REMEDIAL DESIGN PROJECT OPERATIONS PLAN
APPENDIX C

SAMPLING AND ANALYSIS PLAN
FIELD SAMPLING PLAN

Industri-plex Operable Unit 2
(including Wells G&H Operable Unit 3) Superfund Site
Woburn, Massachusetts

Prepared by:

Haley & Aldrich, Inc.
465 Medford Street
Boston, Massachusetts 02129

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DRAFT

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LIST OF ACRONYMS

Acronym	Agency/Organization/Definition
AAD	Atlantic Avenue Drainway
AOB	Ammonia-Oxidizing Bacteria
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
BOD	Biological Oxygen Demand
BOD_5	5-Day Biological Oxygen Demand
CBCA	Cranberry Bog Conservation Area
CD	Consent Decree
COCs	Contaminants of Concern
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EHP	East Hide Pile
EPA	United States Environmental Protection Agency
EqP	Equilibrium Partitioning
FDT	Fluorescent Dye Tracer
FEMA	Federal Emergency Management Agency
FLM	Former Lake Mishawum
FSP	Field Sampling Plan
GIS	Geographical Information Systems
GSIP	Groundwater/Surface Water Investigation Plan
HBHA	Halls Brook Holding Area
IC	Institutional Control
MassDEP	Massachusetts Department of Environmental Protection
MBTA	Massachusetts Bay Transportation Authority
NAD	North American Datum
NAVD	North American Vertical Datum
NBSD	New Boston Street Drainway
NOB	Nitrite-Oxidizing Bacteria
ORP	Oxidation-Reduction Potential
OU1	Industri-plex Superfund Site Operable Unit No. 1
OU2	Industri-plex Superfund Site Operable Unit No. 2
PDI	Pre-Design Investigation
PLFA	Phospholipid Fatty Acid
PVC	Polyvinyl Chloride

LIST OF ACRONYMS
(continued)

Acronym	Agency/Organization/Definition
QAPP	Quality Assurance Project Plan
qPCR	quantitative Polymerase Chain Reaction
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RDWP	Remedial Design Work Plan
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
ROW	Right of Way
SOP	Standard Operating Procedures
SOW	Statement of Work
SWMM	Storm Water Management Model
SWMP	Surface Water Monitoring Plan
SPT	Standard Penetration Testing
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
WHP	West Hide Pile

1.0 INTRODUCTION

This Field Sampling Plan (FSP) is prepared on behalf of Pharmacia Corporation by its Attorney-in-Fact Monsanto Company and Stauffer Management Company LLC as litigation agent for Bayer CropScience, Inc. (Settling Defendants). The FSP describes all sample collection and analysis activities for remedial pre-design investigations (PDIs) proposed in the Remedial Design Work Plan (RDWP) submitted pursuant to the Consent Decree that was lodged on February 27, 2008 with the United States District Court for the District of Massachusetts in connection with Civil Action No. 1:08-cv-10325 (the CD), and with the RD/RA Statement of Work (SOW) that is attached as Appendix D to the CD for Operable Unit No. 2 at the Industri-plex Superfund Site (including Operable Unit 3 of the Wells G&H Superfund Site) in Woburn, Massachusetts (hereinafter "Industri-plex OU2" or "Site"); see Figure 1-1). The PDIs described in this FSP will be completed in accordance with the Record of Decision (ROD), the CD, and the SOW as reflected in the RDWP.

1.1 Name and Location

Industri-plex Superfund Site OU2 Woburn, Middlesex County, Massachusetts

United States Environmental Protection Agency (EPA) Identification Numbers:
Industri-plex - MAD076580950
Wells G&H - MAD980732168

Figure 1-1 is a Site locus. Figure 1.1-1 shows the Site in plain view.

1.2 Remedy Components

EPA's selected remedy consists of the following components:

- Dredging and off-site disposal of contaminated sediments in the southern portion of the Halls Brook Holding Area (HBHA) Pond[1]; dredging and off-site disposal of contaminated near shore sediments at the Wells G&H Wetland and Cranberry Bog Conservation Area (CBCA); and restoration of all disturbed areas. This component will address sediments posing unacceptable human health risks for near shore sediments and unacceptable ecological risks for the southern portion of HBHA Pond.
- Use of the northern portion of HBHA Pond as a sediment retention area that will intercept contaminated groundwater plumes (including arsenic, benzene, ammonia, 1,2-dichloroethane, trichloroethene, naphthalene) from Industri-plex OU1/OU2, treat/sequester surface water contaminants of concern (COCs) (arsenic, benzene, ammonia), and minimize downstream migration of surface water COCs. The northern portion will intercept the contaminated groundwater plumes discharging in the HBHA Pond. Sediments which accumulate in the northern portion of the HBHA Pond may be periodically dredged and sent off-site for disposal. Portions of storm water from Halls Brook, which may interfere with the natural treatment processes occurring within the northern portion of the HBHA Pond, will be diverted to the southern portion of HBHA Pond.
- If necessary, in situ enhanced bioremediation of contaminated groundwater plumes (e.g., benzene) at the West Hide Pile (WHP).

[1] To the extent there is a defined southern cell in the final remedy design.

- Construction of an impermeable cap to line stream channels (i.e., New Boston Street Drainway [NBSD]), and to prevent the discharge of contaminated groundwater plumes, contamination of stream sediments, downstream migration of COCs, and potential impacts to other components of the selected remedy.
- Construction of a permeable cap to prevent contaminated soil erosion (i.e., Area A6), downstream migration of COCs, and potential impacts to other components of the selected remedy.
- Establishing Institutional Control (ICs) to restrict contact with soils, groundwater, or deeper interior wetland sediments with concentrations above Performance Standards and protect the remedy.
- Construction of compensatory wetlands, resource areas, aquatic habitat, etc. for any loss of wetland functions and values associated with the selected remedy (e.g., northern portion of HBHA Pond, Halls Brook storm water by-pass, capped stream channels) nearby in the watershed.
- Long-term monitoring of the groundwater, surface water, and sediments, and periodic five-year reviews of the remedy.

1.3 Document Organization

Section 2 of this FSP describes activities and tabulates sampling methods (applicable Standard Operating Procedures [SOPs] provided in FSP Attachment C1) that will be common to multiple PDIs, including:

- Utility markout
- Sampling methods tabulated for soil, sediment, groundwater, and surface water
- Exploration location surveying methods
- Decontamination and investigation-derived waste management
- Sample handling and analytical methods for each sample medium, indicating appropriate sample containers, preservation, and holding times (SOPs and applicable data quality control requirements are provided in the Quality Assurance/Project Plan [QAPP])

Sampling procedures specific to a single PDI or experimental design are described within the applicable PDI description in Section 3. Section 3 describes the 16 proposed PDIs, grouped as follows:

- Dredging and off-site disposal of contaminated sediments from HBHA Pond, Wells G&H wetland, and the CBCA wetland (PDI-1, PDI-2)
- Use of HBHA Pond to treat contaminants (PDI-3, PDI-4, PDI-5, PDI-6, PDI-7; PDI-8, PDI-15, PDI-16)
- West Hide Pile/Lower South Pond evaluation (PDI-9)
- Impermeable and permeable cap designs for the NBSD and Area A6 (near Atlantic Avenue Drainway [AAD] inlet to HBHA Pond) (PDI-10, PDI-11)
- ICs for Former Lake Mishawum (FLM) Bed, Wells G&H wetland, and CBCA wetland (PDI-12)
- Pond/wetland mitigation site selection and concept design (PDI-13)
- Ammonia in groundwater background investigation (PDI-14)

Each PDI description includes a discussion of the objectives and methodology for the data collection for that PDI. Descriptions of sampling methods are provided in the SOPs included in Attachment C1 to the FSP.

Section 4 provides the schedule for all PDIs.

2.0 TECHNICAL METHODOLOGY

Field methods relevant to the PDIs described in the RDWP and in Section 3 of this FSP are summarized in this section. Specific SOPs are included in Attachment C1 to this FSP. Table 2-1 summarizes the various tasks included as part of each PDI. Table 2-2 summarizes the number and type of samples to be collected or generated as part of each PDI. Table 2-3 summarizes sample container, preservation, and holding time requirements for sample media and specific analyses.

2.1 Utility Mark-out and Geophysical Survey

Underground and overhead utilities in the vicinity of sampling locations will be identified and marked prior to field activities. Mark-out will be conducted in accordance with relevant state and local regulations. Underground utilities will be identified based on Site drawings, utility company identification, communication with Dig Safe System, Inc. (Dig Safe) and/or geophysical survey. Geophysical surveys will be used to identify buried utility lines/pipes, former disposal trenches or pits, limits of existing landfills and/or waste material, as well as other subsurface features that may impact field work. Geophysical techniques that may be used to support field investigations include: magnetometry, ground penetrating radar, terrain conductivity, and borehole imaging. These will be applied, as needed, in accordance with state and local regulations, as well as relevant contractor operational guidelines.

2.2 Exploration Location Survey

A licensed Massachusetts surveyor will be retained to conduct a survey for the purpose of locating any completed explorations. Surveying techniques will be employed by the subcontractor to match site-specific conditions. Horizontal locations will be referenced to the Massachusetts State Planar coordinates (North American Datum [NAD]) 1983). Vertical data will be referenced to the North American Vertical Datum (NAVD, 1988). Data will be collected using appropriate surveyor's equipment, as determined by the subcontractor.

2.3 Soil Investigation

PDI-6, PDI-11, and PDI-12 require surface and subsurface soil samples as summarized in Tables 2-1 and 2-2. Several sampling techniques will be used, such as geotechnical drilling, direct-push boreholes (i.e., GeoProbe® boreholes), test pits, and hand sampling techniques (e.g., hand auger, trowel, slide hammer). These methods will be selected based on their relevance and field conditions present at the time of sampling. Haley & Aldrich personnel will generally perform the hand soil sampling techniques. In the case of boreholes and test pits, subcontractors will perform their tasks according to their contracts and the SOPs described in this FSP. Haley & Aldrich staff will observe subcontractors. The subcontractor will provide Haley & Aldrich staff with soil samples, at which point the H&A personnel will visually classify, log and sub-sample the soil sample. Soil sampling SOPs are included in Attachment C1.

Relevant Field SOPs:
OP1002 - Drilling Safety
OP2000 - Monitoring Field Explorations
OP2001 - Identification and Description of Soils Using Visual-Manual Methods
OP2005 - Test Borings
OP2030 - Direct Push Borings
OP3003 - Surficial Soil Sampling
OP3003A - Addendum to Surficial Soil Sampling
OP3006 - Procedure for Subsurface Soil Sampling for Chemical Analysis

2.4 Groundwater Investigation

PDI-3, PDI-9, PDI-10, PDI-12, and PDI-14 require groundwater sampling as summarized in Tables 2-1 and 2-2. Groundwater will be monitored on the site by sampling existing monitoring wells, and/or installing and sampling new monitoring wells, piezometers, and temporary well points. Several sampling techniques will be used, such as the EPA Low Flow/Minimal Drawdown method, direct push sampling (i.e., use of a GeoProbe®), as well as other situation-specific techniques. Groundwater sampling SOPs are included in Attachment C1.

Relevant Field SOPs:
OP2021 - Piezometers
OP3008 - Manual Water Level Measurement Procedure
OP3009 - Monitoring Well Development Procedure
OP3010 - Groundwater Sampling
OP3011 - Groundwater Sampling Using Direct Push Technology
OP3012 - Low Stress/Low Flow Groundwater Sampling Procedure
OP3018 - Vertical Profiling of Groundwater Using Direct Push Technology
Iron, Ferrous, Methods (Associated with HACH D2800)

2.5 Sediment Investigation

PDI-1, PDI-2, PDI-4, and PDI-9 require sampling sediment as summarized in Tables 2-1 and 2-2. Samples will be collected using several situation-specific procedures, including petite ponar sampler, Ekman dredge sampler, piston or ball-check corer, and peristaltic pumping. Once collected, samples will be subsampled as appropriate for the target analytes. Sediment sampling SOPs are included in Attachment C1.

Relevant Field SOPs:
OP3004 - Sediment Sampling

2.6 Surface Water Investigation

PDI-4, PDI-5, PDI-9, PDI-10, PDI-14, PDI-15, and PDI-16 require surface water sampling as summarized in Tables 2-1 and 2-2. These samples will be collected using several situation-specific procedures, including grab sampling and peristaltic pumping. Surface water sampling SOPs are included in Attachment C1.

Relevant Field SOPs:
OP1008 - Operations Over, Near or on Water
OP3007 - Surface Water SamplingOzark Underground Laboratory, Inc. - Procedures and Criteria
Iron, Ferrous, Methods (Associated with HACH D2800)

2.7 Air Investigation

PDI-5 requires vapor sampling as summarized in Tables 2-1 and 2-2. These samples will be collected using tedlar bags or vendor-specific equipment (Galson Analytical's Anasorb tubes for ammonia and Draeger colorimetric tubes for ammonia and benzene). The air sampling SOP is included in Attachment C1.

Relevant Field SOPs:
OP3023 – Air Sample Collection with Tedlar Bags

2.8 Decontamination and Investigation Derived Waste Management

Reusable equipment must be decontaminated prior to each use, and following each work day, if they are used, in order to prevent cross-contamination. Decontamination procedures are included in Attachment C1.

Wastes associated with sampling (e.g., disposable items, excess sample media), waste from decontamination of reusable equipment, spent personal protection equipment (PPE), and used Health and Safety supplies are classified as Investigation Derived Wastes (IDWs). IDWs must be disposed in accordance with the project guidelines. IDW disposal procedures are included in Attachment C1.

Relevant Field SOPs:
OP3027 - Decontamination Procedure
OP3028 - Investigation Derived Wastes

2.9 General Field Procedures

Procedures relevant to the overall sampling plan are summarized below.

Relevant Field SOPs:
OP3001 - Preservation and Shipment of Environmental Samples
OP3026 - Chain of Custody
OP3029 - Field Data Recording
OP3030 - Field Instruments: Use and Calibration

2.10 Sample Analysis Methods

Samples collected according the procedures above will be analyzed for a variety of chemical and geotechnical properties. These analyses are listed in tables associated with the PDI descriptions in Section 3 of this FSP along with related analysis SOPs in the QAPP.

3.0 PRE-DESIGN INVESTIGATIONS SCOPE OF WORK

Section 3 provides the context for and the intent of the PDIs described herein. The PDI's are organized pursuant to the EDC (Engineering Design Component) structure. More specifically, PDIs are described as follows:

Section 3.1 HBHA Pond
Section 3.2 WHP In-situ Enhanced Bioremediation, as necessary
Section 3.3 Removal and Restoration of Near Shore Sediments from the Wells G&H Wetland and CBCA
Section 3.4 Institutional Controls

To the extent there is overlap (i.e., PDI's described in one EDC that apply to another) a note is included in the associated PDI description if appropriate.

