THE SALVATION ARMY
USA Western Territory
Adult Rehabilitation Centers Command
180 East Ocean Boulevard, 3rd Floor
Long Beach, CA 90802-4709

FOUNDED IN 1865

WILLIAM BOOTH
Founder

ANDRÉ COX
General

JAMES KNAGGS
Territorial Commander

MAN-HEE CHANG
ARC Commander

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By Alameda County Environmental Health at 3:13 pm, Mar 16, 2015

March 9, 2015

RE: Revised Subsurface Investigation Work Plan
The Salvation Army Adult Rehabilitation Center
601 Webster Street
Oakland, CA 94607

"I declare under penalty of perjury that the information and/or recommendations contained in the attached document or report are true and correct to the best of my knowledge."

Submitted by,

LeAnn M. Trimmer, Major
SECRETARY FOR BUSINESS
ARC COMMAND

LMT

Fax: (562)-491-4202
Phone: (562)-491-4102

www.satruck.com
Email: LeAnn.Trimmer@USW.salvationarmy.org

Work Plan for
Continued Subsurface Investigation

The Salvation Army
Adult Rehabilitation Center

601 Webster Street
Oakland, California

Submitted to:

Keith Nowell, PG, CHG
Hazardous Materials Specialist
Alameda County Environmental Health
1131 Harbor Bay Parkway
Alameda, CA 94502-6540

Prepared on behalf of:

Ms. Michele Smith
Property Project Manager
The Salvation Army, ARC Command
180 E. Ocean Boulevard
Long Beach, CA 90802-4709

Major Jack L. Phillips,
Administrator/Bay Area Coordinator
The Salvation Army, Adult Rehabilitation
601 Webster Street
Oakland, CA 94607

Submitted by:

Cardno
Shaping the Future

1117 Lone Palm Avenue, Suite 201B
Modesto, California 95351

Cardno Project Number
Z054000006

February 24, 201

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1.0 SITE LOCATION

The Salvation Army Adult Rehabilitation Center (site) is located at 601 Webster Street in Oakland, California, as shown on the Site Vicinity Map which is included as **Figure 1**. The site is developed as a warehouse and distribution center for The Salvation Army (TSA). The principal land use in the vicinity of the site consists of commercial properties including a used car sales lot, restaurants, a hotel, and several gas stations.

2.0 BACKGROUND

According to TSA, the underground storage tanks (USTs) formerly at the site were used to fuel their commercial truck fleet. In early 2010, TSA made the decision to discontinue on site fueling operations and remove the USTs and dispenser equipment from the site. In November 2010, Terry Hamilton, a California licensed general engineering contractor (Ca. License 339108) excavated and removed one 12,000-gallon diesel UST, one 8,000-gallon gasoline UST, and the associated fuel dispensers.

The UST removal activities occurred during November 22-23, 2010. The USTs were reported to be in good condition with no visible holes or signs of leakage. On November 23, 2010, the two USTs were triple rinsed and rendered inert with dry ice, tested and certified non-hazardous by a Certified Marine Chemist, loaded onto a flatbed truck, and transported to Stanislaus County. The former USTs were to be used as non-potable water tanks in a fire-suppression system. Laboratory analyses of the soil samples collected from the UST excavation indicated that petroleum hydrocarbons (PHCs) related to gasoline were present; however, diesel was not detected.

After initial contact with Oakland City Fire Department (OFD), Cardno developed a limited-scope workplan dated March 18, 2011, for the purpose of deriving information about the magnitude of the release to assist OFD in determining if the case could be closed or if the case should be forwarded to the Alameda County Health Care Services Agency Environmental Health Services, Environmental Protection (ACEH) as a Local Oversight Program (LOP) case. The ACEH was a copied recipient of this workplan.

In February 2013, the ACEH hosted a meeting where representatives of the ACEH, TSA, and Cardno reviewed known information regarding the former UST system and the results of the soil sampling that occurred during the UST system removal activities performed in the fall of 2010. This meeting and subsequent discussions resulted in the completion, submittal, and approval of the *Revised Subsurface Investigation Workplan, The Salvation Army, 601 Webster Street, Oakland, California,* by Cardno, dated February 28, 2013. This workplan provided for the advancement of up to ten soil borings utilizing a Geoprobe narrow-diameter, direct-push, drill rig.

On July 29 and 30, 2013, Cardno ATC and Gregg Drilling mobilized to the site. Unanticipated subsurface conditions resulted in difficulty with use of the Geoprobe acetate soil sample tubes. The unanticipated subsurface conditions limited the depths achieved in the advancement of the borings to 20 feet below ground surface (bgs) and resulted in the advancement of only seven of the ten planned soil borings. The locations of the borings that were advanced are depicted on the Site Plan which is included as **Figure 2**. PHCs were detected in all of the samples collected from the seven borings, with highest concentrations of gasoline detected outside the former excavation in the southern portion of the area investigated. Diesel was also detected in the area directly south of the former excavation. Of the groundwater samples collected, the highest concentrations of gasoline and diesel were detected southwest and south of the former excavation, respectively. The results are described in the Cardno report, *Site Conceptual Model with Data Gap Identification, and Preliminary Subsurface Investigative Report, The Salvation Army Adult Rehabilitation Center, 601 Webster Street, Oakland, CA 94607* dated January 13, 2014.

On July 2, 2014, the ACEH organized and convened a meeting to discuss the efforts need to advance the investigation of the site toward the goal of closure. This workplan contains activities and elements agreed upon in that meeting.

3.0 PROJECT GOALS

The general goals of the project are as follows:

1. Conduct a sensitive receptor survey to identify water supply wells and surface water bodies within 2,000 feet of the site.

2. Evaluate the lateral and vertical extent of soil and groundwater contamination.

3. Evaluate the potential for soil gas intrusion to indoor air.

4. Use the information gained in the proposed investigation to update the site conceptual model (SCM) and evaluate the site with regard to the State Water Resources Control Board's (SWRCB) Low Threat Closure Policy (LTCP).

4.0 SCOPE OF WORK

4.1 SENSITIVE RECEPTOR SURVEY

4.1.1 OBJECTIVES

To identify non-monitoring wells and surface water bodies within 2,000 feet of the site. The resulting information will be included in the updated SCM.

4.1.2 METHODS TO BE EMPLOYED

Cardno will conduct a search for potential receptors within a 2,000-foot radius of the site. Cardno's search will include both Alameda County Public Works and California Department of Water Resources databases. A figure using a photographic base showing the site and nearby features will be prepared that will include the location of the identified sensitive receptors and circles centered on the site having radii of 1,000 and 2,000 feet. The area of the search is depicted on **Figure 3**.

Cardno will use the State Water Resources Control Board's *Technical Justification for Groundwater Plume Lengths, Indicator Constituents, Concentrations, and Buffer Distances (Separation Distances) to Receptors* (SWRCB Low-Threat UST Closure Policy Task Force, Final July 12, 2011) for guidance, as directed by the ACEH. This document is included as **Appendix A.**

4.2 CONTINUED INVESTIGATION OF CONTAMINANT DISTRIBUTION

4.2.1 OBJECTIVES

Evaluate the distribution of soil and groundwater contamination by advancing a combination of Membrane Interface Probe (MIP) and Hollow Stem Auger (HSA) borings and installing groundwater monitoring wells.

4.2.2 PERMITTING AND PLANNING

Cardno will obtain the necessary drilling permits from Alameda County Public Works Agency-Water Resources for the MIP and HSA borings, as necessary.

Cardno will attempt to locate potential subsurface underground utilities at site locations where intrusive soil borings will be undertaken. These will include:

1.) Locations where investigative soil borings will be advanced, and
2.) Locations where permanent groundwater monitoring wells will be installed.
3.) Proposed soil gas sampling points

This work will include notifying Underground Services Alert (USA North) as required by law and employing a private subsurface utility locating service to locate both public and private underground utilities that may be present in the work areas identified above. This information will be added to the information gathered previously, to update the subsurface utilities map. Cardno will notify the ACEH 48 hours in advance of drilling.

4.2.3 METHODS TO BE EMPLOYED

4.2.3.1 Dynamic Workplan

Cardno intends to employ a dynamic work plan as endorsed by the USEPA[1], and the 2012 LUFT manual[2].

Dynamic workplans rely, in part, on an adaptive sampling and analysis strategy. Rather than dictate the details of the sample analysis to be performed and the location and number of samples to be collected, dynamic workplans specify the decision-making logic that will be used in the field to determine which chemical compounds require analysis, where to collect the samples and when to stop sampling. Adaptive sampling and analysis programs change as the conceptual model for the site is refined based on the analytical results produced in the field. A successful adaptive sampling and analysis program requires analytical methods and instrumentation that are field-practical and can produce data fast enough to support the dynamic workplan process.[3]

1. USEPA Site Characterization/Assessment Website http://www.epa.gov/oust/cat/sitechar.htm

2. Leaking Underground Fuel Tank (LUFT) Guidance Manual, California State Water Resources Control Board, September 2012, page 6-3.

3. Excerpt from A Guideline for Dynamic Workplans and Field Analytics: The Keys to Cost-Effective Site Characterization and Cleanup Prepared by Albert Robbat, Jr.Tufts University, Chemistry Department Center for Field Analytical Studies and Technology Medford, Massachusetts, 02155, 1998. A complete copy of this document is included as ***Appendix B.***

MIP borings will be advanced adjacent to and beyond the former UST excavation area. Although MIP borings will not be able to produce the required quantitative results, the real-time qualitative information provided by the MIP technology will allow Cardno to cost-effectively screen a large area of the site for adsorbed-phase PHC, dissolved-phase PHC, and possibly submerged PHC. The quantitative information obtained from the MIP technology will allow for continuous updating of the conceptual model, which in turn will optimize location selection for placement of subsequent MIP borings, HSA borings, and groundwater monitoring wells.

4.2.3.2 Membrane Interface Probe Boring

According to the USEPA, High-resolution site characterization (HRSC) strategies and techniques use scale-appropriate measurement and sample density to define contaminant distributions, and the physical context in which they reside, with greater certainty, supporting faster and more effective site cleanup.[4] Geoprobe Systems has developed multiple HRSC tools for the purpose of subsurface investigation. MIP is one of those tools. The subsurface parts of the MIP system consists of a sophisticated direct push tolerant MIP head, a substantial length of carrier gas tubing and electronics threaded through the direct push sampling rods, and laboratory grade Volatile Organic Compound (VOC) detection equipment at the surface. The MIP head contains parts of three different systems. The first is a heating element that heats the soil, soil gas, and groundwater as the MIP head is affixed to and advances with the tip of threaded conventional direct push rods. The heating element heats the soil, soil gas, and groundwater to 120 degrees Celsius which volatilizes the VOCs instantaneously. The second part of the MIP head is a specially designed membrane surface that allows the heated VOCs present to selectively pass through into the interior of the tool. A stream of inert carrier gas is introduced at the surface and delivered via the descending tubing to the tool head. As the carrier gas moves past the membrane, the VOCs pass through the membrane and mix with the carrier gas. The carrier gas/VOC mixture proceeds up the ascending tube to the surface. At the surface the VOCs are analyzed by a series of laboratory grade detectors. Each detector produces a continuous profile (plotted with respect to depth) to indicate the presence of various VOCs. The detectors selected for this site include a photo-ionization detector (PID) and flame-ionization detector (FID) which are suited for detecting double-bonded and combustible VOCs. The third part of the MIP head is the Electrical Conductivity (EC) detector. This detector identifies the MIP head's position relative to the surface and the soil's conductivity. The log of the soil's conductivity is used to interpret soil lithology when compared to an actual soil log. The MIP head positioning information is used to assist in determining the relative spread or distribution of VOC mass present and their location relative to the surface.

The MIP head is attached to the tip of a column of conventional direct push rods (Geoprobe or CPT) and driven into the soil using a direct-push percussion hammer drill or CPT rig to determine lithology and/or contaminant distribution in real time. A Cardno field geologist will be present to supervise drilling activities and a Cardno senior Geologist will be present or otherwise available to assist in making the dynamic decisions regarding placement and depth of the subsequent borings. The availability of real-time data while in the field allows continuous refinement of the site conceptual model, which drives adaptive approaches to subsequent sampling and remediation activities.

For this investigation, Cardno will utilize Vironex, a State-licensed (C57) drilling company with extensive experience with HRSC tools, including MIP. Vironex's High Resolution Site Profiling group has been providing direct imaging services to the environmental consulting industry since 2003.

4. USEPA Site Characterization/Assessment Website http://www.epa.gov/oust/cat/sitechar.htm

In order to maintain quality assurance and quality control standards during the course of the project, Vironex will perform a response test on the MIP head before and after advancing each MIP boring. The response test consists of exposing the MIP head to a sand sample infused with toluene at a known concentration of 1 part-per-million (ppm) and comparing this to the detected concentration. Response testing conducted during the project will be completed within applicable established Geoprobe guidelines. Additionally, the temperature and pressure of the MIP system's internal carrier gas are continuously monitored during the advancement of each MIP boring to ensure the system is functioning properly. Additional information regarding the MIP technology is included in Vironex's MIP System Overview, which is included as **Appendix C**.

4.2.3.3 MIP Boring Placement

Cardno will start by advancing MIP borings along the following four specific transects as requested by the ACEH and depicted on **Figure 4**:

1. Along the north boundary of the site, north of the location of the former USTs, parallel to 7th Street, as close as operationally possible to the cinder-block wall that defines the truck enclosure. This would include the area of the former fuel dispenser.

2. Along the west boundary of the site, west of the location of the former USTs, parallel to Franklin Street, as close as operationally possible to the cinder-block wall that defines the truck enclosure.

3. Along a line near the base of the loading dock, parallel to 7th Street.

4. Across Franklin Street on the Salvation Army Used Car Lot (TSA-UCL) in a north-south transect parallel to Franklin Street in the inferred down gradient direction from soil boring SB-4. The purpose for placement of these borings is to evaluate potential migration of the dissolved phase PHCs in the groundwater. If dissolved phase PHCs are detected on the TSA-UCL site, then the installation one or more groundwater monitoring wells are likely to be proposed. The borings will be placed, as near to the Franklin Street sidewalk as allowed given the high density of subsurface utilities in the sidewalk along the west side of Franklin Street.

4.2.3.4 Hollow Stem Auger Borings

Following the completion and analyses of the MIP fieldwork, a hollow-stem auger drill rig will be used to advance soil borings for the collection of soil and grab groundwater samples that will used to satisfy the need for quantitative data regarding the lateral and vertical distribution of the PHC release and to install monitoring wells.

A State-licensed (C57) drilling company equipped with pre-cleaned 8-inch hollow stem augers will advance soil borings through the vadose zone to collect soil and groundwater samples. During the auger advancement, soil samples will be collected and field screened by a Cardno field geologist with a PID. The field geologist will characterize the soil in general accordance with the Unified Soil Classification System (USCS). Field observations will be recorded on the field boring logs.

To satisfy the LTCP Media Specific Criteria for Direct Contact and Outdoor Air Exposure, a minimum of eight soil borings will be advanced and soil samples will be collected from within the 0- to 5-foot and 5- to 10-foot bgs intervals of the borings. The soil samples will be analyzed for TPHg, BTEX (Benzene, Toluene, Ethylbenzene, and Total Xylenes), MTBE, and naphthalene.

No fewer than four soil samples from each boring will be selected for submittal for laboratory analyses. The soil samples will generally be collected at five foot intervals and at the soil and groundwater interface. Additional soil samples may be selected and submitted for laboratory analyses if significant changes in lithology are encountered and/or at signs of contamination (odor, discoloration, PID responses, etc.) If there are signs of vadose zone contamination in a particular boring, additional soil samples will be selected for analyses from the interval between ten feet bgs and first encountered groundwater to compare with the Petroleum Vapor Intrusion to Indoor Air criteria of the LTCP. Sample discoloration along with a response on the PID will be the criteria used in the field to determine the potential presence of vadose zone contamination.

A single grab groundwater sample will be collected from each boring at first encountered groundwater. Once saturated soil is encountered at what is anticipated to be approximately 25 to 30 feet bgs, a hydropunch-style sampling tool will be lowered through the augers to the interface with the undisturbed formation. The sampling tool will then be driven to the desired depth and retracted, exposing the screened section of the sampling device. Groundwater will pass through the screen and enter the void made by the tool. This groundwater will then be collected from within the sampling tool with a small-diameter bailer. Collected soil and groundwater samples will be placed in a cooler chilled with ice, and delivered under chain-of-custody documentation to a State-certified analytical laboratory.

Exposed equipment will be decontaminated prior to subsequent drilling and sampling. Augers and other large pieces of equipment will be decontaminated using high pressure hot water spray. Samplers, groundwater pumps, liners, and other equipment will be decontaminated in an Alconox scrub solution and double rinsed with clean tap water. Rinsate will be containerized for later disposal. The boreholes will be grouted to the surface. In areas where boreholes have penetrated existing asphalt or concrete, the borehole will be capped with an equivalent thickness of asphalt or concrete patch to match the finished grade.

4.2.3.5 HSA Boring Placement

Since MIP does not provide quantitative data, HSA borings will be advanced at strategic locations at the site to collect soil and grab groundwater samples. Some of the boring locations are pre-determined based on the configuration of the former gasoline storage and dispensing system at the site, the soil samples collected during their removal, and the limited information provided from the Geoprobe® borings advanced on July 29 and 30, 2013. The locations of the planned HSA borings are depicted on **Figure 5**.

Any additional HSA borings will be advanced at strategic locations based upon the results of the MIP data. Cardno estimates a minimum of eight to ten HSA borings will be advanced in the truck enclosure space. Five of the locations are pre-planned and identified above with the remainder, if any, to-be-determined. One or more additional HSA borings may be installed in the TSA-UCL along the same north-south transect parallel to Franklin as proposed for the MIP borings, if the MIP data suggests the distribution of the released PHCs extended across Franklin Street. Grab groundwater samples will be collected from each of the sampled HSA soil borings, and analyzed for TPHg, BTEX, MTBE, and naphthalene.

4.2.4 MONITORING WELL INSTALLATION

4.2.4.1 OBJECTIVES

To install repeatable sampling points in order to evaluate groundwater quality, the extent of dissolved phase PHCs, and determine groundwater flow direction.

4.2.4.2 MONITORING WELL PLACEMENT

A minimum of three groundwater monitoring wells shall be installed within the Truck Enclosure and possibly one or more off site across Franklin Street in the TSA-UCL. However, like the HSA boring locations, the exact location of the monitoring wells are subject to adjustment based on the information obtained during the MIP and HSA soil boring phases. The ACEH requested monitoring wells in the Truck Enclosure be placed in the following locations:

1. Near the location of the former fuel dispenser in the northwest corner of the Truck Enclosure where the two perimeter concrete-block walls meet near the intersection of Franklin and 7th Streets.

2. At the western end of the southern transect long the concrete-block wall parallel to Franklin Street as near to the building as possible without interfering with the storm drain located adjacent to the building.

