary drilling methods. Core samples collected by auger rigs are typically obtained using split-spoons and shelby tubes. Direct push technologies, which are also known as "direct drive" and "soil probe" technologies, also include cone penetrometer (CPT) and relatively simple, mechanically assisted push samplers (*e.g*., impact hammers, hydraulic presses).

DP systems drive, push, and/or vibrate small-diameter steel rods into the ground. These rods may be fitted with specialized tools to collect subsurface samples and data either continuously or over discrete intervals. A wide variety of sampling tools is available for collecting samples of solids (soil), liquids (free product and groundwater) and gas (soil vapor). CPT cones are specially designed to collect continuous lithologic data as the tools are pushed at a constant rate into the subsurface. The presence of free product can be detected using laser induced fluorescence (LIF) technology or other *in situ* analytical screening methods.

DP technologies are generally suitable to depths of up to 100 feet under ideal conditions (*i.e*., unconsolidated soils free of coarse gravels and cobbles), but at most sites the depth range is between 20 and 60 feet. Deeper penetration typically requires rotary (air or mud) drilling methods. Manual techniques are generally only practical to depths between 0 and 15 feet. None of the DP technologies is applicable for sites overlying bedrock, large cobbles or boulders, or cemented sedimentary rock. Under such circumstances, even augers may not be suitable, in which case rotary drilling/coring techniques may be required.

Direct push techniques offer the following advantages relative to standard soil boring methods:

- Ability to collect samples rapidly and obtain a large number of samples.
- Capability to collect samples of soil, liquid, and gas.
- Little or no generation of soil cuttings.
- Deployment vehicles are more mobile and require less overhead clearance than drill rigs.
- Lower cost per sample in most settings.

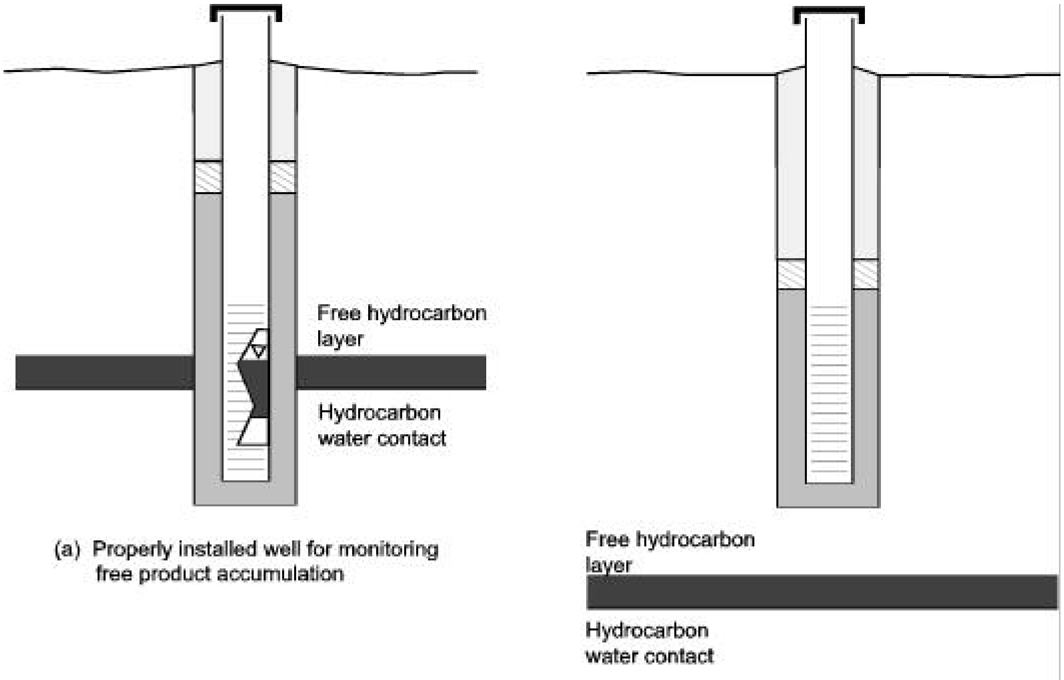
At sites where the use of DP technologies is appropriate, characterization of the subsurface can be more comprehensive than is typically achieved using traditional methods. Where free product recovery (or other remedial alternatives) is required, a more efficient and cost-effective system can be designed for sites that are better characterized. The additional expense of a site characterization conducted using DP technologies can be recovered (possibly many times over) in savings achieved during the remediation phase. However, because the size of the DP borehole is small, installation of free product recovery wells usually must be accomplished with traditional drilling rigs.

Monitor Wells

Properly installed and constructed monitor wells can be used both to delineate the extent of free product and monitor temporal changes in free product accumulations. However, it is also important to realize that monitor wells are subject to significant limitations in their ability to provide accurate measurements of the thickness of free product in the surrounding soil. Free product can accumulate in a well only if the well is open (*i.e.*, screened) across the zone of free product (Exhibit IV-5a). A well screened above the water table will generally be dry (Exhibit IV-5b). A well screened below the zone of free product will collect water but no free product (Exhibit IV-5c). Within a well with a properly positioned screen, the thickness of free product typically fluctuates in response to changes in water table elevation. With each rise (or fall) in water table elevation, the measured thickness of free product also changes, resulting in a different calculation of “actual” thickness in the soil (Durnford, *et al.*, 1991). Where a free product recovery plan relies on wells for free product delineation, the reviewer should check the construction diagram of each well and verify that the open (screened) interval of each well straddles the water table. Where wells are initially installed with short screens (*i.e.*, 5 feet or less), changes in the water table

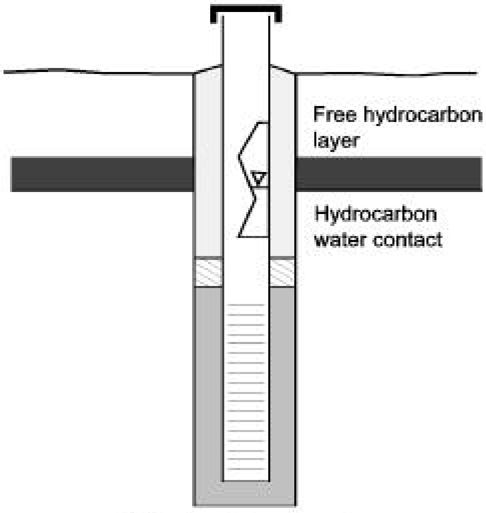
Exhibit IV-5

Monitoring Well Installations And Their Ability To Detect Free Product



(a) Properly installed well for monitoring free product accumulation

(b) Well is dry



(c) Well contains only water

Source: API, 1996. A Guide to the Assessment and Remediation of Petroleum Releases, 3rd edition. API Publication 1628, Washington, DC. Reprinted courtesy of the American Petroleum Institute.

elevation may result in a dry well (declining water table) or in a well that is screened below the zone of free product (rising water table). Even in properly constructed wells, the absence of free product may not necessarily indicate that petroleum hydrocarbons (including free product and residual and trapped fractions) are not present in the soil. Similarly to the observation that water may take days or weeks to enter some monitor wells constructed in clayey soil, free product may not initially appear in monitor wells. Such a condition indicates that the relative permeability with respect to free product is very low, hence the mobility of the free product is also low. This may also result in a lower calculated volume of free product.

Monitor wells may be installed by any of several methods. (See Driscol, 1986, and Aller *et al.,* 1989, for detailed descriptions of modern well drilling methods.) For unconsolidated media, hollow-stem augers are used most commonly. The well casing and screen are inserted through the opening in the auger. Depending on the stability of the well bore, the sand pack, sealing, and grout can be placed as the augers are retracted or after the augers have been removed. After the monitor well has been constructed, it should be developed by surging or pumping until water is free of turbidity. The development of new wells in very fine grained materials may not be practical because of its slow recharge rate. For a well with a slow recharge rate, development involves dewatering the well and allowing it to recover for one or more cycles. The development of the monitor well will tend to pull in free product and overcome capillary barriers as a result of the smearing of fine-grained material on the well bore. Without adequate development, free product may accumulate very slowly in the monitor wells (over a period of months). In these cases, initial estimates of the extent of free product may be understated. Product may also enter slowly, or not at all, if the wrong sized sand (filter) pack has been installed. The sand (filter) pack must be four to six times coarser than the aquifer material (Hampton and Heuvelhorst, 1990). The rate of product entry and recovery in wells can be improved by using hydrophobic filter packs (Hampton, 1993).

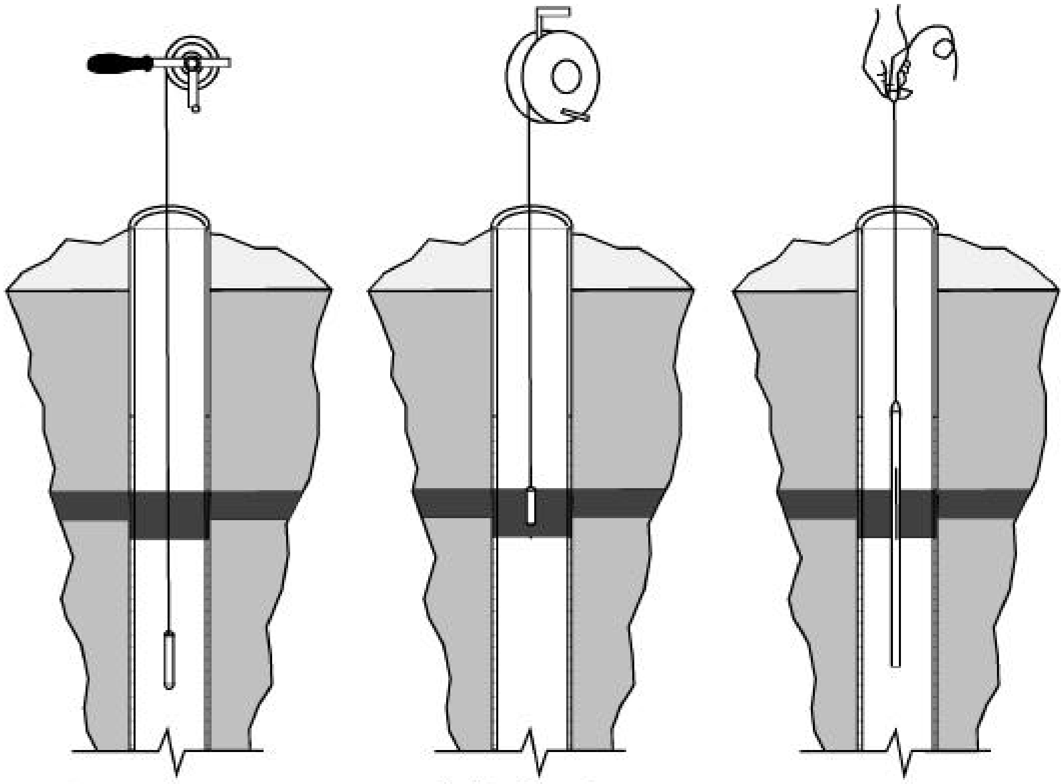
The presence of free product at a well is indicated by the accumulation of a measurable thickness of hydrocarbons in it. Three following methods (see Exhibit IV-6) are commonly used to measure free product thickness in a well:

! Steel tape and paste
! Interface probe, and
! Bailer.