3.1 HBHA Pond

The following sections present the background and goals of PDIs related to using the HBHA Pond for treatment, as described in the RDWP. The following PDIs are discussed in this section:

- PDI-1: HBHA Pond Sediment Dredging
- PDI-3: Groundwater Investigation
- PDI-4: HBHA Pond COC Transformation Processes & Studies (Parts A through C)
- PDI-5: Tank Treatability Studies
- PDI-6: Geotechnical Investigations (Parts A through C)
- PDI-7: HBHA Flood-Routing Modeling Analysis
- PDI-8: HBHA Pond Hydrodynamic Modeling
- PDI-10: Impermeable Caps
- PDI-11: Permeable Caps
- PDI-13: Studies to Locate Property for Wetland Mitigation
- PDI-14: Ammonia Background Investigation
- PDI-15: HBHA Pond Aeration Pilot Test
- PDI-16: Cofferdam Simulation Pilot Test

A number of the PDIs described below are seasonally dependent or have a particular timeframe when the work should be completed to facilitate the schedule and deadlines outlined in the SOW. Additionally, particular PDIs have to be performed later in the remedial design process because they may alter the HBHA Pond hydrodynamics, which will confound the results of PDIs that require ambient conditions.

3.1.1 PDI-1: HBHA Pond Sediment Dredging

The goals of PDI-1 are to address the following data needs:

- Delineate laterally and vertically areas with arsenic concentration in sediment exceeding 273 mg/kg that may require dredging
- Identify debris requiring removal prior to sediment dredging
- Document HBHA Pond bathymetry prior to dredging
- Measure sediment thickness to estimate sediment dredging volume
- Monitor sediment accumulation to evaluate and if possible modify the estimated dredging frequency proposed in the ROD
- Determine geotechnical properties to support design for handling of dredged material
- Determine the most cost-effective means of dewatering dredge spoils

- Determine waste characteristics of sediment for preliminary evaluation of disposal option(s). Final waste characterization sampling and analysis will be established as part of the RA during/following dewatering activities)

3.1.1.1 Investigation Approach

PDI-1 will include the following activities:

- PDI-1 will include aerial photos, existing land survey information, and field reconnaissance of the areas surrounding HBHA Pond to assess space availability for dredging operations, including roadway access, equipment laydown, and sediment processing operations. The selection of suitable space for dredging operations will consider the requirements of (1) other HBHA Pond PDIs that involve equipment mobilization and staging, (2) construction of structures required for the HBHA Pond remedy, (3) recommendations of affected property owners, (4) logistical constraints such as power, access to roadways and the potential impacts from noise and smell, if there is the potential for them to rise to the level of causing a potential significant nuisance to nearby landowners.
- A hydrographic survey will be performed to identify debris, document bathymetry, and measure soft sediment layer thickness for estimating dredging volume. Bathymetry will be recorded along perpendicular transects as illustrated in Figure 3.1.1.1-1.
- Sediment will be sampled to delineate arsenic performance standard exceedances laterally and vertically within the soft sediment layer (described further in Section 3.1.1.2). Samples will also be analyzed for total iron to assist in the evaluation of the fate and transformation of COCs. Sediment samples will be collected at 23 locations as shown in Figure 3.1.1-1. Additional samples may be added if necessary based on the initial sediment data. The sediment sampling locations shown on Figure 3.1.1-1 will be adjusted based on the results of the groundwater plume discharge evaluation (PDI-3) and other studies that will determine where the primary and secondary treatment cells of the proposed HBHA-4 remedy would be located, as dredging will only be required within and to the south of the secondary treatment cell during initial remedy implementation.
- Once the preliminary location of the cofferdams is determined, three additional bulk composite samples will be collected from the portion of the HBHA Pond to be dredged. These samples will be submitted for bench-scale treatability studies as described in Section 3.1.1.2. Each composite will be subsampled and tested for the following parameters: water content, specific gravity, grain size, and organic content (loss-on-ignition). Following completion of the bench-scale treatability tests, aliquots of the dewatered sediments from the initial three composite samples will also be analyzed for waste disposal characterization.
- An array of sediment traps will be installed at three locations within HBHA Pond; each array will consist of 4 traps. One array will be placed in each of the northern, central and southern portions of the pond as shown in Figure 3.1.1-1, each array to be located at the areas where the soft layer thickness is greatest, based on the probing conducted as part of this PDI. Two of the traps will be removed from each array after 12 months; the other two will be removed after 24 months.

3.1.1.2 Sampling and Analysis Methods

Hydrographic survey: HBHA Pond bathymetry measurements will be collected using a SyQwest, Inc. HydroBox dual-frequency precision echosounder. The dual-frequency signal is intended to accurately digitize the surface and bottom of flocculent sediment (if present) and export the two depth values to the data acquisition software. A dual-frequency (33-kHz and 200-kHz, 8-degree and 20-degree, respectively) transducer and a narrow-beam (3-degree) 200-kHz transducer will be available. The single-frequency transducer will be used in water depths less than five feet.

Digital global position system (GPS) equipment will be used to establish horizontal position. Measured depths will be converted to bottom elevations based on water level elevation data recorded using an In-Situ Mini-Troll pressure transducer at a surveyed project benchmark. GPS and echosounder equipment will be calibrated following procedures consistent with *Hydrographic Surveying, Manual #1110-2-1003* (USACE, 2004). The bathymetry will be ground-truthed using a small boat and a low pressure, 1-ft diameter sounding plate attached to a measuring tape to determine the top of the soft sediment layer and sediment probes (e.g., ¼-in steel rod) to confirm the thickness of soft sediment. In addition, side-scan sonar will be used to survey the Pond bottom for debris.

Sediment Sampling: Sampling and analysis methods for sediments are summarized in Tables 3.1.1.2-1 and 3.1.1.2-2. A manually deployed coring device, consisting of a 2-inch or 3-inch diameter Lexan tube equipped with either a ball check or a piston head will be used. The coring device must be advanced manually into the underlying sand/gravel/clay layer, which should serve as a "plug" for the cores. Field sampling personnel must be able to recognize penetration of the underlying consolidated layer based on an increase in resistance to manual pushing, prior to refusal. The bottom of cores will be capped before breaking the water surface. Sediment recovery will be measured upon retrieval of each core, and after gravity settling. Overlying water will be drained from cores prior to processing, which involve splitting the cores on a flat surface for examination and logging. Draining will be performed by drilling small holes in the coring tubes at the top of the cohesive sediment layer, to avoid loss of "flocculent" fine-grained particles. If a "flocculent" layer is evident, it may have to be subsampled from the top of the core tube in an upright position, to avoid sloughing and mixing with underlying soft sediments during processing. A composite sample will be collected from each distinct layer; including the underlying native sand/gravel/clay layer. If distinct "flocculent," "sludge," and "sandy" layers are subsampled, the upper two layers will be analyzed for arsenic; the underlying sandy layer will be archived for possible analysis (69 samples estimated). The data will be used to assign a binary designation to identify samples as either exceeding the arsenic Performance Standard or not exceeding the Performance Standard for arsenic (i.e., samples with arsenic in excess of 273 mg/kg in either the flocculent or sludge layers (collectively, the soft sediment) versus samples with less than 273 mg/kg arsenic in soft sediment). All samples will be analyzed for total iron to evaluate fate and transformation of COCs.

HBHA Pond sediments will be freeze-dried as part of the sample preparation for arsenic and total iron analysis. Freeze drying increases solids content and will be implemented in order to eliminate the need to reject non-detect results (for samples with less than 30 % solids) or all results (for samples with less than 10 % solids), per the 1996 Region I Validation Guidelines. Additionally, freeze-dried sediments will be stored frozen, extending holding times up to 1 year.

For non-compliant sampling cells (i.e., cells having an arsenic concentration exceeding 273 mg/kg in soft sediments), the soft sediment layer, which may or may not include distinct flocculent and sludge layers, will be composited and archived for possible measurement of the following geotechnical properties on select samples once the scope of sediment dredging is better defined (e.g., following completion of PDI-3 and other investigations):

- Water content
- Grain size (sieve and hydrometer)
- Atterberg limits
- Organic content (loss on ignition)
- Specific gravity

Five to ten samples will be submitted for geotechnical analyses described above.

Samples for Treatability Tests: Up to three bulk composite samples (minimum 25 gallons) will be collected (by piston core or other means) from more than one sample location where the Performance

Standard is exceeded for up to four types of treatability testing. A decision on which non-compliant cells to composite from will be made based on the results of the geotechnical testing above. The type of treatability test performed will depend on the characteristics of the sediment and the disposal location for the sediment. Each of the four tests, as described below, is proposed as a possible candidate for the bench scale testing. After the Pond characterization testing is complete, one or more of the tests could be excluded if the sediment characteristics indicate no need for the test (e.g., if the sediment is sand, there would be no need for a settling test). These additional bulk composite samples will also be analyzed for the geotechnical parameters listed above.

The bench-scale treatability includes testing to assess the dewatering of the Pond sediments using a passive dewatering pond (large-diameter settling test), geotextile bags, or recessed chamber filter presses. The bench-scale treatability also includes solidification testing to determine the effect of different solidifying agents on the sediment from the Pond.

A. Large-diameter Settling Test - The large-diameter settling test measures the rate at which fine solids (smaller than 100-micron) will settle in a pond under quiescent conditions. The procedure for the large-diameter settling test is contained in the United States Army Corps of Engineers Engineering Manual, Confined Disposal of Dredged Material (EM 1110-2-5027, excerpt in Attachment C2 to this FSP).

A figure showing the settling column is contained in the excerpt in Attachment C2. The settling column is an 8-inch diameter clear polyvinyl chloride (PVC) tube with a detachable bottom section. The tube is suspended from the ceiling by hooks during the test. The detachable bottom section contains a three-inch diameter drain and a mechanism to agitate the test dredge slurry using compressed air. The clear column has sampling ports spaced at 6-inch intervals starting 6-inches from the top of the column for the recovery of water samples at different heights during the test. The column holds approximately 15 gallons of sediment and water mixture.

The test is run by mixing sediment into water at the expected solids concentration that will occur during dredging.

An interface between the slurry and clear water is measured over time to determine the drop in height of the interface. The settling rate of the sediment and the solids content of the settled solids are recorded during the test and are used to size a hydraulic containment facility for the sediment, predict the size of the containment needed to store the sediment, and to assess the likely solids content (and/or the water quality) of discharge water from the containment facility.

B. Hanging Tube Test (Koerner 2005) - To test the dewatering characteristics of pond sediment in a geotextile tube, a one-foot diameter tube of fabric is hung from a frame and filled with 20% solids slurry (approximately 5 gallons) of the sediment. A single geotextile fabric similar in physical properties to fabric used on fine sediment dewatering projects at other sites will be used to test each sample. The drainage rate and water quality will be measured as described in Koerner and Koerner (2005), included in Attachment C2 to this FSP. In addition, to the procedure described in Attachment C2, solids content of the material in the bag will be measured at 1-day, 7-days, 14-days and 28-days after filling the tube. The water content samples will be removed from the center of the sediment column in each bag using a thin tube sampler to recover the entire depth of the sediment.

Some of the 20% solids slurry sample may be treated with a cationic polymer during mixing to simulate the improved solids retention that is likely with flocculated solids.

C. American Petroleum Institute (API) Filtrate Loss Test (API 13A, American Society for Testing and Materials [ASTM] D5891) - The procedure as published by API is described in Section 4.5 of the procedure included in Attachment C2. The API filtrate loss test is conducted to determine the dewatered characteristics of sediment that is dewatered by pumping sediment into a chamber of a recessed chamber plate and frame filter press.

For the HBHA Pond sediment, the sample will first be de-sanded to remove the particles that are coarser than approximately 100 microns. The sample will then be slurried at 5 to 7.5 % solids by weight and treated with cationic polymer to thicken the slurry to 20 to 25 % solids (thicker if possible in the thickening step). This pretreatment of the sediment models the removal of sand by hydrocyclones or screens prior to filter pressing and the addition of polymer to thicken the solids and remove free water prior to press operations.

The API filtrate loss test apparatus will have a 5-micron filter paper installed in the base, the test cylinder will be filled to within $^{1}/_{2}$ inch of the top and the top will be installed and clamped in place. The test will be run using compressed air for pressurizing the apparatus to 60 to 80 pounds per square inch (psi). Drainage of water from the test apparatus will be measured during the test. The test will be allowed to run for 30 to 60 minutes depending on the amount of continued drainage.

After the test is completed, the shear strength of the filtrate will be measured with a hand torvane and the solid residual will be removed and tested to determine the solids content and unit weight (based on the assumption of full saturation). The properties after testing will be compared to the properties of the fine sediment prior to the test and estimates of the sediment condition for landfilling will be made from the test results.

D. Solidification Test - The goal of this testing will be to determine what solidifying agents and weights of agents will cost effectively improve handling and disposal properties of the sediment. Solidification testing is performed on the homogenized sediment removing only the very largest particles prior to the test. The testing will include the use of quick lime, Portland cement, and other agents that may be readily available in the Boston metro area.

The test procedure using plastic cups is as follows:

1. A quantity of the hand mixed sediment adequate for the production of three test cups of mix is removed from the sediment pail.
2. The removed sediment is mixed in a stainless steel bowl and three water content samples are taken to determine the starting water content (solids content).
3. A quantity of the sample that is larger than required to fill one test cup is weighed and placed in the mixing bowl of a mixer.
4. The appropriate weight of solidification agent is added to the bowl and is mixed for 30 seconds.
5. The mixed sediment is then placed into a 16-oz plastic cup and weighed to determine the starting weight of the solidified sediment.
6. The plastic cup is nested in a styrofoam cup to limit heat loss from the sides of the cup, but remains open on the top.
7. Twenty-four hours later the weight of the solidified sediment is taken again and the strength of the mixture is measured using a pocket torvane.
8. After the torvane test, a water content sample is taken and the remainder of the sample is subjected to a paint filter test.
9. During the paint filter test, the tabletop on which the samples sits is vibrated for 30-minutes to simulate the effects of transportation in a dump truck box.

10. If the sample loses water, the sample is recorded to have failed the paint filter test.

It is expected that at least three combinations of different weights of sediment will be used for each sample (i.e., 5%, 7.5%, and 10% by wet weight).

Preliminary Waste Disposal and Water Treatment Characterization: To assist in evaluating management/disposal options for dredged sediment, approximately three bulk composite samples of sediment that has been subjected for treatability testing will also be analyzed for the following Resource Conservation and Recovery Act (RCRA) waste disposal characteristics:

- TCLP Metals
- Corrosivity
- Reactivity
- Ignitability
- Paint Filter Test

In addition, effluent from successful dewatering tests will be sampled for COCs to determine the need for designing wastewater treatment. It is anticipated that the dredging design will include returning dewatering effluent to the Pond, with or without treatment as determined by sampling up to nine effluent samples (three bulk samples and three dewatering tests) for the following analytes:

- Dissolved Arsenic
- Particulate Arsenic (measured as the difference between total and dissolved)
- Benzene
- Ammonia

Laboratory methods for sample preparation and analysis of the above parameters are listed in Tables 3.1.1.2-1 and 3.1.1.2-2.

3.1.2 PDI-3: Groundwater Investigation

PDI-3 was developed to evaluate groundwater contamination related to the design of the primary and secondary treatment cells, to evaluate plume stability over time, to assist in the development of the environmental monitoring plan, and to assist in determining the extent of the surface area potentially subject to groundwater ICs (PDI-12). The data collected under this PDI will also assist in the design of impermeable caps (PDI-10) and in the ammonia background evaluation (PDI-14).