3. Along the eastern most north/south transect at the intersection of the southern and eastern transects.

4. A fourth well could be located on the TSA-UCL parcel if information obtained in the during the MIP and HSA soil boring phases suggests the dissolved phase PHC plume extends to this parcel.

The proposed monitoring well locations are shown on **Figure 6**.

4.2.4.3 METHODS TO BE EMPLOYED

Well Construction

The proposed groundwater monitoring wells will be constructed of 2-inch inside diameter Schedule 40 polyvinyl chloride (PVC) casing with approximately 15 feet of 0.010-inch slotted screen. The top of the screened interval will be placed approximately five feet above the depth of encountered groundwater depth. The annulus of the screened portion of the groundwater monitoring well will be backfilled with a #3 Monterey sand (or equivalent) filter pack from the bottom of the borehole to approximately two to three feet above the top of the screen. An approximately two-foot layer of medium bentonite chips will be placed on top of the filter pack and hydrated to form an annular seal. The remaining annular space will be filled with a neat cement grout. To protect the integrity of the wells, locking, watertight well plugs will be installed on each well and a watertight wellhead labeled "monitoring well" will be installed in concrete over well. The proposed groundwater monitoring well construction details are proved as **Figure 7**.

Well Surveying

Once the proposed groundwater monitoring wells have been installed, the locations and elevations of the wells will be surveyed to Geotracker standards. The new wells will be surveyed to NAD83 horizontal datum and NAVD88 vertical datum by a California Licensed Professional Land Surveyor.

Well Development & Sampling

The groundwater monitoring well development will occur a minimum of 72-hours after installation. A surge and bail technique will be used to develop the wells. During well development, the temperature, pH, and electrical conductivity during each successive purge volume (casing and sand pack), will be recorded. Development will continue until the discharge water is relatively clear and free of sediment, and the temperature, electrical conductivity, and pH have stabilized.

4.2.5 GROUNDWATER SAMPLING

4.2.5.1 OBJECTIVES

The primary objective of groundwater sampling is to determine the water quality.

4.2.5.2 METHODS TO BE EMPLOYED

Prior to groundwater sample collection, the locking well caps will be removed to let the pressure inside the well equilibrate with atmospheric pressure for approximately 20 to 30 minutes. An electronic interface probe will be used to detect the potential presence of phase-separated hydrocarbons and measure the thickness. If phase separated hydrocarbons are present the well will not be sampled. To prevent cross-contamination, monitoring equipment that comes in contact with groundwater will be scrubbed with a solution of Alconox® detergent and rinsed with distilled water prior to use in each well.

Both the static groundwater level and total depth of the well will be measured from a reference point on the top of the well casing and recorded. Fluid measurements will be recorded to the nearest 0.01-foot. The static groundwater level and total depth of the well will then be used to calculate the total volume of water in the well.

Prior to the collection of groundwater samples, a minimum of three well volumes (casing and sand pack) will be purged from each well using a 2-inch Grundfos® submersible pump or a disposable polyethylene bailer. Periodic measurements (at approximate 5-gallon intervals) of temperature, pH, and specific electrical conductivity will be collected during purging. When three successive stabilized readings are obtained, the well will be sampled. If the well is low yielding and is pumped or bailed dry, the well will be allowed to recover at least 80% of the static groundwater level. If the well does not recover 80% within a 24-hour time frame, a sample will be collected and recovery noted on the Groundwater Sampling Log.

Groundwater samples will be collected from the well using a disposable polyethylene bailer. Each sample will be collected in laboratory certified clean 40-milliliter volatile organic analysis (VOA) vials and 1-liter glass bottles. Preservatives will be pre-added by the laboratory as appropriate for the analyses selected. Each VOA vial will be filled completely with sample to eliminate headspace and create a positive meniscus. Each VOA vial will be capped with a convex Teflon® septa. Each vial will be observed to ensure that no air bubbles are present within the vial. Samples will be marked for identification, placed in a cooler chilled with ice, and transported to a State-certified laboratory for analyses. Chain-of-custody records will be maintained and accompany samples to the analytical laboratory. Groundwater purged from the well will be stored on site in 55-gallon drums pending proper disposal. Cardno will notify the ACEH 48 hours in advance of commencing fieldwork.

4.2.6 LABORATORY ANALYSES OF COLLECTED SAMPLES

4.2.6.1 SOIL AND GROUNDWATER SAMPLES

All soil and groundwater samples will be analyzed as follows:

EPA Method 8015M
Total Petroleum Hydrocarbons as Gasoline (TPHg)
EPA Method 8260B
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)
Methyl Tertiary-Butyl Ether (MTBE)
Tertiary Butyl Alcohol (TBA)
Di-Isopropyl Ether (DIPE)
Ethyl Tertiary Butyl Ether (ETBE)
Tertiary Amyl Methyl Ether (TAME)
1,2-Dichloroethane (1,2-DCA)
Ethyl Dibromide (EDB)
Naphthalene[1]

[1] Soil samples collected from the upper 10 feet of the vadose zone are to be analyzed for naphthalene to supply data used in the Direct Contact to Outdoor Air Exposure evaluation of the LTCP.

4.2.6.2 SOIL GAS SAMPLES

4.2.7 PRELIMINARY INFORMATION SHARING

At the request of the ACEH, Cardno will provide preliminary data collected from the soil and groundwater portion of the investigation to the ACEH before conducting the soil gas portion of the investigation. The preliminary data may include:

- Laboratory test results,
- Boring logs,
- Well construction details,
- Depth to water data,
- Geologic cross sections

4.2.8 MANAGEMENT OF INVESTIGATION DERIVED WASTE

Investigative derived wastes (IDW) including soil cuttings, wash water, decontamination rinsate water, and purge water will be contained in Department of Transportation (DOT) approved 55-gallon drums. The drums will be labeled as non-hazardous waste and will be temporarily staged onsite pending laboratory results. Disposition of the IDW will be conducted by an appropriate waste disposal subcontractor and will be managed in accordance with State and local guidelines.

4.3 SOIL GAS INTRUSION STUDY

This part of the workplan is also subject to modification due to information obtained during the investigative work described in the previous sections.

4.3.1 OBJECTIVES

To assess whether or not the contaminants in the subsurface soil and/or groundwater pose a significant risk of adversely affecting human health through direct contact with contaminated soil or inhalation of volatilized contaminants.

4.3.2 SAMPLING LOCATIONS

The locations of the three soil gas sampling probe/sub-slab points are presently proposed to be installed in the basement area of the Salvation Army building. **Figure 8** depicts the proposed locations of the soil gas sampling probes / sub-slab soil gas points. If information obtained in the field during the MIP and HSA soil boring phases indicates alternate locations would be more appropriate, then the locations will be adjusted accordingly.

4.3.3 METHODS TO BE EMPLOYED

Soil gas samples will be collected from beneath the Salvation Army Building, analyzed for vapor phase PHC contaminants, and compared to established standards determined to be protective to human occupants. Cardno will follow the methodology for soil gas sampling established in the Final *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance)* October 2013, prepared by the San Francisco Bay Regional Water Quality Control Board.

4.3.3.1 Option 1: Semi-Permanent Soil Gas Sampling Probe Installation

Probe Installation

A six-inch diameter core will be cut in the concrete at each of the agreed upon locations. A California C57-licensed drilling company will advance each boring using a hand auger to an estimated depth of between four and six feet bgs. Soil cuttings, if any, will be stored on site in DOT approved 55-gallon drums and labeled as non-hazardous waste pending laboratory analyses

Upon completion of each boring, a semi-permanent vapor probe assembly will be installed. Each vapor probe will be constructed using 0.25-inch outer diameter (OD) Teflon tubing fitted with an ESP brand stainless steel wire screen tip implant at the base of the vapor probe. The aboveground Teflon vapor probe tubing will be fitted with a swaglok valve for future purging and vapor sample collection. The annulus will be backfilled with six inches of 2/12 Monterey sand and overlain with hydrated granular bentonite to seal the annular space above the sampling interval to prevent ambient air intrusion within the boring annulus. Each aboveground vapor probe assembly will be secured directly below the ground surface.

Probe Purging, Testing, and Sampling Methodology

The gas sampling probes will be allowed to equilibrate for minimum of 48-hours before sampling. An above ground sample collection train will be subsequently assembled that includes a three-way sample port assembly. One port will be attached to a Teflon tube connected to the subslab soil gas sampling probe. The second port will be connected to a vacuum/pressure gauge to measure the vacuum while purging. The third port will be used to withdraw soil gas samples. Sample withdrawal rates are restricted to 100 to 200 milliliters per minute (mL/min) through the use of a flow constrictor device within the sampling train.

A 60-ml plastic syringe will be used to remove three purge volumes of air from the soil gas sampling probe assembly. Purge volumes are derived by adding the annular void space created within the substrate below the vapor pin as a result of boring through the slab and the internal volume of sampling train. Once purging is complete, the syringe will be removed and replaced with a 200-ml/minute flow restrictor connected to a dedicated 400-ml SUMMA® canister provided by an off-site analytical laboratory. This completes the sampling train.

The probe sampling train will then be subjected to "shut in" and leak testing. The "shut in" test checks the integrity of the sampling train by establishing a vacuum of approximately 10 to 15 inches of mercury (inHg) by momentarily opening the valve to the SUMMA® canister and then holding steady for approximately 10 minutes. The vacuum of 10 to 15 inHg must be maintained over the 10 minutes to pass this test.

During purging and sampling activities, a "leak test" will be conducted. A temporary plastic enclosure will be constructed to envelope the sampling train. A leak check compound such as 1,1 difluoroethane (1,1-DFA) is introduced into the enclosure This set up exposes the sample train's connections, surface bentonite seals, and the top of the temporary soil gas probe to the leak check compound. If the analytical results indicate the presence of the leak detection compound, then the sample may be considered to be diluted with the ambient air, and resampling may be warranted.

Immediately prior to sampling, the manifold and tubing assembly will be purged of approximately three volumes of air using a 60-ml plastic syringe.

Soil Gas Sample Collection

One soil gas sample will be collected from each soil gas sampling point using the SUMMA® canister. Once the soil gas samples are collected, the SUMMA® canisters will be submitted under chain-of-custody procedures to an off-site State-certified laboratory for chemical analyses.

4.3.3.2 Option 2: Semi-Permanent Sub-Slab Soil Gas Sampling Point Installation

Probe Installation

Cardno field technicians will install semi-permanent sub-slab soil gas sampling points (Vapor Pins) in the northern area of the basement in general accordance with the manufacturer's instructions. Details regarding Vapor Pins and installation procedures are provided in **Appendix D**. Cardno will notify the ACEH 48 hours in advance of commencing fieldwork.

Probe Purging, Testing, and Sampling Methodology

The gas sampling points will be allowed to equilibrate for minimum of 48-hours before sampling. An above ground sample collection train will be subsequently assembled that includes a three-way sample port assembly. One port will be attached to a Teflon tube connected to the subslab soil gas sampling point. The second port will be connected to a vacuum/pressure gauge to measure the vacuum while purging. The third port will be used to withdraw soil gas samples. Sample withdrawal rates are restricted to 100 to 200-ml per minute through the use of a flow constrictor device within the sampling train. A 60-ml plastic syringe will be used to remove three purge volumes of air from the soil gas sampling point assembly. Purge volumes are derived by adding the annular void space created within the substrate below the vapor pin as a result of boring through the slab, and the internal volume of sampling train.

Once purging is complete, the syringe will be removed and replaced with a 200-ml/minute flow restrictor connected to a dedicated 400-ml SUMMA® canisters canister provided by an off-site analytical laboratory. This completes the sampling train.

The probe sampling train will then be subjected to “shut in” and leak testing. The “shut in” test checks the integrity of the sampling train by establishing a vacuum of approximately 10 to 15 inHg by momentarily opening the valve to the SUMMA® canister and then holding steady for approximately 10 minutes. The vacuum of 10 to 15 inHg must be maintained over the 10 minutes to pass this test.

During purging, testing, and sampling activities, a “leak test” will be conducted. A temporary plastic enclosure will be constructed to envelope the sampling train. A leak check compound such as 1,1 difluoroethane (1,1-DFA) is introduced into the enclosure This set up exposes the sample train’s connections, surface bentonite seals, and the top of the temporary soil gas point to the leak check compound. If the analytical results indicate the presence of the leak detection compound, then the sample may be considered to be diluted with the ambient air, and resampling may be warranted.

One soil gas sample will be collected from each soil gas sampling point using the SUMMA® canister. Once the soil gas samples are collected, the SUMMA® canisters will be submitted under chain-of-custody procedures to an off-site State-certified laboratory for chemical analyses.

4.3.4 SOIL GAS SAMPLE ANALYSES

Each soil gas sample will be analyzed as follows:

EPA Method TO-15	
Total Petroleum Hydrocarbons as Gasoline (TPHg)	Tertiary Amyl Methyl Ether (TAME)
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)	Ethyl Tertiary Butyl Ether (ETBE)
Methyl Tertiary-Butyl Ether (MTBE)	1,2-Dichloroethane (1,2-DCA)
Tertiary Butyl Alcohol (TBA)	Ethyl Dibromide (EDB)
Di-Isopropyl Ether (DIPE)	Naphthalene[2]
1,1-difluoroethane (1,1-DFA)[1]	
ASTM D 1945	
Oxygen[3]	

[1] 1,1-DFA = leak detection compound
[2] Soil gas samples collected are to be analyzed for Naphthalene to supply data used in the Direct Contact to Outdoor Air Exposure evaluation of the LTCP.
[3] For determination of possible bioattenuation zone.

The TO-15 analytical method will be used since this method typically provide the lowest practical detection limits and better accuracy when compared to EPA Methods 8015M and 8260B. The laboratory may use EPA Method 8260B to screen the sample for high concentrations to prevent instrument damage.

Cardno will request detection limits for the analytes of interest that are less than or equal to the commercial/industrial scenario screening levels provided in Table E of the Environmental Screening Levels (ESLs) for Indoor Air and Soil Gas (Vapor Intrusion Concerns) as published by the RWQCB San Francisco Bay Region in December 2013.

4.3.5 ASSESSMENT OF RISK TO INDOOR AIR

Cardno will use a tiered approach to evaluate the risk posed by the potential presence of PHC vapors in the subsurface resulting from the PHC release.

The soil vapor data will be compared to the *California Human Health Screening Levels (CHHSLs) for Indoor Air and Soil Gas* dated January 2005 provided by the California Environmental Protection Agency. Additionally, the soil vapor data will be compared to the values listed in Table E: Environmental Screening Levels (ESLs), Indoor Air and Soil Gas (Vapor Intrusion Concerns) of the document titled *User's Guide: Derivation and Application of Environmental Screening Levels* as prepared by the California Regional Water Quality Control Board, San Francisco Bay Region in the Interim Final document dated December 2013.

If the CHHSLs and ESLs for commercial/industrial exposure scenarios are exceeded, Cardno will model the highest analyte concentrations established in the soil vapor data, employing the USEPA sanctioned, Johnson and Ettinger vapor intrusion model algorithm, Version 2.0, dated January 2005. This model will estimate the individual and cumulative hazard quotient values and carcinogenic risk values for the selected analytes. This model was selected based on the predominant silty and sandy soil beneath the site.

5.0 REPORT PREPARATION

Upon receipt of the analytical data, Cardno will prepare a report for submission to the ACEH. This report will include:

- Descriptions of the field activities;
- The results of the Sensitive Receptor Survey;
- An updated Subsurface Utilities map;
- Boring/well logs;
- Laboratory derived analytical data presented in tabular form, isoconcentration maps that depict the estimated horizontal extent of PHC impacted soil and groundwater;
- A risk analyses of the impacts of the released hydrocarbons including a description of the risk analyses process;
- Updated Site Conceptual Model;
- Identification of remaining data gaps;
- Recommendations for further courses of action, if warranted.

6.0 PROJECTED TIMETABLE

Once approval of this workplan has been received from the ACEH, Cardno will confirm a schedule for field activities. Cardno will notify the ACEH at least 48 hours prior to beginning any field activities. The summary report will be submitted to the ACEH approximately 60 days following competition of field activities.

If you have questions or require additional information regarding this workplan, please contact us at (209) 579-2221.

Sincerely;

Michael D Sonke

Michael D. Sonke
Project Manager
for Cardno
Direct Line +1 209 579 2221
Email: mike.sonke@cardno.com

Todd Hafner

Todd Hafner, P.G.
CA Professional Geologist No. 8090
for Cardno
Direct Line +1 209 579 2221
Email: todd.hafner@cardno.com

TODD C. HAFNER
No. 8090

REFERENCES

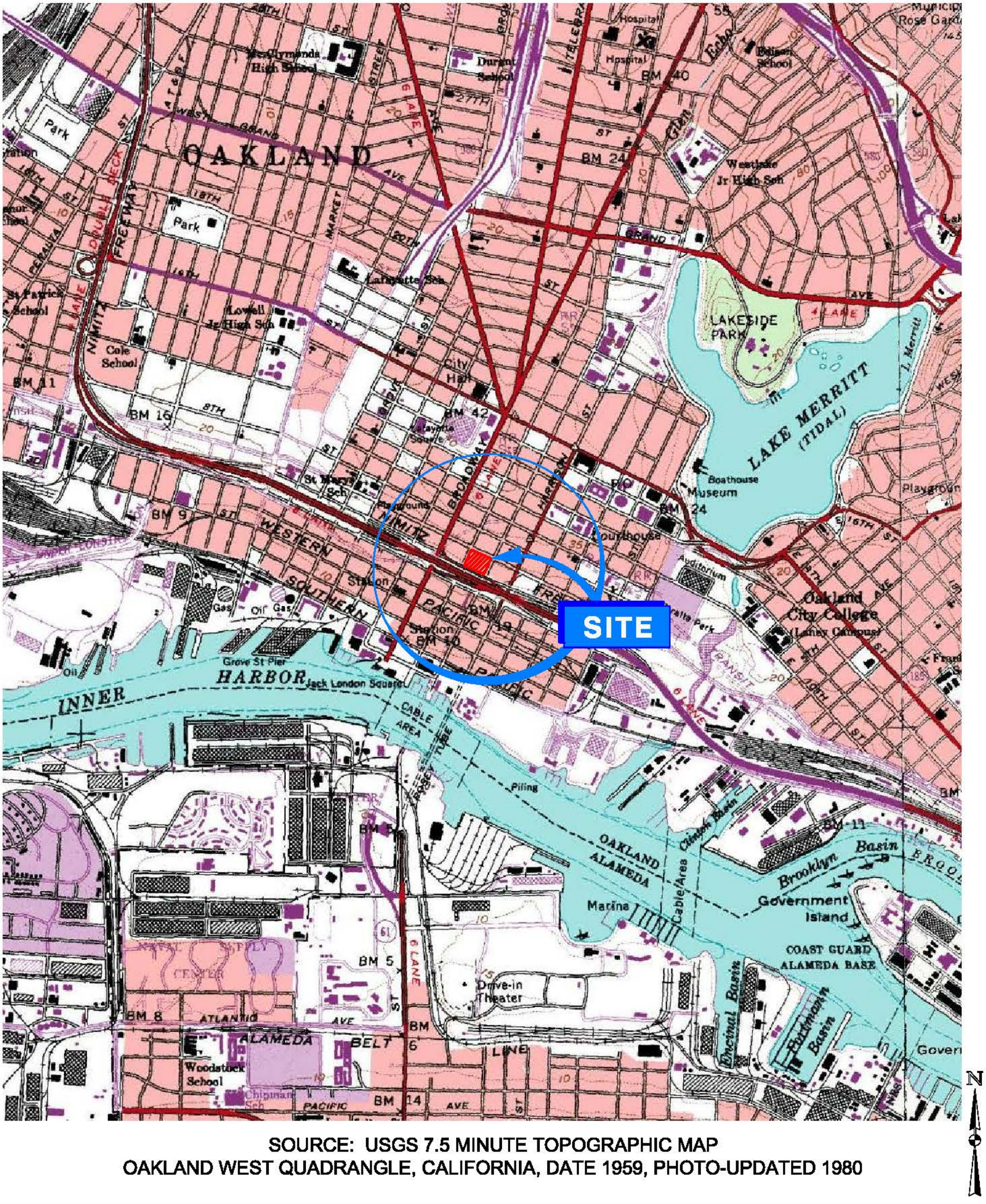
USEPA Site Characterization/Assessment Website http://www.epa.gov/oust/cat/sitechar.htm

Leaking Underground Fuel Tank (LUFT) Guidance Manual, California State Water Resources Control Board, September 2012, page 6-3.