The pastes used with the steel tape are sensitive to hydrocarbons and water. Commercially available interface probes sense the presence of both oil and water. The first two methods are accurate to within about 0.01 foot and are

Exhibit IV-6

Methods For Measuring Accumulations Of Free Liquid Hydrocarbons In A Well



a. Steel tape with water and hydrocarbon-finding pastes

b. Interface probe

c. Bailer

Source: API, 1996. A Guide to the Assessment and Remediation of Petroleum Releases, 3rd edition. API Publication 1628, Washington, DC. Reprinted courtesy of the American Petroleum Institute.

convenient for determining the elevation of the air/free product and oil/water interfaces. Whenever possible measurements should be taken using either steel tape and paste or an interface probe. A bailer is a transparent cylinder with a check valve at its base. The bailer method can significantly under- or over-estimate the thickness of free product in the well and should not be used for determining the elevations of air/free product and free product/water interfaces. Disposable bailers, which are commonly dedicated to monitoring wells containing free product, typically collect an unrealistically small product thickness because of the small size of the intake holes. The use of bailers should be limited to verification of the presence of free product in a well or collection of a sample of it. Bailers can be used to remove liquids from monitoring wells during bail-down tests that are designed to determine the rate of free product recovery into wells.

Volume Estimation

Knowledge of the volume of hydrocarbons in the subsurface is useful for evaluating the performance of a free product recovery system in terms of both total volume recovered and time required for recovery. In some instances the original release volume may be unknown but can be estimated by calculating the volume of free product present in the subsurface. Several methods can be used to estimate hydrocarbon volumes. These include:

- Compilation of historical information on release events and from inventory records.
- Soil sampling and analysis for total petroleum hydrocarbons.
- Correlation of the thickness of free product measured in monitoring wells to total volume of free product.
- Evaluation and projection (extrapolation) of free product recovery data.

The first two approaches yield estimates of total hydrocarbons--residual and free--present in the subsurface. The last two methods--product thickness measured in monitor wells and recovery data--provide estimates of the volume of free product. None of these four methods are entirely precise in most settings because of limited and uncertain data. Even where substantial data are available and several estimation methods used, volume estimates with an uncertainty of minus 50 percent to plus 100 percent are the best that can be expected.

Exhibit IV-7 presents a brief summary of the salient points of each of these four methods.

The relative mass present as free and residual liquid hydrocarbons is large compared to the mass of dissolved or vapor phase hydrocarbons in most subsurface settings. Residual hydrocarbons may represent as much as 50 to 80 percent of the total volume that was originally released. Recoverable free product typically represents 20 to 50 percent of the total. The ratio of free product to residual liquid hydrocarbons tends to decrease with time as plume migration and other processes occur that trap free hydrocarbons (*e.g.*, rising or falling water table). The relative permeability (and mobility) of the free product decreases as more of the free product is recovered and the level of liquid hydrocarbon saturation decreases. When the saturation approaches the residual saturation of the geologic medium, free product will stop flowing readily into monitor/recovery wells. At this point, the recovery well or recovery system should be switched to operate intermittently or possibly turned off altogether. Small quantities of liquid hydrocarbons may continue to slowly drain into wells, but the rates of drainage are usually not sufficient to justify continuous operation of the recovery system.

Volume Estimates Based On Release History

Historical records of release events and hydrocarbon inventories can be used to estimate the total amount of hydrocarbons lost. When accurate inventory or release data are available, the amount lost is likely to be greater than the amount in the subsurface as a result of volatilization and biodegradation. The reliability of historical data ranges widely, but generally, the older the information, the less reliable it is. Furthermore, historical data generally cannot be used to characterize phase distribution in the subsurface.

Even though volume estimates based on release and inventory data may have limited reliability, these estimates are useful in at least two important ways. First, the volume estimate based on historical data can be compared with volume estimates obtained with other approaches to provide a check on the other methods. Second, historical information on when releases began can provide a basis for initial estimates of the extent of free product migration that can be used to assist in locating sampling points and wells for site characterization.

Exhibit IV-7
Methods For Volume Estimation

Method	Approach & Results	Advantages	Disadvantages
Release History	Review inventory records to determine volume(s) and date(s) of release(s).	Relatively simple and statistically accurate if accurate historical data are available.	Data rarely accurate given numerous potential error sources (*e.g.*, measurement technique, volume changes due to temperature)
TPH Concentration in Soil Samples[1]	Convert TPH concentrations in soil samples to saturations and integrate these values over the area of contamination.	Data are relatively easy to collect; several methods are available for data integration.	Calculations required are relatively complicated; requires a lot of data to reduce uncertainty associated with calculated volume; results may differ among various methods for data integration; TPH analysis may not be representative of actual petroleum hydrocarbon saturations.
Product Thickness in Wells	Measure the thickness of the accumulated layer of free product in all monitoring wells.	Free product thickness measurements in monitor wells are routinely collected on a regular basis; the thickness of the free product layer in the monitor well can be measured quite accurately; several methods are available for data analysis.	Product thickness in wells usually exaggerates the thickness in the aquifer--this effect is more pronounced in finer-grained geologic materials; none of the methods that correlate product thicknesses measured in wells to actual product thickness in the soil are reliable either in the field or in the laboratory.
Extrapolation of Recovery Data	Sum the cumulative product recovery volume and an estimate of the residual volume.	Recovery data are routinely collected.	Works best during later stages of recovery; many factors can bias recovery (*e.g.*, smearing); requires two types of data.

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[1] The U.S. Air Force is currently working on an alternative method of using TPH values based on examination of TPH fractions. EPA will release information on this process after peer review has been completed.

Volume Estimates Based On Soil Samples

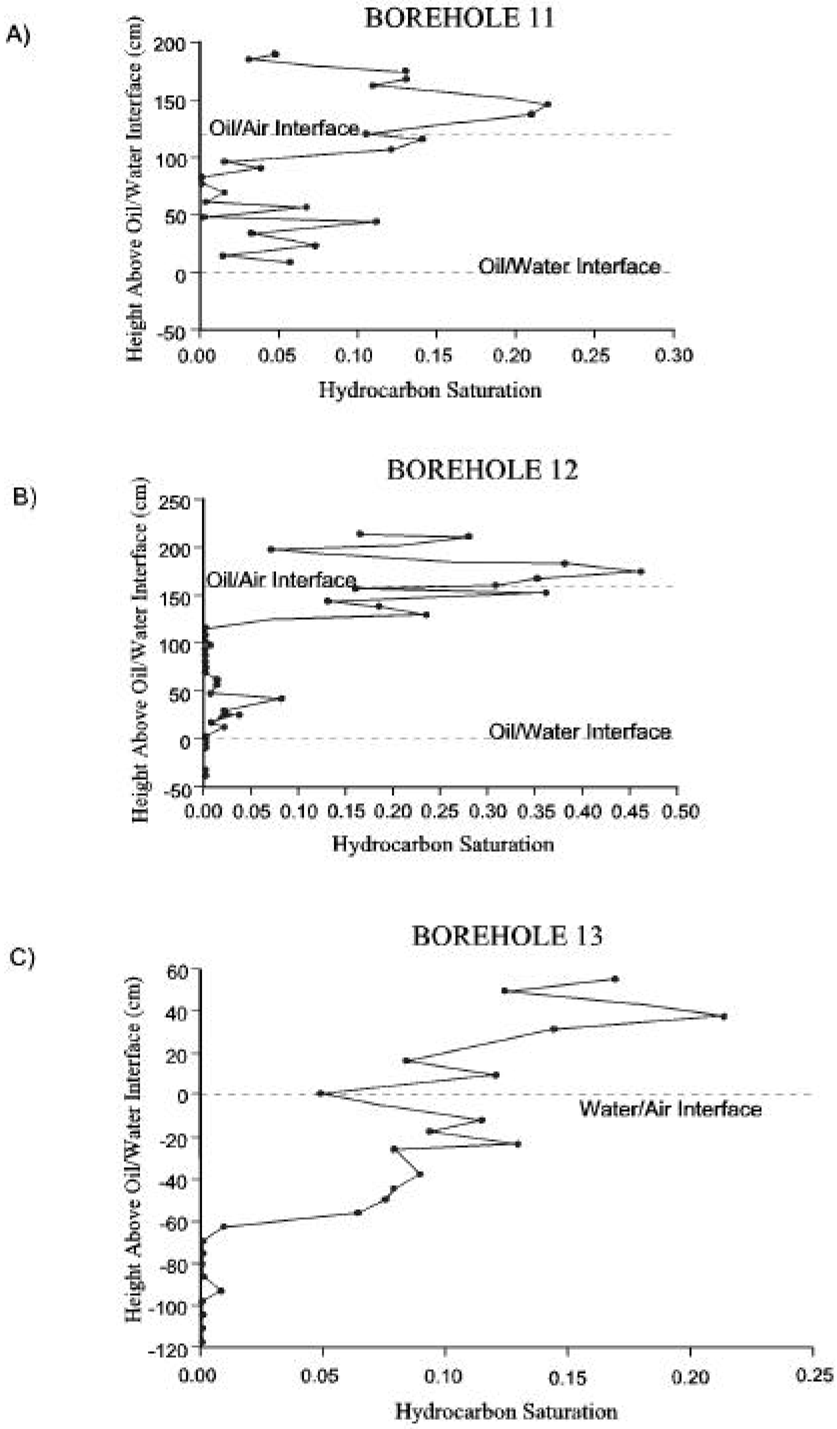
Estimation of the volume of free product in the subsurface based on soil sample data first requires the collection of soil samples and their subsequent analysis for hydrocarbon content. Hydrocarbon content in soil samples can be measured by a variety of standard laboratory methods. These methods include solvent extraction, solvent extraction with distillation, and centrifuging (Cohen and Mercer, 1993; Cohen *et al.*, 1992). The total petroleum hydrocarbons (TPH) analysis commonly used in site assessments is based on solvent extraction. For sites where sufficient TPH data are available, volumes of hydrocarbons in the unsaturated and saturated zones can be estimated. One limitation of TPH data is that it does not distinguish between individual petroleum hydrocarbons or between petroleum hydrocarbons and other non-petroleum organic matter that may be present in the soil sample.

The estimation of hydrocarbon volumes based on soil sample data is subject to significant uncertainty because of the sparseness of the data and the often extreme variability in hydrocarbon concentration within the soil. Exhibit IV-8 shows how variable hydrocarbon saturation can be within the same boring and between three different borings at a typical site. The detail shown in Exhibit IV-8 is much greater than that obtained during most site characterization investigations, but even with this amount of detail at one or more boring, there is still tremendous uncertainty about concentrations in the soil between the borings.

The procedure for estimating liquid hydrocarbon volumes from TPH data involves two calculation steps: (Step 1) TPH results are converted to saturation values at each point, and (Step 2) the volume of liquid hydrocarbons is determined by integrating point saturation data over the volume of subsurface where hydrocarbons are present. The conversion calculation (Step 1) is straightforward and is illustrated in Exhibit IV-9. Integration of the total hydrocarbon volume (Step 2) can be accomplished using standard interpolation and integration techniques. As a simple example, TPH (saturation) results are plotted at their collection locations on a site map. Contours of equal saturation are drawn on the map. The area and volume represented by each contour level is then calculated. Integration is merely the summation of the individual volumes. There are a number of more sophisticated techniques, including computer software, but discussion of these is beyond the scope of this manual. It is also important to recognize that interpolation and integration methods yield only approximations of what is actually present in the field and different methods using the same data set can result in volume estimates that range from minus 30 percent to plus 50 percent. In general, as the number of data points increases the error associated with the method decreases.