As this PDI includes a focused (smaller scale) assessment of groundwater discharge in the vicinity of HBHA Pond as well as a larger scale groundwater investigation, PDI-3 is subdivided into 2 parts: PDI-3A Groundwater Discharge to HBHA Pond, and PDI-3B Sitewide Groundwater Plume Investigation as described below.

3.1.2.1 PDI-3A: Groundwater Discharge to HBHA Pond

The goal of this PDI will be to:

- Delineate the horizontal extent of the contaminated groundwater plume discharging into the Pond above surface water Performance Standards for site COCs
- Define the location of the cofferdams for the purpose of containing the COCs within the Pond

A. Investigation Approach

To evaluate the area of current contaminated groundwater discharge, a groundwater investigation will be conducted along both the eastern and western shoreline and along the centerline of HBHA Pond in three phases. Phase I consists of groundwater profiling at thirteen locations along the eastern and western shoreline of the HBHA Pond as shown on Figure 3.1.2.1-1. As part of the Early Action Remedial Design Activities conducted in accordance with the 13 August 2008 letter submitted by *de maximis inc*. to EPA six groundwater profiling locations have been completed along the eastern shore of HBHA Pond. Therefore seven additional profiling locations are proposed in this work plan to complete Phase I of PDI-3. Groundwater profiling on the eastern and western shoreline will be completed using direct push technology (DPT) driving a groundwater sampling tool (e.g., GeoProbe™ groundwater profiler, Waterloo Profiler™) and low-flow sampling methods to the extent feasible. Samples would be collected from the water table to the top of bedrock or to a total depth of approximately 30 ft (based on MSGRP RI data for depth to bedrock in the vicinity), whichever is less, at 10-ft increments using a sampler point with a 4 to 5-ft screened interval. Therefore at each location, groundwater samples will be collected at approximately 5 to 10 ft (water table), 15 to 20 ft (near the depth of the bottom of HBHA Pond) and 25 to 30 ft (below the Pond) or refusal, whichever is encountered first.

Phase II will involve installation and sampling of approximately nine temporary drive point piezometers along the centerline of HBHA Pond as shown on Figure 3.1.2.1-1. Drive point piezometers will consist of a drive-point device (e.g., Solinst Model 615 Drive-Point Piezometer) with a 1-ft screen driven a minimum of 2 ft into the sand underlying the recent sediments in the Pond. Groundwater samples will be collected from each piezometer and submitted for analysis of site COCs. Based on the groundwater analytical results it is anticipated that up to four piezometers will remain in place up to one year after installation to help evaluate gradients between the groundwater and surface water along the centerline of HBHA Pond. The drive point will be fixed with HDPE tubing that is attached to buoys at the water surface. The tubing will be sealed with a sampling port at the surface.

Phase III will involve the installation of five monitoring well pairs along the eastern shore, western shore, and northern portions of the HBHA Pond to evaluate seasonal fluctuations in groundwater discharge and determine vertical gradients. The data collected during Phase I and II will determine the number required, locations, and the depth of the screened intervals of these monitoring wells. The monitoring wells installed along the shoreline will be 1-inch diameter wells with either a 5 or 10-ft screen depending on depth, installed with a DPT rig.

B. Sampling and Analysis Methods

Sampling and analysis methods for groundwater collected as part of PDI-3A are summarized in Tables 3.1.2.1-1 and 3.1.2.1-2.

1. *Phase I Groundwater Profiling* - Phase I explorations will be conducted in north-south transects along the eastern and western shoreline of the Pond extending south of the known limits of contamination (Figure 3.1.2.1-1). Groundwater profiling will be completed using direct push technology (DPT) driving a groundwater sampling tool (e.g., GeoProbe™ groundwater profiler, Waterloo Profiler™) and low-flow sampling methods to the extent feasible. Samples would be collected from the water table to the top of bedrock or to a total depth of approximately 30 ft, whichever is less, at 10-ft increments using a sampler point with a 4 to 5-ft screened interval. Therefore at each location, groundwater samples will be collected at approximately 5 to 10 ft (water table), 15 to 20 ft (near the depth of the bottom of HBHA Pond) and 25 to 30 ft (below the Pond) or refusal, whichever is encountered first.

   All groundwater samples will be submitted to the fixed laboratory for analysis of arsenic (total and dissolved), ammonia, ammonia by-products including nitrates, nitrites, and total nitrogen

(including TKN), benzene, 1,2-dichloroethane, trichloroethene, naphthalene and total iron (unfiltered). Groundwater samples will also analyzed in the field for ferrous iron using a Hach Spectrophotometer. Sulfate, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total alkalinity will be collected at two groundwater profiling locations along the eastern shoreline and two groundwater profiling locations along the western shoreline of HBHA Pond. Conventional water quality parameters (dissolved oxygen (DO), pH, temperature, specific conductivity, ORP) will be collected using a multiprobe and a flow-through cell during purging. Turbidity will be measured using a separate Hach turbidimeter. Analytical parameters are summarized in Tables 3.1.2.1-1 and 3.1.2.1-2.

A total of thirteen profiling locations are planned as shown on Figure 3.1.2.1-1. Note that six of the profiling locations (DP-1 through DP-6) along the eastern shoreline of HBHA Pond were completed in March 2009 consistent with the scope described in a letter to EPA dated 13 August 2008 from demaximis with the subject "Early Action Remedial Design Activities Industri-Plex OU2 Superfund Site, Woburn, MA."

2. *Phase II Barge-mounted Groundwater Sampling HBHA Pond* - Phase II will consist of collecting groundwater samples from the aquifer beneath HBHA Pond. Groundwater samples will be collected from nine locations in HBHA Pond as shown on Figure 3.2.1.1-1 to supplement Phase I results. As the groundwater flow paths will be upward toward the Pond bottom, one sample will be collected from each location. A drive-point device with a 1-ft screen will be driven a minimum of 2 ft into the sand underlying the recent sediments in the Pond. This waterborne phase will be coordinated with barge-mounted investigations planned for other remedial components (e.g., cofferdam), to the extent practicable. Based on the groundwater analytical results it is anticipated that up to four piezometers will remain in place up to one year after installation to help evaluate gradients between the groundwater and surface water along the centerline of HBHA Pond. The drive point will be fixed with HDPE tubing that is attached to buoys at the water surface. The tubing will be sealed with a sampling port at the surface.

   Samples will be analyzed consistent with Phase I (Tables 3.1.2.1-1 and 3.1.2.1-2). Sulfate and alkalinity will be collected at two of the HBHA Pond locations. Conventional water quality parameters (DO, pH, temperature, specific conductivity, ORP) will be collected using a multiprobe and a flow-through cell during purging. Turbidity will be measured using a separate Hach turbidimeter.

3. *Phase III Installation of Monitoring Wells* - Following completion of Phase I and II, up to five monitoring well couplets will be installed along the shoreline of HBHA Pond to allow seasonal monitoring of the contaminated groundwater discharge in the vicinity of HBHA Pond as shown on Figure 3.1.2.1-1. The data collected during Phase I and II will determine the number required, actual locations, and the depth of the screened intervals of these monitoring wells. The monitoring wells installed along the shoreline will be 1-inch diameter wells with either a 5 or 10-ft screen depending on depth, installed with a Direct Push Rig. At each couplet location the shallow well is anticipated to be installed at approximately 15 ft bgs and the deeper well is anticipated to be installed at a depth of 30 ft bgs.

   Monitoring wells will be sampled on a quarterly basis for one year to evaluate seasonal variability in groundwater gradients and chemistry. Samples will be analyzed for arsenic (total and dissolved), ammonia, ammonia by-products including nitrates, nitrites, and total nitrogen (including TKN), benzene, 1,2-dichloroethane, trichloroethene, naphthalene, ferrous and total iron (unfiltered) as well as water quality parameters as described in Phase I.

3.1.2.2 PDI-3B: Sitewide Groundwater Plume Investigation

The various hide piles located in Industri-plex OU1 represent a significant source of the groundwater plumes observed at the Site; however, there are no permanent monitoring wells to evaluate how the plumes may be changing over time. As groundwater discharge is the most significant known contribution of contaminants to HBHA Pond, the design of the final remedy needs to contemplate potential changes in the strength and location of the groundwater plumes over time. The goal of this PDI will be to address the following:

- Time-series data for the COC's at select locations to assist in the design of the final remedy for the Pond
- Define portions of the Site requiring ICs to prevent exposures to groundwater
- The design of a long-term groundwater monitoring network

These goals will be achieved by conducting a Snap-shot groundwater sampling program and installation of several permanent monitoring wells at the site as described in the following sections.

Snap-Shot Groundwater Sampling Investigation

A. Investigation Approach

To evaluate the stability of the groundwater plume, we propose conducting a Snap-Shot groundwater investigation along several transects between the East Hide Pile (EHP) and WHP and HBHA Pond. As discussed during a meeting with EPA on January 22 2010, these transects were developed to partially coincide with previous Groundwater/Surface Water Investigation Plan (GSIP) sampling events completed in 2001-2002 to evaluate if there have been measurable changes in contaminant concentrations at these locations. Further, the locations take into account that data is available for monitoring locations managed by Olin Chemical and the Woburn Landfill. Figure 3.1.2.2-1 shows the locations of the proposed sampling transects and the 24 snap-shot sampling locations.

B. Sampling and Analysis Methods

The Snap-shot groundwater investigation will be completed using DPT driving a groundwater sampling tool (e.g., GeoProbe™ groundwater profiler, Waterloo Profiler™) and low-flow sampling methods.

Samples would be collected from approximately 5 ft below the water table. Conventional water quality parameters DO, pH, temperature, and specific conductivity,) will be collected using a multiprobe and a flow-through cell during purging. Turbidity will be measured using a *separate* Hach turbidimeter. Samples will be submitted to a fixed lab for analysis of total and dissolved arsenic, benzene 1,2 dichloroethane, trichloroethene, naphthalene, and ammonia. Sample analyses are summarized in Tables 3.1.2.2-1 and 3.1.2.2-2.

Monitoring Well Installation

Monitoring well installations are proposed at several locations where groundwater contamination was known to exist previously. Three wells are proposed in support of PDI-9 (see section 3.2 for more detailed description) and three monitoring well couplets are proposed between the hide piles and HBHA Pond.

A. *Investigation Approach*

Monitoring wells will be installed using a cased borehole and drive & wash techniques. Boreholes will be advanced by driving 4-inch diameter casing. Soil will be flushed from within the casing using a rollerbit and drill water. All wash water will be contained with wash tub during drilling. Investigation derived waste (e.g., drill water and cuttings) will be managed in accordance with *OP3028 - Investigation Derived Wastes.*

The well couplets will consist of a shallow well (e.g., 10 to 20 ft bgs) and a deep well (e.g., 25 to 35 ft bgs) which is consistent with the depth intervals samples during MSGRP RI work performed in these areas. Monitoring wells will consist of 2-inch diameter schedule-40 PVC with machine slotted well screens. Screened sections will be backfilled with filter sand approximately 1 to 2 ft above the top of the screened section. A minimum 2 ft thick bentonite seal will be placed above the sand pack and the remainder of the borehole will be backfilled with bentonite grout. The well will be completed at the ground surface with either a flush-mount roadway box or with a protective casing such as a guard pipe and padlock depending upon site conditions. A reference mark (e.g., notch) will be made on the top of the PVC riser that will be surveyed and used for determining depth to groundwater measurements. Following installation monitoring wells will be developed in accordance with Operating Procedure: OP3009 Monitoring Well Development Procedure.

B. *Sampling and Analysis Methods*

It is anticipated that one round of groundwater samples will be collected during the Pre-Design phase. Groundwater samples will be collected from monitoring wells using low-flow sampling methods to the extent feasible. Conventional water quality parameters (DO, pH, temperature, and specific conductivity, ORP) will be collected using a multiprobe and a flow-through cell during purging. Turbidity will be measured using a *separate* Hach turbidimeter. Samples will be submitted to a fixed lab for analysis of total and dissolved arsenic, benzene 1,2 dichloroethane, trichloroethene, naphthalene, and ammonia. Sample analyses are summarized in Tables 3.1.2.2-1 and 3.1.2.2-2.

3.1.3 PDI-4: HBHA Pond COC Transformation Processes & Studies

This PDI further evaluates the COC transformation processes within the HBHA Pond and how these processes may be enhanced in the primary and secondary treatment cells designs. The primary goals of PDI-4 include:

- Improve understanding of the COC (ammonia, arsenic, and benzene) contribution, distribution, and mixing in the water column in HBHA Pond (particularly above, below and across the chemocline) caused by groundwater and surface water discharges, as well as sediment diffusion
- Estimate COC transfer from deep to shallow surface water in the HBHA Pond and COC contribution and transfer from shallow surface water which may require treatment in the secondary treatment cell (and where appropriate the shallow surface water above the chemocline in the primary treatment cell)
- Estimate hydraulic residence time information under various flow and/or weather conditions for remedy design
- Identify COC transformation processes and rates of reaction which may be enhanced in the final design of the primary and secondary treatment cell
- Collect multi-depth water quality profiling data throughout the HBHA Pond to support this PDI and others such as PDI-8, -15 and -16

- Collect data to further understand the potential impact of various surface flows, temperature, wind, sun, etc., on the chemocline relative to the final design of the remedy
- Evaluate potential field monitoring equipment and accuracy (e.g., temperature, pH, conductivity, DO, ORP, ferrous iron, and ammonia)

The data generated under this PDI will be considered in the Northern Portion of HBHA Pond (e.g., primary and secondary treatment cells) component design of the selected remedy, including the design and location of any surface water flow controls to adjust (as appropriate) residence time within the primary and/or secondary treatment cells.

3.1.3.1 PDI-4A: Estimating Residence Times

The purpose of PDI-4A is to obtain quantitative data relative to hydraulic residence times in the HBHA Pond.

The objectives of this PDI are to:

- Estimate residence times of water from Halls Brook and AAD (if flowing)[2] to the Pond to the outlet of the Pond, and estimate the relative contribution of surface water from each of the inlets at the outlet (i.e., dilution).
- Estimate the diffusion rate of a conservative Fluorescent Dye Tracer (FDT) from below the chemocline to above the chemocline (mass transfer across the chemocline boundary).
- Collect data suitable to verify the hydrodynamic model (see PDI-8) by the measurement of FDTs in selected areas of the HBHA Pond and the HBHA Wetland.

A. Investigation Approach

A bench test was conducted by Ozark Underground Laboratory, Inc. (OUL) in April 2009 to evaluate the types of dyes that could be used in the HBHA Pond and surface water inlets. The bench test evaluated water collected from Halls Brook, the HBHA Pond water below the chemocline and the HBHA Pond water above the chemocline. The bench test also included a test to evaluate the effectiveness of the granulated activated carbon (GAC) packets in adsorbing the dyes and then releasing them into the eluting solutions in the laboratory. Results of the bench test are included as Attachment C3. Based on the results of the bench test, OUL identified three dyes that can be detected using the GAC packets, including fluorescein, eosine and rhodamine WT. In order to detect the dyes within the HBHA pond, the dye concentration of the HBHA pond will need to be 1 ug/l (ppb) fluorescein, 5 ppb eosine, and 20 ppb rhodamine WT.