A Guideline for Dynamic Workplans and Field Analytics: The Keys to Cost-Effective Site Characterization and Cleanup Prepared by Albert Robbat, Jr.Tufts University, Chemistry Department Center for Field Analytical Studies and Technology Medford, Massachusetts, 02155, 1998. A complete copy of this document is included as **Appendix B**.

SFBRWQCB. 2011d. *Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air(Vapor Intrusion Guidance)*. October.2013 San Francisco Bay Regional Water Quality Control Board, 1515 Clay Street, Suite 1400, Oakland, CA 94612
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/ESL/Users_Guide_Dec_2013.pdf

FIGURES



SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP
OAKLAND WEST QUADRANGLE, CALIFORNIA, DATE 1959, PHOTO-UPDATED 1980

FIGURE 1

SITE LOCATION MAP

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CALIFORNIA

Cardno ATC
Shaping the Future

1117 LONE PALM AVE., SUITE 201
MODESTO, CA 95351
Ph: (209) 579-2221

PROJECT NUMBER: 054.25026.0001

DESIGNED BY: MDS	APPROVED BY: JH	DATE: 8-14-14
REVIEWED BY: MDS	DRAWN BY: DAW	SCALE: 1:24,000

FILE: W:\25026 Modesto\Cad Files\1-25026.0001-Salvation Army Oakland.dwg

NOTE: SCALE AND LOCATIONS ARE APPROXIMATE

SITE PLAN

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CA

PROJECT NUMBER: Z0540000066
APPROVED BY: M. SONKE
DATE: 2/18/15
DRAWN BY: DAW

FIGURE
2

Cardno
Shaping the Future
1117 Lone Palm Avenue, Ste. 201
Modesto, California 95351
Ph: (209) 579-2221 *** Fax: (209) 579-2225

FILE: W:\Modesto (25026)\Z054000006\1-Salvation Army Oakland.dwg Feb 24, 2015 - 4:08pm denise.walp

NOTE: SCALE AND LOCATIONS ARE APPROXIMATE

FIGURE 3

SENSITIVE RECEPTOR SURVEY: AREA OF SEARCH

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CALIFORNIA

Cardno ATC
Shaping the Future

1117 LONE PALM AVE., SUITE 201
MODESTO, CA 95351
Ph: (209) 579-2221

PROJECT NUMBER: 054.25026.0001		
DESIGNED BY: MDS	APPROVED BY: JH	DATE: 8-14-14
REVIEWED BY: MDS	DRAWN BY: DAW	SCALE: 1" = 1,000'

FILE: W:\25026 Modesto\Cad Files\1-25026.0001-Salvation Army Oakland.dwg

LEGEND

- APPROXIMATE FACILITY BOUNDARY
- FORMER UST
- FORMER EXCAVATION
- TRUCK SHOP ENCLOSURE AREA
- ○ FORMER DIRECT PUSH BORING
- ● PROPOSED MIP BORING LOCATION

0 20' 40'

SCALE, FT

N

NOTE: SCALE AND LOCATIONS ARE APPROXIMATE

FIGURE 4

DATE: 2/18/15

DRAWN BY: DAW

PROJECT NUMBER: Z0540000066

APPROVED BY: M. SONKE

Cardno
Shaping the Future

1117 Lone Palm Avenue, Ste. 201
Modesto, California 95351
Ph: (209) 579-2221 *** Fax: (209) 579-2225

MIP BORING LOCATIONS

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CA

FILE: W:\Modesto (25026)\Z054000006\1-Salvation Army Oakland.dwg Feb 18, 2015 – 3:38pm denise.walp

LEGEND

- APPROXIMATE FACILITY BOUNDARY
- FORMER UST
- FORMER EXCAVATION
- TRUCK SHOP ENCLOSURE AREA
- ○ FORMER DIRECT PUSH BORING
- FORMER TANK PIT BORING
- PROPOSED HSA BORING LOCATION

0 20' 40'

SCALE, FT

NOTE: SCALE AND LOCATIONS ARE APPROXIMATE

N

FIGURE 5

DATE: 2/18/15

PROJECT NUMBER: Z0540000066

DRAWN BY: DAW

APPROVED BY: M. SONKE

Cardno
Shaping the Future
1117 Lone Palm Avenue, Ste. 201
Modesto, California 95351
Ph: (209) 579-2221 *** Fax: (209) 579-2225

HSA BORING LOCATIONS

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CA

FILE: W:\Modesto (25026)\Z054000006\1-Salvation Army Oakland.dwg Feb 18, 2015 - 3:38pm denise.walp

NOTE: SCALE AND LOCATIONS ARE APPROXIMATE

GROUNDWATER MONITORING WELL LOCATIONS

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CA

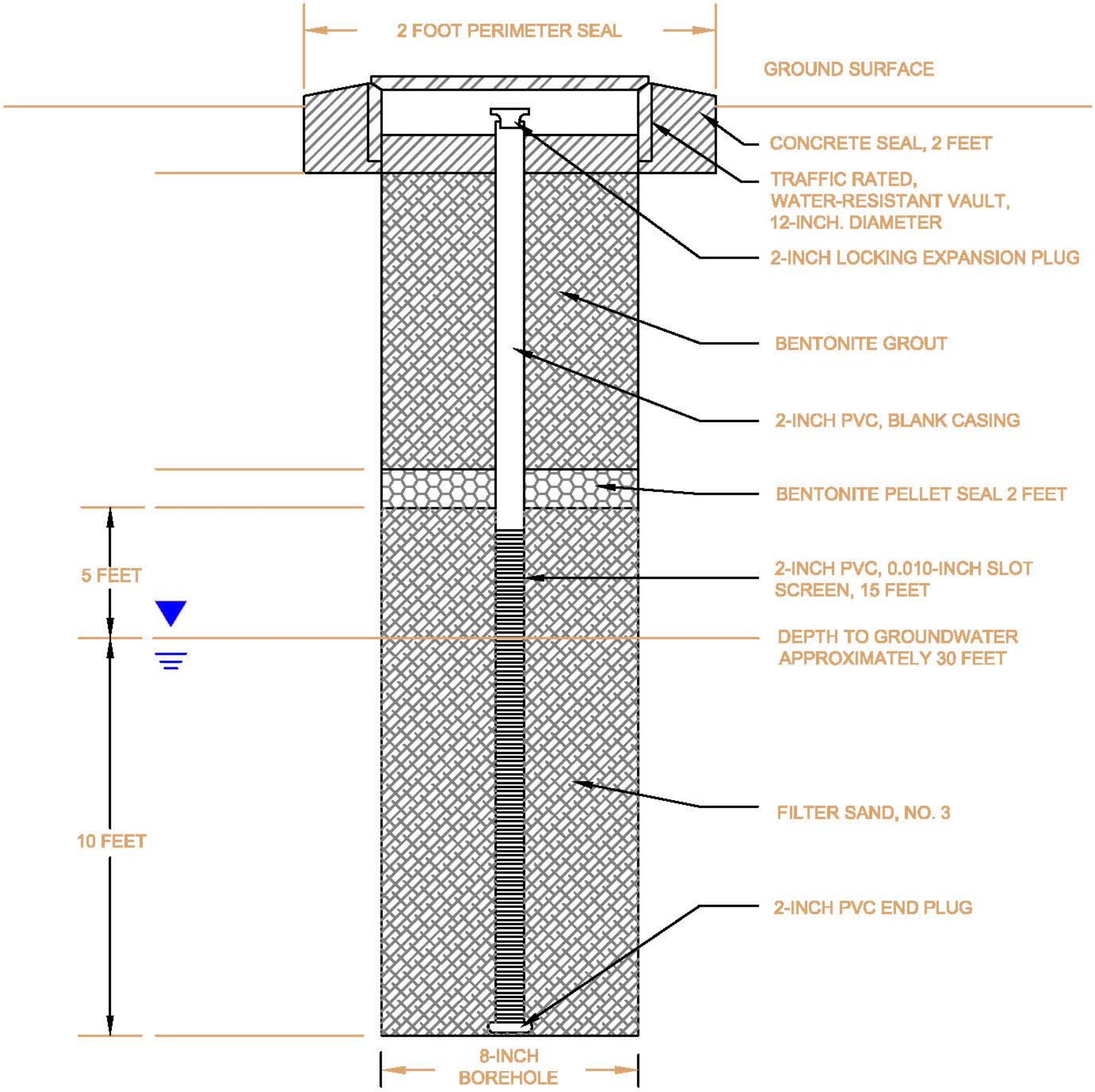
PROJECT NUMBER: Z0540000066	DATE: 2/18/15
APPROVED BY: M. SONKE	DRAWN BY: DAW

FIGURE
6

Cardno
Shaping the Future
1117 Lone Palm Avenue, Ste. 201
Modesto, California 95351
Ph: (209) 579-2221 *** Fax: (209) 579-2225

FILE: W: \Modesto (25026)\Z054000006\1–Salvation Army Oakland.dwg Feb 18, 2015 – 3:38pm denise.walp

TYPICAL MONITORING WELL CONSTRUCTION



NOTE: NOT TO SCALE

FIGURE 7

CONSTRUCTION DETAILS: MONITORING WELLS

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CALIFORNIA

Cardno ATC
Shaping the Future

1117 LONE PALM AVE., SUITE 201
MODESTO, CA 95351
Ph: (209) 579-2221

PROJECT NUMBER: 054.25026.0001		
DESIGNED BY: MDS	APPROVED BY: JH	DATE: 8-14-14
REVIEWED BY: MDS	DRAWN BY: DAW	SCALE: N.T.S.

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NOTE: SCALE AND LOCATIONS ARE APPROXIMATE

FIGURE 8

PROPOSED LOCATIONS:SOIL GAS POINTS

THE SALVATION ARMY
601 WEBSTER STREET
OAKLAND, CALIFORNIA

Cardno ATC
Shaping the Future

1117 LONE PALM AVE., SUITE 201
MODESTO, CA 95351
Ph: (209) 579-2221

PROJECT NUMBER: 054.25026.0001

DESIGNED BY: MDS	APPROVED BY: JH	DATE: 8-14-14
REVIEWED BY: MDS	DRAWN BY: DAW	SCALE: 1" = 30'

FILE: W:\25026 Modesto\Cad Files\1-25026.0001-Salvation Army Oakland.dwg

APPENDICES

Appendix A

Technical Justification for Groundwater Plume Lengths, Indicator Constituents, Concentrations, and Buffer Distances (Separation Distances) to Receptors

The purpose of this document is to provide technical justification for the four classes of low-threat groundwater plumes that are described in the Groundwater section of the Low-Threat UST Closure Policy (the Policy). The fifth plume class is a site-specific evaluation.

The Policy Stakeholder Group chose benzene, MTBE, and TPHg as adequate indicator constituents for the groundwater *plume lengths* discussed in the Policy. The technical justification for using these three constituents, discussed in more detail below, relies heavily on the facts that (1) benzene has the highest toxicity of the soluble petroleum constituents, (2) MTBE typically has the longest plume lengths, and (3) TPHg represents the additional dissolved hydrocarbons that may be present resulting from a typical petroleum release. Although TPHd is not used to describe plume lengths (largely because the hydrocarbons in the TPHd carbon range are of low solubility), other technical considerations associated with the use of TPHd data are discussed below.

Benzene and MTBE are used in research studies as key indicator constituents for the threat (human health risk and nuisance) posed by groundwater plumes from petroleum releases because (1) benzene has the highest toxicity of the soluble petroleum constituents, and (2) MTBE typically has the longest plume lengths and has a low secondary MCL (taste and odor threshold of 5 micrograms/liter [ug/l]).

Several significant multi-site studies of groundwater plume lengths from petroleum release sites have been conducted across the U.S. since the mid-1990s. These studies included sites where remediation had been performed and sites where no active remediation had been performed. Most of these studies focused on benzene plumes (e.g., Rice, et al. 1995; Rice et al. 1997; Busheck et al. 1996; Mace, et al. 1997; Groundwater Services, Inc. 1997; API 1998); three studied benzene and oxygenate plumes (including MTBE) (Dahlen et al. 2004; Shih et al. 2004; Kamath et al. in press). Most of these plume studies are further discussed in detail in the Fate and Transport chapter of the California LUFT Manual.

In summary for all of these multi-site studies, the average benzene plume length was less than 200 feet and 90% of the benzene plumes were less than 400 feet long. The peer-reviewed study by Shih et al. (2004) of plume lengths at 500 UST sites in the Los Angeles area is widely relied upon as representative of current knowledge of plume lengths at UST sites in California. Results for benzene, MTBE and TPHg from Shih et al. (2004) are as follows:

Constituent (and plume limit concentration)	Average Plume Length (feet)	90th Percentile Plume Length (feet)	Maximum Plume Length (feet)
Benzene (5 ug/l)	198	350	554
MTBE (5 ug/l)	317	545	1,046
TPHg (100 ug/l)	248	413	855

Data are from Shih et al. (2004). Plume lengths were measured from the source area.

Although the California MCL for benzene is 1 ug/l, Shih et al. (2004) used a plume limit concentration of 5 ug/l because of statistical uncertainty with concentrations too close to the laboratory reporting limit. The benzene plume lengths at a 1 ug/l concentration limit would be expected to be slightly longer than those shown here.

Ruiz-Aguilar et al. (2003) studied UST sites in the Midwest with releases of ethanol-amended gasoline (10% ethanol by volume) and found that benzene plume lengths may increase by 40% to 70% due to the addition of ethanol in gasoline (replacing MTBE). Ethanol is preferentially biodegraded over the benzene, which results in a longer benzene plume. However, the Policy addresses this potential for expansion of the plume lengths by adding safety factors of 100% to 400%.

It is well documented that, due to effective solubility, the hydrocarbons that will dissolve at measurable amounts into groundwater from a petroleum fuel release (including gasoline, kerosene, jet fuel, diesel or heavier fuels) are limited to primarily the very small aliphatics (less than C7) and the C14 or smaller aromatics (e.g., Shiu et al. 1990; Coleman et al. 1984). The C15 and larger hydrocarbons have very low effective solubilities and are not found in the dissolved phase of a petroleum fuel release. The carbon range of the potential dissolved hydrocarbons (less than or equal to C14) is largely covered by the TPHg carbon range (approximately C5 to C12). Therefore, TPHg should be sufficient to represent the dissolved hydrocarbons that may be present in addition to benzene and MTBE from virtually any type of product release. TPHd was not included as an indicator constituent for groundwater plume length because the vast majority of the TPHd carbon range (approximately C12 to C22) is higher than the carbon range for the possible dissolved hydrocarbons (less than or equal to C14). Oxygenates other than MTBE were not included as indicator constituents because Shih et al. (2004) documented that MTBE had the longest plume length of any of the oxygenates (MTBE, TBA, DIPE, TAME, ETBE) at any percentile, and Kamath et al. (in press) found that TBA plumes were comparable in length to MTBE plumes. Therefore, MTBE can be used as a conservative indicator for the other oxygenates including TBA.

For groundwater samples analyzed for TPHd for comparison to Water Quality Objectives (WQOs), a silica gel cleanup (SGC) should be included for the following reasons. It is well known that the TPHd analysis (Method 8015B) is not specific to hydrocarbons unless a SGC is used; otherwise the reported TPHd concentration can include polar non-hydrocarbon compounds in addition to the hydrocarbons that may be present in a water sample (e.g., Zemo and Foote

2003). These polar compounds can be from various sources, including metabolites from biodegradation of petroleum (primarily alcohols and organic acids, with possible phenols, aldehydes and ketones). At sites with biodegrading petroleum, the majority of the organics being measured as "TPHd" (without SGC) can be polar compounds and not dissolved hydrocarbons. WQOs for diesel-range petroleum hydrocarbons for health risk or taste and odor concerns are based on the properties of the dissolved hydrocarbons assumed to be present and not on the properties of the polar compounds. For example, the health-based ESL for TPHd is based on the assumption that 100% of the TPH has a toxicity equivalent to the C11 to C22 aromatics, and the taste and odor value for TPHd is based on the dissolved phase of fresh diesel/kerosene (which would be primarily the C14 and smaller aromatics) (SFRWQCB 2008). The San Francisco Bay RWQCB recognized that reported TPHd concentrations may include polar compounds and issued a guidance memorandum recommending that SGC be routinely used so that "….. decisions could be made based on analytical data that represents dissolved petroleum." (SFRWQCB 1999). Only the hydrocarbon component of the TPHd concentration should be compared to the TPHd WQOs, and thus SGC is necessary to separate the hydrocarbons from the polar compounds in a groundwater sample prior to analysis. It is well established that a SGC does not remove the dissolved hydrocarbons in a sample (e.g., Lundegard and Sweeney 2004). Further, the potential for removal of hydrocarbons by a SGC is always monitored as part of the routine laboratory quality assurance reporting where lab control samples are spiked with a hydrocarbon (surrogate), are subjected to a SGC, and recovery of the surrogate is measured and must be within acceptable ranges.

The four classes of stabilized plume lengths and buffer distances from the plume edge to the closest water supply well or surface water (receptors) that are defined as "low threat" in the Policy are initially based upon the plume lengths from the studies cited above, but also are based on additional safety factors that the Stakeholder Group considered applicable to be protective in a state-wide policy document. For example, based on the plume studies, *a total separation distance from the source area to the receptor of about 500 feet should be protective for 90% of plumes from UST sites, and a total separation distance from the source area to the receptor of about 1,000 feet should be protective for virtually all plumes from UST sites*. Conversely, the "low-threat classes" require a known maximum stabilized plume length (which reduces uncertainty as to how long the plume might become in the future), and include additional safety factors and concentration limits developed by the Stakeholder Group.