Exhibit IV-8

Measured Hydrocarbon Saturation Profiles At Three Boreholes Showing Variability Due To Vertical Heterogeneity



Source: From Huntley, et. al., 1992

Exhibit IV-9

Calculation Procedure To Convert TPH Data From Soil Samples To Hydrocarbon Saturations

TPH analysis results for soil samples may be converted to hydrocarbon saturation by the following equation:

$$S_o = TPH \times \frac{(1 - f)\, r_{gr} \times 10^{-6} \,\frac{kg}{mg}}{f \;\, r_o}$$

where:

S_o = total hydrocarbon saturation (dimensionless)
TPH = total petroleum hydrocarbon concentration in mg/kg
r_{gr} = grain density (typically 2.65 g/cm^3)
f = porosity (dimensionless)
r_o = density of the hydrocarbon, liquid (g/cm^3).

This equation applies to both the unsaturated and saturated zones.

The amount of free hydrocarbon present can be calculated if residual hydrocarbon saturation is known or estimated. Usually residual saturations are not known or measured, but literature values (*e.g.*, Mercer and Cohen, 1990) can be used as estimates. The free hydrocarbon saturation is given by:

$$S_{of} = S_o - S_r$$

where:

S_{of} = free hydrocarbon saturation
S_r = residual hydrocarbon saturation.

Volume Estimates Based On Product Thickness In Wells

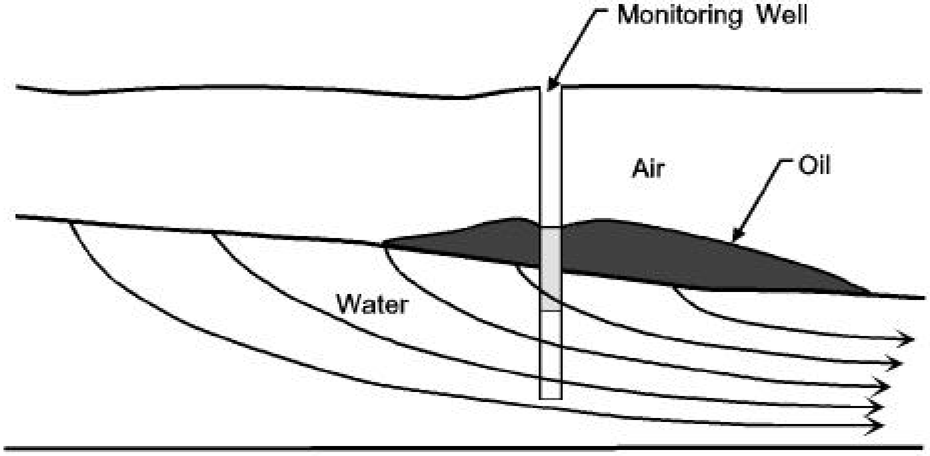
The limitations of monitor wells in providing representative measurements of free product thickness in the adjacent soil are well documented. Fluctuations in the water table can result in large differences in measured hydrocarbon thickness even though the in situ volumes are not significantly changed. Increases in hydrocarbon thickness are commonly observed with declining water tables. API (1989) attributes the thickness increase to drainage from the unsaturated zone. As the water table falls, hydrocarbons previously trapped as a residual phase can become remobilized and enter into wells. Kemblowski and Chiang (1990) relate the changes to preferential fluid flow through the well (Exhibit IV-10).

Many investigators have tried to develop methods to explain how small amounts of mobile hydrocarbons can lead to exaggerated thicknesses of hydrocarbons measured in wells. Hampton and Miller (1988) and Ballestero *et al.*, (1994) provide comprehensive reviews of the methods used to estimate the thickness of free product in the adjacent soil from measurement in monitor wells. A comparison of the predictability of these alternative methods indicates an order of magnitude accuracy of the predicted versus the measured free product thickness among the methods. These investigations can be grouped into two primary approaches: (1) Derivation of empirically-based correlations--typically based on fluid density differences, grainsize of the geologic media, or height of the water capillary fringe, and (2) development of models based on idealized capillary pressure-saturation curves. In spite of the intense attention that has been focused on developing a correlation between free product thickness measured in wells and volume of free product in the soil, none of the available methods has been particularly reliable when tested either in the field (Durnford *et al.*, 1991; Huntley *et al*., 1992; and Ballestero *et al*., 1994) or even in the laboratory (Hampton and Miller, 1988). Durnford *et al*., (1991) summarize the limitations of the methods developed to relate the free product thickness measured in monitor wells to the volume of free product in the soil as follows:

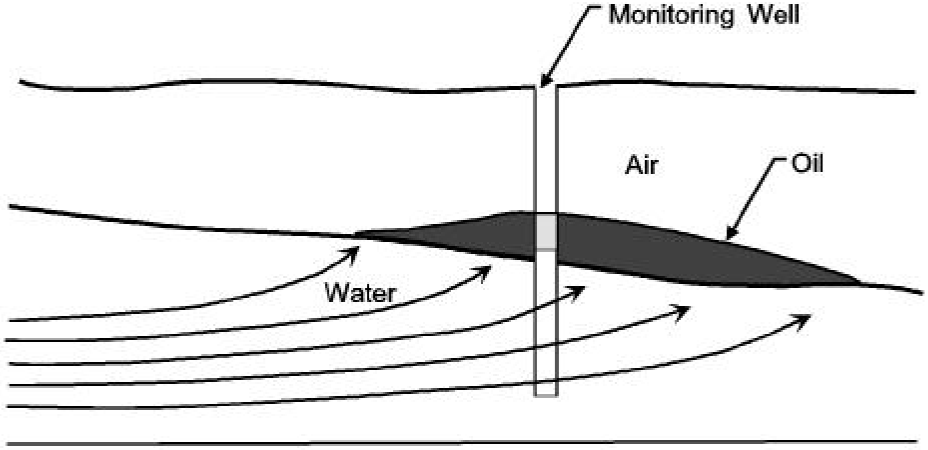
- Free product thicknesses observed in monitoring wells change over time as the water table fluctuates. Each different measured thickness of free product results in a different calculation of free product in the aquifer, even if the actual volume of free product (including residual and trapped) hasn’t changed.

Exhibit IV-10

Effects Of Falling Or Rising Water Table On Hydrocarbon Thicknesses Measured In Wells



(a) Hydrocarbon thickness increase for falling water table



(b) Hydrocarbon thickness decrease for rising water table

Source: Kemblowski and Chiang, 1990

- None of the estimation methods accounts for residual and trapped petroleum hydrocarbons--a portion of these fractions can be returned to the free product fraction as the water table moves up or down.

- Methods that are based on measurement of soil and fluid properties require measurements (*e.g.*, curves of capillary pressure vs water saturation) that are difficult to obtain in the field, and laboratory-derived measurements may not accurately represent field conditions.

- None of the methods account for spatial variability (heterogeneity) of aquifer parameters. The movement of free product is strongly dependent upon aquifer heterogeneities, which are rarely represented adequately by "average" properties.

Despite the drawbacks with these volume estimation methods, they are frequently used in practice. To illustrate how some of these methods are used, we present a comparison of seven methods reported in Ballestero *et al.*, (1994). The seven different approaches can be grouped into the following four categories:

- Correlation based on the density of the liquid hydrocarbon (de Pastrovich *et al.*, 1979);

- Correlation based on properties of the geologic medium (Hall, *et al.*, 1984);

- Correlation based on the height of the water capillary fringe (Blake and Hall, 1984; Ballestero *et al.*, 1994; and Schiegg, 1985); and

- Models based on idealized capillary pressure relationships for homogeneous porous media (Farr *et al.*, 1990; and Lenhard and Parker, 1990).

Exhibit IV-11 summarizes the results of calculations for each of the different methods listed above using data from laboratory experiments reported by Abdul *et al.*, (1989), with additional parameter values acquired (where

Exhibit IV-11

Comparison Of Seven Alternative Methods For Correlation Of Product Thickness Measured In A Monitor Well To Actual Thickness In The Soil

Calculated Results (Hydrocarbon Thickness in Soil)

Measured hydrocarbon thickness in the soil (cm)	**de Pastrovich *et al*. (1979)**	**Hall *et al*. (1988)**	**Blake and Hall (1984)**	**Ballestero *et al*. (1994)**	**Schiegg (1985)**	**Farr *et al*. (1990)**	**Lenhard and Parker (1990)**
---	1.1	-6.5	-16	-16	-28	2.3	7.1
1	12	50.5	1.1	1.1	29	24.3	74.3
3	13	55.5	4.4	4.4	34	26.2	80.2
7	13.9	60.5	9.7	9.7	39	28.1	86.1
13	16	71.5	13.4	13.4	50	32.4	99.1

Note: All values in centimeters except those for Farr *et al*. (1990) which are volume in cm^3/cm^2.

This comparison is based on a study published by Ballestero *et al*. (1994) using data published in Abdul *et al*. (1989). Additional data required for the methods of Lenhard and Parker (1990) and Farr *et al*. (1990) were obtained from their respective papers. Note that the results presented above are only applicable for the data specified in this example. The use of different data may alter the relative performance of the methods. Refer to the Appendix for a more complete presentation of the individual equations used in this comparison.

necessary) from the individual papers. A more complete presentation (including the equations, variable descriptions, input data and discussion of the salient features) is included in the Appendix. It is important to realize that the relative performance of these methods is dependent upon the specific experimental conditions. Given another set of data obtained from a different experiment using different soil (with different grainsize, porosity, and residual saturation) and different liquid hydrocarbon, the relative performance may be radically different. To reiterate from the opening paragraph in this section, none of the available methods has been particularly reliable when tested in either the field or the laboratory. For any given site, it is probably not likely that the method that will ultimately yield the closest match to conditions in the field can be chosen *a priori*. However this is not to say that there is no point in using these methods to estimate free product volumes. On the contrary, free product thickness data collected from monitor wells is typically plentiful, easily collected, and is usually accurate. In many instances these data may be all that are available. What is most important is to not rely too heavily on one method over another. The best approach is to use more than one method so that a probable range of volumes can be calculated.

Volume Estimates Based On Extrapolation Of Free Product Recovery Data

The difference between the volume of free product released and the volume recovered equals the volume remaining in the subsurface. Often the volume of the release is not known, but in theory it can be determined if the volume of free product that has been (or is anticipated to be) recovered and the volume remaining (or is anticipated to remain) in the subsurface is known. Knowledge of any of these three volumes is associated with a degree of uncertainty, and it is usually not possible to quantify the error associated with estimates of these volumes. Many factors contribute to this uncertainty. Some of the components of the types of petroleum hydrocarbons typically stored in USTs are volatile and/or soluble, and are therefore not likely to be measured as residual hydrocarbons. Biodegradation may further decrease the amount of hydrocarbons present in the subsurface. As was discussed previously, hydrocarbon saturations in soil borings are highly variable in both the vertical and horizontal directions. Samples with anomalously high or low saturations can bias estimates of total residual hydrocarbons remaining in the subsurface. Also, it is important to recognize that the rate of free product recovery typically exhibits a logarithmic decrease with time. The rate of decrease can be quite variable even on the same site due to heterogeneities in the soil which influence residual saturation and relative permeability. The estimate of product remaining in the subsurface as either free or residual changes constantly with time as recovery progresses. Despite these limitations, this method may offer the best (or only) means for estimating volumes at a particular site. Although this method works best late in the recovery phase (after the cumulative recovery curve levels off), it can be used at any time with the understanding that volume estimates based on early recovery data will be associated with a higher degree of uncertainty. Methods to estimate free product recovery rates are presented in the following sections.