During the test, a single slug of the appropriate amount of dye (based on the then current flow) will be released into each inlet upstream of the mouth to allow adequate mixing before the dye slug enters the HBHA Pond. The water below the chemocline will be dosed at the deepest point of the north basin. Surface water samples will be taken at two locations (the Pond outlet and HBHA Wetland outlet) following the release of the fluorescent dye. Dye will be absorbed by GAC packets located at three locations along six east-to-west transects across the HBHA pond and at three depths at each location, and submitted for analysis. The details of the FDT are described in more detail below.

Sampling and Analysis Methodology - The first task, the bench-scale test, was conducted in April 2009 as described above, and attached as Attachment C3. Based on this bench test, there is some ability of the natural pond water to quench the fluorescence of all three dyes; however the amount of quenching does

[2] ROW No. 9 drainage culvert is excluded since it does not exhibit significant flows due to Pond backwater effects. If in the future a better understanding of the discharge from ROW No. 9 becomes necessary, ROW No. 9 could be included in the tracer tests or a subsequent test.

not reduce the utility of the three dyes. Over a period of 8-days the dyes are stable in the HBHA pond water. In order to achieve the desired dye concentrations in the pond during the test, it proposed that dye will be mixed on-site using water from the injection location and mixed with 10% dye solution. In order to minimize density driven flux, the injected dye and water mix will be such that the specific gravity of the mix will be about the same as the specific gravity of the pond water. Further, since source water from the surface water of HBHA pond will be used on-site to mix the dye, there will be a negligible temperature gradient of the injected dye mix. Details of the bench test and the testing of the GAC packets are included in the OUL bench test in Attachment C3. Sampling and analysis methods are summarized in Tables 3.1.3.1-1 and 3.1.3.1-2.

Once one of the three dyes is selected for each individual surface water inlet, discharge measurements will be taken near the mouth of each surface water inlet to the HBHA Pond, as well as at the outlets of the Pond and the wetland at Mishawum Road. For the dye tracer study, a single slug of the appropriate amount of dye (based on the then current flow) will be fed (over a period of approximately 10 minutes) into each inlet upstream of the mouth to allow adequate mixing before the dye slug enters the HBHA Pond. The water below the chemocline will be dosed at the deepest point using a submerged horizontal diffuser device that will be engineered to distribute the FDT in the north basin. Surface water samples will then be automatically collected at discrete intervals (based on the flow measured during the test) at the inlets using an ISCO sampler at the Hall's Brook inlet (ISCO-1)[3], the outlet of the HBHA Pond (ISCO-2), and the HBHA Wetland culvert at Mishawum Road (ISCO-3).

Dye will also be collected passively by adsorption onto GAC; the GAC packets will be suspended (on a tether with an anchor and buoy) at consistent depth intervals (two in the water above the chemocline and one in the water below the chemocline) and at consistent locations throughout the Pond. At the deeper sections of the pond, two GAC packets will be suspended above and two will be suspended below the chemocline. The GAC will absorb the total amount of dye that passes through the packet at the particular depth at which they are deployed. Numerous studies by OUL have shown that the GAC packets retain their absorptive capacity (one acre/packet) in the field under extreme conditions. The bench tests described previously evaluated the absorptive capacity of the GAC packets using water obtained from the Site. Six east-to-west transects will be located with three buoys per transect (see Figure 3.1.3.1-1). Based on OUL's experience in both the lab and the field, the packets provide better overall resolution than grab samples taken at discrete intervals when deployed according to SOPs (see attachment C1) because the packets represent an integrated sample over the deployment period. Both the discrete ISCO water samples and the GAC packets would then be sent to OUL for extraction and measurement of the fluorescent dyes.

If the GAC packets are replaced at regular periods (e.g., every 1 or 2 days), the data gathered from the extracted dye(s) may provide a quantitative estimate of the distribution of each individual FDT and represent a quantitative integration of mass flux at the monitoring location. The ISCO data on the Pond effluent will provide a quantitative measure of the dyes concentration/mass flux (combined with flow rate data). These data can be used to determine the residence time associated with water originating from each of the compartments where dye is released and estimate dilution (i.e., relative contribution) of water from each of the inlets to the Pond. Combined, these two types of information (GAC packets and ISCO data) improve understanding of the Pond hydrodynamics (i.e., the stagnant parts of the Pond vs. those portions of the Pond that exhibit the greatest flow contribution and potential short circuiting), as well as associated residence time and dilution.

If necessary, an additional optional FDT study could be completed during the winter months. Although efforts will be made to reduce environmental variability between each dye test, it is generally accepted that no two dye studies are alike. To the extent additional tests are performed, information gained from

[3] The purpose of ISCO-1 is to gather data from the dye release in Halls Brook before it enters the Pond, and will only be operated at the beginning of the FDT during the initial dye release step.

the initial tracer study will be considered and small changes may be made (e.g., changes in the dosing rate, dye concentration, or both) to make sure that the subsequent tests result in a more effective data set. Some tests may also be performed without deployment of the GAC packets. These tests will be aimed at determining residence time and dilution only, or could be used for the initial test to optimize execution of test protocols.

As a safety measure during inclement weather (e.g., storm events), preprogrammed submersible water quality sondes will be employed to assess the magnitude and extent of chemocline disruption caused by storm water flow rather than an FDT study. These sondes will be deployed in accordance with PDI-4C described in more detail below.

3.1.3.2 PDI-4B: COC Transformation Processes

Ammonia is one of three COCs which the selected remedy requires to be removed or reduced in concentration in the Pond. As summarized in Section 2.3 of the RDWP, the fate and transport mechanism for arsenic is established and benzene transformation is rapid based on the low benzene concentrations observed in the surface water above the chemocline. Ammonia transformation pathways and rates of reaction in the Pond are not currently fully understood; a clear understanding of ammonia processes is necessary to optimize and enhance ammonia removal in the Pond and designing a remedy that does not have a deleterious affect on ongoing remedial (i.e., biodegradation) processes. To this end, PDI-4B is designed to achieve the following two objectives:

- Identify the dominant ammonia fate and transformation pathway(s)
- Derive an empirical estimate of the ammonia transformation rates [4]

PDI-4B consists of the following: sediment and surface water samples for microbial analyses and bench-scale microcosms. In order to validate the observations and further enhance the data required for the remedial design, a two step plan is proposed.

1. **Step 1 - Basic Surface Water Monitoring and Microbial Testing:** In the first step, nitrogen species data from surface water sampling at the inlets, outlet, and within the Pond that is gathered in various other PDIs and studies (PDI-4C and the Surface Water Monitoring Plan (SWMP)) will be evaluated. In addition to these data, the microbiological populations present at several locations in the Pond will be assessed to reveal the dominant ammonia transformation pathway(s). This assessment will be accomplished by collecting and identifying bacteria (by genetic testing) to determine which bacteria involved in the nitrogen cycle are present (refer to Figure 3.1.3.2-1). For example, this portion of the testing will investigate the presence of ammonia-oxidizing bacteria (AOB) that oxidize NH_3 or NH_4^+ to NO_2^-, and nitrite-oxidizing bacteria (NOB) that oxidize NO_2^- to NO_3^-, and anammox (bacteria that anaerobically oxidize NH_3 or NH_4^+ to N_2 gas).[5] The relative abundance of ammonia-degrading bacteria may be assessed using real-time quantitative polymerase chain reaction (qPCR) target assays developed for ammonia-oxidizing bacteria. In addition, denitrifying bacteria will be performed if a method becomes available. To evaluate which pathway(s) (if any) dominate below or above the chemocline, samples will be collected and analyzed to quantitatively measure the response of the total bacterial community and the nitrogen cycling bacteria. Sampling and analysis methods are summarized in Tables 3.1.3.2-1 and 3.1.3.2-2.

[4] Ammonia transformation rates will be evaluated to the extent ammonia is being transformed rather than diluted (Note: other PDIs collect data to support mass balance estimates and verification of the magnitude of ammonia loss through mixing and outflow [dilution] rather than reaction).

[5] The relative abundance of the different ammonia-degrading bacteria will be assessed using real-time quantitative polymerase chain reaction (qPCR) target assays developed for ammonia-oxidizing bacteria using both DNA and RNA.

2. **Step 2 –Screening Level Bench-Scale Microcosm Study**: We anticipate completion of a screening level bench-scale microcosm study that will provide additional information on the dominant ammonia transformation processes in the Pond. The Screening Level Microcosm Work Plan is included in Attachment C6.

After Steps 1 and 2 are complete, the data will be evaluated to decide whether ammonia transformation rates can be estimated from the available data.

A. Investigation Approach

We will assess the microbiology present at several locations in the Pond to determine whether the dominant ammonia transformation pathway occurs by ammonia-oxidizing bacteria or by anammox. The proposed microbiological monitoring consists of sampling two media, as follows:

- Sediment: A surface sediment sample will be collected at each of the three monitoring stations (north, central, and south) in the Pond. Sediment samples will be analyzed using qPCR for functional genes related to AOB, NOB, and anaerobic ammonia oxidation bacteria (anammox).
- Surface Water: At the three monitoring stations (north, central, and south), a water sample will be collected in the water above the chemocline, below the chemocline, and at chemocline (i.e., at the interface between the two compartments). Water will be passed through a 0.2 micron filter to collect the particulate fraction. Particulates will be analyzed using qPCR techniques similar to sediment samples above.

The results provided will include the amount of total bacteria, and the relative proportion of bacteria in each compartment of the nitrogen cycle (nitrification, denitrification), and anaerobic ammonia oxidation by anammox. The results will also include a ratio of total bacteria to each of these specific functional bacteria in the Pond at the given depths and times.

3.1.3.3 PDI-4C: Surface Water Profiling

A. Objectives

PDI-4C is designed to collect data regarding the variability and sensitivity of the chemocline in the natural setting (i.e., prior to remedy construction) and water quality in the Pond. To this end, a combination of 1) permanent fixed conductivity, temperature, depth (CTD) sensors with data logging capability will be deployed at various locations and depths in the Pond; 2) surface water sampling for base and storm flow conditions on a similar frequency/schedule as the SWMP; and 3) meteorological station data to correlate weather conditions with these two preceding data types, as further discussed below. The intent is to have data representative of water quality entering, within, and leaving the Pond for a given monitoring event, and the associated weather during and between such events.

B. Technical Approach and Monitoring Program

The technical approach to PDI-4C consists of three main elements: real-time field water quality monitoring in the Pond, periodic water quality sampling in the Pond, and collection of meteorological data adjacent to the Pond. These three components are presented below.

<u>Field Water Quality Monitoring</u>

Field water quality within the Pond will be monitored by installing and collecting data from three fixed surface water monitoring stations configured with conductivity, temperature, and depth probes (CTD

probe stations[6]) with data logging capability. These locations include RM-1 at the north, RM-2 at the south, and RM-3 in the middle of the Pond (see Figure 3.1.3.3-1). These locations may be adjusted to further support PDI-15 and -16. The three fixed CTD stations will be established as vertical monitoring stations within the HBHA Pond, the depth configuration of which is described in more detail below.

The depth configuration or vertical intervals at each of the three monitoring stations (RM-1, -2, and -3) have been established based on the approximate chemocline depth measured during the Early Action data collection phase. Generally, the chemocline depth and water quality differences (above and below the chemocline at a given location) measured below water surface varies by location (e.g., the chemocline at RM-1 is typically shallower and more abrupt in the transition compared to RM-2). To capture sufficient vertical data density proximal to the chemocline, we propose arranging the CTD sensors at 25 cm vertical intervals in the vicinity of the chemocline, with CTD sensors approximately every 50 cm above and below the interval where more dense CTD placement is proposed. Figure 3.1.3.3-2 has been developed to show the chemocline depth variability and the proposed layout of the CTD sensors for each of the three CTD stations.

To convert the CTD sensor measurements at various depth increments to an elevation, an electronic staff gauge in HBHA Pond will be used to record the fluctuations in the water surface elevation. Subsequent data reduction will provide a means to translate the measured chemocline depth below the water surface to a consistent datum using the water surface elevation data.

It is anticipated that the CTD sensors will be deployed for a year, if possible, to capture the behavior of the chemocline under various conditions, including seasonal effects.

Sampling Water Quality Profile

Surface water sampling will be conducted on a periodic basis[7] to augment field data collected with the CTD sensor array. Given the large database of existing data to correlate field measurements with fixed laboratory data in the Pond, sampling and analytical work will only be performed at RM-1 and RM-2 (RM-3 will have CTD data to correlate water quality); see discussion below on which locations will be sampled for fixed laboratory analysis.

Sampling the water quality profile includes depth discrete sampling in the water column in the Pond. To supplement the existing data and provide a more complete water quality assessment, surface water samples will be collected to profile the water column as follows (Tables 3.1.3.3-1 and 3.1.3.3-2).

- **Sampling Locations -** Two (2) locations in the Pond (RM1 and RM2), as shown on Figure 3.2.2.3-1.
- **Sampling Depths -** Water samples will be obtained at intervals generally coinciding with the CTD sensor depths (see Figure 3.1.2.3-2). Approximately nine or ten samples per location are expected.
- **Sampling Methods -** Discrete surface water grab samples will be collected at each sample location and depth described above using a peristaltic pump and tubing weighted at the bottom.

[6] Based on field observations to date, undesirable biological growth (e.g., biofouling) may occur on the sensors and is thus a consideration for deployment and maintenance of the CTD sensors. The initial portion of the deployment period for the CTD sensors may include a single location (e.g., at RM-1) to test and evaluate performance prior to purchasing and installing the full complement of CTD sensors for all three locations.

[7] The trigger for a storm flow monitoring event will consider the types of storm events previously monitored. The intent of the storm flow monitoring in PDI-4 is to collect profiling data during events of varying magnitude to establish a baseline for a range of storms. Because the Settling Parties have collected several storms in the range of 2.5 or more inches of precipitation already, the storm-based sample event trigger under this PDI will be storms of magnitude greater than approximately 2.5 inches, considering such factors as rainfall intensity, snowmelt, etc.

The tubing will be lowered to the required depth and the tubing will be purged before collecting the surface water samples. Attachment C1 provides surface water sampling SOPs.

- **Analytical Parameters (Fixed Lab) -** Samples will be transported under chain of custody procedures to Alpha Analytical Labs and analyzed for the following parameters:
  - arsenic (total and dissolved)
  - nitrogen suite (ammonia, nitrate, nitrite, and TKN, which, when combined with ammonia result for a given sample, allows for total organic nitrogen [TON] via calculation)[8]
  - benzene
  - total suspended solids (TSS)
  - total iron (unfiltered)
- **Sonde-based Field Parameters -** In addition to fixed laboratory analytical parameters described above, a full spectrum water quality sonde capable of collecting temperature, specific conductance, dissolved oxygen, pH, ORP, and turbidity will also be used during sample collection.
- **Spectrophotometer Field Parameter -** Ferrous iron will be analyzed in the field using a HACH spectrophotometer.
- **Frequency –** Significant surface water quality profiling has been completed as part of the Early Action activities at the Site, therefore limited supplemental data is necessary for design purposes. It is anticipated that approximately 4 additional baseflow and 2 storm flow sampling events will be completed under PDI-4C or as necessary to support other PDI activities in HBHA Pond.