Stakeholder Group participants also recognize and acknowledge that this Policy is consistent with other State and local practices regarding impacts to groundwater caused by other anthropogenic releases. For example, State and local agencies establish required separation distances or "setbacks" between water supply wells and septic system leach fields (typically 100 feet), and sanitary sewers (typically 50 feet; [DWR 1981]).

The Stakeholder Group acknowledges that the biodegradation/natural attenuation of petroleum hydrocarbon and oxygenate plumes has been documented by many researchers since the 1990s.

All of this work shows that biodegradation/natural attenuation of petroleum hydrocarbons and MTBE occurs under both aerobic and anaerobic conditions, but the rate of degradation/attenuation depends on the individual constituent and the plume geochemical conditions. The maximum concentrations for benzene and MTBE specified in the low-threat classes below are expected to biodegrade/naturally attenuate to WQOs within approximately 10 to 30 years, based on commonly-accepted rate constants for typical plume conditions and calculations (e.g., Wilson 2003; USEPA 2002). A time period of multiple decades or longer to reach WQOs has been determined to be "reasonable" for plumes of limited extent in existing State Water Board closure orders for UST sites (e.g., Order WQ 98-04 [Matthew Walker]).

TBA is a byproduct of biodegradation of MTBE, and TBA concentrations can build up temporarily in the anaerobic portion of a plume. With respect to the natural attenuation of TBA, Kamath et al. (in press) recently studied benzene, MTBE and TBA plumes at 48 UST sites (30 sites in California) and found that (1) most (68%) of the TBA plumes were stable or decreasing in size, and (2) in the stabilized plumes, the median attenuation rate for TBA was similar to the rates for MTBE and benzene. These findings indicate that TBA should not pose a significant threat to groundwater resources, and are consistent with the finding from Williams (in press) that TBA and MTBE have been detected in only a very limited number of public drinking water supply wells in California between 1996 and 2010. The average annual detection frequencies at any concentration and at concentrations greater than the WQO (12 ug/l for TBA and 5 ug/l for MTBE), through 2010 are: 1.4% and 0.2% for TBA, respectively, and 1.6% and 0.8% for MTBE, respectively (Williams, in press).

The following paragraphs present and discuss the key rationales for low-threat plume lengths, maximum concentrations, and separation distances for each low-threat class. Note that the specified concentrations are maximums, and would likely occur in only a few wells; the average concentrations in the plume would be lower. Note also that these groundwater plume class criteria (concentrations, plume lengths and separation distances) are only one component of the overall evaluation of site conditions that must be satisfied to be considered for closure as a low-threat site under the Policy.

Class 1: The "short" stabilized plume length (<100 feet) is indicative of a small or depleted source and/or very high natural attenuation rate. The 250 feet distance to a receptor from the edge of the plume represents an additional 250% "plume length" safety factor in the event that some additional unanticipated plume migration was to occur.

Class 2: The "moderate" stabilized plume length (<250 feet) approximates the average benzene plume length from the cited studies. The maximum concentrations of benzene (3,000 ug/l) and MTBE (1,000 ug/l) are conservative indicators that a free product source is not present. These concentrations are approximately 10% and 0.02%, respectively, of the typical effective solubility of benzene and MTBE in unweathered gasoline. These concentrations are expected to biodegrade/naturally attenuate to WQOs within a reasonable time frame. The potential for vapor intrusion from impacted groundwater must be evaluated separately as per the vapor intrusion section of the Policy. The 1,000 feet distance to the receptor from the edge of the plume is an additional 400% "plume length" safety factor in the event that some additional unanticipated plume migration was to occur. Also note that California Health and Safety Code §25292.5 requires that UST owners and operators implement enhanced leak detection for all USTs within 1,000 feet of a drinking water well. In establishing the 1,000 feet separation requirement the legislature acknowledged that 1,000 feet was a sufficient distance to establish a protective setback between operating petroleum USTs and drinking water wells in the event of an unauthorized release.

Class 3: The "moderate" stabilized plume length (<250 feet) approximates the average benzene plume length from the cited studies. The on-site free product and/or high dissolved concentrations in the plume remaining after source removal to the extent practicable (as per the General Criteria in the Policy) require five years of monitoring to validate plume stability/natural attenuation (i.e., to confirm that the rate of natural attenuation exceeds the rate of NAPL dissolution and dissolved-phase migration). The potential for vapor intrusion from free product or impacted groundwater must be evaluated separately as per the vapor intrusion section of the Policy. The 1,000 feet distance to the receptor from the edge of the plume is an additional 400% "plume length" safety factor in the event that some additional unanticipated plume migration was to occur, and is consistent with H&S Code §25292.5 as discussed above.

Class 4: The "long" stabilized plume length (<1,000 feet) approximates the maximum MTBE plume length from Shih et al. (2004). The maximum benzene and MTBE source area concentrations (1,000 ug/l each) in the stable plume are expected to biodegrade/naturally attenuate to WQOs within a reasonable time frame. The maximum benzene concentration would not pose a vapor intrusion risk over the extent of the plume (assuming that five feet of bioreactive vadose zone is available over the extent of the plume; see justification for vapor intrusion screening criteria for details). The 1,000 feet distance to the receptor from the edge of the plume is an additional 100% "plume length" safety factor in the event that some additional unanticipated plume migration was to occur, and is consistent with H&S Code §25292.5 as discussed above.

Notes on Free Product Removal

State regulation (CCR Title 23, Division 3, Chapter 16, Section 2655) requires that "responsible parties"…. remove free product to the maximum extent practicable, as determined by the local agency…" (Section 2655a) "…. in a manner that minimizes the spread of contamination into previously uncontaminated zones"… (Section 2655b), and that "[a]batement of free product migration shall be the predominant objective in the design of the free product removal system" (Section 2655c). Over the years there has been debate on the meaning of the terms "free product" and "maximum extent practicable". Product (light non-aqueous phase liquid [LNAPL]) can exist in three conditions in the subsurface: residual or immobile LNAPL (LNAPL that is trapped in the soil pore spaces by capillary forces and is not mobile), mobile LNAPL (enough LNAPL is present in the soil pore spaces to overcome capillary forces so that the LNAPL can move) and migrating LNAPL (mobile LNAPL that is migrating because of a driving head). "Residual LNAPL", "mobile LNAPL" and "migrating LNAPL" are described in detail in several peer-reviewed technical documents, including the 2009 Interstate Technology Regulatory Council (ITRC) Technical/Regulatory Guidance "Evaluating LNAPL Remedial Technologies for Achieving Project Goals". Given the predominant objective of <u>abatement of migration</u>, the term "free product" in the State regulation is primarily equivalent to "migrating LNAPL" (which is a subset of "mobile LNAPL"), and secondarily equivalent to "mobile LNAPL". Whether LNAPL is mobile (and therefore could potentially migrate) or not is usually tested by observing recharge of LNAPL after removing LNAPL from a monitoring well. Whether LNAPL is migrating or not is tested by monitoring the extent of the LNAPL body (usually using the apparent product thickness in monitoring wells) at a certain water level elevation over time. If the extent at that water level elevation does not expand, then the LNAPL is not migrating. Therefore, LNAPL must be removed to the point that its migration is stopped, and the LNAPL extent is stable. Further removal of non-migrating but mobile LNAPL is required to the extent practicable at the discretion of the local agency. Removal of mobile LNAPL from the subsurface is technically complicated, and the definition of "extent practicable" is based on site-specific factors and includes a combination of objectives for the LNAPL removal (such as whether the mobile LNAPL is a significant "source" of dissolved constituents to groundwater or volatile constituents to soil vapor, or whether there is a high likelihood that hydrogeologic conditions would change significantly in the future which may allow the mobile LNAPL to migrate) and technical limitations. The typical objectives for LNAPL removal, technologies for LNAPL removal and technical limitations of LNAPL removal are discussed in several peer-reviewed technical documents including the 2009 ITRC Guidance (see especially Section 4 "Considerations/Factors Affecting LNAPL Remedial Objectives and Remedial Technology Selection", Table 4.1 [Example Performance Metrics], Table 5-1 [Overview of LNAPL Remedial Technologies], and Table 6-1 [Preliminary Screening Matrix]).

References

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Appendix B

A Guideline
for

Dynamic Workplans and Field Analytics:
The Keys to Cost-Effective Site Characterization and Cleanup

Prepared by

Albert Robbat, Jr.
Tufts University, Chemistry Department
Center for Field Analytical Studies and Technology
Medford, Massachusetts, 02155
tel: 617-627-3474 and fax: 617-627-3443

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1.0 Introduction

The ability to rapidly assess the disposition of environmental contaminants at purported or existing hazardous waste sites is an essential component of the nation's environmental restoration program. Each site, whether owned by the public or private sector, must be evaluated to determine whether risk to human health or the environment exists. If the data obtained supports the notion that no risk or an acceptable level of risk exists for the intended land usage then no further action may be required. If, on the other hand, sufficient risk has been determined to warrant a full site characterization, the site investigation effort must delineate the nature, extent, direction, concentration and rate of movement of the contamination along with the physical and chemical site attributes.

Despite the best efforts of the U.S. Environmental Protection Agency[1] (EPA) and other federal agencies including the Departments of Defense and Energy to validate field analytical technologies, field analytics has not played a significant role in either hazardous waste site assessments or cleanup. In 1995, the EPA issued a Request for Proposals in support of President Clinton's efforts to promote application of innovative environmental technologies and to address the many factors that might pose barriers toward their commercialization. The President's Environmental Technology Initiative (ETI) is focused on accelerating environmental protection, strengthening America's industrial base, and increasing exports of U.S. technologies and expertise. The Tufts project was directed at two key objectives identified in the FY95 strategic plan: namely, strengthening the capacity of technology developers and users to succeed in environmental innovation *and* strategically investing EPA funds in the development and commercialization of promising new environmental monitoring, control, and remediation technologies.

The dynamic workplan guidance document represents one aspect of these objectives. The document is aimed at helping federal and state regulators, siteowners and their consulting engineers, and remediation companies understand what is involved in constructing and carrying out a dynamic workplan. The purpose of the document is to illustrate the many factors that should be considered in incorporating field analytical instrumentation and methods into an adaptive sampling and analysis program for expediting the site investigation process. This dynamic process should result in a faster, better, and hopefully cheaper site characterization and cleanup. With this goal in mind, field analytical technologies developed by the Tufts' Center for Field Analytical Studies and Technologies and with in-kind support from several commercial companies were demonstrated in the context of a dynamic workplan/adaptive sampling and analysis strategy. The ETI project, in part, supported an ongoing soil investigation study at Hanscom Air Force Base (Bedford, MA), see Hanscom report.[2] With the assistance of EPA Region 1, the Air Force and its contractor (CH2MHill), a video tape was produced illustrating the dynamic site investigation process.

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[1] E. Koglin and L. R. Williams, Trends in Analytical Chemistry, 13, 294-299 (1994).

[2] A. Robbat, Jr., Tufts University, Case Study: Dynamic Workplans and Field Analytics: The Keys to Cost-effective Site Investigations, 1997.

1.1 Dynamic Workplans

Successful hazardous waste site investigations should be focused with goals and objectives clearly defined. This does not mean, as has been past practice, that the site investigation process should result in workplans that are “etched in stone.” Figure 1 depicts a traditional sampling and analysis program. The workplan relies on pre-specified sampling locations, numbers of samples collected and the types of analysis to be performed. The traditional site investigation is static in its application. It does not provide a framework for changes in direction based on what is learned in the field. Samples are collected, packaged and typically sent off-site for analysis. Because data turnaround times range from several weeks to several months, analytical results are unavailable during the field investigation phase to address data “surprises” or concerns while the sampling team is still on site. Experience has shown that multiple field investigations within the same or subsequent seasons are required to fill data gaps. The traditional process results in several trips to the field by the sample collection and survey teams before the site investigation can be completed. This static process typically occurs during hazardous waste site cleanups as well.

Dynamic workplans, as shown in Figure 2, provide an alternative to the traditional approach. Dynamic workplans rely, in part, on an adaptive sampling and analysis strategy. Rather than dictate the details of the sample analysis to be performed and the location and number of samples to be collected, dynamic workplans specify the decision-making logic that will be used in the field to determine which chemical compounds require analysis, where to collect the samples and when to stop sampling. Adaptive sampling and analysis programs change as the conceptual model for the site is refined based on the analytical results produced in the field. A successful adaptive sampling and analysis program requires analytical methods and instrumentation that are field-practical and can produce data fast enough to support the dynamic workplan process.

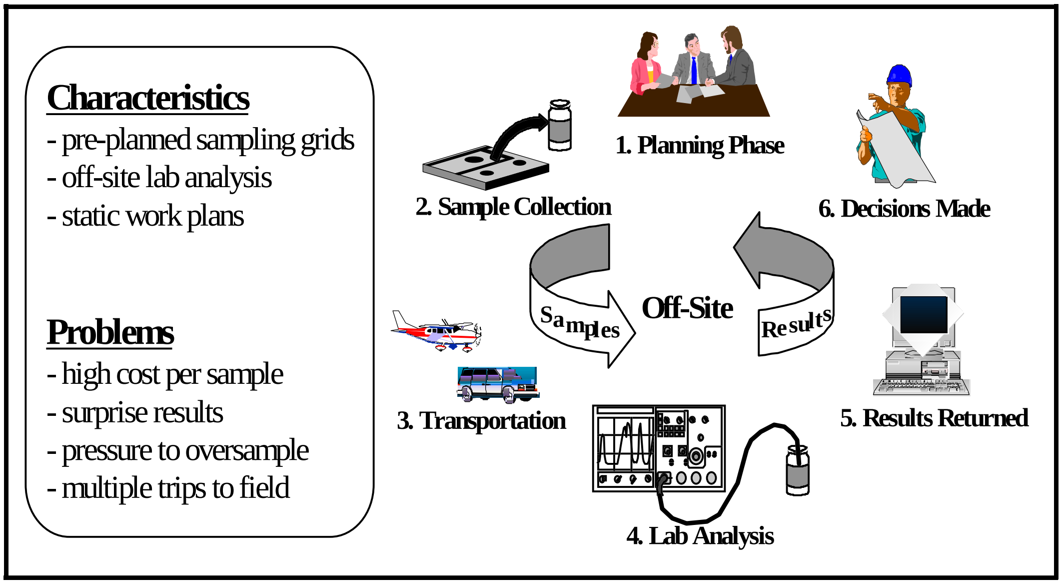
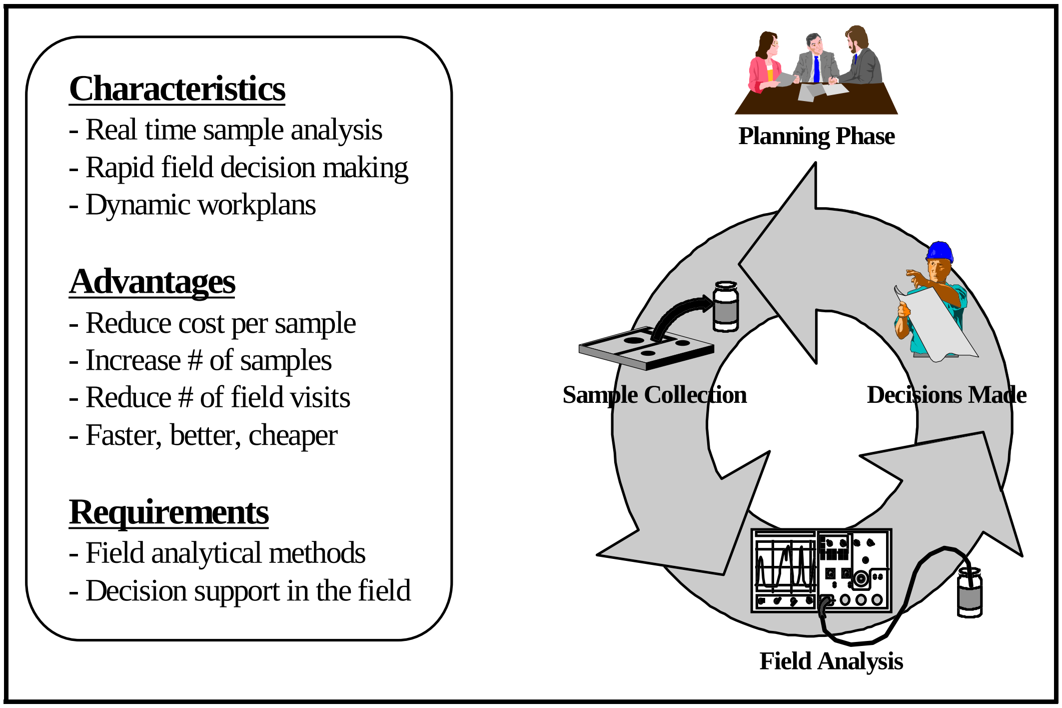


Figure 1. Traditional Site Investigation



Characteristics
- Real time sample analysis
- Rapid field decision making
- Dynamic workplans

Advantages
- Reduce cost per sample
- Increase # of samples
- Reduce # of field visits
- Faster, better, cheaper

Requirements
- Field analytical methods
- Decision support in the field

Figure 2. Dynamic Workplan Approach

1.2 Factors to be Considered

When deciding to carry out a Dynamic Workplan/Adaptive Sampling and Analysis program for projects consisting of complex chemical and physical site conditions, environmental contamination, and long duration, several factors should be considered before embarking on this approach. For example:

- Is it possible to assemble a well-rounded core technical team including analytical chemists, engineers, geologists, geochemists, geophysicists, hydrogeologists, risk assessors, and regulators?

- Will the core technical team be in the field for the duration of the field investigation? Is the decision making process well-defined and is the authority vested in an appropriate technical team member?

- Has the action level for field decisions, which rely on developing an understanding of the scientific and engineering questions under investigation, been established as part of the data quality objectives?

- Will the project objectives permit screening and semi-quantitative data or will quantitative data only be required to meet data quality objectives?

- Will more than ten percent of the samples analyzed in the field be sent off-site for laboratory confirmation analysis? Has the methodology for determining field and laboratory data comparisons been addressed?

- When selecting the field instrument or method, have measurement selectivity, sensitivity, precision, accuracy, representativeness, and action levels been addressed?

- When selecting the field instrument or method, have the measurement attributes listed above been addressed in sample throughput rates and cost? (Note that the number of sample cleanup steps and the time needed to prepare samples for analysis to meet the site-specific data quality objectives may limit throughput rates and increase sample costs.)

- Can standard operating procedures and method detection limit studies be completed before mobilization to evaluate matrix interferences that might be associated with a particular field technology?

- Will data management tools and geostatistical sampling tools be integrated into the field investigation?

- Is the site accessible for field analytic deployment including mobile laboratories, electrical power (line voltage versus a generator), and water if necessary?