Estimation Of Recovery Rates

An important design consideration for free product recovery is the rate at which liquid hydrocarbons can be collected by pumping or skimming techniques. The rate of recovery will depend on the design of the recovery system, the type(s) and distribution of free product in the subsurface, and the hydrogeological conditions. Expected recovery rates are used to size the free product storage tanks and oil/water separators, and, to a lesser degree, to select and size recovery equipment and treatment equipment. Not only is it important to estimate the initial recovery rates but also to predict how the recovery rates will change with time after recovery starts. Estimates of recovery rates can be obtained from field tests (*e.g.*, bail down tests, pumping tests) or from multiphase flow analysis. Usually, recovery rates of free product decline after startup because wells and trenches are located in areas where the volumes of free product are highest. In some settings where wells or trenches pull free product from some distance, recovery rates may increase for a significant duration before declining.

Bail Down Test And Pumping Tests

A bail down test involves removing the free product from a well by bailing and measuring the thickness of and depth to free product in the well as it recovers. These tests have been used to estimate free product thickness by some investigators (Hughes *et al.*, 1988; Wagner *et al.*, 1989; and Gruszczenski, 1987) with limited success. These tests can easily provide estimates of initial recovery rates for a skimming type operation (see Exhibit IV-12, Method 1). In order for the results of a bail down test to be applicable, the free product recharge rate should be slow relative to the rate of groundwater recharge. Where free product recharges the well in less than a few minutes, it is difficult to accurately monitor recovery rates (Hampton, 1993).

For systems where free product will be collected by active pumping of groundwater and product, a pumping test can be used to estimate initial free product recovery rates (see Exhibit IV-12, Method 2). Pumping tests (or aquifer tests) are usually performed to determine groundwater flow properties such as hydraulic conductivity and transmissivity. Estimates of free product recovery rates can be obtained by collecting additional data in conjunction with a standard (groundwater) pumping test or by conducting a specialized pumping test or pilot test.

Exhibit IV-12

Sample Calculations For Estimating Initial Free Product Recovery Rates

Method 1. Bail down testing (Applicable to skimming-type recovery systems).

Field Data

Recovery Time		Free Product Thickness (ft)
2	min	0.01
4	min	0.03
10	min	0.12
30	min	0.30
1	hour	0.51
2	hours	0.85
4	hours	0.95
8	hours	0.98
24	hours	1.15
48	hours	1.10

Inside Diameter of Well Screen = 4 inches
Radius = 2 inches
= 0.166 foot

1. Maximum thickness from table. = 1.15 feet

2. 80% x maximum thickness recovery.
(0.8 x 1.15) = 0.92 foot

3 Time corresponding to 80% of recovery interpolated from table.
3 hours 24 min = 204 min

4. Compute gallons per foot of oil thickness in well screen.
π x (well radius in ft)^2 x (conversion factor ingal/ft^3) = gal/ft
π x (0.166)^2 ft^2 x 7.48 gal/ft^3 = 0.65 gal/ft

5. Compute average recovery rate to 80% recovery.
0.65 gal/ft x 0.92 ft/204 min = 0.003 gal/min = 4.2 gal/day

Method 2. Constant rate pump test (Applicable to free product recovery with water level depression).

Field Data

Time Since Pumping Started		Cumulative Hydrocarbons Collected
10	min	0.0 gal
20	min	0.3 gal
40	min	0.8 gal
1	hour	2.5 gal
2	hours	5.8 gal
4	hours	14.6 gal
8	hours	23.8 gal
24	hours	52.1 gal

Pumping Rate = 10 gal/min

1. Compute average hydrocarbon recovery rate from table for 24 hours.

52.1 gal/24 hours = 2.17 gal/hour
= 0.0361 gal/min

2. Compute

$$\text{Hydrocarbon Recovery Ratio} = \frac{\text{Hydrocarbon Recovery Rate}}{\text{Total Pumping Rate}}$$

$$\frac{0.0361\text{ gal/min}}{10\text{ gal/min}} = 0.00361 = 0.361\%$$

A standard pumping test involves pumping groundwater at a constant rate and monitoring changes in groundwater elevations in the pumping and nearby wells during the test. If free product is present in the vicinity of the well, the pumped fluid will contain both free product and groundwater. The ratio of free product recovered to total fluid recovered can be determined at different times during the test by collecting samples of pumped fluid. These samples may show considerable variability, so as many samples as practicable should be collected during the test. Where the ratios of recovered product to total fluid are more than a few percent, simple volume measurements of the separated liquids may be used to determine the recovery ratio (see Exhibit IV-13). Usually the recovery ratio of free product to total fluid is less than a few percent, in which case the ratio may be determined by a standard TPH or oil and grease analytical method.

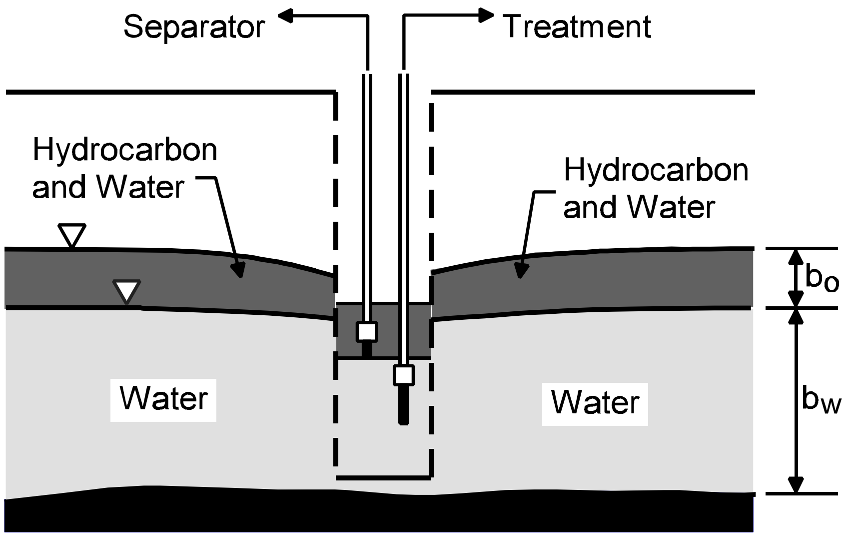
Estimates of free product recovery rates can also be obtained from pilot tests or records of free product pumping that may have been performed as an interim or emergency removal action. Information from pilot tests or prior free product recovery systems provide the best estimates of expected free product recovery rates because the duration and rates of pumping are usually much greater than those of bail down or pump tests.

Multiphase Flow Analysis

The theory of multiphase flow in porous media has been widely used in petroleum reservoir engineering for over 50 years. During the past decade, these same theories have been applied to analysis for environmental applications. Because multiphase flow theory results in complex non-linear partial differential equations, few simple solutions to practical problems are available. One such solution is presented in the preceding section (see Exhibit IV-13). Commonly, the governing equations are solved by a variety of sophisticated numerical techniques using computer models.

Exhibit IV-13

Computational Procedure For Determining Ratio Of Free Product Recovery To Total Fluid Recovered From A Single Recovery Well



Basic Equations:

Mobility of Water $= \dfrac{k\,k_{rw}\,r_w\,g}{m_w}$

Transmissivity of Water, T_w $= \dfrac{b_w\,k\,r_w\,g}{m_w}$

Mobility of Free Product $= \dfrac{k\,k_{ro}\,r_o\,g}{m_o}$

Transmissivity of Free Product, T_o $= \dfrac{b_o\,k\,\overline{k_{ro}}\,r_o\,g}{m_o}$

where:

k is the intrinsic permeability (L^2)
k_{rw} is the relative permeability of water (dimensionless)
k_{ro} is the relative permeability of free product (dimensionless)
$\overline{k_{ro}}$ is the average relative permeability of free product layer (dimensionless)
r_w is the density of water (ML^{-3})

r_o is the density of free product (ML^{-3})
g is the gravitational constant (LT^{-2})
m_w is the viscosity of water ($ML^{-1}T^{-1}$)
m_o is the viscosity of free product ($ML^{-1}T^{-1}$)
b_o is the thickness of free product layer (L)
b_w is the thickness of aquifer below free product layer (L)

Assumed: Water transmissivity of free product layer is negligible

Exhibit IV-13 (continued)

Computational Procedure For Determining Ratio Of Free Product Recovery To Total Fluid Recovered From A Single Recovery Well

General Equation:

$$\text{Ratio} \left(\frac{\text{Free Product Recovery Rate}}{\text{Total Fluid Recovery Rate}} \right) = \frac{Q_o}{Q_o + Q_w} = \frac{T_o}{T_o + T_w}$$

$$= \frac{b_o \overline{k_{ro}}\, r_o / m_o}{b_o \overline{k_{ro}}\, r_o / m_o \quad + \quad b_w r_w / m_o}$$

where:

Q is volumetric flowrate of free product (o) or groundwater (w)

Assumed: Same hydraulic gradients exist in free product layer and groundwater

EXAMPLE:

A 2-foot-thick hydrocarbon layer has an average hydrocarbon saturation of 0.5, a viscosity of 4 centipoise, a density of 0.9 g/cm^3. The average relative permeability for a free product saturation of 0.5 is assumed to be 0.25. The pumping well is screened across the hydrocarbon layer to the base of the aquifer which has a saturated thickness of 20 feet including the hydrocarbon layer.

$$\frac{Q_o}{Q_o + Q_w} = \frac{T_o}{T_o + T_w} = \frac{2\,ft \times 0.25 \times 0.9\,g/ml/4cp}{2\,ft \times 0.25 \times 0.9\,g/ml/4cp \;+\; 18\,ft \times 1g/ml/1cp}$$

$$= \frac{0.1125}{0.1125 + 18} = 0.0062$$

For a total fluid production rate ($Q_o + Q_w$) of 2 gallons per minute, determining free product recovery rate, Q_o.

$$Q_o = \text{Ratio x } (Q_o + Q_w) = 0.0062 \text{ x } 2 \text{ gpm} = 0.0124 \text{ gpm}$$

Calculations Of Initial Free Product To Total Fluid Recovery Ratio. A straightforward calculation based on the relative mobility of free product and water can be used to determine the ratio of free product to total fluid production under pumping conditions in a single well. This procedure is described and illustrated in Exhibit IV-13, which shows that for thin hydrocarbon layers and moderately high viscosities, the recovery of free product will be a small portion of the total fluid production in the well.

Use Of Computer Models. In theory, computer models based on multiphase flow concepts can be used to predict free product recovery rates. Selection of a model for a particular site must be made carefully because all models are not appropriate for all sites. Factors to be considered include; complexity of site geology, availability of input data, and special features of the site (*e.g.*, pumping wells, fluctuating water table). Some of the numerous multiphase flow models that have been developed include:

- Simplified models simulating downward migration of liquid hydrocarbons through the unsaturated zone, radial transport of a hydrocarbon lens in the watertable, and radial migration of hydrocarbons to a recovery well (El-Kadi, 1992; El-Kadi, 1994; Weaver *et al*., 1994; and Charbeneau and Chiang, 1995).

- Complex numerical models (finite-difference and finite-element) of immiscible multiphase flow in porous media in cross-section or three-dimensional (Faust *et al*, 1989; Kaluarachchi and Parker, 1989; Katyal *et al*., 1991).

- Complex numerical models of areal hydrocarbon migration in unconfined aquifers simplified from 3-D to 2-D (Kaluarachchi *et al*., 1990).