Meteorological Station

A meteorological station (approximately 10 to 15 ft high) has been installed on land at the northern end of the Pond as part of Early Action activities. This station is located in an upland area just north of the Pond and has been collecting weather data including wind speed and direction, temperature, relative humidity, barometric pressure and rainfall since July 2009. If it is within the electronic data storage limits of the instrument, the data will be recorded in increments that are similar to the CTD sensors.

C. System & Data Management

Electronic data will be manually downloaded from each CTD sensor, the electronic staff gauge, and the meteorological station on a regular basis according to the manufacturer's recommendations for sensor calibration and the integral data logging capability of the equipment. CTD sensors deployed in the Pond will also be cleaned of any biomass on a routine basis before re-immersion in the Pond, as needed. The data will be uploaded to a field-based laptop computer or other appropriate device. Each variable would then later be tabulated and interpreted to locate the trends with depth and the relationship with weather conditions, time of day, flow rates, and other relevant factors.

3.1.4 PDI-5: Tank Treatability Studies

PDI-5 includes treatability studies that will provide data to design the treatment component of the HBHA-4 remedy described in the ROD. Given the likelihood that volatilization alone may prove insufficient in providing the level of treatment necessary to achieve Performance Standards for ammonia, additional testing has been included in this PDI to test the effects of biological degradation on ammonia present in the Pond. Aerobic biological degradation of ammonia is typical in municipal and industrial wastewater treatment, and it is viewed as the only other method for ammonia treatment that is technically practical. The additional tests proposed in this PDI will give insight into additional mechanisms (e.g., anammox)

[8] Unless specifically stated otherwise, the standard nitrogen analytical suite (ammonia, nitrate, nitrite, and TKN (to obtain TON)) excludes dissolved nitrogen gas (fixed nitrogen) and has been operationally defined as the "total nitrogen" concentration when the applicable species are summed (nitrate + nitrite + ammonia + TON = total nitrogen).

that may increase COC removal. Enhancements to biological activity, including growth media and nutrient addition, will also be tested.

The goal of this PDI is to provide the following design information related to removing ammonia, arsenic, and benzene from the Pond water:

- Ability of volatilization alone to remove ammonia to meet the Performance Standards, (e.g., assessment of the viability of the ammonia removal mechanism proposed in the ROD)
- Contribution of aerobic biological degradation to ammonia removal
- Estimate, where concentrations are above detection limits, the removal efficiency for benzene via aeration from both volatilization and biological degradation pathways
- Assessment of the need for substrate to support microbial growth and nutrient requirements for biological growth in the Pond if dispersed growth alone is not sufficient to meet Performance Standards
- Volatilization or biological attenuation rates to allow sizing of the secondary treatment cell
- Settling rates for arsenic

PDI-5 will utilize surface water drawn directly from the HBHA Pond and will be implemented during summer/warm and winter/cold temperature conditions (sequencing depends on the approval date for this PDI) to evaluate treatment of COCs under varying temperature conditions. The testing program performed second (i.e., the test performed during the other season) may be modified or streamlined based on the results of the first tank treatability test stage. In addition, pending the sequencing of PDI-5 and the screening level microcosm bench-scale study mentioned in PDI-4B, PDI-5 may be modified or streamlined, taking the results of preceding studies into consideration.

3.1.4.1 Investigation Test Apparatus

The test apparatus will be the same for the aeration/volatilization and biological tests and will consist of the following:

- Two positive displacement pumps to extract water from above and below the chemocline (two separate streams) from the northern portion of the Pond (see Figure 3.1.4.1-1), and transfer water to the equalization tank in the testing area, at controllable flow rates. The position of the chemocline will be identified by vertical profiling with a YSI sonde (or similar instrument; collect data on DO, temperature, pH, specific conductance, ORP) in order to insure that water from the desired depth is extracted for the tank treatability tests.
  - Total flow from the Pond will exceed the total flow needed in the test tanks, and excess water will be piped to the collection sump tank.
  - Total suspended solids concentrations from the pump intake above the chemocline and below the chemocline will be used to determine the appropriate pipe diameters for the two water sources.
  - If based on the data collected during the initial summer tests indicate that a winter test should be conducted on site, we will evaluate measures to protect against temperature losses/gains during the winter months.
  - Transfer piping will be installed along the Atlantic Avenue Drainway and will be placed in white PVC piping to help minimize temperature impacts during transfer to the equalization tank.
- One equalization tank to provide relatively consistent feed to four test vessels (note that the equalization tank will be mixed using an inline static mixer, in order to minimize the potential for volatilization of ammonia or benzene prior to treatment).
- Four peristaltic feed pumps, to feed each of the test vessels at a controllable feed rate. The pumps may not be identical based upon flow rates required to the test vessels (see Section 3.2.3.2).
- One custom-built four-compartment tank, with each compartment to serve as a test vessel.

- One regenerative blower, to provide air flow to the test vessels. The blower shall be fitted with the following:
  - Piping to each of the tanks to deliver a range of air flow rates to the tanks as described in Section 3.2.3.2
  - A variable speed drive to control the overall speed of the blower and thus overall air flow rate
  - Air rotameters with an integral high-resolution valve on the air piping to each tank, to control and measure air flow to the individual test vessels
  - A vent valve to relieve excess air to the atmosphere to allow for balancing of air flow rates
  - One or more perforated membrane fine-bubble diffusers (the quantity of diffusers will be based on the desired air flow rate to the tank, and the ability of the dispersers to operate properly at different air flow rates) to disperse the air through the tank and enhance oxygen transfer
- Three chemical metering pumps, to feed phosphorus-based nutrients to the tanks, during Phase II of the biological testing (described below).
- One chemical tank to contain the phosphorus-based nutrients.
- One vertical settling tank with four sampling ports located at various depths along the straight side of the tank. The influent piping on this tank will be connected to the effluent of the test tank with the longest retention time (aeration phase) and the highest practicable aeration rate (see below), and controlled with a gate valve. The tank will be used to analyze arsenic settling rates.
- Discharge Sump and Pump: Piping from each of the test vessels will feed a discharge sump, which will contain water that will either be discharged to AAD or be pumped back to the Pond away from the positive displacement pumps extracting water for the test, pending other activities occurring in the pond at the time of the initial test.
- Various flowmeters, valves, water analysis meters, pressure gauges, and sample ports as need to monitor test conditions.
- Building ventilation fans and heaters will be used as needed to maintain water tank temperatures to approximately match typical pond conditions.

A preliminary Process Flow Diagram (PFD) of the test setup is presented in Figure 3.1.4.1-2. A layout of the testing apparatus is presented in Figure 3.1.4.1-3.

3.1.4.2 Process Parameters

This section will define the operational parameters for PDI-5 and the rationale behind each of the parameters. Calculations have been performed based on existing data, and may change prior to test implementation based on data collected in the interim.

A. Influent Water Quality Basis

Two main influent water quality conditions will be tested, including water representative of: 1) above the chemocline; and 2) a mixture from both above and below the chemocline. The tests will be run in series to reduce the amount of acclimation time related to interruptions in flow of source water, and to allow for the scope of subsequent experiments to be modified from description herein based on preceding test/experiment results. This will be important as the 30% Remedial Design schedule is set at 360-days, and other in-pond PDI work will be suspended to the extent practicable while the tank treatability test is running.

At least one of the test scenarios (the first Physiochemical Removal test) will be performed on a mixture of waters from above and below the chemocline. The test is intended to simulate two conditions: 1) test treatment of water with higher COC concentrations than may be currently present above the chemocline; and 2) while potential disruption of the chemocline will be minimized as part of the remedial design, testing for the treatment of Pond waters after a potential Pond mixing event. Testing

aeration/volatilization at a higher ammonia concentration also allows greater analytical resolution because the ammonia concentration in influent and effluent from the tank is expected to be significantly higher than the method detection limit for ammonia. Chemical gradients are also larger when testing at a higher ammonia concentration. As such, this test is expected to have a slight bias towards affirming volatilization as a feasible approach; a negative outcome for this test will imply that ammonia at a lower concentration cannot be removed by volatilization.

To estimate the "nominal" water quality for the mixture case, calculations were based on the volumetric ratio of the waters above and below the chemocline in the Pond. The percentage of Pond volume which is above the chemocline (estimated to be the top 200 cm of the water column) versus that below the chemocline is estimated based on Pond bathymetry data taken from the Natural Attenuation Study (Ford, 2004). Based on the conceptual location of the cofferdams in the ROD (near the Halls Brook inlet), we have estimated the primary treatment cell would contain volumetric ratio of approximately 88% from above the chemocline and 12% from below the chemocline. Therefore, based on pond volume alone, a mixture of 85 to 90% from above the chemocline and 10 to 15% from below the chemocline would be representative of primary cell under mixed conditions, and will therefore be the mixture used for tests that call for a mixture of water above and below the chemocline.

Average ammonia concentrations from the North Station (e.g., above the chemocline) are estimated at 12.7 mg/l, while average ammonia concentrations below the chemocline are 409.6 mg/l (Ford 2005b). Using an 85% to 15% mixture of water above the chemocline to water below the chemocline, the estimated volume-weighted average ammonia concentration of the mixture would be approximately 72 mg/l. This represents approximately a 5-fold increase over waters above the chemocline and an order of magnitude increase over the average HBHA Pond outlet concentration of 7.8 mg/l.

B. Volatilization Test - Water Flow Rate / Retention Time

This test is designed to simulate what may potentially occur if an aeration system based on volatilization was installed in the Pond. While there is currently no design finalized for the treatment cell, we have estimated the dimensions of a conceptual treatment cell at 20 to 50 ft in length, in the 200 ft wide, 7 to 10 ft deep Pond. This provides a treatment volume ranging from 209,455 to 748,052 gallons. With Pond discharge rates ranging from 404 to 6076 gallons per minute (gpm) (Tetra Tech NUS, Inc. [TtNUS], 2005 and pre-RDWP approval PDI data) during baseflow conditions, the calculated retention time within the treatment cell could range from one-half hour (smallest treatment volume, highest flow) to over 30 hours (largest treatment volume, smallest flow).

More likely retention times range from 2 hours (largest volume, largest flow) to 8 hours (smallest volume, smallest flow). In order to evaluate the most likely residence times, the range of flows in the volatilization test (using the 500 gallon nominal testing volume) range from 1.0 gpm (8 hour retention) to 4.2 gpm (2 hour retention). This range is reasonable for pump control during the test and data extrapolation. Therefore, three separate flow rates will be used for testing purposes in the volatilization test: 1.0 gpm (8 hour retention), 2.1 gpm (4 hour retention) and 4.2 gpm (2 hour retention).

C. Volatilization Test – Air Flow Rate

Air flow rate in a full scale system will likely range up to 2,000 cfm, which would require several large blowers (40 – 50 HP each). In a full-scale system, this would provide an air-to-water ratio (volume to volume) of approximately 3 to 40, based on base flow through the Pond of approximately 400 to 6,000 gpm, as described above). To cover the full range in the tank treatability studies, the volatilization testing will be performed at a total four air-to-water ratios: 5, 10, 20, and 30, which correlates to a range in air flows from 0.7 scfm (1 gpm at a 5:1 air-to-water ratio) to 17 scfm (4.2 gpm at a 30:1 air-to-water ratio) as shown in the table below.

WATER FLOW RATE (GPM)	WATER FLOW RATE (CFM)	5:1 A/W AIR FLOW RATE (CFM)	10:1 A/W AIR FLOW RATE (CFM)	20:1 A/W AIR FLOW RATE (CFM)	30:1 A/W AIR FLOW RATE (CFM)
1.0	0.134	0.7	1.3	2.7	4
2.1	0.281	1.4	2.8	5.6	8.4
4.2	0.561	2.8	5.6	11.2	16.8
TOTAL	-	4.9	9.7	19.5	29.2

D. Volatilization Test – Settling Rate

When steady state conditions are met during the last volatilization test (e.g,. after 36 hours), discharged water from Tank #2 will be diverted to the settling tank. This tank will have the highest retention time (8 hours) and highest air to water ratio (30:1 air to water ratio). This water will be diverted for approximately 3.5 hours after the steady-state samples are taken to fill the 200 gallon tank. After the tank is filled, samples will be taken from each of the four sample ports along the straight side of the tank (the first, baseline event) and analyzed for arsenic (total and dissolved), as well as total suspended (TSS) and total dissolved solids (TDS). This sampling process will be repeated every:

- 4 hours for the first two events (2 events)
- 12 hours for the next three days (6 events)
- 24 hrs (daily) thereafter for 4 additional days (4 events)
- 72 hrs *(every three days) for the next 9 days (3 events)*

The above monitoring includes a total of 16 events, performed over a period of about 17 days. If visible precipitate forms in the bottom of the tank a sample can be collected using a peristaltic pump.

E. Biological Test – Water Flow Rate/Retention Time

Biological activity is expected to require longer retention times, so if biological processes are integrated in the final design, the secondary cell will likely be larger. Therefore testing for biological degradation will utilize retention times of 8 hour and 24 hours. As described above, flow rates would then equate to 1.0 gpm (8 hour retention in a 500 gallon tank) and 0.33 gpm (24 hour retention in the same tank).

F. Biological Test – Air Flow Rate

Air flow rates into the biological testing will use periodic adjustments of air flow rates in the test vessels to provide an effluent oxygen concentration of 6.0 to 7.0 mg/l. The blower will be sized to provide 10 times the oxygen needed to provide this level of oxygen to the water or 1 liter per minute (0.033 scfm) at 8 hours retention time (1 gpm flow), and 0.3 liters per minute (0.012 scfm) at 24 hours retention.

G. Biological Test – Biological Growth Media

The second phase of the biological testing will include an evaluation of the potential increase in biological activity when a growth media is added to the treatment vessels. Lantec Products Inc, a leader in tower packing and media, was contacted to identify a packing media product that would meet the needs of the project from both a testing perspective and for full scale application. Lantec recommended their Q-Pac product, a state-of-the-art medium for microorganism growth in fixed-film bioreactors. The structure contains 30 ft^2 of surface area per cubic foot of media, which expands to 60 to 90 ft^3/ft^2 when a biofilm is present. The high void fraction (96.1%) resists fouling, and its shape promotes the sloughing of biomass. The packing media will be manually placed into the treatment vessels in such a way that it remains submerged during the testing. Data sheets and case studies for the use of Q-PAC in bioreactors are presented in Attachment C4. Once the pre-design investigation is complete, the results will be used to evaluate the feasibility of various media configuration technologies in full-scale application. In addition, any full scale design will evaluate, as needed, multiple types of growth media that could be placed in the Pond to achieve the required microbial growth. The final design could incorporate several different types of growth media as well to achieve the performance goals.