- Has sufficient space been provided to house analytical instruments and staff, sample preparation, and data management in the field laboratory? Has proper ventilation been incorporated into the field laboratory?

- Does the length of the project and the potential overall cost savings warrant this approach?

2.0 Dynamic Workplan Guideline: Purpose and Objective

Dynamic workplan investigations are site dependent. They include field-based technologies and methods that produce chemical, physical, geological, and hydrogeological information about the site. The data generated must be of sufficient quality, with respect to measurement precision, accuracy, sensitivity, and completeness, to support the objectives of the site investigation or cleanup. The dynamic workplan plan guide described herein is not intended to be all inclusive. It does not address subsurface sampling tools; methods for collecting soil, water, or air samples; remote sensing and geophysical surveys; mathematical or computer modeling; nor will it discuss computer-based statistical sampling or the various site visualization tools. Depending on project objectives, a successful *dynamic* hazardous waste site investigation or cleanup will require one or more of these tools.

The guidance document is aimed at integrating field analytics into the Dynamic Workplan/Adaptive Sampling and Analysis process. It is intended to lay the foundation for incorporating an iterative process into the static but widely-used Data Quality Objectives (DQOs) framework for decision making planning. The guideline outlines field analytical instrument implementation, an adaptive sampling and analysis strategy, and site requirements.

3.0 The Dynamic Workplan Process

In the traditional approach, major decisions concerning the direction of the site investigation or cleanup are generally made by the project manager after the field work has been completed. A report is prepared presenting the findings to the appropriate regulatory body. Discussions begin about whether sufficient information has been obtained to address the scientific and engineering questions of concern. Typically, several field mobilizations occur, reports are written, with many meetings held between the siteowner and its environmental consulting company *and* the siteowner and federal and/or state regulatory agencies. In contrast, these same decisions are made in the field in an adaptive sampling and analysis program. In constructing the dynamic workplan, it is important to determine prior to mobilization what decisions will be made, how these decisions will be made, and who will make them in the field.

<u>Step 1: Select the core technical team whose responsibility it will be to prepare the dynamic workplan.</u> The technical team should possess expertise in analytical chemistry, geology, geochemistry, geophysics, hydrogeology, and risk analysis. The team helps with data management, QA/QC, risk assessment, fate and transport modeling, remedial action, community relations, and health and safety. The technical team will be responsible for:

1) gathering all available information for the site,

2) developing an initial “conceptual” model for the site,

3) identifying the technical objectives and goals to be accomplished,

4) supervising the field effort, making adjustments to the conceptual model based on the data produced in the field, and

5) evaluating the conceptual model and decisions made with respect to federal, state, and local regulations.

The core technical team will be responsible for making decisions in the field. One member of the team must have final decision making authority and responsibility to keep the site investigation process moving forward at a reasonable scientific and cost-effective pace. Some have proposed that the technical team be on site during the entire site investigation study[3]. This may not be practical or economically feasible for every project and is probably unnecessary given the currently available computer and telecommunication technologies. At least one member of the technical team should be on site at all times. This person must have a working knowledge of all aspects of the investigation or cleanup DQOs and be in daily communications with technical team members via electronic data transfer. Field personnel (and off-site technical team members) should be in regular communication with staff from federal and/or state regulatory agencies to ensure that decisions made in the field, typically under the pressures of time and field-resources utilization, are in conformance with the dynamic workplan framework.

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[3] ASTM Draft Provisional Standard Guide for Expedited Site Characterization of Vadose Zone and Ground Water Contamination, July, 1996.

Step 2: Develop the Initial Conceptual Model and Decision Making Framework.

Initial Conceptual Model. The initial conceptual model contains the best-available information at the start of the project. It depicts the three-dimensional site profile based on vadose zone and ground water flow systems that can exert influence on contaminant movement. Key site features such as roads, buildings, hydrography, depth to bedrock, direction of ground water flow, and potential preferential pathways for contaminant transport are mapped. Map cross sections should include water levels, high and low permeability zones, and aquifers. The conceptual site model is updated as additional data becomes available during the site investigation or cleanup process. The conceptual model is dynamic in nature and changes to reflect the increased site knowledge gained from field activities.

To assure efficient, effective decision-making the regulatory oversight organization should be included in developing the dynamic workplan. Stakeholders should 1) agree at the beginning on the most likely kinds of action(s) to be taken as a result of the field data, 2) implement the appropriate action on a daily basis as the data is generated, and 3) take new directions when the data suggests deviations from the conceptual model. It should be pointed out that site delineation is an iterative process and should be viewed as an ongoing experimental project.

The Decision Making Framework. The initial conceptual model is based on the Data Quality Objectives (DQO) for the site. The DQO process involves a series of planning steps designed to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate for the intended application. It relates data needs to specific decisions to be made[4]. Briefly, the data quality objective process involves:

- Statement of the Problem. Concisely describe the overall study objectives outlining the scientific and engineering issues to be addressed. Review prior field studies and existing information to gain an understanding of the problem(s). Fuse soft information with hard data.

- Identify the Decisions to be Made that Will Address Each Problem. Independently, and then collectively, identify the types of decisions that will solve the problem(s) and the quality of sample collection and field analytical data required.

- Identify the Inputs to the Decision. Identify the information that needs to be learned in the field and the type of data quality needed to make field decisions.

- Define the Study Boundaries. Specify the range of conditions (time periods and situations) to which field decisions will apply, and within which field data will be collected.

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[4] EPA QA/G-4, "Guidance for the Data Quality Objectives Process" September 1994.

- Develop Decision Rules. Integrate the decision outputs from previous steps into an "if...then..." statement that defines the conditions that would cause the decision maker in the field to choose alternative actions and/or take different directions to solve the problem(s).

- Specify Acceptable Limits on Decisions. Define the decision maker's continuation on a given pathway or alternative action based on field data produced on site: Has the direction followed gone far enough such that any further continuance provides no or marginal added value on a cost/benefit basis?

- Optimize the Conceptual Model. Evaluate information from each previous step and generate alternative sampling and analysis pathways and data quality requirements based on the initial conceptual model. Refine the model and/or pathways toward collecting additional on-site data as new information is provided.

The DQO process is used to define the quantitative and qualitative criteria for determining when, where, and how many sample measurements to collect and at what desired confidence level. Because several different data qualities may be appropriate to answer the site-specific scientific and engineering questions that must be addressed, the term sufficient or acceptable data quality is meaningful only when the intended uses for the data are known. The intended use of the data today may be different from tomorrow. Therefore, it cannot be overemphasized that cost-effective site investigations are highly dependent on anticipating data usage during the life of the characterization-to-cleanup program.

<u>Step 3: Develop Standard Operating Procedures.</u> The next step in developing a dynamic workplan is to establish standard operating procedures (SOPs). SOPs for sample collection and analysis should be produced along with other SOPs required to answer site-specific questions, e.g., geophysical and hydrogeological surveys, etc. The SOPs should be developed by the core technical team and approved by the appropriate regulatory body prior to initiating field activities. The field methods should be "performance based" and provide data of sufficient quality to meet the DQOs, see Section 4. The USEPA is encouraging the use of field analytical technologies and methods to expedite hazardous waste site investigations and cleanups in Superfund, RCRA, and Brownfields[5]. Because these technologies and methods may not be amenable to typical CLP or SW846 methods, QC procedures or data reporting formats, supporting data produced from the proposed field techniques should be provided to document data quality. Note that CLP and SW846 methods are not always required by the EPA to generate data.

<u>Step 4: Develop Data Management Plan.</u> Critical to the success of the dynamic process is the ability to manage and easily use all of the data produced in the field. Data integration (chemical, physical, geological, hydrological), sampling, and analysis protocols should be incorporated into

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[5] May 1, 1996, Federal Register 61FR 19431-19463.

an overall data management plan. Protocols for sample logging, analysis, data reduction, and site mapping should be established. Several different organizations may be involved in this process. The data management plan should be established with rules and responsibilities defined prior to mobilization for the collection, assimilation, and presentation of the field generated data. As an example, computers housed in the sample receiving, organics, and metals analysis laboratories can be electronically linked through Ethernet connections to the data management trailer on site. Sampling logging information and the results of the analysis can be managed through a Laboratory Information Management System or through the use of spread sheets. The data can then be downloaded to a computer containing site visualization software for conceptual model update and review. In this manner, contaminant profiles are more easily understood facilitating the on-site decision making process.

Step 5: Develop Quality Assurance Project Plan. This document contains the sampling method, analytical procedures, and appropriate quality assurance (QA) and quality control (QC) procedures. Quality assurance/quality control (QA/QC) defines the responsibility of the technical team and regulators. It describes the procedures to be used to monitor conformance with, or documentation and justification of departure from the SOPs. The overall goal is to ensure that data of known and adequate quality have been produced to support the decision making process. Again, data of varying quality can be produced to support a range of activities from sample collection to risk assessment.

Step 6: Prepare Health and Safety Plan. Finally, a health and safety plan is produced as part of the Dynamic Workplan/Adaptive Sampling and Analysis project. DQOs should be established for the field analytical tools used to monitor worker and community safety and should be presented in the health and safety plan.

After all field organizations have mobilized and all analytical instruments have been calibrated, it is recommended that a dry run be made to ensure that all participants understand their respective roles and that the quality control (QC) systems from sample collection-to-analysis-to-site contaminant visualization are well-understood and can be easily implemented. On-site data verification may also be desirable for projects of large scope and duration.

3.1 Adaptive Sampling and Analysis Strategy

Figures 3 and 4 illustrate the adaptive sampling and analysis strategy for a hypothetical soil screening site investigation aimed at determining contaminant risk to ground water and human health. Figure 3 depicts the decision making flow chart for the investigation. Figure 4 describes the change in analysis based on what is found at the site. Once the initial sampling data (Round 1) is obtained the conceptual model is evaluated for accuracy. Typically, several sampling rounds are required before confidence in the conceptual model is obtained. The number of sampling rounds, made during the same mobilization, is dependent on the DQO specifications for confirming the absence of contaminants in areas thought to be clean (candidates for no further

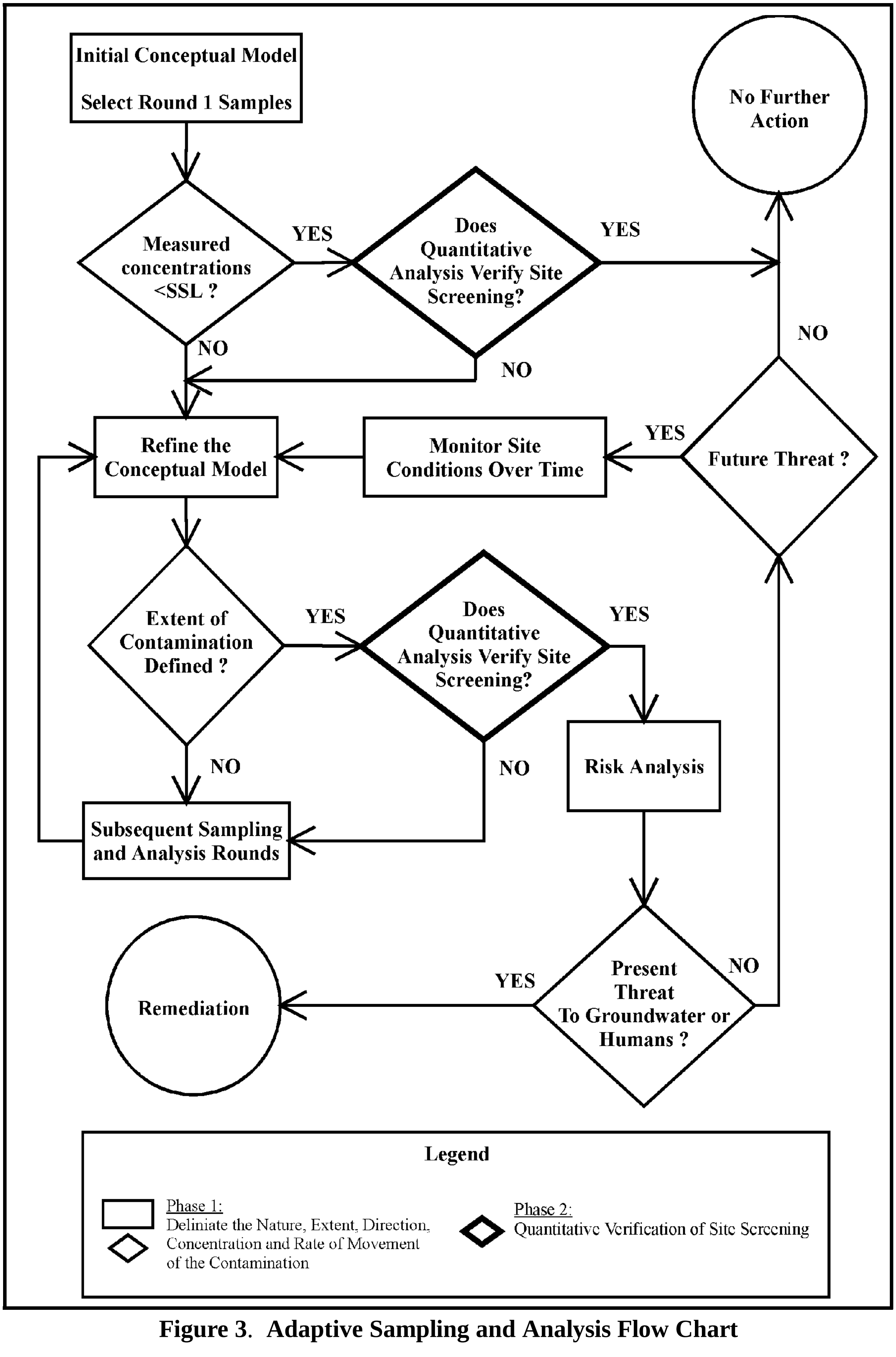

Figure 3. Adaptive Sampling and Analysis Flow Chart

action) *and* for determining the extent, direction, concentration, rate of contaminant migration, volume of contaminated soil and its risk to ground water and human health. Once the soil contamination profile objectives have been met and a verified conceptual model is produced, the data should be capable of delineating whether a particular area of investigation falls within three categories, namely:

- the site is clean or poses acceptable risk - no further action required
- the site is highly contaminated and well above action levels for acceptable risk - remedial action begins
- the site poses marginal risk - cost/benefit of an immediate cleanup not warranted, monitor for future action.

In the example provided, Round 1 samples are analyzed for the full Contract Laboratory Program (CLP) Target Compound List for volatile organic compounds (VOCs), semivolatile organic compounds (semi-VOCs), and metals if no prior field studies have been made. Target compound analysis is then performed for those contaminants found in each subsequent sampling round. As the analyte list decreases, more samples may be analyzed during the workday. Following the decision making logic through to completion, if site samples contain no detectable contaminants above the Soil Screening Levels (SSL) established for the site, site verification is made based on quantitative field analytical measurements. Several outcomes are possible. First, if the quantitative data verifies the field screening data and the data supports the conceptual model, no further action should be required at the site. Second, the comparison between field screening and quantitative measurements are within the site-specific DQOs for the data but the results do not support the conceptual model. In this case, additional sampling rounds are required to refine the model. Third, the comparison between quantitative and screening data fall outside of the acceptable DQOs, reassessment of the field screening tool is then required.

Following the alternative pathway, i.e., site screening measurements result in contaminant concentrations greater than the SSL's, sampling continues and the conceptual model is refined until the site-specific DQOs are met. The findings from the site screening effort are again verified by quantitative field analysis. Once the site data and conceptual model are verified, risk-based decision making occurs with respect to human health and the environment: that is, remediate or monitor for a future threat. At this point, new workplans must be produced to address site remediation or long-term monitoring needs. It should be pointed out that not all present or future threats will necessarily lead to a cleanup remedy. For example, the contamination may be technically impracticable to cleanup (dense non-aqueous phase liquids in bedrock) or natural attenuation may be proposed for the site.

Rather than relying on fixed grids, sampling is directed by geostatistical sampling tools that can predict where the next round of samples is collected. Because quantitative measurements are made on-site, greater confidence should be obtained in the sampling program. Phase 2 in Figure 4 illustrates one approach for verifying the site screening results. Recall that screening, semi-quantitative, or quantitative data can be generated in Phase 1 to develop the site model. If screening quality data, e.g., enzyme kits, is generated then more quantitative field, analytical data should be produced to verify the results from the site screening phase. The number of locations within and surrounding each contaminated and non contaminated area as well as the number of depth samples at each location should be determined by the core technical team. An example is provided in the figure. The purpose of Phase 2 is to test the model and to verify the analytical results.

In an adaptive sampling and analysis program, contaminated areas are more heavily sampled than in traditional site characterization studies. Therefore, if semi-quantitative or quantitative field analytics is performed, no additional "quantitative" data may be necessary other than what is typical to verify data from one fixed-based laboratory versus another. Rapid, 5 to 15-minutes per sample, measurements should provide the majority of analyses during Phase 1, with 10% to 25% of these samples analyzed quantitatively in Phase 2. Off-site laboratory analysis should be performed only when on site quantitative analysis is not possible or cost-effective (Phase 3).