Despite the seemingly wide variety of models that are available, in practice the usability of models for reliable prediction of free product recovery rates is limited for a variety of reasons. Many of the models require data that are not measurable in the field (*e.g.*, relative permeability-capillary pressure relations). Mishra *et al*. (1989) present one solution to this problem; they developed a model to estimate relative permeability-capillary pressure relations from grain-size curves, which can be developed relatively easily from soil samples. The problem is that each soil sample would yield a different grain-size curve, and hence, different relative permeability-capillary pressure curves. As even subtle heterogeneities can radically influence the movement of free product in the subsurface, no single curve is likely to be adequate to characterize the entire site. Collection of a sufficiently large number of samples may be prohibitive. Assumptions such as vertical equilibrium and vertical uniformity, which are usually required by the simpler two-dimensional models, are not generally applicable.

More often than not model simulations are very accurate only over the period for which field data are available. Models are calibrated given a set of field data (*e.g.*, water table elevations, volume of product recovered) collected over a specified period of time. Model parameters are then adjusted so that the simulated results as closely as possible match the field data. As more field data are collected, model parameters are adjusted so that the simulation results once again closely match the field data. This process is typically repeated every time additional data are available. Often the final set of model parameters is quite dissimilar from the initial set. If the initial parameters are used over the entire simulation period, then the match is usually best during the early stages and worsens as the simulation progresses. Conversely, if the final parameters are used to simulate the behavior measured in the field, the match is typically poor during the initial stages, but improves as simulation time progresses up to the point in time that the latest data are available. It is reasonable to expect that the simulation results would begin to worsen as the simulation continued to progress into the future.

Appropriate use of models generally requires that they be used by persons experienced in the use of models. As the complexity of the site and the selected model both increase, so must the sophisitication of both the modeler and the computer. Adequately trained modelers command relatively high hourly billing rates. A single simulation using a complex, multi-phase model may take 24 hours or more to run even on today's fastest desk top computers. Often clients are billed for computer time as part of the overall cost for computer modeling. Between the labor rates and the computer usage rates, several simulations of even a small site can result in a large invoice.

Because of limited reliability and expense of use, multiphase computer models are seldom used to estimate recovery rates for a free product recovery plan. For sites with large spills or large volumes of free product in the subsurface, the expense and effort associated with these models may be warranted if it can help significantly reduce the cost of recovery or improve the effectiveness of free product recovery. Where models have been used to design free product recovery systems, the analysis is likely to contain significant uncertainty that should be explicitly addressed in the model description.

Recoverability Of Free Product

Chapter IV has presented several methods for evaluating the volume and recoverability of free product. This section presents a discussion limited to those factors that are most relevant to the recovery of the principal types of petroleum products typically stored in USTs (*i.e.*, gasolines, middle distillates, and heavy fuel oils).

It has been established that the thickness of free product measured in wells usually exceeds the thickness that is present in the surrounding soil. Volume estimates based strictly on measured thickness in wells are erroneous and are often significantly greater than the volume of product that was released. Many methods have been developed to correlate the measured thickness to volume in the soil, but none of the available methods is reliable at all sites. Different methods applied to the same site may yield radically different volume estimates. It is, therefore, important not to rely on the estimate of any single method. Comparison of several estimates may provide a reasonable range for the estimated volume. This range may span an order of magnitude.

The steps involved in estimating the volume of free product in the subsurface include measurements of thicknesses in wells, borings, and excavations; determination of the direction(s) of groundwater flow and free product migration; and estimation of the retention capacity of the soil. Once the probable extent and realistic thicknesses of the free product plume (or pool) have been determined, a variety of techniques are available to calculate the total volume of the release. Under the most favorable conditions, only a fraction of the total release will be recoverable. Recoverable volumes typically range from 20 to 50 percent of the total release. Factors that influence the recoverable percentage include water table fluctuations (which can create a "smear zone"), depth to water table, and soil properties (*e.g.*, heterogeneity, pore size, layering).

The initial rates of product recovery are best estimated from bail down tests and pumping tests. Knowledge of the expected recovery rates are important in sizing components of the treatment process. Often the recovery of product declines significantly from initial rates, especially for wells located where free product volume is highest. Various computer models can, in theory, be used to predict future rates of free product recovery. However, these models are expensive to use and have limited reliability.

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Appendix 5

Well Construction Diagram

LABELLA Associates, P.C.
300 STATE STREET, ROCHESTER, NEW YORK
ENVIRONMENTAL ENGINEERING CONSULTANTS

PROJECT
Phase II Environmental Site Assessment
690 St. Paul Street
Rochester, New York

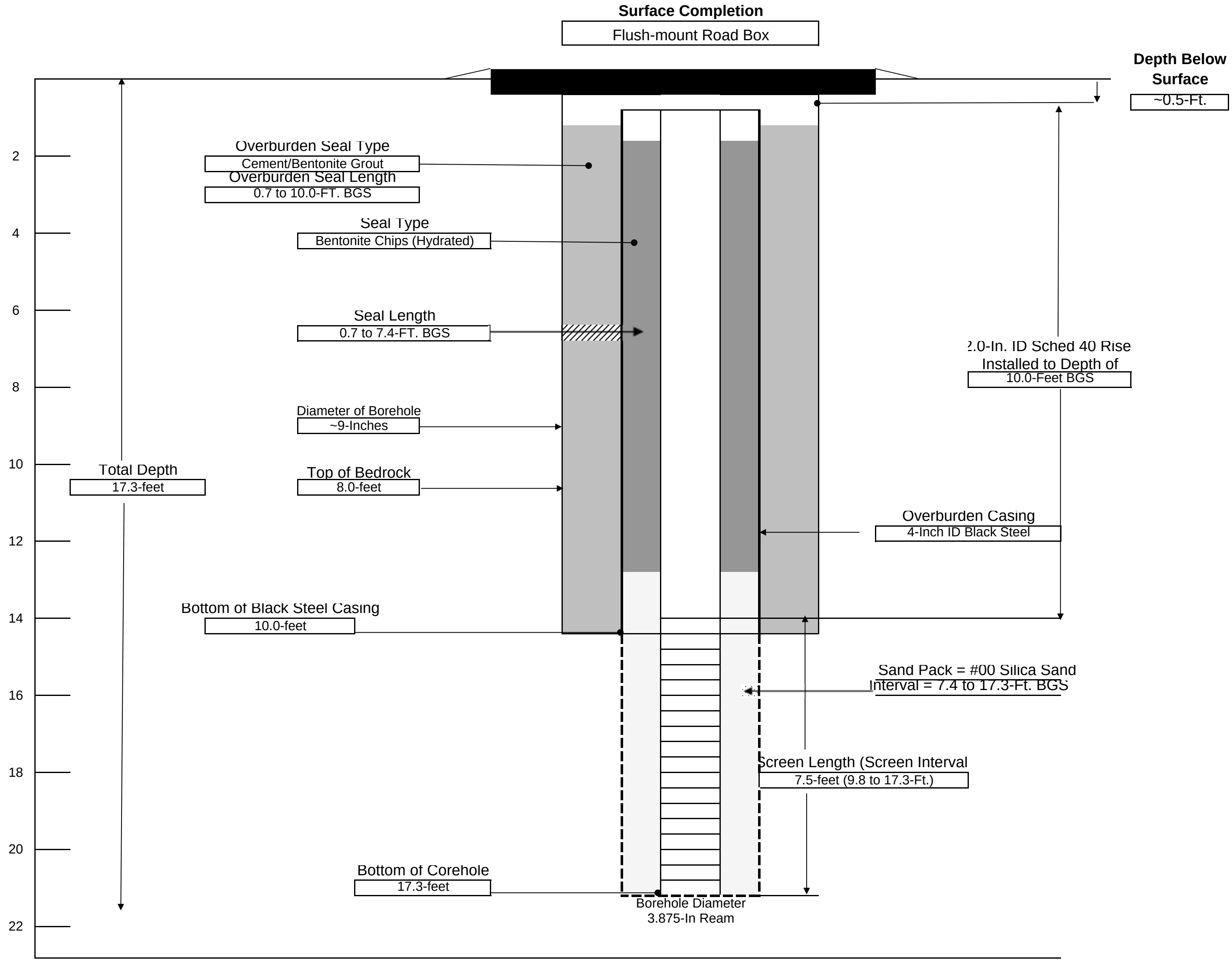
WELL ID **BW-1**
SHEET 1 OF 1
JOB # 208492
CHKD. BY:

CONTRACTOR Nothnagle Drilling Co.
DRILLER Steve Gelser
LABELLA REPRESENTATIVE: C. A. Stiles
BORING LOCATION
GROUND SURFACE ELEVATION DATUM
START DATE 18-Aug-08 END DATE 20-Aug-08

TYPE OF DRILL RIG: CME Model 75 Truck-mount Rotary Drill Rig
AUGER SIZE AND TYPE 6.25" ID Hollow Stem Augers
OVERBURDEN SAMPLING METHOD No Soil Sampling Conducted
ROCK DRILLING METHOD HX (3.875" ID) Water rotary Core Barrel

WATER LEVEL DATA

DATE	TIME	WATER	REMARKS



NOTE ALL DIMENSIONS IN FEET UNLESS OTHERWISE INDICATED

GENERAL NOTES:
1) STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL
2) WATER LEVEL READINGS HAVE BEEN MADE AT TIMES AND UNDER CONDITIONS STATED, FLUCTUATIONS OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

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PROJECT
Genesee Valley Real Estate Company
690 Saint Paul Street
Rochester, New York