H. Biological Test – Nutrient Addition

Current data indicates that biological growth in the Pond may be phosphorus-limited (Early Action samples collected by Haley & Aldrich on 15 October 2009 at RM-1 contained total phosphorus at 0.056 to 3.31 mg/L and orthophosphate at non-detect to 0.009 mg/L). Typical ratios of nitrogen to phosphorous (N:P) to support biological growth vary, but a ratio of 20:1 (N:P) is a generally accepted standard for nutrient addition experiments; this ratio will be used for the tank treatability studies. Therefore, an EPA-approved phosphorus-based nutrient will be added to the treatment tanks in Phase II of the biological testing at a rate of 5% of the influent ammonia concentrations (i.e., a ratio of 20:1 for N:P). While the actual rate will be field verified, calculations indicate that this will be 0.5 mg/l for water above the chemocline and 4.0 mg/l for the mixture of water above and below the chemocline subject to adjustment based on measured ammonia.

3.1.4.3 Investigation Approach and Methods

The following investigation approach is organized in two subsections related to the two main types of experiments: 1) the volatilization test methods designed to evaluate physiochemical removal mechanisms; and 2) the biological test methods designed to evaluate the role of biologically-mediated reactions/treatment in ammonia and benzene removal.

A. Volatilization Test Method

The test shall be conducted with each of the four test vessels shall be set up to have water flow through the vessel at varying rates, as follows:

- Tank 1 (Control) – No Aeration: 2.1 gpm
- Tank 2 (8 hr retention) – 1.0 gpm
- Tank 3 (4 hour retention) – 2.1 gpm
- Tank 4 (2 hour retention) – 4.2 gpm

This test shall be performed concurrently using the four tanks; the first test will utilize a mixture of waters from above and below the chemocline (at the ratios described above). Depending on the amount of ammonia removed, a second test may be performed with water from above the chemocline only, for a total of up to eight (8) individual volatilization experiments.

Air shall be passed through the system at a given air-to-water ratio for a period of 36 hours, at which time a set of samples shall be taken as described below. The air-to-water ratio shall then be increased, and the system shall operate for another 36 hours before samples are again taken. This procedure shall be repeated until all four (4) air-to-water ratios identified above have been tested. Water flow rates through the tanks shall remain constant during all volatilization testing.

Sampling Locations
Water analyses shall be performed at the following locations:

- **Influent Basis:** Influent of the control test vessel (as an indicator and baseline of influent water quality for each test vessel).
- **Effluent:** Effluent of each test vessel to measure net change in the tank relative to the influent. A total of four (4) individual test vessels.

Based on these locations for the first Physiochemical Removal test, each sample event will consist of five (5) discrete samples for each of the four (4) air-to-water ratios described above (20 samples total). If ammonia is sufficiently removed to meet the Performance Standards, another Physiochemical Removal test will be performed with the waters from above the chemocline only, which will result in another 20 samples. If insufficient ammonia is removed, then volatilization testing will cease, and the biological testing will commence.

Water Chemistry Analysis
One set of analyses will be performed after each 36 hour equalization period and will be tested as follows:

- Conventional (Real-time) Parameters:
  - Total Flow (gal)
  - pH
  - Temperature
  - Oxidation-Reduction Potential (ORP)
  - DO
  - Ammonia field screen (ion-selective electrode on Sonde)
  - Iron (ferrous)
- Laboratory Analytical Parameters:
  - Ammonia/ammonium
  - TKN
  - Nitrite
  - Nitrate
  - 5-Day Biological Oxygen Demand (BOD5)
  - COD
  - Total Suspended Solids (TSS)
  - Arsenic (total and dissolved)
  - Iron (total)
  - Benzene

Water quality monitoring of the effluent of the equalization tank or influent to the control tank will also be performed for conventional parameters (including temperature) listed above during the volatilization test on a continuous basis using a Sonde with an ion-selective electrode for ammonia. Water inside the equalization tank will be monitored for conventional parameters at multiple depths during each sampling event. Initially, total and dissolved arsenic and DO measurements will be taken at the pump intake and of the effluent of the equalization tank (or the influent to the control tank).

Air Testing
In addition, one air sample shall be taken from the exhaust / head space over each tank during each sampling event. These air samples will be used to determine that, during the volatilization test, the ammonia and benzene that leaves the water is present in the air (i.e., removal is by volatilization opposed to biological degradation), via a mass balance. All samples will be analyzed by GC VPSOP (H&A) with 25% of the samples analyzed by EPA Method TO-15 (Alpha Analytical) for confirmation.
Tables 3.1.4.3-1 and 3.1.4.3-2 show a summary of sampling, timing, and testing procedures.

B. Biological Removal Test Method

The biological test shall be performed as longer-term tests until steady-state discharge concentrations are reached at the discharge of all tanks. In addition, biological growth media (Lantec Q-Pac® or equivalent) will be placed into select aeration tanks utilized in the previous volatilization tests to identify if biological activity can be enhanced. The tests shall be performed as flow-through tests with a control tank for each test to identify growth rates of thin-film biological activity on the media. The first Biological Removal test will be performed with water only from above the chemocline, and based on the amount of ammonia removed during that test, another Biological Removal test may follow, with a mixture of water from above and below the chemocline to be combined in an equalization tank as described above. This will be the order for each Phase of testing.

For Phase I of the testing, no nutrients will be added to the tested waters. Each test(s) will be performed as follows:

- Tank 1 (Control Tank): 8-hour retention time (1 gpm), no aeration, no media
- Tank 2: 8-hour retention time, aeration, no media
- Tank 3: 8 hour retention time, aeration, media
- Tank 4: 24-hour retention time, aeration, media

Currently available data indicates that the biological activity may be nutrient limited, and that the addition of phosphorus at a 20:1 (N:P) ratio may increase biological activity and sustainability. Phase II tests will mirror the first test, with the addition of a phosphorus-based nutrient as follows:

- Tank 1 (Control Tank): 8-hour retention time, no aeration, no media, no nutrient addition
- Tank 2: 8-hour retention time, aeration, media, no nutrient addition
- Tank 3: 8-hour retention time, aeration, media, nutrient addition
- Tank 4: 24-hours retention time, aeration, media, nutrient addition

Test Sequence and Phases
While it is difficult to predict the amount of time required for a biological system to be established, time frames are estimated to provide an overview of the testing procedure.

<u>Phase I Acclimation and Testing (No Nutrient Addition)</u>: It is anticipated that 4 to 6 weeks, or longer if necessary, will be required before the biological system is established (i.e., bacteria fully populate the media) and reaches steady state, although the acclimation period will be extended if equilibration takes longer (see below). After the first week, aeration rates will be adjusted on a daily basis to ensure that a discharge dissolved oxygen level of between 6.0 and 7.0 mg/l is maintained. Sampling shall be conducted at the following periods of the initial acclimation period (days after initiation)[9]: 0, 7, 14, 21, 28, and weekly thereafter if needed to establish steady state. However, depending on the results collected on the initial weekly intervals, the intervals may be extended (e.g., biweekly or other appropriate frequency) if biological growth rates and steady state require a longer time period than anticipated. When results from two consecutive weekly events in at least two of the three testing vessels (excluding the control vessel) indicate similar results [e.g., the net change (influent minus effluent sample

[9] Note: Throughout this PDI, sample events that fall on weekends will be adjusted to the nearest normal workday.

locations) between two consecutive events is within 10% of each other, or all are non-detect] for ammonia and benzene, the sampling frequency will increase to verify steady state. At this point in time, one additional sample event will be performed approximately 3 days later. Assuming this final sample event shows consistent results with the two prior events (i.e., the three events remain within 10% of each other or non-detect), then these final three events will define steady state performance. If the third event indicates steady state has not been achieved, testing frequency will be adjusted as appropriate given variability/trend observed in the sampling events. At least two of the three testing vessels (excluding the control vessel) must show this steady-state operation, as all tanks will begin Phase II testing at the same time. Until this condition is satisfied, testing will continue unless a field decision is made otherwise.

The control tank will remain empty until steady-state in the other tanks is reached at which time flow will begin through the tank and it will be sampled accordingly. This procedure is intended to prevent biological growth from forming on the walls of the control tank during the acclimation period and biasing results.

The first Biological Removal test will be run with water from above the chemocline, followed by either a nutrient addition phase (see below), or a test with the mixture of water above and below the chemocline without nutrient addition.

Phase II Re-Acclimation and Testing (Nutrient Addition): The addition of nutrients to three of the four tanks in the test system (excluding the control tank) will begin after the completion of Phase I. Since biological activity is already established, it should take much less time to reach steady state conditions in the second phase of testing. We have assumed this will require 14 days. During this operational time, oxygen levels at the discharge will continue to be monitored and corrected to ensure levels remain in the range of 6.0 to 7.0 mg/l. Sampling will take place on Phase II day seven (7) and every three (3) days thereafter. Similar to Phase I, Phase II steady state will be considered complete when results from three consecutive discharge samples in at least two of the three testing vessels (excluding the control vessel) indicate similar results (e.g., within 10% of each other, or all non-detect) for ammonia and benzene. Once steady state is achieved based on three consecutive events, Phase II will be considered complete and the three steady state events will define performance[10].

Tanks may remain in operation following the completion of Phase II in order to perform further testing pending the schedule of other in-pond PDIs. The scope of further testing is unknown at this time, but it may include repeating some of the aforementioned tests under different environmental conditions, inlet concentrations, flow rates and/or media types. Further testing may also include an analysis of long-term performance (e.g., on the scale of months) and/or an assessment of long-term operational needs for a biological system. An addendum to this FSP will be submitted if additional testing is necessary.

Sampling Locations

The same five (5) sample locations described above for the volatilization setup will be used to monitor performance during the biological test.

Water Chemistry Analysis

Chemical testing shall be performed based on the schedule identified above. Based on the following assumptions, we have estimated this may require anywhere from twelve (12) sample events, if only two Phase I tests are run, to twenty (20) sample events if two Phase I tests and two Phase II tests are run:

- Phase I Acclimation and Testing (No Nutrient Addition): 38 days (5 weeks of weekly sample events followed by 1 event 3 days thereafter) yields six (6) events, excluding the time zero events that is included in the aeration experiment described above. Depending on the amount of ammonia removed, a second Phase I Biological Removal test may be performed with the mixture

[10] The Control tank will be drained following Phase I and then resume operation once Phase II reaches steady-state.

of waters from above and below the chemocline, therefore adding another six (6) sampling events.

- Phase II Re-acclimation and Testing (Nutrient Addition): 16 days (1 week of weekly sample events followed by 3 subsequent events 3 days apart) yielding four (4) events. Depending on the amount of ammonia removed, a second Phase I Biological Removal test with nutrients may be performed with the mixture of waters from above and below the chemocline, therefore adding another four (4) sampling events.

Depending on time required to reach steady state, the number of sampling events may vary. Each sampling event shall consist of the following analyses at the influent and effluent of each test tank.

- Conventional (Real-time) Parameters:
  - Total Flow (gal)
  - pH
  - Temperature
  - ORP
  - DO
  - Ammonia field screen (ion-selective electrode on Sonde)
  - Iron (ferrous)
- Laboratory Analytical Parameters:
  - Ammonia/ammonium
  - TKN
  - Nitrite
  - Nitrate
  - BOD5
  - COD
  - TSS
  - Arsenic (total and dissolved)
  - Iron (total)
  - Benzene
  - Total Phosphorus (Phase II Testing only)
  - Orthophosphate (Phase II Testing only)
  - Alkalinity ($CaCO_3$)

Water quality monitoring of the effluent of the equalization tank or influent to the control tank will also be performed for conventional parameters listed above during the biological tests on a continuous basis using a Sonde with an ion-selective electrode for ammonia. Water inside the equalization tank will be monitored for conventional parameters at multiple depths during each sampling event.

Air Testing

In addition, one air sample shall be taken from the exhaust / head space over each tank during each sampling event. These air samples will be used to quantify the amount of benzene or ammonia, if any, that is being lost to volatilization during the biological testing. Tables 3.1.4.3-1 and 3.1.4.3-2 show a summary of sampling, timing, and testing procedures.

Biological Analytical Parameters

At the conclusion of each Phase I and II tests, laboratory identification of microbiology will be performed, including microbe counts and genetic testing. Samples will be collected from up to two (2) tanks from each Phase I and II test to evaluate differences in the microbial community across a broad spectrum of conditions.

Bio-traps®[11] will be used as sample media, if biological growth is insufficient or in the case where samples are collected from tanks with no media. Alternatively, biological growth will be directly scraped from the media or some of the media could be removed itself for such analysis.

Two samples from each of the water types shall be pulled at the end of each Phase. After each Phase I test, one sample shall be collected from the control tank and analyzed, and one sample shall be collected from one of the three remaining tanks and analyzed. After each Phase II test, samples should be collected from the two remaining tanks and analyzed.

Specific analyses include using qPCR for functional genes related to AOB, NOB, and anaerobic ammonia oxidation bacteria (anammox) for qualitative comparison of microbe community, as well as phospholipid fatty acid (PLFA), which provides an estimated quantity of viable cells.

3.1.5 PDI-6: Geotechnical Investigations

The geotechnical investigation scope is dependent on the results of contaminant plume delineation and water treatment system studies that will determine which engineered structures are needed and where they will be located. Therefore, the geotechnical scope will also be partially dictated by the schedule of these studies and the overall project schedule.

The geotechnical investigation is divided into three groups. The first group (Scope PDI-6A) includes explorations along an alignment crossing the HBHA Pond for the cofferdam and storm flow bypass. The second group (Scope PDI-6B) includes explorations conducted along the western shoreline of the HBHA Pond for a storm flow bypass or holding and dissipation system, if required. Finally, the third group (PDI-6C) includes geotechnical explorations to assess subsurface conditions near the AAD and BECO inlets to HBHA Pond in the event energy dissipation systems are needed there to manage storm flows that would otherwise disrupt the chemocline.

The goal of the geotechnical PDIs will be to address the following data needs:

The goal of the geotechnical PDIs will be to address the following data needs:

- **Scope PDI-6A (HBHA-4 Cofferdam and Storm Flow Bypass) -** Provide geotechnical information for design of structures identified in relation to HBHA-4. The location of the cofferdams may be farther south than shown in the ROD and, if so, the exploration locations will be moved to the actual proposed alignment and additional explorations will be required as described below.
- **Scope PDI-6B (Halls Brook Storm Flow Bypass/ Holding & Dissipation System) -** If studies determine that the cofferdams are to be located to the south of Halls Brook, either a storm flow bypass and/or holding and dissipation system may be constructed to maintain the chemocline in the Pond during storm flows. These structures would be constructed along the western shoreline of the Pond and partially in the water.
- **Scope PDI-6C (AAD and BECO Storm Energy Dissipation Systems) -** If studies identify that water entering the north end of the Pond by AAD or the BECO drainway could disrupt the chemocline in the primary treatment cell, energy dissipation structures may be needed at either or both of these inlets. PDI-6C will collect geotechnical data to support the design of such structures

These components of PDI-6 are presented below.

[11] A Bio-Trap® is a device used to collect microorganisms from groundwater or surface water. The Bio-Trap® is packed with Bio-Sep™ beads, a coated granular carbon material that provides an optimum substrate for bacterial growth.