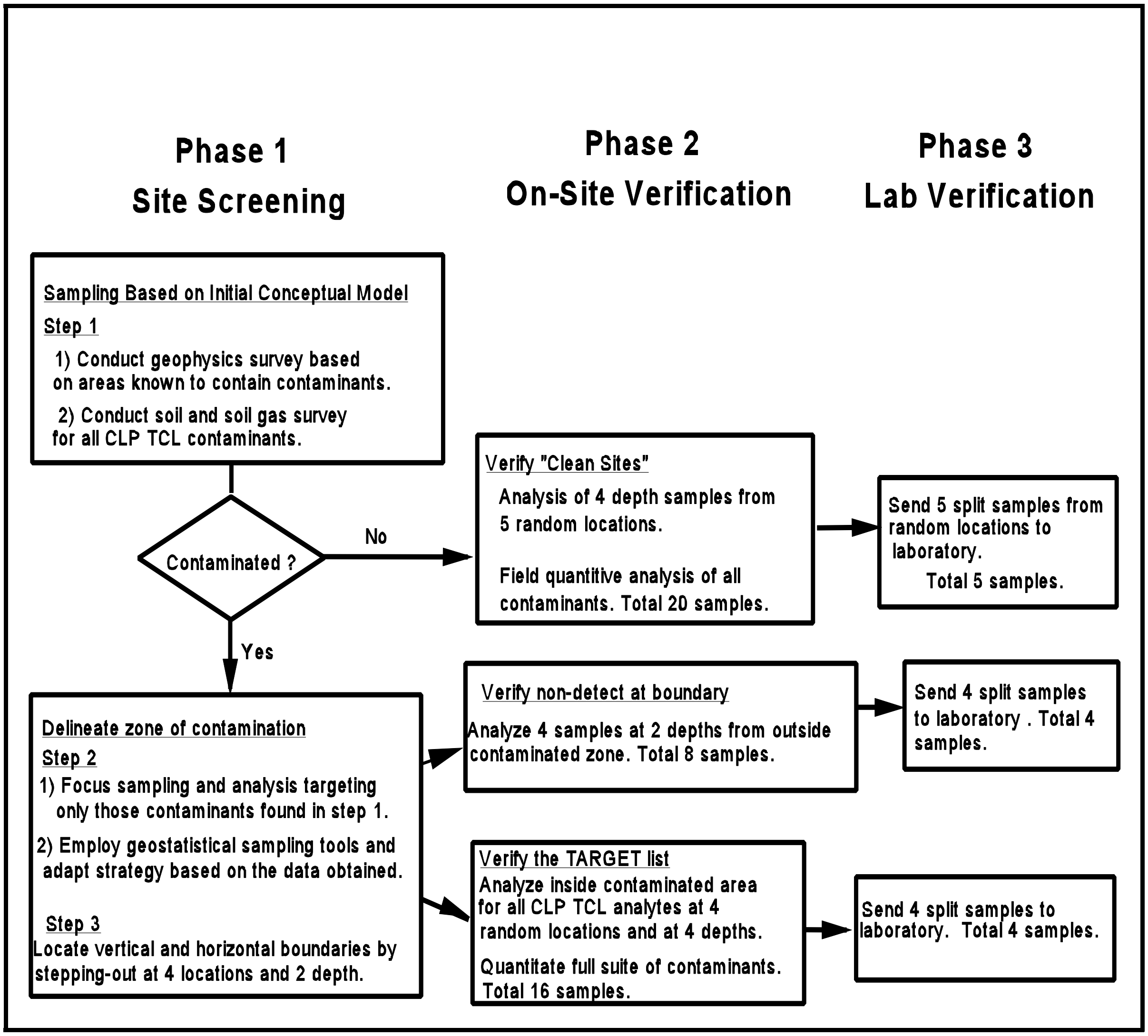

Figure 4. Example of Sampling and Analysis Flow Chart

Field results will differ from off-site laboratory results for VOC contaminated soil samples, with field measurements generally producing higher measurement concentrations because of analyte loss during off-site sample transport and storage. Care must be taken when these types of comparisons are made. Because site investigation and cleanup decisions are made based on field data, off-site laboratory analysis should be performed on no more than 10% of the samples analyzed quantitatively in the field. Field techniques that produce different data quality with the same instrumentation offer cost advantages over analytical techniques that produce either screening level or quantitative data[6]. Time and total project cost savings result when the sample load best matches the sample throughput rate of the instrumentation maximizing the effectiveness of field personnel and equipment, see Section 4.

Finally, field work begins based on the initial conceptual model. As new data are generated scientists and engineers may disagree over the direction(s) taken. Experience has shown that this will most likely occur based firstly on field discipline and secondly on stakeholder bias. One or more changes in direction should be proposed, with start/stop decisions delineated in the dynamic workplan. New results should refine the conceptual model and dictate future directions. Clearly articulated parameters with respect to sample number and DQO specifications obtained as a function of time should be identified in the workplan to set constraints on how long a particular pathway is followed before altering the investigation direction. One member of the siteowner technical team and one member of the regulatory oversight agency must have final site decision making authority. Site work stops when answers to the questions posed in the workplan meet site-specific confidence levels established as part of the DQO process. To ensure that site-specific goals have been met, the project team should statistically evaluate the results of its findings[7]. An adaptive sampling and analysis program focuses staff, equipment, and financial resources in areas where contamination exists while providing a cursory inspection in areas that pose no or little risk to human health and the environment.

4.0 Introduction to Field Analytics

The selection of field analytical methods is critically dependent on the need to make decisions in the field rapidly. Field analytical techniques should be capable of providing data from minutes to tens of minutes. They should have documented measurement sensitivity, precision, and accuracy to meet site investigation and cleanup DQOs. The simpler the technique the more likely it will be used in the field. Field instruments must be transportable, operate under adverse conditions, and provide improved cost/benefit over laboratory analysis. For projects of short duration and low sample volume, staff and equipment mobilization expenses may make field analytics a cost-prohibitive option. In addition, if quantitative measurements are required for all samples, field analytics may not provide a cost-effective means for obtaining site data. Rarely is this the case. Almost all projects will require screening or semi-quantitative data during the field

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[6] B. M. Abraham, T-Y Liu, and A. Robbat, Jr., Hazardous Waste & Management, 10, 461-473, 1993 *and* K. Jiao and A. Robbat, Jr., J. of AOAC International, 79, 1996.

[7] Guidance for Data Quality: Practical Methods for Data Analysis, EPA QA/G-9 EPA/600/R-96/084, July 1996.

screening phase of the site investigation. Even short projects of one to three days, where six to twelve samples per day may be collected, will benefit from field measurements. For example, head space gas chromatography (GC) can be simple and fast for the analysis of VOCs in soil and water samples during underground storage tank removal or well installation and monitoring. Enzyme kits can provide rapid detection of polychlorinated biphenyls (PCBs) or explosives during site characterization or remediation. Field instrumentation, such as in situ fiber optics and electrochemical sensors or portable GCs can be used to provide a security system to monitor underground subsurface contamination migration, process control, or fugitive emissions during site cleanups or long-term monitoring operations.

Field analytics can be routinely used to monitor worker and community health and safety during site investigations and cleanups. For example, the protection of workers from exposure to hazardous substances during sampling is of primary concern. In this case, sampling speed and limited sample handling is an important aspect of the measurement process. The sampling and measurement methods must be suitable to meet guidelines set forth by the National Institute for Occupational Safety and Health.

4.1 Field Measurement and Contaminants of Concern

The action level (or level of concern) defines the contaminant concentration needed to produce useful data to answer site-specific scientific and engineering questions. The selected field method must demonstrate method detection limits below the action level established for the site. The action level defines the concentration at which decisions can be made, including:

- nature and extent of contamination, i.e., field data supports the overall site investigation

- risk to human health and the environment, i.e., field data provides input into baseline risk assessment process

- achievement of cleanup objectives, i.e., field data supports site compliance with regulatory-imposed concentration levels

As an example, the EPA has compiled a list of contaminant soil screening levels for land usages based on different risk factors. These generic soil screening levels take into account the natural attenuation processes for the migration to ground water pathway(s) that can reduce contaminant concentrations in the subsurface. To insure that the field analytical instrumentation and methods selected in the workplan are amenable to a given site, site-specific method detection limit studies should be performed for each class of contaminants (e.g., VOCs, semi-VOCs, and metals) from soil obtained from the site prior to the field investigation. This will help to determine whether matrix interferents or target compounds mask (e.g., portable GC) or cross-react (e.g., enzyme/wet chemical kits) with targeted organics or metals (e.g., by electrochemical detection).

4.2 Field Analytical Techniques

Field analytics can be divided into two categories: real-time and “near” real-time measurements. Real-time measurements include those techniques that provide instantaneous analysis without the need for sample pretreatment. Examples include ion selective electrodes, fiber optic sensors, hand-held gas monitors, direct measuring GC’s, and portable x-ray fluorescence (XRF) instruments. With the exception of XRF, these tools are typically used as continuous or in situ monitors for either gaseous or liquid streams.

Near real-time measurements typically include the more quantitative analytical techniques. They generally require some sample pretreatment prior to analysis of complex samples. These techniques include wet chemical and enzyme immunoassay kits; GC with a variety of non-specific detectors such as photoionization (PID) and flame ionization (FID), class-selective detectors such as electron capture (ECD for PCBs and chlorinated pesticides) or chemiluminescence (CD for nitrated explosives), and compound-specific detection by mass spectrometry (MS for identification of individual organic compounds); total petroleum hydrocarbon (TPH) analyzers; *and* inductively coupled plasma/optical emission spectroscopy (ICP/OES); XRF; and anodic stripping voltammetry for metals analysis. The size and experimental operating features dictate whether they are classified as field portable or transportable (laboratory-grade) instruments. For example, portable GCs are typically small in size, can operate off batteries but have ovens that cannot be temperature programmed (isothermal operation) or have slow temperature program ramps from ambient to 200 ^{0}C.[8] In either case, these GCs are best suited to qualitative analysis of VOCs. In contrast, GC/MS instruments require a generator or a line voltage power source, but can produce quantitative analysis of VOCs and semi-VOCs in the field.

In many instances, it is not necessary to have quantitative data for every sample during PCB, PAH, or explosives soil remediation. For example, when excavating soil, measurement accuracy can be as high as 40-70% as long as measurement precision is known. Enzyme kits and rapid screening GC with ECD, FID, or MS can provide this level of data quality. Quantitative analysis, on the other hand, is needed only for the pit closure samples to verify that the cleanup DQOs have been met. Field GC/MS can provide the necessary measurement sensitivity, precision, and accuracy to meet most site-specific cleanup DQOs. Similarly, VOC soil and water analysis by rapid screening GC with ECD/FID or MS is sufficient to determine vadose zone and ground water contamination profiles. More quantitative GC/MS data are required to determine the threat to ground water and the associated risks to human health and the environment. Performance-based methods can provide maximum flexibility to meet site-specific data needs.

A considerable amount of field analytical methods are available. Not every field method is amenable to the full range of environmental contaminants. Some are selective by design (enzyme and wet-chemical kits), while others are limited in scope (portable GC and XRF) or by media type (fiber optic, acoustic wave, and electrochemical sensors). Sample throughput rates in the field can also limit the effectiveness of field analytical measurements. Careful consideration should be given to these issues before selection of field analytical techniques or methods. The amount of sample preparation prior to analysis will determine the sample throughput rates that can be achieved. Experience has shown that field GC/MS can provide both screening and

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[8] Analytical Chemistry, 69, 195A-200A, 1997.

quantitative data for the full range of organics depending on the sample introduction system and data analysis software used. Data quality and throughput rates must be determined before the decision is made as to which field analytical technologies or methods are appropriate. An initial documented statement for the end use of the data incorporated into the data decision process will ensure that inappropriate data uses do not occur.

4.3 Sample Throughput Rates and Analytical Properties

No one laboratory technique or method is universally accepted for all EPA listed organic or inorganic contaminants. The selection of field methods for site characterization and cleanup depends on the material to be examined, contaminants and action levels of concern, QC requirements, sample throughput rates, and cost. Selection of field methods also depends on the type of data quality required to answer site-specific questions. It is important to have a clear understanding of the particular analytical properties required to meet site-specific DQOs and how the economic considerations of a given analytical problem affect some properties over others.

Accuracy and Representativeness are two key attributes of data quality. Accuracy refers to the closeness of the result between the measured and actual (“true”) analyte concentration in the sample. Accuracy can be calculated based on the degree of agreement between the observed value and the accepted reference value. Commercially prepared standard reference materials (SRM) or site-specific SRM’s are often used to determine accuracy. Representativeness is defined as the consistency between the result and the measured sample as well as between the result and the definition of the analytical problem. Representativeness is the degree to which data accurately and precisely represents the frequency distribution of a specific variable. Measurement accuracy can be influenced by the required measurement sensitivity, selectivity, and precision whereas representativeness is affected by sampling location exactness and sample homogeneity consistency. The influence of sampling on analytical quality is, overall, crucial. For example, blood-sugar from a diabetic more than 1-hr after a hypoglycemic attack is not representative of the blood-sugar concentration at the time of the attack. Likewise, collecting soil samples two feet apart and expecting one of the samples measured by the field laboratory to be representative of the other sample analyzed by either the on-site or off-site laboratory is unreasonable. No other analytical property can be justified without representativeness. Because of subsurface soil inhomogeneities, collecting the many statistical samples necessary to gain the confidence needed to delineate the extent, direction, concentration and rate of contaminant movement is generally too costly in the traditional site investigation approach. The adaptive sampling and analysis strategy helps to focus the sampling effort in areas where contamination has been identified which, in turn, results in more data produced in the areas where it is needed. Nonetheless, the analytical measurement process is most often the bottleneck that controls the rate of the site investigation when compared to sample collection.

Assuming representative samples have been collected, measurement accuracy is directly dependent on the relationship among three key analytical parameters: precision, selectivity, and sensitivity. Accurate results cannot be obtained unless the measurement technique produces selective detection and adequate sensitivity. Selectivity refers to the instrument’s or method’s ability to respond to target compounds in the presence of nontarget sample constituents. For example, if the analytical technique responds to the presence of matrix interferents or cross-reactive target compounds, measurement identity is affected and thus, accuracy. Moreover, if the analyte concentrations in the sample are at or just below the method detection limit, the measured concentrations may be inconsistent (precision). Measurement precision is the degree to which a set of analyses of the same parameter conforms to itself. To achieve unambiguous analyte identification and the desired method detection limit, extensive sample preparation procedures may be required to remove matrix constituents, dilute, or pre-concentrate the sample extract. These additional steps lengthen the overall time of the analysis (sample throughput rate).

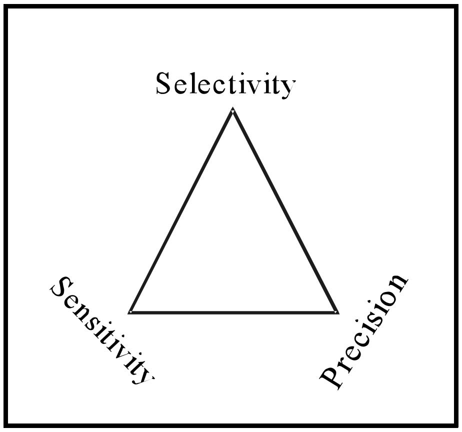

Figure 5. Data Attributes

Generally, as one property of the equilateral triangle is improved, one or both of the remaining analytical properties can become distorted. For example, increasing the number of sample preparation steps prior to the analytical measurement can result in loss of analyte, which, in turn, can influence measurement sensitivity and thus, accuracy (false negative). Another example is the detection of nitrated explosives by selective reagents such as enzymes. Field-practical enzyme immunoassay kits can significantly reduce the time of analysis over laboratory high performance liquid chromatography (HPLC) methods by eliminating the need for sample cleanup procedures. False positive detection is possible, however, due to cross-reactivity with other nitrated organic compounds that might be present in the sample. Although advancements in analytical instrumentation, sophisticated spectral deconvolution software routines, and compound-specific reagent chemistry have increased laboratory productivity, sample throughput rates and data quality are greatly influenced by the triangular interactions among selectivity, sensitivity, and precision. As increasingly more stringent measurement accuracy is specified, sample throughput rates decrease. For example, several published reports document the wide range of measurement precision and accuracy that is obtained when employing EPA method 8080 (20-min/sample) as compared to the more comprehensive congener-specific (90-min/sample) analysis for PCBs.[9,10,11]

The relationship between sample throughput rate, data quality, and field investigation costs can be viewed as follows. Assume a 10-hr workday with two hours set aside for lunch, daily meetings, instrument maintenance and lab cleanup. Also assume that each analysis requires a 5-min cycle time before the next sample can be analyzed and that any sample preparation procedures that might be necessary to remove nontarget matrix interferences occur separately from the analysis. Table 1 summarizes the relationship between number of samples that can provide information about the site and the number of QC or re-analysis samples required to

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[9] R. Eganhouse, and R. Gossett, Anal. Chem., 63, 2130-2137 (1991).

[10] D. Kimbrough, C. Rustum, and J. Wakakuwa, Analyst, 119, 1277-1281 (1994).

[11] G. Frame, J. Cochran, S. Bøwadt, JHRC., 19 657-668 (1996).

determine data quality as a function of sample throughput rate. Assume that in this hypothetical site investigation 300 soil samples are analyzed for PCBs at a soil screening level of 0.5-ppm to determine risk to ground water.

Table 1. Number of Samples Analyzed per Day

	TDGC/MS or Enzyme Kit 10-min/sample		EPA method 8080 20-min/sample	
Total Site Samples	300	300	300	300
Site Samples Analyzed Per Day	22	18	14	10
Site Samples Re-analyzed	3	5	0	2
Blanks	2	2	1	2
Replicate Analysis	2	3	1	2
Accuracy (SRM)	1	2	1	1
Initial/Final Calibration	2	2	2	2
Total Analysis/Day	32	32	19	19
Total Field Days	14	17	22	30

The number of field days needed to complete the site investigation presumes no loss of time for instrument breakdown, repair and/or re-calibration. If, for example, five samples are re-analyzed rather than three due to matrix interferents, detector overload, or frequency of field duplicates *and* three samples are analyzed to determine measurement precision and accuracy, a total of 17 site samples can be analyzed per day as compared to 22 for the 10-min analysis. Increasing the number of quality control or re-analysis samples decreases the number of site samples that can provide information about the site. A total of 18-days will be needed to complete the project as compared with 14-days when the sample throughput rate is 10-min/sample.

When analyzing soil samples by EPA method 8080 in the field, adding additional non site samples will result in the project being completed in 30-days versus 22-days. Apparent is the fact that the sample collection and field analysis rates must be matched and that the site-specific DQOs be well-understood in the context of selecting appropriate field analytical techniques, methods, and QC procedures. If, for example, PAHs must also be analyzed, then no additional analysis time is required by TDGC/MS, i.e., PCBs and PAHs are analyzed simultaneously. When standard laboratory technologies or enzyme kits are employed two separate analyses must be performed, increasing total project costs. Note that these field laboratory costs do not represent total project costs. For TDGC/MS analyses minimal sample preparation is required. Although the extraction and cleanup of 20 samples can be accomplished in two hours for method 8080, the field laboratory must accommodate the sample preparation station and staff to achieve reasonable throughput. Expenses for the sampling crew and core technical team plus any other field services work must be added to the overall project costs.

When the principal organic contaminants and action levels are known, the selection of the field method should be straightforward. In complex mixtures, indicator compounds such as trichloroethene, carbon tetrachloride, or benzene may be used as surrogates for fast GC analysis. Although dual detector GC with ECD and either FID or PID costs less than most field or laboratory GC/MS instruments and, until recently have been easier to operate, only MS can provide unambiguous identification of VOCs. Contaminant concentrations, persistence in the environment, mobility and/or fate can be estimated from the detection of indicator compounds. If the principal contaminants at a site are unknown, field GC/MS provides the only reliable means of determining compound identity and concentration. For VOC analysis, purge and trap GC/MS can be performed as easily in the field as in the laboratory.

For semi-VOCs sample preparation is the rate-determining step when analyzing the EPA listed target compounds. Semi-VOCs must be extracted from soil or water into an organic solvent prior to analysis. Depending on the complexity of the matrix, the extract is further separated into fractions that contain compounds of similar chemical characteristics (e.g., PCB/pesticides, PAHs, explosives, acids, base/neutrals). These fractions may require additional separation before analysis by GC with ECD or MS; HPLC with UV and/or fluorescence detection; or by class-specific reagent chemistry such as the enzyme immunoassay kits. Sample cleanup, pre-concentration and/or sample dilution add extra steps to the measurement process and must be factored into field-practical sample throughput rates. Until recently, on-site analysis has only been possible for PCBs (portable GC with electron capture detection) and explosives (enzyme kits) because of time and cost constraints (sample preparation) in the field. In contrast to class-selective analysis provided by these technologies, TDGC/MS can provide rapid compound-specific analysis of most semi-VOCs.