BORING: RW-East
SHEET 1 OF 1
JOB # 209280
CHKD. BY: ED

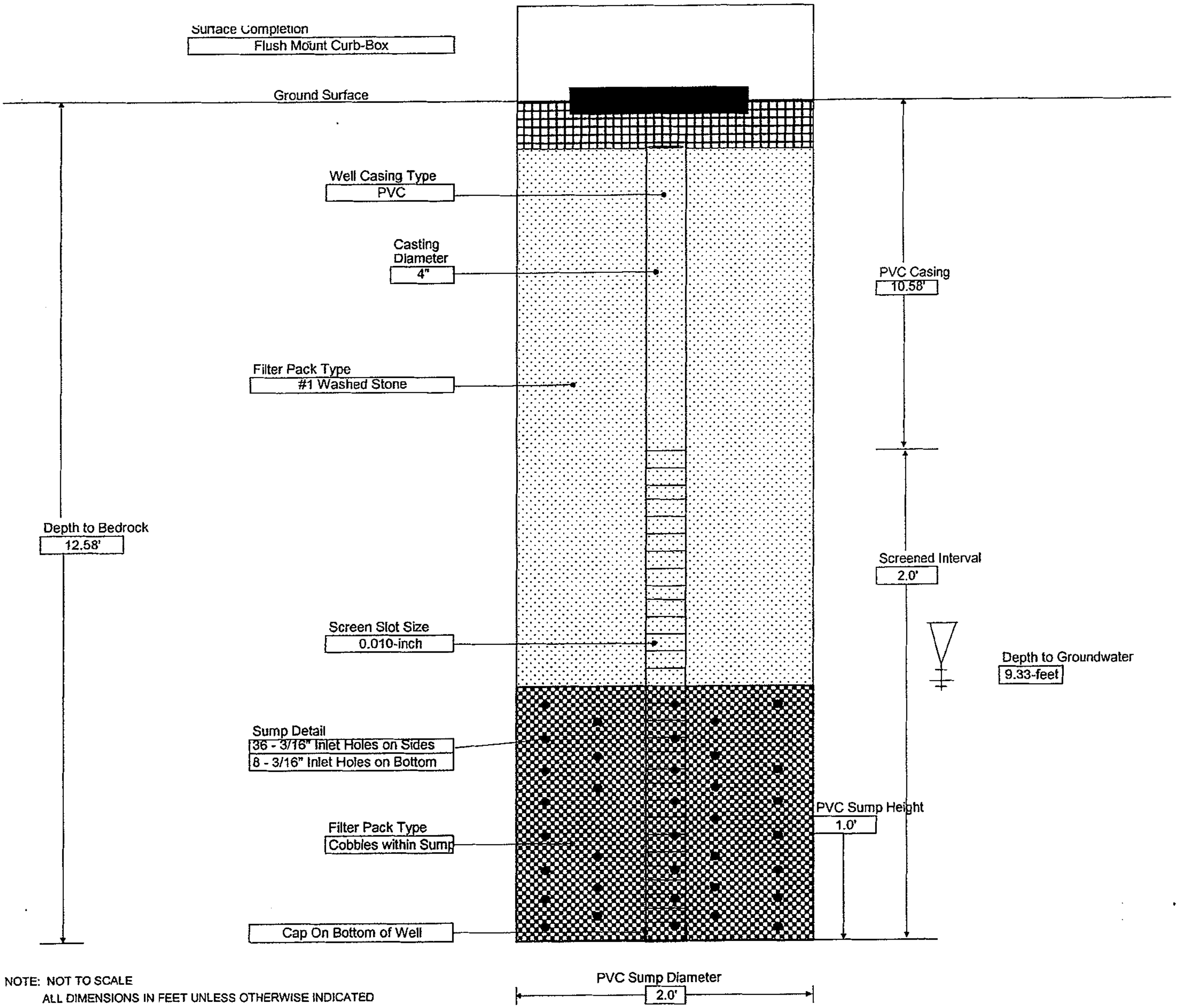
CONTRACTOR: Genesee Valley Real Estate
DRILLER:
LABELLA REPRESENTATIVE: C.A. Stiles

BORING LOCATION: Southern Remedial Excavation
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: September 2008 END DATE: September 2008

TYPE OF DRILL RIG: N/A
AUGER SIZE AND TYPE: N/A
OVERBURDEN SAMPLING METHOD: N/A
ROCK DRILLING METHOD: N/A

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS



NOTE: NOT TO SCALE
ALL DIMENSIONS IN FEET UNLESS OTHERWISE INDICATED
RW-EAST & RW-WEST CONSTRUCTED TO SAME DIMENSIONS

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PROJECT
Genesee Valley Real Estate Company
690 Saint Paul Street
Rochester, New York

BORING: RW-West
SHEET 1 OF 1
JOB # 209280
CHKD. BY: ED

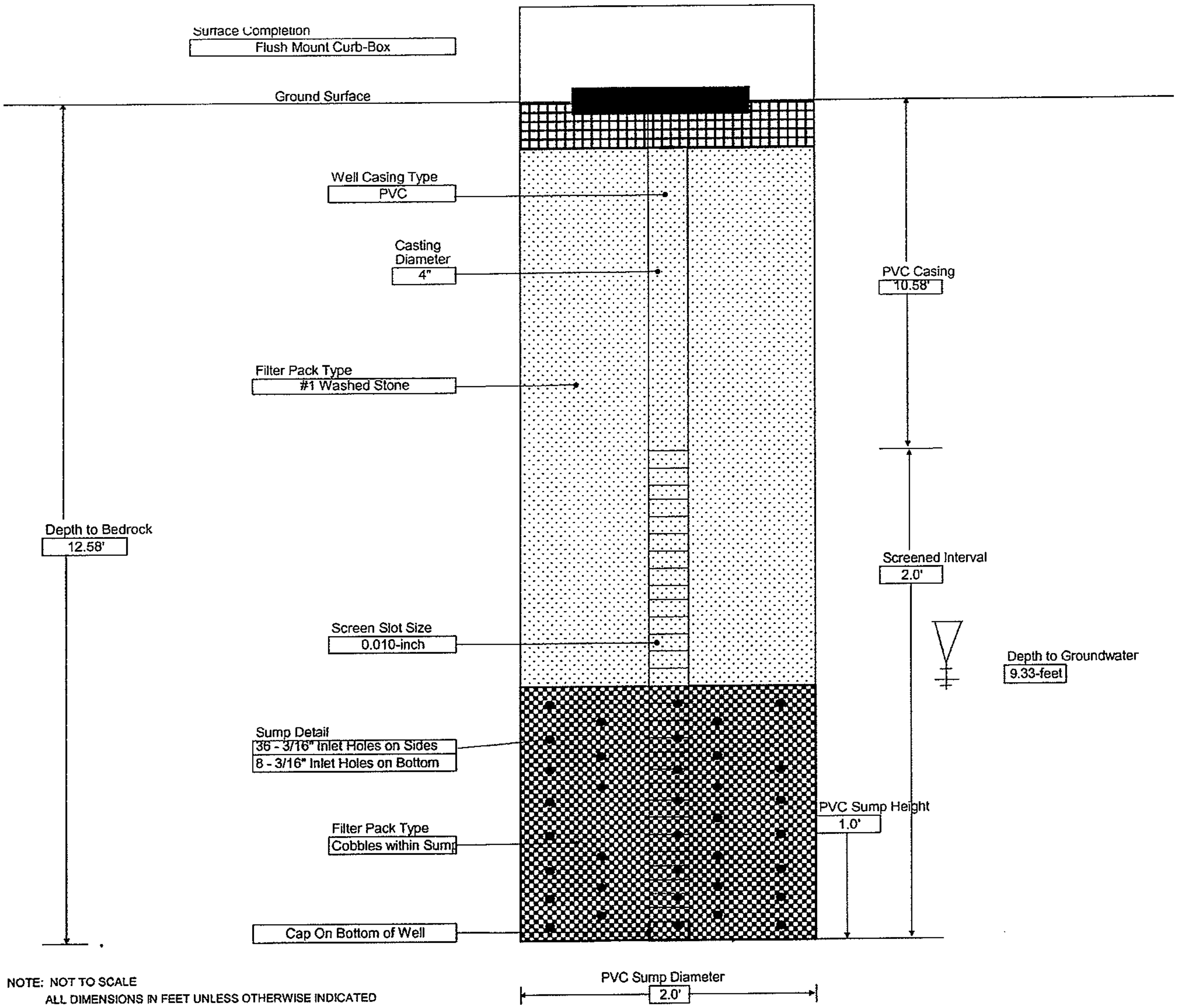
CONTRACTOR: Genesee Valley Real Estate
DRILLER:
LABELLA REPRESENTATIVE: C.A. Stiles

BORING LOCATION: Southern Remedial Excavation
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: September 2008 END DATE: September 2008

TYPE OF DRILL RIG: N/A
AUGER SIZE AND TYPE: N/A
OVERBURDEN SAMPLING METHOD: N/A
ROCK DRILLING METHOD: N/A

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS



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LABELLA Associates, D.P.C. 300 STATE STREET, ROCHESTER, NEW YORK ENVIRONMENTAL ENGINEERING CONSULTANTS	**Appendix 5** PROJECT Design Phase Investigation - AOC #6C NAPL Area 690 Saint Paul Street, Rochester, New York	BORING: BW-14 SHEET 1 OF 1 JOB # 209280 CHKD. BY: JMG

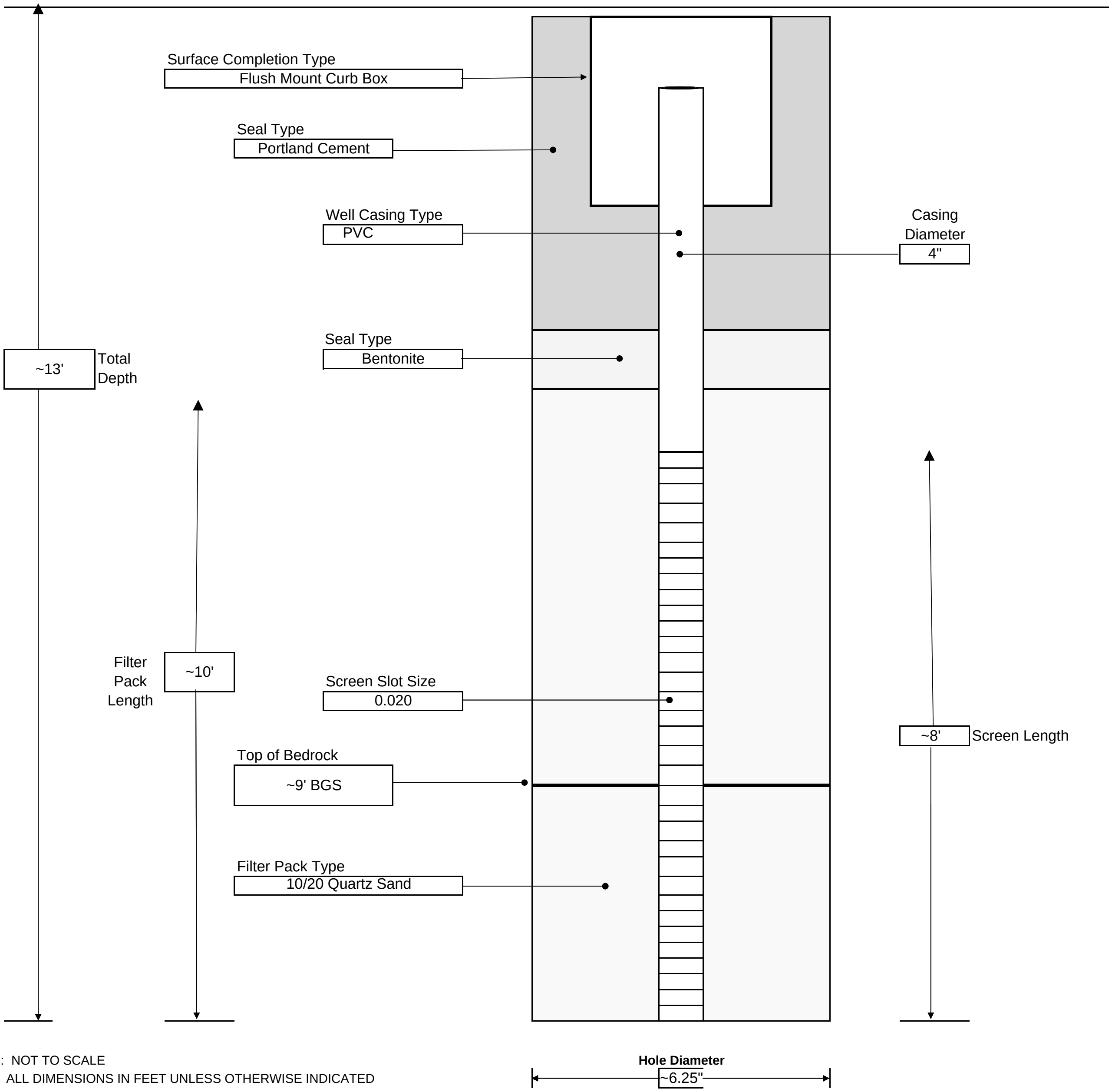
CONTRACTOR: Parratt Wolff
DRILLER:
LABELLA REPRESENTATIVE: M Winderl

BORING LOCATION: AOC #6C
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: 2/26/2015 END DATE: 2/27/2015

TYPE OF DRILL RIG:
AUGER SIZE AND TYPE: Hollow-Stem; 6.25" Inner Diameter
OVERBURDEN SAMPLING METHOD: Direct-Push
ROCK DRILLING METHOD: NX Core Barrel

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS



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GENERAL NOTES:
1) STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL
2) THE ABOVE IS THE PROPOSED DESIGN FOR THREE WELLS IN AOC #6C; DEPTHS MAY VARY SLIGHTLY BASED ON FIELD CONDITIONS.