3.1.5.1 PDI-6A: HBHA-4 Cofferdam and Storm Flow Bypass

Sampling and Analysis Method - The PDI-6A geotechnical exploration scope includes the following activities (Tables 3.1.5.1-1 and 3.1.5.1-2):

- Advance two (2) land and four (4) water based borings averaging 40 ft below the existing ground surface/mud line. These cofferdam boring explorations are labeled PSC-1 through PSC-6 on Figure 3.2.4.1-1[12]. The two land borings would be performed at each end of the HBHA-4 cofferdam alignment. One additional 50 ft-deep land boring PSC-7 will be advanced closer to the rail road tracks in the vicinity of sewer line easement. SPT samples will be collected at 5 ft intervals with additional samples collected as required to define the fill natural soil interface. Undisturbed (Shelby) tube samples will be taken if fine grained soils are encountered for geotechnical laboratory strength testing. No samples of the Pond bottom sediments would be taken as part of this geotechnical exploration program.
- An environmental soil sample will be collected at 5 to 10 ft below the ground surface/mud line in four (4) of the bore hole explorations to establish the level of contamination in soils at this depth to facilitate proper handling and safety procedures in the geotechnical testing laboratory. This soil sample will be tested for arsenic (total), ammonia, and benzene. Index testing will be performed on selected SPT samples. If fine grained soils are encountered, geotechnical strength and/or consolidation testing of the undisturbed tube samples may be also undertaken.
- Excavate three (3) test pits in the storm flow bypass area down to approximately 1 ft below the water table (TP-1 through TP-3 in Figure 3.1.5.1-1). Test pits would be backfilled with excavated soil at the completion of the work.
- Drive and wash cased boreholes are proposed for the soil borings. Water from the Pond will be used in drilling and all drilling fluids and cuttings will be discharged into drums for disposal. The boreholes will be grouted and any excess grout will also be disposed of using drums.
- The soil testing to be conducted is dependent on the soil types encountered. ASTM standards will be followed for geotechnical testing. In addition to index testing for soil classification purposes, one-dimensional consolidation testing may be appropriate if cohesive or organic soils are encountered and triaxial strength testing may be appropriate if weak cohesive soils are encountered. The testing program is also subject to modification depending on changes to the type of structures being designed.

The location of the cofferdam structure is dependent on the results of field studies to delineate where contaminant plumes enter the Pond. If it is determined that the structure needs to be constructed in the southern third of the HBHA Pond, the PDI-6B explorations will be added to the PDI-6A scope.

3.1.5.2 PDI-6B: Halls Brook Storm Flow Bypass/ Holding & Dissipation System

As described in the RDWP, the Halls Brook holding and dissipation system will include an energy dissipation system, stilling basin, and an overflow weir installed along the western edge of the Pond, if constructed. Redirecting and distributing Halls Brook flow with this structure is intended to maintain the integrity of the chemocline.

A. *Sampling and Analysis Methods* - The PDI-6B geotechnical exploration scope includes the following:

- <u>Energy Dissipation Structure</u>: One 40-ft deep soil boring (designated PSC-6 on Figure 3.1.5.1-1) is proposed along Halls Brook between the Massachusetts Bay Transportation

[12] Geotechnical testing under PDI-6A will not be completed until the approximate location of the cofferdams is determined during PDI-3 Groundwater Discharge Evaluation. As such, the locations shown on Figure 3.1.5.1-1 are estimated, and subject to change based on the location of the proposed cofferdams.

Authority (MBTA) ROW (boundary to be determined based on an upland land survey as summarized below) and the edge of the Pond. In addition, test pit explorations TP-1 through TP-3 would be performed at the locations shown on Figure 3.1.5.1-1.

- Stilling Basin: Test pit explorations TP-4 through TP-8 will be performed at the locations shown on Figure 3.1.5.1-1. Soil/sediment characterization will involve collecting and analyzing approximately ten (10) soil/sediment samples from the test pits for arsenic in test pits along the Pond's shoreline for soil management considerations.
- Holding and Dissipation Structure/Storm Flow Bypass: Approximately one (1) soil boring will be performed at the water's edge and three (3) soil borings will be completed from a barge in the Pond along the holding and dissipation structure alignment. These borings will be approximately 40 ft deep and are designated W-1 through W-4 on Figure 3.1.5.1-1. An environmental soil sample will be collected at 5 to 10 ft below the ground surface/mud line in four (4) of the bore hole explorations to establish the level of contamination in soils at this depth to facilitate proper handling and safety procedures in the geotechnical testing laboratory. This soil sample will be tested for arsenic, ammonia, and Volatile Organic Compound (VOCs) (to include benzene).
- Adjacent Features: One (1) 50-ft deep soil boring (designated PSC-7 on Figure 3.1.5.1-1) will be located between the railroad tracks and the sewer line easements. Additional samples of soil from fills, organic layers, or granular soils will be recovered for geotechnical analysis. If there are loose granular soils in this area, they could settle when subjected to vibration from installing sheet piling. This boring will be used to help assess the general stability of the railroad embankment and what effect the proposed construction might have on the railroad tracks.

The following sampling-related activities will be performed as part of the above exploration work (Tables 3.1.5.2-1 and 3.1.5.2-2):

- Drive and wash cased boreholes are proposed for these investigations. Water from the Pond will be used in drilling and all drilling fluids and cuttings will be discharged into drums for disposal.
- SPT samples will be obtained at 5-ft intervals in the borings and up to four (4) undisturbed (Shelby) tube samples will be taken if fine grained soils are encountered for geotechnical laboratory strength testing. Up to four (4) extra SPT samples will be taken per hole on average to help delineate the fill/natural soil interface.
- Geotechnical laboratory index testing will be performed on the SPT samples obtained. If fine grained soils are encountered, a limited amount of geotechnical strength testing of undisturbed tube samples may be undertaken.
- As discussed above, environmental laboratory testing will be performed on samples obtained from the geotechnical investigation.

3.1.5.3 PDI-6C: AAD and BECO Drainway Storm Energy Dissipation Systems

As described in the RDWP, this PDI was developed to collect information that would assist in the design of storm energy dissipation structures at the mouth of the ADD and BECO, if necessary.

A. Sampling and Analysis Methods

The PDI-6C geotechnical exploration scope includes the following:

- Three soil borings in the vicinity of the AAD inlet and two soil borings in the vicinity of the BECO inlet (locations to be determined based on field conditions) with an average depth of up to 40 ft unless soil conditions dictate otherwise. Drive and wash cased boreholes are proposed for these investigations. Water from the Pond will be used in drilling and all drilling fluids and cuttings will be discharged into drums for disposal.

- SPT samples will be obtained at 5-ft intervals in the borings and up to four (4) undisturbed (Shelby) tube samples will be taken if fine grained soils are encountered for geotechnical laboratory strength testing. Up to four (4) extra SPT samples will be taken per hole on average to help delineate the fill/natural soil interface.
- Geotechnical laboratory index testing will be performed on the SPT samples obtained. If fine grained soils are encountered, a limited amount of geotechnical strength and consolidation testing of undisturbed tube samples may be undertaken.

Locations are shown on Figure 3.1.5.1-1, and sampling and analysis methods are summarized in Tables 3.1.5.3-1 and 3.1.5.3-2.

3.1.6 PDI-7: HBHA Flood-Routing Modeling Analysis

The objective of this PDI is to analyze potential flooding impacts of the HBHA remedy on the HBHA watershed, and associated mitigation strategies. To satisfy this objective, the flood-routing modeling analysis will employ the following approaches:

- Establish baseline flooding conditions in sufficient detail to accurately predict water surface profiles and floodplain inundation in the vicinity of the HBHA
- Quantitatively evaluate potential flooding impacts of the ROD remedy, both in the HBHA Pond and downstream
- Quantitatively evaluate potential flood mitigation approaches for the respective remedial design
- Use Federal Emergency Management Agency (FEMA)-approved modeling approaches for floodplain delineation
- Use a model for flooding analysis that is well-suited to supporting the evaluation of ROD remedy
- Use a model with output that is suitable for establishing boundary conditions for existing hydrologic and hydraulic models of the Aberjona River
- Employ a “documented, industry-standard model”

3.1.6.1 Modeling Approach

The objectives will be accomplished by constructing and calibrating a numerical surface water model for the site. Predictive simulation of potential design options using the calibrated model will assist in evaluating potential remedies and provide a quantitative understanding of flooding impacts associated with these remedies. The proposed steps involved with model development, calibration and use are listed below. These tasks will be performed jointly by VHB and Geosyntec.

- Perform site visits and surveying to verify key model inputs (e.g., locations, sizes, materials, and other characteristics of storm drains, pipes, and culverts) and collect any necessary physical information on surface water drainage features.
- Construct a numerical model (using EPA’s Storm Water Management Model Version 5.0.018 [SWMM5]) of existing conditions at the site. This model will be calibrated against ambient and extreme events using available rainfall and flow data.
- Predict the extent of flooding for various storm events (e.g., 2-, 10-, 25-, 50-, and 100-year storm events) using the calibrated model.
- Model potential remedies for the HBHA Pond using the calibrated model to assess their impact on flooding in the area. In particular, flooding during storm events (e.g., 2-, 10-, 25-, 50-, and 100-year storm events) will be predicted and compared against results from the existing conditions simulations. The model may also be used as a design tool for predictive simulations to assist with the design of remedy components including but not limited to primary and secondary treatment cells, Halls Brook by-pass/holding and energy dissipation system, AAD and BECO energy dissipation system, and to minimize flood storage losses, as needed.

Table 3.1.6.1-1 summarizes data to be used for model calibration, including station, data type, recording interval, dates recorded and data sources.

3.1.7 PDI-8: HBHA Pond Hydrodynamic Modeling

The goal of this PDI will be to develop a model to better understand the impacts of the remedy proposed in the ROD. Specifically, hydrodynamic modeling of the HBHA Pond will be performed to assess (1) environmental factors that may lead to mixing in the Pond, (2) the potential changes in flow and mixing in the Pond once it is segmented by cofferdams, (3) the affect of storm discharges from Halls Brook and AAD on mixing within the Pond, and (4) gain a better understanding of pond hydrodynamic (e.g., identify preferential flow versus stagnant zones in the Pond). Modeling is also intended to provide insight on flow in the HBHA Pond during periods when data cannot be collected either due to safety reasons (e.g., large storms and/or winter conditions) or because of the timeframe for remedial investigation and design.

3.1.7.1 Proposed Modeling Approach

Based on the current understanding of the Industri-plex OU2 project, a three-dimensional computational fluid dynamics (CFD) model will be used to simulate the impact that the flow dissipater/diversion weir design may have on the hydrodynamics of HBHA pond.

The selected hydrodynamic model for PDI-8 is Estuary Lake and Coastal Ocean Model (ELCOM), which was originally developed by Centre for Water Research at the University of Western Australia and is now commercially available. ELCOM is a three dimensional computational fluid dynamics program designed for practical numerical simulation of hydrodynamics and thermodynamics for inland and coastal waters. ELCOM will be used to simulate the impacts of the proposed stormwater diversion or velocity dissipater structure(s) on the hydrodynamics of HBHA Pond. A comprehensive description of the equations and methods used in the models is provided in the “Estuary Lake and Coastal Ocean Model: ELCOM v2.2 Science Manual” by Hodges and Dallimore (2006), and the “Estuary Lake and Coastal Ocean Model: ELCOM v2.2 User Manual” by Hodges and Dallimore (2007). Table 3.1.7.1-1 provides a comparison of the capabilities of ELCOM relative to other CFD models.

The model outputs will provide information on the extent of surface water mixing and associated velocities under various flow conditions. From the resulting velocity field and information on the characteristics of the bottom sediments, we may be able to then make a qualitative evaluation of whether the shear stresses generated by the weir inflow or base flow input to the primary treatment cell would be large enough to stir up the sediments or disturb the chemocline, respectively.

If necessary, ELCOM can also be used to assess the circulation patterns within the Pond to identify recirculation zones for various aeration technologies being evaluated or to make recommendations on whether the aeration technologies were providing sufficient energy for mixing.

The model will be used to help develop a remedial approach that minimizes mixing contaminated water that remains at depth in HBHA Pond, and avoids contaminated sediment resuspension. The model will be verified by the FDT study described in PDI-4A.

3.1.8 PDI-10: Impermeable Caps

The goals of this PDI will be to:

- Identify the location and extent of surface water channels (e.g., New Boston Street Drainway) along which impermeable cap(s) need to be designed and installed to mitigate contaminated groundwater discharge
- Improve understanding of the hydraulic connection between the groundwater and surface water in these channels

3.1.8.1 Investigation Approach and Methods

- Collect groundwater samples from just below the water table using a series of 18 temporary, shallow drive-point piezometers (e.g., Solinst Model 615 drive-Point piezometer) and low-flow sampling techniques along surface water channels as shown on Figure 3.1.8.1-1. A reference mark will be made on each piezometer and it will be surveyed relative to a fixed benchmark to provide groundwater elevation data. Once the evaluation is complete, the piezometers will be removed.
- Collect 18 groundwater samples from the drive-point piezometers using low-flow sampling techniques. Samples will be collected with a peristaltic pump with a sampling port located between the piezometer and the peristaltic pump minimizing the potential for any off-gassing during sample collection. Both filtered and unfiltered samples will be collected and submitted to a fixed laboratory for arsenic analysis and unfiltered samples will be collected for benzene and ammonia analysis. Filtered groundwater samples will be passed through a 0.45-micron filter; filtered groundwater data will be used to delineate the extent of arsenic discharge along the NBSD.
- Collect surface water samples (18 samples in total) from NBSD and the wetland area adjacent to each drive-point piezometer location to evaluate impacts to surface water. Both filtered and unfiltered samples will be collected for arsenic analysis and unfiltered samples will be collected for benzene and ammonia analysis. Filtered samples will be passed through a 0.45-micron filter. Surface water samples will be analyzed for arsenic, benzene, and ammonia. Samples will be collected with a peristaltic pump with a sampling port located between the piezometer and the peristaltic pump minimizing the potential for any off-gassing during sample collection.
- Sampling and analysis activities are summarized in (Tables 3.1.8.1-1 and 3.1.8.1-2).
- Sampling will not be conducted until at least 3 days have passed since the installation of the piezometers or any other intrusive work in the channels.
- Field parameters including DO, temperature, specific conductivity, pH, and ORP will be collected using a flow-through cell during sampling. Turbidity will be collected using a separate Hach turbidimeter.
- Evaluate the hydraulic connection between the groundwater and surface water at each location by measuring the elevation of the surface water at each piezometer location form the surveyed reference mark on each piezometer. Groundwater and surface water elevations will be compared at each piezometer/staff gauge pair to determine the gradient between groundwater and surface water. The rationale for implementing this task is to confirm that the groundwater observed in the piezometers is actually discharging along NBSD. An attempt will be made to collect data during seasonal high water if possible.

3.1.9 PDI-11: Permeable Caps

The goal of this PDI will be to identify the horizontal extent, in the vicinity of HBHA Pond, of soils exceeding the arsenic sediment standard of 273 mg/kg for the purposes of designing a permeable cap that will prevent erosion and potential migration of these soils into the HBHA Pond.