Similarly, the same rationale applies to the analysis of soil contaminated by metals. Portable XRF provides screening level to semi-quantitative data without the need for sample preparation. Sample throughput rates exceed the data turnaround times that can be produced by field-based ICP/OES instruments. ICP/OES, however, provides more quantitative data at concentrations several orders of magnitude less than XRF can achieve. In contrast, metals analysis by electrochemical detection (anodic stripping) requires sample preparation for soil samples but not water samples and is more selective and sensitive than portable XRF instruments. As discussed above, every analytical measurement requires a trade-off among the properties precision, selectivity, and sensitivity.

4.4 Site or Facility Requirements

The physical layout of the site must have access to deploy and setup a field laboratory if the field activities extend beyond a one-week period. The site or facility should have line voltage power or a dependable source of electricity from a generator if a wide variety of field instruments and computing power are required. Power from a generator must be put through a filter to smooth out voltage fluctuations to protect analytical instruments and computers. The mobile laboratory or facility must have the proper footprint to house instruments, hoods, computers, refrigerators, and staff comfortably. The mobile laboratory should be heated in the winter and cooled in the summer. For instruments like the ICP/OES, field laboratory temperatures must be climate controlled to within ± 10 ^{0}C to achieve high quality data. Proper ventilation must be provided to protect worker safety and to separate volatile vapors produced during sample preparation procedures from cross-contaminating the organics analysis laboratory.

Access to on-site field laboratories should be limited to authorized personnel. Instrumentation, laboratory equipment, and utilities should be maintained to perform the required operations. Safety equipment should be available and readily accessible, e.g., eye wash, fire blanket, safety supplies. All instruments and equipment should be kept secured when not in use. These are customary practices of fixed-based laboratory operations.

Design and implementation of sampling programs should address situations or conditions necessary for the controlled use, storage, and disposal of sample material (e.g., soil discard, purged waters), equipment decontamination residues and remnants of samples. It should also ensure that all activities that may impact environmental data are documented and recorded in field notebooks. Field analysis will result in the production of waste materials commonly handled in off-site laboratory operations. Regulatory acceptance of these waste handling procedures should be obtained and incorporated into the workplan.

4.5 Quality Control

Sampling designs should minimize integrations between high and low concentration areas, as well as minimize common utilization of equipment, instrumentation, and facilities. A formal active contamination control program should exist that minimizes the potential spread of contamination. The collection of grab samples, e.g., individual samples collected at a specific time and location, is acceptable for TPH, semi-VOCs, VOCs, and metals. Composite samples, collected by homogenizing a sample interval or sample collection from different locations and times, are acceptable for TPH, semi-VOCs, and metals. A composite sample is not acceptable for VOCs since analyte will be lost during the homogenization process.

Prior to selecting the field analytical methods, it should be well-understood by all stakeholders as to the quality of acceptable data that will be sufficient to address site investigation or cleanup DQOs. The DQOs will dictate the limits of measurement error, selectivity, sensitivity, and resolution for the field measurement and how these attributes affect sample throughput rates, the on-site decision making process, and cost. DQOs should, therefore, dictate acceptable limits for measurement precision, accuracy, representativeness, and completeness. Once these attributes have been defined, specific QC criteria (e.g., initial and continuing calibrations, laboratory control check sample (SRM) accuracy), frequency (e.g., every 10th or 20th predetermined, random, or positively detected sample) and, number (e.g., n = 2 or more) of repetitive sample analysis can be determined. This information must be included in the site specific-SOPs.

Goals for precision and accuracy should be established in the dynamic workplan. For example, site characterization, treatability study, or remedial action measurement precision or accuracy may differ greatly and should be based on the criteria needed to answer project-specific questions concerning the stated problem(s). A well-defined description of precision and accuracy benchmarks, instruments, field methods, chemical standards and reagents employed should be documented.

Goals for data representativeness should be addressed qualitatively since sampling locations, depths, intervals, frequency of split sampling and of QC check samples may change in the field based on new directions and requirements.

Goals for completeness and comparability of investigation are achieved when the study goals have been met. An analytical measurement value is considered complete if QC results are within acceptable ranges. There can be no assurances that the data produced by standard laboratory methods and instruments are any better than the field data. Comparability should be based on how well the field and laboratory produced data within their respective internal and external QC checks *and* through some minimum level of field versus laboratory data comparison (e.g., ≤ 100% may be an acceptable error range for some types of data usages). Federal and state regulators, siteowners, and their consulting engineers have a tendency to be risk-averse. Typically, the highest level of data quality is requested whether needed or not. As shown in Section 4.3, improper matching of sample collection, sample analysis throughput rates, and site-specific DQOs can easily lead to inefficient sampling and analysis programs and thus, cost.

5.0 Dynamic versus Traditional Investigation and Cleanup Costs

Dynamic workplans provide the framework for collecting chemical, physical, geological, and hydrological data in one or two field efforts as compared to the phased engineering approach of collecting data then evaluate, collect more data then evaluate ... until sufficient information is obtained to meet the study objectives. Fixed-based (commercial) laboratories should be able to generate data of comparable (either screening or quantitative data) quality at lower per sample costs than field/mobile laboratories. Economies of scale should be more easily achieved by fixed-based laboratories since they are designed for mass production. However, steep sample surcharges (100-200%) are generally added to the base price if samples are moved up in the queue to obtain one to three day data turnaround times. Moreover, fixed-base laboratory sample analysis costs vary greatly between regional (typically local non Contract Laboratory Program) and national laboratories.

Comparing the selection of field instruments as a function of cost is difficult. Field instruments and methods should be chosen first to meet the data quality requirements and second based on their ability to match the rate at which samples are collected. To illustrate the first point, assume that the 16 target compound PAHs and PCBs require soil analysis to determine risk to ground water and that the action levels for PAHs are between 2-ppm (benz(a)anthracene, dibenz(a,h)anthracene) and as high as 40,000-ppm (fluoranthene and pyrene) *and* 1-ppm for total PCBs. These values are based on the 20DAF soil screening levels (SSLs, USEPA 1996), which refer to a dilution-attenuation factor (DAF) of 20. The SSLs take into account the natural attenuation process for the migration to ground water pathway that can reduce contaminant concentrations in the subsurface. Assume that the action level for the site has been established at one-half the 20DAF. For PAHs and PCBs these values are 1-ppm and 0.5-ppm, respectively. The method detection limit (sensitivity) has been determined at 0.5-ppm for GC/FID and 0.3-ppm for TDGC/MS.

Table 2 lists site-specific action levels for the hypothetical site investigation along with the data quality attributes, sample analysis, and the total number of samples analyzed per day throughput rates for field GC/ECD, TDGC/MS, and enzyme kit analyses. Tables 1 and 3 illustrate the impact of sample analysis rate and the number of site samples that can be analyzed per day. It may be necessary to make trade-offs among the data quality attributes of selectivity, sensitivity, and precision in conjunction with sample throughput rates to meet the site-specific DQO's and action levels *and* to provide a cost-effective field analytics program. This type of review should be made to insure that the selected field technology meets the site-specific DQOs established for the investigation or cleanup verification program.

The second point is not a trivial or obvious statement. If sample analysis lags behind sample collection, sample collectors and decision support staff sit idle waiting for data to be produced. On the other hand, if sample collection is operating below capacity, analytical instruments and field-laboratory personnel sit idle. In both cases, site investigation efficiency and cost is lost. Therefore, it is essential that the analytical team member play an integral role in designing the sample collection program. Moreover, combining field screening and on-site quantitative analysis into the program should increase the total number of samples analyzed while decreasing the number of samples sent off-site for traditional laboratory analysis.

Table 3 summarizes the field and laboratory sample charges and data turnaround times for the analysis of VOCs, PCBs, PAHs, explosives, and semi-VOCs. Shown in the Appendix are assumptions and costs used to determine the TDGC/MS, portable GC, and enzyme/colorimetric kit per sample charges. Commercial laboratory charges vary widely depending on the size and revenue amount of the laboratory and the number of national programs the laboratory participates in (e.g., Contract Laboratory Program, U.S. Army Corps of Engineers, HAZWRAP, and state certified programs). Field analytical technologies can provide analyses comparable in cost to regional or local laboratories employing EPA standardized methods with same or next day data turnaround times as compared with 14 to 35-days by commercial laboratories. Field analytics compete best when total project cost is considered and when it is incorporated into the Dynamic Workplan/Adaptive Sampling and Analysis Program. Cost savings can be realized when:

- sample selection and locations are optimized. Increased sampling efficiencies result in more targeted sample collection efforts minimizing the handling of samples that provide little value toward answering site-specific DQOs - <u>faster</u> site characterizations and verification of cleanup.

- the identity of the contaminants becomes known. Increased field analytical productivity is obtained when the type of analysis performed is more targeted resulting in more samples analyzed per day - <u>faster</u> site characterizations and verification of cleanup.

- more data are produced in less time. More informative decisions are made that improve the site delineation process, i.e., the separation of highly contaminated areas from non-contaminated areas - <u>better</u> site characterizations and verification of cleanup.

- a more detailed picture of the site is obtained, viz., the nature, extent, direction, concentration and rate of contaminant movement. Increased confidence in evaluating the risk to human health and the environment results - <u>better</u> site characterizations and verification of cleanup.

- more efficient utilization of human and financial resources is obtained. Increased project efficiencies lead to more data obtained at lower total project costs - <u>cheaper</u> site characterizations and verification of cleanup.

The rationale for selecting an adaptive sampling and analysis program should be based on the inherent efficiencies obtained when decisions are made in the field and the overall total project cost savings that can accrue.

Table 2. Comparison of Field Technologies for PCBs and PAHs

Polycyclic Aromatic Hydrocarbons					Polychlorinated Biphenyls		
Site-specific DQO's and Action Level	**Attributes**	**GC/FID**	**TDGC/MS**	**Enzyme Kits**	**GC/ECD**	**TDGC/MS**	**Enzyme Kits**
Yes	**Selectivity**	No	Speciate	class-specific	Yes	Speciate	class-specific
1-ppm/PAH 0.5-ppm total PCB	**Sensitivity**	0.5-ppm	0.3-ppm	MFG. and Compound Dependent	0.03-ppm	0.2-ppm	Aroclor Dependent 0.5 to 1-ppm
≤ 40%	**Precision**	≤ 40%	≤ 40%	MFG. Dependent ≤ 40%	≤ 30%	≤ 40%	MFG. Dependent ≤ 40 %
No	**Accuracy biased toward: false positive**	Yes	No	Yes	Yes	No	Yes
No	**false negative**	No	No	No	No	No	No
	Analysis Rate/Sample	20-min	10-min	10-min	20-min	10-min	10-min
	Total Number of Samples Analyzed per 10-hr work day	19	32	32	19	32	32

Table 3. Field and Laboratory Cost and Data Turnaround Time Comparison

Analyte	Regional Laboratory Data Turnaround: 14 Calendar Days	National Laboratory Contract Laboratory Program Data Turnaround: 35 Calendar Days	Field TDGC/MS Data Turnaround: Next Day	Field GC/PID or GC/ECD Data Turnaround: Next Day	Strategic Diagnostic Enzyme Kits Data Turnaround: Same Day
VOCs	$125/sample SW 846 method 8240/8260 25-min/sample analysis	$165/sample SW 846 method 8240/8260 25-min/sample analysis	$100/sample modified 8260 20-min/sample	$88/sample modified 8021/8015 or headspace analysis 25-min/sample	Not Applicable
PCBs	$100/sample SW 846 method 8080 20-min/sample analysis; sample preparation 2-hr/batch of 20 samples	$150/sample SW 846 method 8080 20-min/sample analysis; sample preparation 2-hr/batch of 20 samples	$100/sample modified 8270 10-min per analysis; sample preparation 1-hr/batch of 20 samples	$88/sample field method 20-min analysis; sample preparation 1-hr/batch of 20 samples	$102/kit field method 10-min analysis time; sample preparation 1-hr/batch of 20 samples
PAHs	$145/sample SW 846 method 8100/8310; 20-min/sample analysis, sample preparation 2-hr/batch of 20 samples	$255/sample SW 846 method 8100/8310 20-min/sample analysis; sample preparation 2-hr/batch of 20 samples		Not Applicable	$102/kit field method 10-min analysis time; sample preparation 2-hr/batch of 20 samples
Explosives	$180/sample SW 846 8330/USAED 30 20-min/sample analysis; sample preparation 18-hr/batch of 20 samples	$220/sample SW 846 8330/USAED 30 20-min/sample analysis; sample preparation 18-hr/batch of 20 samples	$100/sample modified 8270 10-min per analysis; sample preparation 1-hr/batch of 20 samples	Not Applicable	$102/kit field method TNT & RDX kits required 20-min per analysis; sample preparation 1-hr/batch of 20 samples
Semi-VOCs	$400/sample SW 846 method 8270 40-min/sample analysis; sample preparation 4-hr/batch of 20 samples	$450/sample SW 846 method 8270 40-min/sample analysis; sample preparation 4-hr/batch of 20 samples	$150/sample modified 8270 20-min per analysis; sample preparation 1-hr/batch of 20 samples	Not Applicable	Not Applicable

Appendix

Field Analysis Costs

Table 4 illustrates the per sample costs for field-based TDGC/MS, GC with PID or ECD, and wet chemical or enzyme kit analysis. In the cost example, a Hewlett Packard GC/MS (model GCD) was modified to introduce samples via thermal desorption (TD), with the data analysis accomplished by the Ion Fingerprint Detection™ (IFD) software. Field GC/MS instruments such as the Viking Instrument, ~ $120,000 when fully equipped, will add $5.50 to the GC/MS sample cost shown in the table. The TDGC/MS with the IFD software can provide simultaneous detection of PCBs and PAHs in complex petroleum contaminated soil samples in 10-min. The Photovac GC/PID can provide full VOC analysis in the field. As discussed in Section 4, photoionization (PID) and electron capture (ECD) detectors provide qualitative compound-specific information as compared to the MS. These GC detectors can not provide unambiguous compound identification but can provide rapid field screening analysis of VOCs. The cost of a field-based GC/ECD has also been estimated for PCB analysis. The enzyme or colorimetric kit costs shown in the table have been calculated based on an average per kit price that assumes 40 analysis per calibration for either the Ensys or Ohmicron kits. Sample analysis of less than 40 samples per calibration will result in increased sample costs.

The cost analysis is based on a one time purchase of capital equipment and includes any modifications that are required to produce high throughput field analysis; a vehicle for field transport of staff, instrument and supplies; and generator for power. Annual operating costs assume a total of 4,500 soil samples will be analyzed over a 180-day field season by two chemists. This represents an average of 25 samples analyzed per day. Since nearly 70% of the cost to provide service is in salary any additional field days will reduce the per sample cost, while booking work for less than the assumed 180-days will increase the respective sample analysis cost. Finally, the per sample cost was calculated over a five year period. The calculation takes into account the time value of money based on present value of future costs to provide the service. It ignores inflation and assumes a 4% discount rate. Details of the capital purchases and annual operating costs can be found in Tables 5 and 6. Although commercial laboratories provide volume pricing, no one project or account will dramatically affect the laboratory life-cycle per sample cost. Included in the commercial laboratory per sample charges are costs for staff, equipment, supplies, space, management, accounting, marketing and sales. An industry conservative 2.5 multiplier was used to estimate the field comparable per sample charges for each technology.

Table 4. Field Analytical Measurement Costs

	TDGC/MS	**GC/PID or ECD**	**Enzyme Kits**
Initial Capital Costs	$76,000	$47,500	$27,500
Total Annual Operating Costs	$178,828	$161,978	$283,595
Present Value of Life-Cycle Costs (assume 4% discount)	$903,890	$797,383	$595,699 (direct costs) $770,818 (kits)
Total Number of Samples Analyzed Over 5-years	22,500	22,500	22,500
Cost per sample analysis	$40	$35	$27 direct cost plus $34/kit
Total Sample Cost with 2.5 multiplier*	$100	$88	$102

* Overhead cost provided by Steve Maxwell, Technology Strategic Group, Boulder, Colorado

Table 5. Capital Equipment Costs

	Capital Equipment		**Capital Equipment**		**Capital Equipment**	
Instrument Costs	HP GC/MS full VOC and SVOC analysis 486 computer, operating/data analysis software and libraries, LaserJet printer, split/splitless inlet, diffusion/rouging pumps	$45,000	Photovac GC/PID full VOC capability oven/column & re-charge battery, start up kit, printer & cable	$26,500	SDI Enzyme Kits PAH, PCB, and Explosives Spectrometer, balance, and computer and printer	$6,500
Modifications	Thermal Desorption Unit	$10,000				
Vehicle	Van	$20,000	Van	$20,000	Van	$20,000
Power Supply	2.5 kW generator	$1,000	2.5 kW generator	$1,000	2.5 kW generator	$1,000
	Total Cost	$76,000	**Total Cost**	$47,500	**Total Cost**	$27,500

Table 6. Annual Operating Expenses

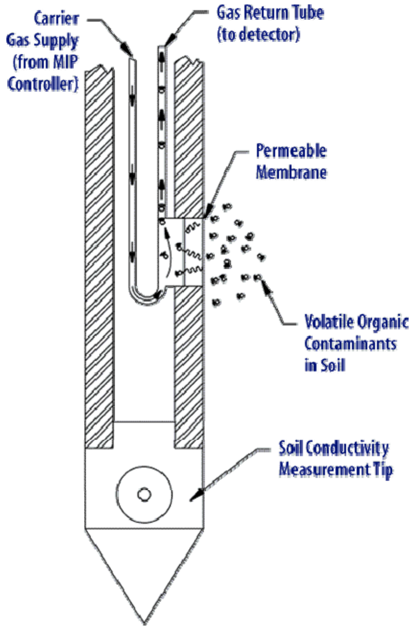
	GC/MS Operating Costs		**Portable GC Operating Costs**		**Enzyme Kits Operating Costs**	
Labor	two full time chemists	$120,000	two full time chemists	$120,000	two full time chemists	$100,000
Software	Ion Fingerprint Detection™	$10,000				
Materials and Supplies	GC columns (13), fittings, and septa	$6,500	GC columns (13), fittings, and septa	$6,500	$37/sample average kit price, PAH, PCB, explosive	$166,500
	electron multiplier &source	$3,000	detector lamp	$650	detector lamp	$550
	pump oil	$1,000				
	helium carrier gas ($4/day at 180-day)	$720	He carrier gas ($4/day at 180-day)	$720		
	calibration standards	$3,500	calibration standards	$3,500		
	reagent water ($4/day at 180-day)	$720	reagent water ($4/day at 180-day)	$720	reagent water ($4/day at 180-day)	$720
	vials ($175/case)	$10,938	vials ($175/case)	$10,938	vials ($175/case)	$10,938
	spatula	$50	spatula	$50	spatula	$50
	syringes (15)	$1,000	syringes (15)	$1,000		
	coolers (3)	$120	coolers (3)	$120	coolers (3)	$120
	solvents (40-L)	$750	solvents (40-L)	$750	solvents (10-L)	$187
Vehicle Costs	insurance	$1,500	insurance	$1,500	insurance	$1,500
	maintenance ($100/month)	$1,200	maintenance ($100/month)	$1,200	maintenance ($100/month)	$1,200
	gas (20K miles/year at $1.33/gal)	$1,330	gas (20K miles/year at $1.33/gal)	$1,330	gas (20K miles/year at $1.33/gal)	$1,330
Overhead	QA/QC 2-months	$12,000	QA/QC 2-months	$12,000	QA/QC 2-months	$12,000
	maintenance contract HP	$4,500	maintenance	$1,000		
	Total	$178,828	**Total**	$161,978	**Total labor and supplies**	$128,595
					Cost of 4,500 kits, $37 each	$166,500

Appendix C

Appendix A – MIP System Overview

The MIP is a direct push tool that produces continuous chemical and physical logs of the vadose and saturated zones. It locates VOCs in-situ and shows you where they occur relative to the geologic and hydrologic units. Vertical profiles, transects, 3D pictures and maps can all be produced from the electronic data generated by the MIP logs. Its unique capability of providing reliable, real-time information allows you to make better and timely decisions while your team is still in the field.