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FIGURE 5

PROJECT
Design Phase Investigation - AOC #6C NAPL Area
690 Saint Paul Street, Rochester, New York

BORING: BW-15
SHEET 1 OF 1
JOB # 209280
CHKD. BY: JMG

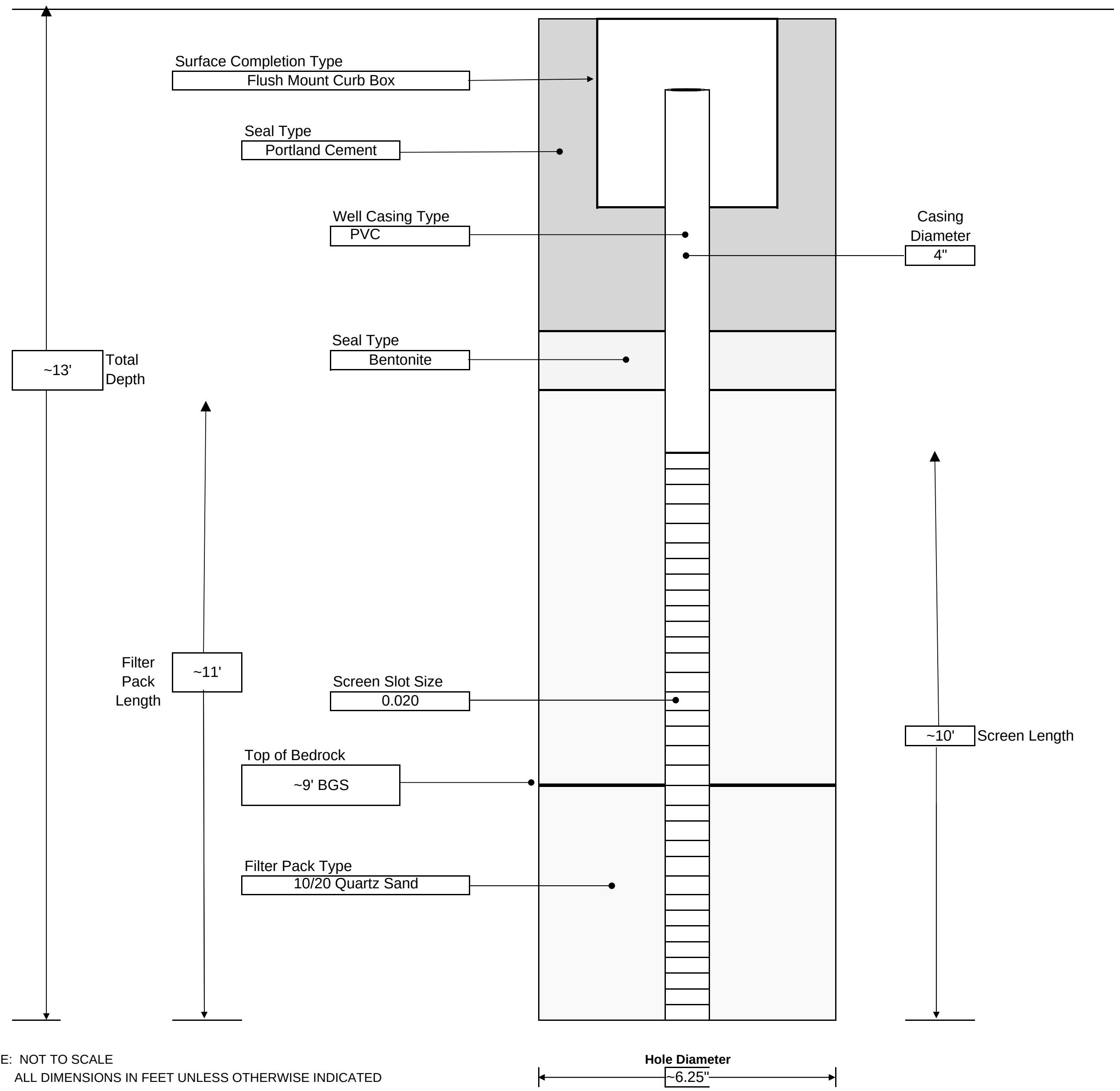
CONTRACTOR: Parratt Wolff
DRILLER:
LABELLA REPRESENTATIVE: M Winderl

BORING LOCATION: AOC #6C
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: 2/26/2015 END DATE: 2/27/2015

TYPE OF DRILL RIG:
AUGER SIZE AND TYPE: Hollow-Stem; 6.25" Inner Diameter
OVERBURDEN SAMPLING METHOD: Direct-Push
ROCK DRILLING METHOD: NX Core Barrel

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS



Surface Completion Type: Flush Mount Curb Box
Seal Type: Portland Cement
Well Casing Type: PVC
Casing Diameter: 4"
Seal Type: Bentonite
Total Depth: ~13'
Filter Pack Length: ~11'
Screen Slot Size: 0.020
Top of Bedrock: ~9' BGS
Screen Length: ~10'
Filter Pack Type: 10/20 Quartz Sand
Hole Diameter: ~6.25"

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FIGURE 5

PROJECT
Design Phase Investigation - AOC #6C NAPL Area
690 Saint Paul Street, Rochester, New York

BORING: BW-16
SHEET 1 OF 1
JOB # 209280
CHKD. BY: JMG

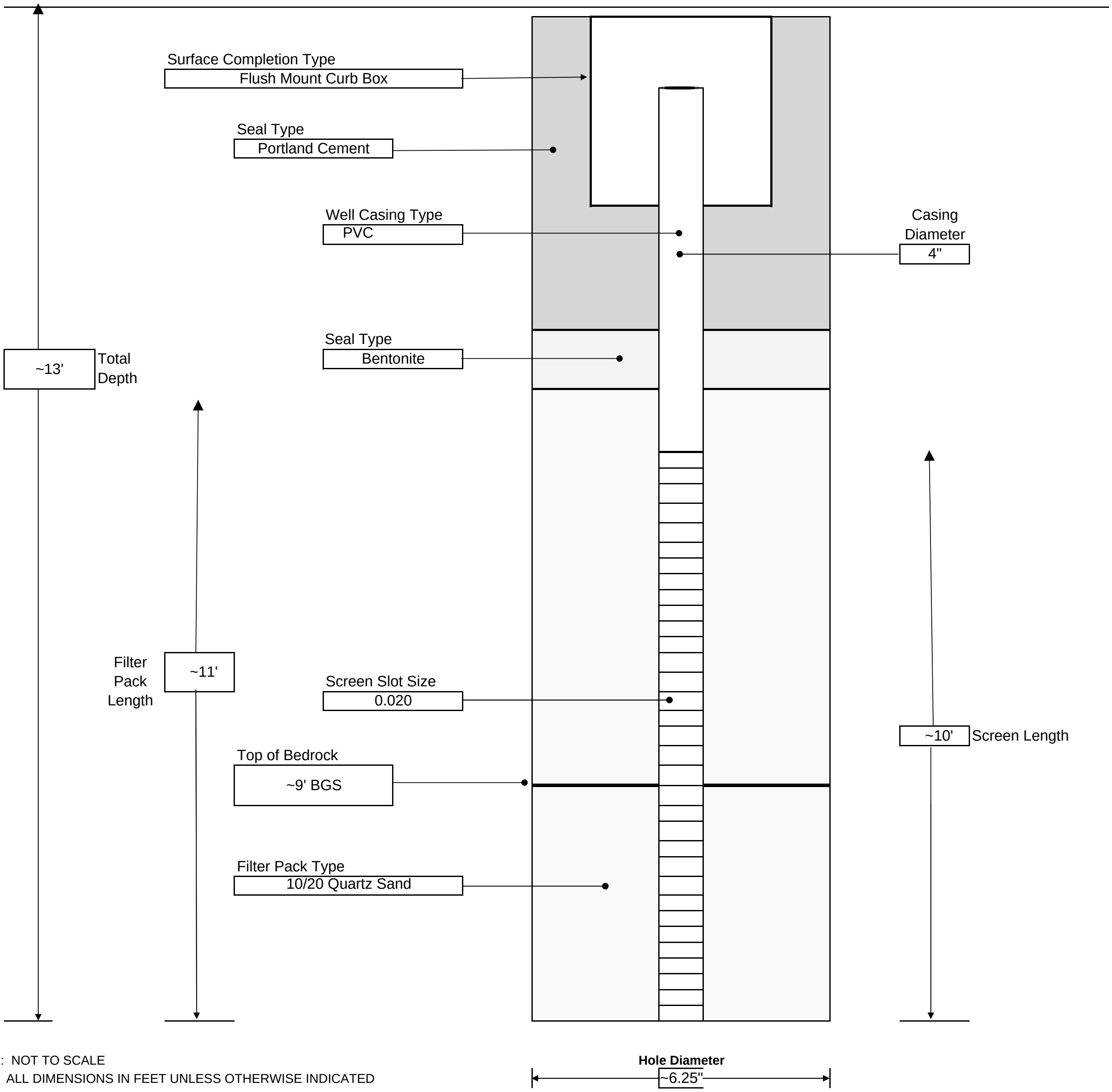
CONTRACTOR: Parratt Wolff
DRILLER:
LABELLA REPRESENTATIVE: M Winderl

BORING LOCATION: AOC #6C
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: 2/26/2015 END DATE: 2/27/2015

TYPE OF DRILL RIG:
AUGER SIZE AND TYPE: Hollow-Stem; 6.25" Inner Diameter
OVERBURDEN SAMPLING METHOD: Direct-Push
ROCK DRILLING METHOD: NX Core Barrel

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS



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LABELLA Associates, P.C. 300 STATE STREET, ROCHESTER, NEW YORK ENVIRONMENTAL ENGINEERING CONSULTANTS	PROJECT 690 Saint Paul Street Rochester, New York BCP Site #C828159 IRM - AOC #1: Former Oil House Area	BORING: REC-B-East SHEET 1 OF 1 JOB # CHKD. BY:

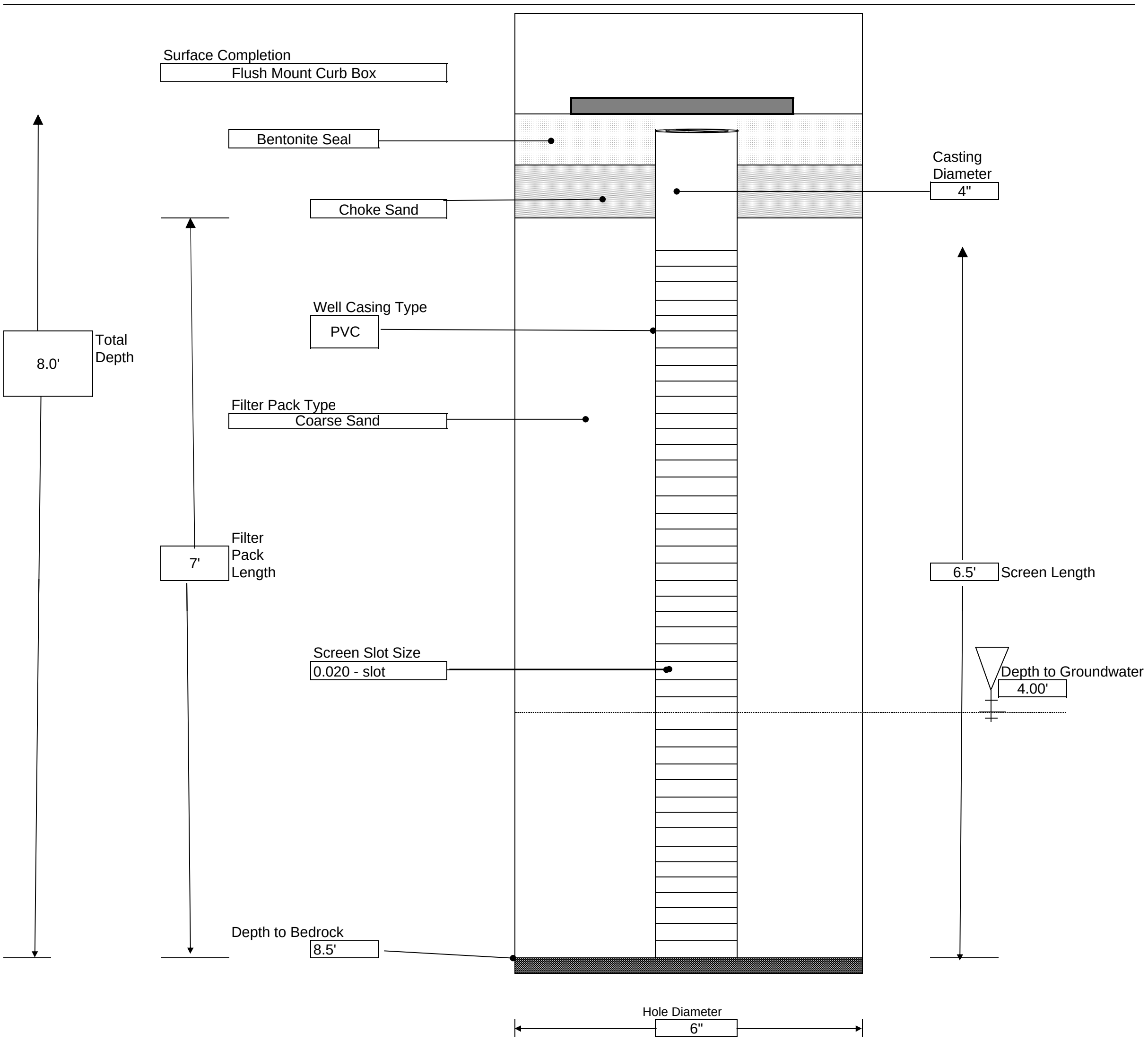
CONTRACTOR: Nothnagle
DRILLER: Steve Laurenty
LABELLA REPRESENTATIVE: J. Gillen

BORING LOCATION:
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: 1/19/2012 END DATE: 1/19/2012

TYPE OF DRILL RIG:
AUGER SIZE AND TYPE: N/A
OVERBURDEN SAMPLING METHOD:
ROCK DRILLING METHOD: N/A

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS
1/20/2012	1415	4.00'		



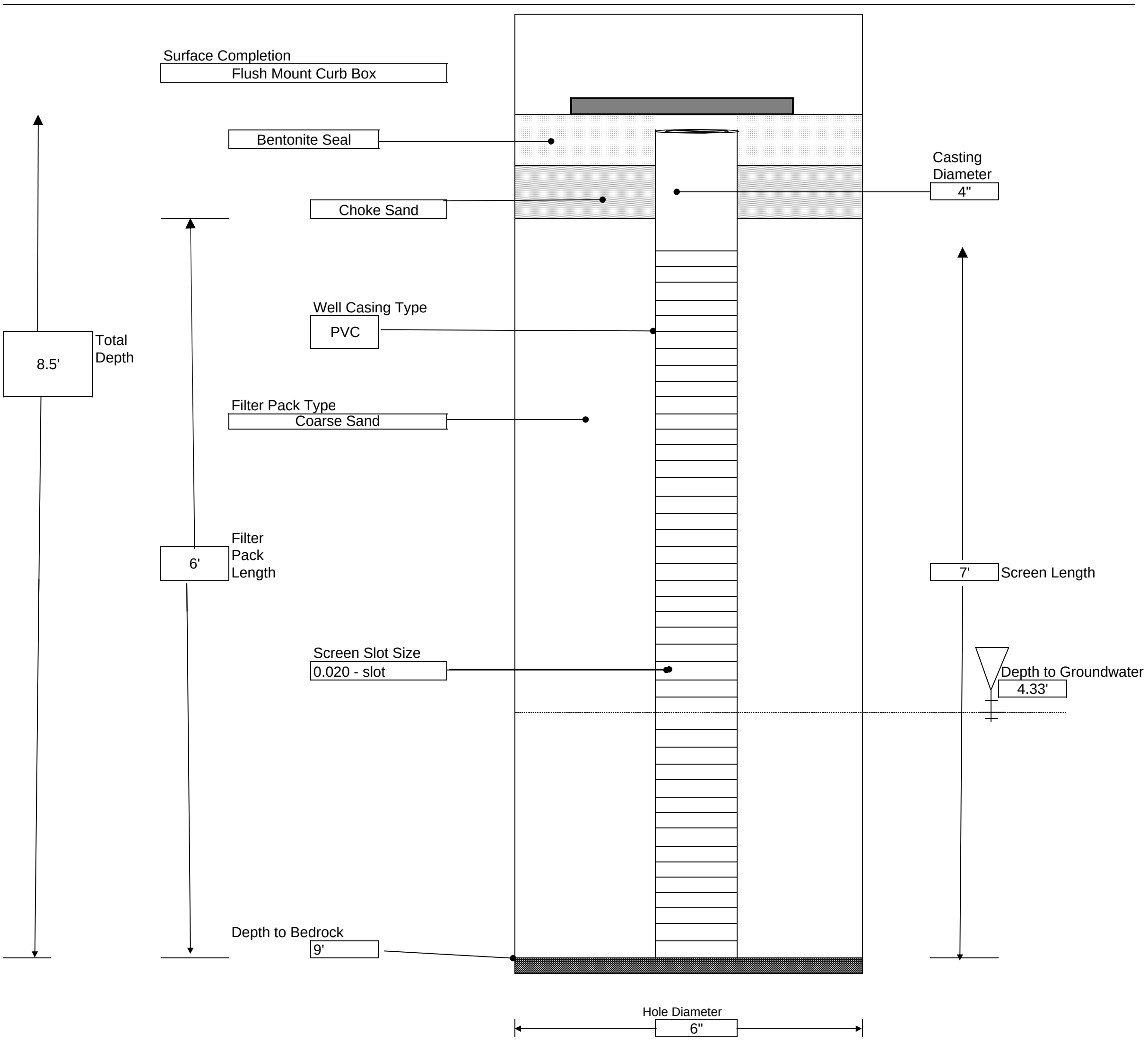
LABELLA Associates, P.C. 300 STATE STREET, ROCHESTER, NEW YORK ENVIRONMENTAL ENGINEERING CONSULTANTS	PROJECT 690 Saint Paul Street Rochester, New York BCP Site #C828159 IRM - AOC #1: Former Oil House Area	BORING: REC-B-West SHEET 1 OF 1 JOB # CHKD. BY:

CONTRACTOR: Nothnagle
DRILLER: Steve Laurenty
LABELLA REPRESENTATIVE: J. Gillen
BORING LOCATION:
GROUND SURFACE ELEVATION: N/A DATUM: N/A
START DATE: 1/19/2012 END DATE: 1/19/2012

TYPE OF DRILL RIG:
AUGER SIZE AND TYPE: N/A
OVERBURDEN SAMPLING METHOD:
ROCK DRILLING METHOD: N/A

WATER LEVEL DATA

DATE	TIME	WATER	CASING	REMARKS
1/20/2012	1245	4.33'		



Surface Completion
Flush Mount Curb Box

Bentonite Seal

Choke Sand

Casing Diameter
4"

Total Depth
8.5'

Well Casing Type
PVC

Filter Pack Type
Coarse Sand

Filter Pack Length
6'

Screen Length
7'

Screen Slot Size
0.020 - slot

Depth to Groundwater
4.33'

Depth to Bedrock
9'

Hole Diameter
6"

APPENDIX 6

Absorbent Sock Specification

EXCLUSIVE!

PIG Sump Skimmer — Sized to pull oil out of your sumps, tanks and bilges.

- **Simply lower floating skimmer** into any water-based liquid to absorb oils without taking in water
- **Bright white color** makes absorbed oil easier to see; clearly shows saturation level
- Can be **incinerated after use** to reduce waste or for fuels blending
- SKM400, SKM401 and SKM404 **meet NFPA 99 standards for static decay**

PIG Monitoring Well Skimming Socks are just the right size for keeping an eye on well maintenance.

SKM403
Tie skimmer to grate with a rope (not included) for easy retrieval during inspections and changeouts.

PIG® Sump Skimmer

Item #	Size	Unit	Abs. Up To	1-2	3-9	10+
SKM413	Ext. Dia. 8" x 30"L	6 socks	20 gal./box	**$143**	**$137**	**$133**
SKM412	Ext. Dia. 5" x 30"L	6 socks	9 gal./box	**$121**	**$115**	**$109**
SKM400	Ext. Dia. 3" x 30"L	15 socks	9.5 gal./box	**$103**	**$97**	**$91**
BEST SELLER! **SKM403**	Ext. Dia. 8" x 18"L	12 socks	21.6 gal./box	**$156**	**$152**	**$144**
SKM411	Ext. Dia. 5" x 18"L	12 socks	10 gal./box	**$132**	**$128**	**$121**
SKM404	Ext. Dia. 3" x 18"L	25 socks	9.38 gal./box	**$110**	**$105**	**$101**

PIG® Monitoring Well Skimming Sock

Item #	Size	Unit	Abs. Up To	1-2	3-9	10+
SKM401	Ext. Dia. 1.5" x 18"L	30 socks	4 gal./box	**$75**	**$73**	**$71**

> ***"Your skimmers…have saved our bacon."***
>
> "Your skimmers and oil-only line of products have saved our bacon many times during unannounced environmental regulators' visits. They are impressed with the way they absorb all the oil. They commented that they don't drip oil while being retrieved from the sump."
>
> — Robert B.
> SKM400 Customer

PIG Rigid Monitoring Sock — Small diameter sock lets you know if there's oil in your monitoring well.

- Rigid polypropylene case keeps **small-diameter sock in direct contact with liquids** at all times for maximum efficiency
- Design **prevents bunching or bending** when lowered into spaces as tight as 2" wide
- Perfect for **soaking up unwanted oil-based fluids** that collect in monitoring wells, tanks, bilges, underground substations, stormwater drains and other limited-access applications
- Large apertures in casing **allow oil to easily pass through to the absorbent sock** without blinding like smaller-aperture cases

SKM415
Eyelet on each end lets you attach ropes and weights (not included).

PIG® Rigid Monitoring Well Sock

Item #	Size	Unit	Abs. Up To	1-2	3-9	10+
SKM415	Ext. Dia. 1.5" x 23"L	12 socks	1.7 gal./box	**$133**	**$125**	**$120**