The MIP is a downhole tool that heats the soils and groundwater adjacent to the probe to 120 degrees C. This increases volatility and the vapor phase diffuses across a membrane into a closed, inert gas loop that carries these vapors to a series of detectors housed at the surface. Continuous chemical logs or profiles are generated from each hole. Soil conductivity is also measured and these logs can be compared to the chemical logs to better understand where the VOCs occur. The MIP technology is only appropriate for volatile organic compounds (VOCs). The gas stream can be analyzed with multiple detectors, for example an electron capture detector is used to detect chlorinated solvents, a photo-ionization detector is used to detect petroleum hydrocarbons, and a flame ionization detector is used to detect methane.



Equipment:

- Geoprobe 6600
- MIP Controller (Nitrogen Flow and Heater)
- Geoprobe FC 5000 Computer
- HP 5890 Gas Chromatograph
- XSD (Halogen Specific Detector)
- ECD (Electron Capture Detector)
- PID (Photo Ionization Detector) 10.2 eV Lamp
- FID (Flame Ionization Detector)
- 150' Heated Trunkline
- 1.75" O.D. 6520 MIP Probe
- 1.5" O.D. Drive Rods

Detector Overview

- ECD – Electron Capture Detector uses a radioactive Beta emitter (electrons) to ionize some of the carrier gas and produce a current between a biased pair of electrodes. When organic molecules contain electronegative functional groups, such as halogens, phosphorous, and nitro groups pass by the detector, they capture some of the electrons and reduce the current measured between the electrodes.
- PID – Photo Ionization Detector sample stream flows through the detector's reaction chamber where it is continuously irradiated with high energy ultraviolet light. When compounds are present that have a lower ionization potential than that of the irradiation energy (10.2 electron volts with standard lamp) they are ionized. The ions formed are collected in an

electrical field, producing an ion current that is proportional to compound concentration. The ion current is amplified and output by the gas chromatograph's electrometer.

- FID – Flame Ionization Detector consists of a hydrogen / air flame and a collector plate. The effluent from the GC (trunkline) passes through the flame, which breaks down organic molecules and produces ions. The ions are collected on a biased electrode and produce an electric signal.

MIP Data Collected

- Depth - Data is collected from twenty data points per foot. 0.05', 0.10', 0.15', etc…
- Electrical Conductivity - Electrical Conductivity data is measured/collected in milli-siemens per Meter (ms/M). The conductivity of soils is different for each type of media. Finer grained sediments, such as silts or clays, will have a higher EC signal. While coarser grained sediments, sands and gravel, will have a lower EC signal. The coarser grained sediments will allow the migration of contaminants and the finer grained sediments will trap the contaminant.
- Speed / Advancement Rate - Speed data is measured/collected in feet per minute (ft/min). Speed is an indication of the physical advancement rate of the MIP probe. Speed of the MIP probe can vary due to operator advancement and dense soil types. Speed log can provide soil type information which can be correlated with electrical conductivity. Lower advancement speed, correlated with lower conductivity or larger grained soils would more than likely be associated with dense or compacted sands.
- Temperature - Temperature data is measured/collected in Degrees Celsius. Temperature is an indication of the physical temperature of the MIP block. Minimum and Maximum temperature is collected at each vertical interval. Vironex's temperature protocol indicates that the MIP probe temperature shall maintain a minimum temperature of 75 Degrees Celsius.
- Pressure - Pressure data is measured/collected in PSI. Pressure is an indication of the internal pressure of the nitrogen lines located within the trunkline and the pressure behind the membrane. Minimum and Maximum temperature is collected at each vertical interval. Geoprobes temperature protocol indicates that the MIP probe pressure shall not exceed 1.5 PSI difference from baseline.
- Detector (XSD, ECD, PID, FID) - Detector responses are measured/collected in micro Volts (uV). Detector responses are an indication of relative contaminant responses. Minimum and Maximum detector responses are collected at each vertical interval.

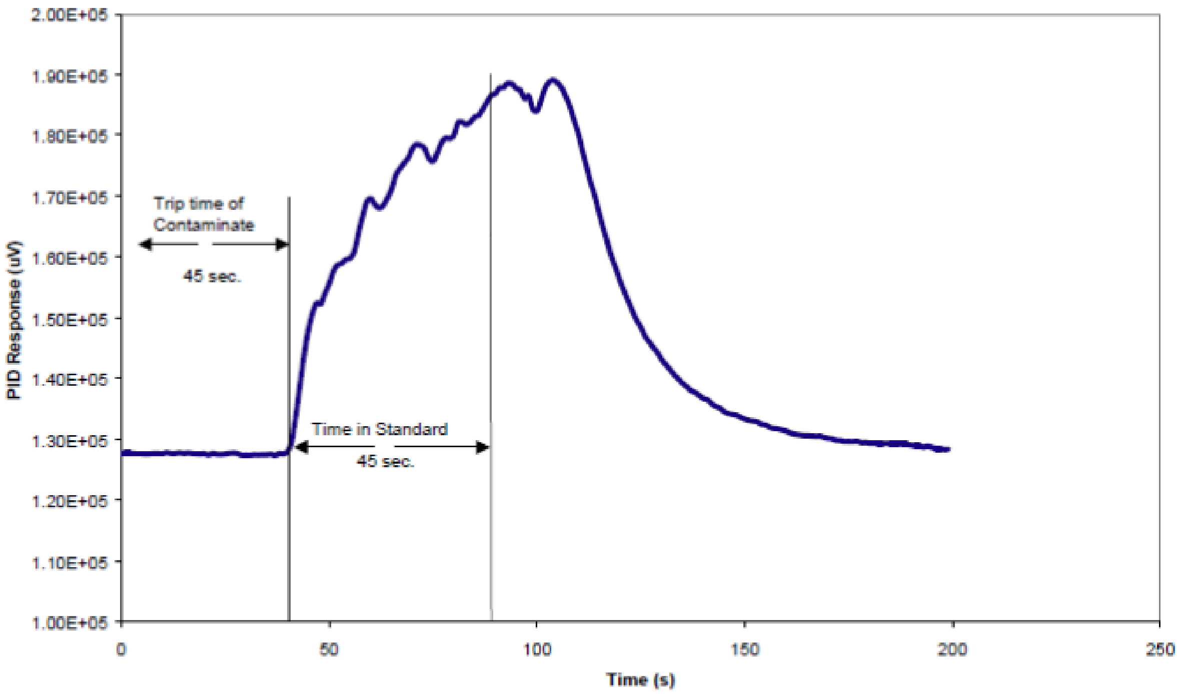
Response Testing

Response testing is an integral part of ensuring the quality of data from the MIP system. Response testing must be conducted before and after each log. This will ensure the validity of the data and the integrity of the system. Response testing also provides for comparison of data for later MIP logs at the same site. However, results of the response test may change due to membrane wear from soil contact and abrasion.

Prior to conducting a response test, a response test standard solution is prepared by adding an appropriate volume of stock standard solution to 0.5 liters of clean water in a suitable measuring container (beaker or graduated cylinder) to produce a working standard, for example, 10 µL of 50 mg/mL concentration stock standard is added to 0.5 liters of water to yield a 1mg/L working standard. Generally, response test standard solutions are prepared using trichloroethene and toluene. However, response test standard solutions may be prepared based on the specific contaminants of concern at a site of necessary. Also prior to conducting the response test, the MIP is placed in clean water until detector response stabilization has occurred.

The working standard is poured into a 2-inch diameter by 30-inch long PVC or stainless steel pipe that is capped at one end. A stabilized MIP is inserted in the working standard for a duration of 30 seconds (Note: in the response test shown below, the MIP was inserted into the working standard for a duration of 45 seconds). At the end of 30 seconds the MIP is removed from the working standard, and placed into clean water. The working standard cannot be reused after a response test.

The results of the response test are shown on the MIP data acquisition unit (shown below). The trip time is measured by recording the time between the moment when the MIP is placed in the working standard solution and the response of the detectors, as viewed on the MIP data acquisition unit. The baseline and peak response value are also recorded for comparison with other MIP response tests. The trip time is entered manually into the data acquisition system account for the time it takes for compounds in the subsurface to travel the length of the trunkline during the MIP boring.



PID Response Test – 10 ppm Benzene

Appendix D

Cox-Colvin
& ASSOCIATES, INC.
ENVIRONMENTAL SERVICES

Standard Operating Procedure Installation and Extraction of the Vapor Pin™

December 3, 2013

Scope:

This standard operating procedure describes the installation and extraction of the Vapor Pin™ for use in sub-slab soil-gas sampling.

Purpose:

The purpose of this procedure is to assure good quality control in field operations and uniformity between field personnel in the use of the Vapor Pin™ for the collection of sub-slab soil-gas samples.

Equipment Needed:

- Assembled Vapor Pin™ [Vapor Pin™ and silicone sleeve (Figure 1)];
- Hammer drill;
- 5/8-inch diameter hammer bit (Hilti™ TE-YX 5/8" x 22" #00206514 or equivalent);
- 1½-inch diameter hammer bit (Hilti™ TE-YX 1½" x 23" #00293032 or equivalent) for flush mount applications;
- ¾-inch diameter bottle brush;
- Wet/dry vacuum with HEPA filter (optional);
- Vapor Pin™ installation/extraction tool;
- Dead blow hammer;
- Vapor Pin™ flush mount cover, if desired;
- Vapor Pin™ protective cap; and
- VOC-free hole patching material (hydraulic cement) and putty knife or trowel.

Figure 1. Assembled Vapor Pin™.

Installation Procedure:

1) Check for buried obstacles (pipes, electrical lines, etc.) prior to proceeding.

2) Set up wet/dry vacuum to collect drill cuttings.

3) If a flush mount installation is required, drill a 1½-inch diameter hole at least 1¾-inches into the slab.

4) Drill a 5/8-inch diameter hole through the slab and approximately 1-inch into the underlying soil to form a void.

5) Remove the drill bit, brush the hole with the bottle brush, and remove the loose cuttings with the vacuum.

6) Place the lower end of Vapor Pin™ assembly into the drilled hole. Place the small hole located in the handle of the extraction/installation tool over the Vapor Pin™ to protect the barb fitting and cap, and tap the Vapor Pin™ into place using a dead blow hammer (Figure 2). Make sure

the extraction/installation tool is aligned parallel to the Vapor Pin™ to avoid damaging the barb fitting.

Figure 2. Installing the Vapor Pin™.

For flush mount installations, unscrew the threaded coupling from the installation/extraction handle and use the hole in the end of the tool to assist with the installation (Figure 3).

Figure 3. Flush-mount installation.

During installation, the silicone sleeve will form a slight bulge between the slab and the Vapor Pin™ shoulder. Place the protective cap on Vapor Pin™ to prevent vapor loss prior to sampling (Figure 4).

Figure 4. Installed Vapor Pin™.

7) For flush mount installations, cover the Vapor Pin™ with a flush mount cover, using either the plastic cover or the optional stainless-steel Secure Cover.

8) Allow 20 minutes or more (consult applicable guidance for your situation) for the sub-slab soil-gas conditions to equilibrate prior to sampling.

9) Remove protective cap and connect sample tubing to the barb fitting of the Vapor Pin™ (Figure 5).

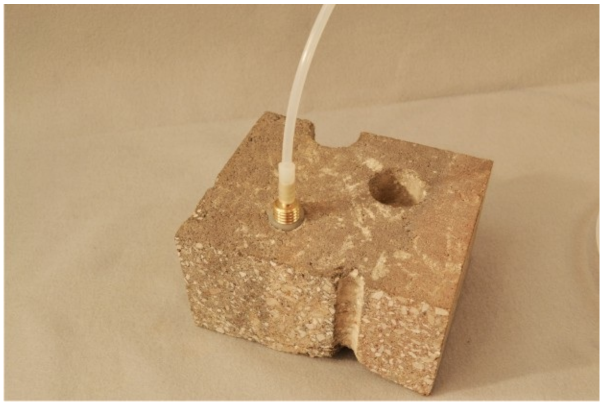


Figure 5. Vapor Pin™ sample connection.

10) Conduct leak tests in accordance with applicable guidance. If the method of leak testing is not specified, an attractive alternative can be the use of a water dam and vacuum pump, as described in SOP Leak Testing the Vapor Pin™ via Mechanical Means (Figure 6).

Figure 6. Water dam used for leak detection.

11) Collect sub-slab soil gas sample. When finished sampling, replace the protective cap and flush mount cover until the next sampling event. If the sampling is complete, extract the Vapor Pin™.

Extraction Procedure:

1) Remove the protective cap, and thread the installation/extraction tool onto the barrel of the Vapor Pin™ (Figure 7). Continue turning the tool to assist in extraction, then pull the Vapor Pin™ from the hole.

2) Fill the void with hydraulic cement and smooth with the trowel or putty knife. Urethane caulk is widely recommended for installing radon systems and can provide a tight seal, but it could also be a source of VOCs during subsequent sampling.

Figure 7. Removing the Vapor Pin™.

3) Prior to reuse, remove the silicone sleeve and discard. Decontaminate the Vapor Pin™ in a hot water and Alconox® wash, then heat in an oven to a temperature of 130° C.

The Vapor Pin™ to designed be used repeatedly; however, replacement parts and supplies will be required periodically. These parts are available on-line at www.CoxColvin.com.

Replacement Parts:

Vapor Pin™ Kit Case - VPC001
Vapor Pins™ - VPIN0522
Silicone Sleeves - VPTS077
Installation/Extraction Tool - VPIE023
Protective Caps - VPPC010
Flush Mount Covers - VPFM050
Water Dam - VPWD004
Brush - VPB026
Secure Cover - VPSCSS001
Spanner Wrench - VPSPAN001

Cox-Colvin & Associates, Inc.
Environmental Services

Standard Operating Procedure Use of the Vapor Pin™ Drilling Guide and Secure Cover

December 3, 2013

Scope:

This standard operating procedure (SOP) describes the methodology to use the Vapor Pin™ Drilling Guide and Secure Cover to install and secure a Vapor Pin™ in a flush mount configuration.

Purpose:

The purpose of this SOP is to detail the methodology for installing a Vapor Pin™ and Secure Cover in a flush mount configuration. The flush mount configuration reduces the risk of damage to the Vapor Pin™ by foot and vehicular traffic, keeps dust and debris from falling into the flush mount hole, and reduces the opportunity for tampering. This SOP is an optional process performed in conjunction with the SOP entitled "Installation and Extraction of the Vapor Pin™". However, portions of this SOP should be performed prior to installing the Vapor Pin™.

Equipment Needed:

- Vapor Pin™ Secure Cover (Figure 1);
- Vapor Pin™ Drilling Guide (Figure 2);
- Hammer drill;
- 1½-inch diameter hammer bit (Hilti™ TE-YX 1½" x 23" #00293032 or equivalent);
- 5/8-inch diameter hammer bit (Hilti™ TE-YX 5/8" x 22" #00226514 or equivalent);
- assembled Vapor Pin™;
- #14 spanner wrench;
- Wet/Dry vacuum with HEPA filter (optional); and
- personal protective equipment (PPE).

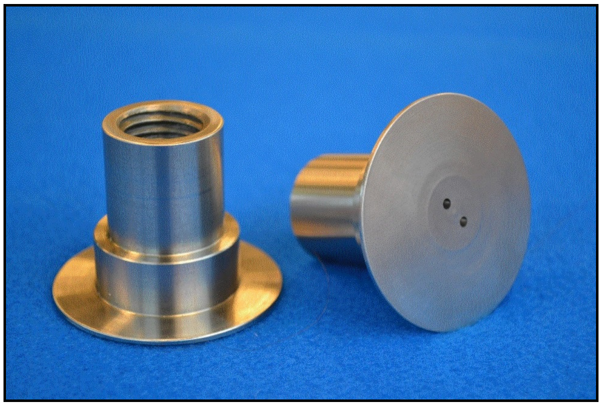


Figure 1. Vapor Pin™ Secure Cover.

Figure 2. Vapor Pin™ Drilling Guide.

Installation Procedure:

1) Check for buried obstacles (pipes, electrical lines, etc.) prior to proceeding.

2) Set up wet/dry vacuum to collect drill cuttings.

3) While wearing PPE, drill a 1½-inch diameter hole into the concrete slab to a

depth of approximately 1 3/4 inches. Pre-marking the desired depth on the drill bit with tape will assist in this process.

4) Remove cuttings from the hole and place the Drilling Guide in the hole with the conical end down (Figure 3). The hole is sufficiently deep if the flange of the Drilling Guide lies flush with the surface of the slab. Deepen the hole as necessary, but avoid drilling more than 2 inches into the slab, as the threads on the Secure Cover may not engage properly with the threads on the Vapor Pin™.

Figure 3. Testing Depth with the Drilling Guide.

5) When the 1½-inch diameter hole is drilled to the proper depth, replace the drill bit with a $^5/_8$-inch diameter bit, insert the bit through the Drilling Guide (Figure 4), and drill through the slab. The Drilling Guide will help to center the hole for the Vapor Pin™, and keep the hole perpendicular to the slab.

6) Remove the bit and drilling guide, clean the hole, and install the Vapor Pin™ in accordance with the SOP "Installation and Extraction of the Vapor Pin™".

Figure 4. Using the Drilling Guide.

7) Screw the Secure Cover onto the Vapor Pin™ and tighten using a #14 spanner wrench by rotating it clockwise (Figure 5). Rotate the cover counter clockwise to remove it for subsequent access.

Figure 5. Tightening the Secured Cover.

<u>Limitations:</u>

On slabs less than 3 inches thick, it may be difficult to obtain a good seal in a flush mount configuration with the Vapor Pin™.

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