3.1.9.1 Sampling and Analysis Methods

Figure 3.1.9.1-1 depicts the north end of the Pond and shows via hatching the area identified in the ROD as the area to be capped. PDI-11 sampling will be performed adjacent to the area assumed to require capping to determine the limits of capping. The extent of residual arsenic needing to be capped will be determined by collecting fifteen (15) composite soil samples from 0 to 6, 6 to 18, and 18 to 36 inches bgs at the north end of the Pond at locations shown on Figure 3.1.9.1-1. The locations were selected by considering previous sampling (see MSGRP RI), and depth intervals are consistent with the MSGRP RI. Summaries of the planned sampling and analysis are presented in Tables 3.1.9.1-1 and 3.1.9.1-2. These soil samples will be analyzed for total arsenic.

3.1.10 PDI-13: Studies to Locate Property(ies) for Construction of Compensatory Wetlands

The goal of this PDI is to identify suitable locations for wetland mitigation as required based on the final remedy design configuration.

3.1.10.1 Proposed Investigation Approach

While PDI-13 does not involve sampling of media, reconnaissance studies to identify potentially suitable locations for pond or wetland mitigation is necessary. Due to the potential ramifications associated with limited supply of usable properties and the nature of the future remediation work, it will be beneficial to conduct the work early in the data collection process.

The team will identify potential pond or wetland mitigation sites within the Aberjona River watershed using aerial photography, geographical information systems (GIS) data, and other available data, including consultation with the Woburn and Reading Conservation Commissions, the Massachusetts Riverways Program, the Massachusetts Wetlands Restoration Program, and the Mystic River Watershed Association. Our team will develop a report describing each potential site, the amount and type of mitigation pond or wetland available, and any constraints or issues related to developing a replacement pond or wetland.

Our team will consult with the federal regulatory agencies to review potential mitigation goals and mitigation sites, and will undertake field investigations of mitigation sites that are acceptable to the regulatory agencies and for which access is available. Field investigations will identify existing wetland boundaries, topography, and constraints to pond or wetland construction such as ledge, contaminated soils, or underground utilities. VHB will verify the amount and type of wetland resource areas (land under a waterbody, bank, bordering vegetated wetland, bordering land subject to flooding, etc.), requiring compensatory mitigation. This process will be documented in a report and will identify sites that are suitable for pond or wetland mitigation construction.

3.1.11 PDI-14: Ammonia Background Investigation

The goals of this PDI are to

- Obtain groundwater data that is representative of off-site background (upgradient) concentrations of ammonia
- Identify any other sources that may be contributing ammonia to Industri-plex OU2

This PDI will also fill groundwater and surface water data gaps regarding Industri-plex ammonia contributions to help understand other potential sources upgradient/upstream of Industri-plex OU-1 which may contribute to surface water ammonia at HBHA Pond.

3.1.11.1 Investigation Approach and Methods

Because the Site is in an urban setting, the possibility exists that the contribution of ammonia in groundwater from off-site sources may be significant (e.g., landfills, hazardous waste sites, historical piggeries, past and/or current industrial operations, etc.[13]). The boundaries of the investigation have been determined by both groundwater divides identified in recent historical studies (e.g., GSIPs), as well as areas that show undetected and/or very low (e.g., <0.05 mg/L) concentrations of ammonia in groundwater.

PDI-14 involves a study to locate potential sources of ammonia contamination outside Industri-plex OU2 that contribute to the Pond. The general sequence for PDI-14 involves: 1) historical data review; 2) screening reconnaissance (e.g., surface water sampling); 3) groundwater investigation; and 4) groundwater monitoring.

Phase I - Historical Data Review

Surface and groundwater ammonia concentrations obtained from historical reports (e.g., Roux, 2002; Ford, 2004; TtNUS, 2005) have already been reviewed as part of Early Action activities. Historic aerial photographs and maps identifying locations of alternative source areas (e.g., Olin Chemical, piggeries) were examined, which assisted in Phase II (below).

Phase II - Screening Reconnaissance

As part of the Early Action studies, monitoring of surface water bodies has already been conducted, and has provided useful information in terms of the contribution of off-site sources to the HBHA. Grab samples were collected from thirteen locations as shown on Figure 3.1.11.1-1 and sent to Alpha Analytical for analysis of ammonia, nitrite, nitrage, TKN, and TON (by calculation). In addition, field parameters (ammonia $NH4^{+}/NO3^{-}$ via ion-selective probe, DO, pH, ORP, specific conductance, temperature, and turbidity) were measured in the field using a multiprobe. Estimates of surface water flow rate (using an electromagnetic flowmeter and the estimated discharge cross section) were also performed. The results of the surface water sampling performed indicated that potential off-site sources of ammonia contribute to concentrations observed in surface water (e.g., Olin Chemical, Woburn Landfill).

Per EPA's comments dated 18 December 2009, the surface water sampling program will be expanded to include existing locations from the Olin Chemical Superfund Site and the Woburn Landfill as shown on Figure 3.1.11.1-1. Publically-available surface water data from these locations will be used in the screening reconnaissance.

In addition, surface water investigations that are proposed in PDI-9 and PDI-10 will be used in this investigation and are also shown on Figure 3.1.11.1-1.

Phase III – Groundwater investigation

Numerous groundwater investigations are proposed in PDI-3B, PDI-9, PDI-10, and PDI-12B and groundwater data we presume are available from the Olin Chemical Superfund Site and the Woburn Landfill to further evaluate the degree that upgradient ammonia sources contribute to OU2. Conventional water quality parameters (dissolved oxygen, ORP, pH, temperature, specific conductivity, turbidity) will be collected using a multiprobe and a flow-through cell during purging. No additional groundwater

[13] As an example, Halls Brook flows over two exposed sewer lines immediately before discharging into the HBHA Pond. These sewer lines also run along the western bank of the HBHA Pond, where groundwater is expected to pass before discharging into the HBHA Pond. If the integrity of these lines is compromised, they could be an alternate source of ammonia to the HBHA Pond.

sampling locations, therefore, are proposed for PDI-14. Figure 3.1.11 -1 provides a comprehensive view of both the types and locations of existing and proposed sampling locations to be used for PDI-14. This sampling network will capture data on ammonia (as well as benzene and arsenic) from sources that may be migrating into OU2 (e.g., Olin Chemical, Woburn Landfill, active New Boston Street facilities).

Phase IV - Monitoring

Based on the results of the data collection proposed in the various PDIs supporting PDI-14, a groundwater monitoring program will be developed as part of the remedial design process and incorporated in the Environmental Monitoring Plan, as necessary.

3.1.12 PDI-15: HBHA Pond Aeration Pilot Test

PDI-15: HBHA Pond Aeration Pilot Test is designed to gather data to assess the performance and prepare the full-scale design of a surface water aeration device to increase oxygen mass flux in the water column. Increasing oxygen mass flux into the water column is anticipated to enhance treatment of arsenic, ammonia, and benzene. Consistent with the ROD and SOW, investigations regarding the design and construction of the primary and/or secondary treatment cells in the HBHA Pond, including various vertical (e.g., secondary treatment cell) and shallow horizontal (e.g., primary treatment cell) aeration studies to enhance treatment of contaminants of concern (including methods for increasing oxygen levels in surface water) are necessary under the Remedial Design.

PDI-15 is designed to produce a more thorough understanding of the following general processes and system performance characteristics:

- Underlying geochemical behavior and mixing characteristics in the Pond
- Effect of increasing dissolved oxygen at depth on surface water/Pond effluent quality
- Surface water quality before, during, and immediately after the test
- Performance characteristics of the aeration device(s)
- System operating parameters and monitoring requirements
- Maintenance requirements and operating costs for aeration devices
- Technology applicability

This PDI will assess the relative performance of two aeration technologies (low-speed surface aerator and surface aspirating aerator) to increase oxygen levels in the surface layer of water in the Pond (primary cell/northern portion of the pond), as well as test vertical mixing of the complete water column in the southern portion of the pond using a low-speed surface aerator. These two test stages and other considerations applicable to PDI-15 are summarized below.

3.1.12.1 Aeration as a Remedial Component

The aeration approach relies on the following general operating principles:

- Actively controlling the chemocline elevation in the water column by increasing DO levels (i.e., providing greater oxygen into the water column than would occur naturally, thus encouraging the chemocline interface to occur at greater water depth).
- Increasing the proportion of the water column that could support ammonia- and benzene-degrading bacteria (via aerobic pathways).
- Minimizing potential contaminant outflow during storms by a combination of the first two operating principles, as well as integrating appropriate water inflow controls (e.g., level spreader/weir) to the extent these are necessary based on the outcome of hydrodynamic modeling.

3.1.12.2 Aeration Technology

The technology screening summarized in Table 3.1.12.2-1 resulted in the retention of the following aeration technologies capable of providing oxygen while minimizing the chance of chemocline disruption:

- **Surface Aspirating Aerator:** A diffused air system consisting of inclined propeller, motor, and shaft that draws in air at the hub above the water line and discharges air and water mixture into the water. The propeller turbulence shears and disperses the bubbles, thus enhancing oxygen transfer.
- **Low-speed Surface Aerator (SolarBee®):** A low-speed, axial, surface impeller aerator [the unit proposed for testing operates at about 60 rotations per minute (rpm) (nominal at full charge)].

3.1.12.3 Investigation Approach

We propose installing two low-speed surface aerators: one in the north end and the other in the south end of the Pond. The secondary phase will involve the replacement of the northern low-speed surface aerator with the surface aspirating aerator so that the relative performance of the two devices with respect to controlling the chemocline can be better evaluated. The secondary phase will also permit the collection and comparison of other valuable information, such as operating characteristics, maintenance requirements, ease of use, etc.

The following summarizes the sequence, approximate duration, and associated rationale for the main tasks associated with this PDI:

Task 1 Baseline Monitoring..... 2 weeks (prior to initiating aeration devices)

The purpose of baseline monitoring is to gather data to establish water quality in the Pond prior to introducing the aeration devices. It is assumed that the majority of the baseline data will be collected during the implementation of PDI-4C.

Note: As described in the main RDWP text, it may be possible to overlap portions of PDI-15 and PDI-16 to facilitate evaluation of aeration effects in the north and south portions of the pond. Refer to the RDWP for a detailed discussion of such sequencing considerations.

Task 2 Test A (Low-speed Surface Aerator; SolarBee®)..... 6 weeks

The purpose of Test A is to obtain data necessary to assess aeration as means of treating COCs. Test A involves operating the low-speed surface aerator in the both the north and south ends of the pond (although the target aeration zone for the north and south pond tests differ, as further discussed below). The operating period should overlap warmer seasons, when Pond effluent has been observed at concentrations approaching the ammonia Performance Standard (NRWQC)[14], and thus most effectively test the performance of the aeration approach.

In addition, as described in the RDWP, it may be beneficial to overlap portions of PDI-16 with PDI-15. By simulating a cofferdam per PDI-16 and compartmentalizing (separating) the pond into northern area and the rest of the pond, assessing the influence of shallow aeration in the northern portion of the pond separate from the full water

[14] The ammonia NRWQC is temperature and pH dependent. At a given pH, the ammonia NRWQC is lower in warmer water temperatures.

column mixing in the southern end of the pond may be more readily performed. Test sequencing and configuration are further discussed in the RDWP text.

Task 3 Test B (Surface Aspirating Aerator; Aeromix® AquaTornado) ..... 4 weeks

This task involves replacing the low-speed surface aerator in the north end of the Pond with the surface aspirating aerator. The purpose of which is to compare and contrast the performance of another aeration device for this application.

Task 4 Post-Pilot Test Water Quality Monitoring ..... 2 weeks

Evaluate the recovery of the system to steady state or quasi-equilibrium (see PDI-4C).

Total: ..... 14 weeks

3.1.12.4 Preparation and Setup Procedures

The following outlines the sequence of procedures to be followed to execute the test.

A. Site Preparation Activities

Prior to testing various aeration devices, site preparation activities will be implemented, including the following major tasks:

- Install temporary power poles and electrical wiring
- Remove vegetation, as necessary, to facilitate Pond access
- Establish fixed buoys for aeration device(s) and monitoring stations
- Install silt curtain in the south end of the Pond as a contingency measure for solids generation control
- Measure water depth at the aerator setup location
- Install aeration system and fixed surface water monitoring stations unless already installed (see PDI-4C)
- Conduct baseline monitoring (see below)

B. Setup Locations

The low-speed surface aeration devices by SolarBee® will be installed in the northern and southern ends of the Pond. The setup locations are shown on Figure 3.1.12.4-1. The actual setup location will depend on the water depth in the vicinity and other factors. At the conclusion of Test A (SolarBee®), the northern aerator will be replaced with the surface aspirating aerator and Test B (Aeromix®) will begin. While Test B is occurring, the southern SolarBee® unit will continue to operate to gather additional information on its performance. The CTD sensor profiling stations established under PDI-4C will be used in PDI-15. To the extent necessary, the location of the CTD sensors at RM-1 and RM-2 may be adjusted to facilitate aerator setup in the deeper water depth areas.

C. Aeration Device Setup

The tested aeration devices subject to pilot testing involve slightly different setup configuration. The configuration of each is summarized as follows:

Low-speed Surface Aerator (SolarBee®)
The low-speed surface aerator manufactured by SolarBee® floats on pontoons and is fixed in place with mooring anchors. The intake tube is adjustable and will be positioned within the upper surface layer of the water column and adjusted downward to a specific target water depth in a progressive manner to avoid abrupt destratification. As noted above, the vertical interval of water aeration varies between the north and south end of the pond, as follows.

Northern Pond Test Location (Proximate to RM-1) - For the test conducted in the northern end of the pond, the water intake will generally be limited to shallow water depths near the chemocline depth (typically, approximately 175 cm to 200 cm below water surface during base flow events measured at RM-1). Such shallow horizontal aeration studies are intended to evaluate methods to enhance treatment of COCs by increasing oxygen levels in surface water layer in the primary treatment cell.

Southern Pond Test Location (Proximate to RM-2) - For the setup in the southern portion of the pond, the water intake for the aeration device will be lowered to near the sediment-water interface (kept sufficiently above it to avoid scouring sediment). Such "full" water column aeration is similarly intended to assess the benefits in COC treatment by increasing oxygen levels in surface water to simulate the secondary cell.

The low-speed surface aeration system proposed for the Aeration Pilot Test uses solar power (with backup power as needed from the grid) to drive an impeller system. The impeller system creates a flow pattern that drives oxygen mass flux (re-aeration) and distributes oxygen-rich water within the target interval. To accomplish this, the aerator also creates a more uniform density profile in the target zone so that the water column is readily mixed with minimal energy input, facilitating the delivery and spatial distribution of oxygen.

Surface Aspirating Aerator
Similarly, the surface aspirating aerator, which will be set up in the northern portion of the pond in the vicinity of RM-1 (replacing the northern low-speed surface aerator), floats on pontoons and is fixed in place using mooring anchors. Operating parameters, such as, but not limited to, the angle (relative to horizontal) of the surface aspirating aerator device, will be adjusted as needed to control and optimize the aeration penetration depth and oxygen distribution. The steepest angle of the device will be determined in the field based on observations of the penetration depth of air bubbles.

Water column monitoring and stage height data will be used to estimate the treated water depth interval.

D. Water Quality Monitoring Locations

The CTD sensors/stations installed and operated for PDI-4C, as well as periodic sampling of the water column for fixed lab analysis as per PDI-4C, will be utilized for PDI-15. In addition, a mobile profiling sonde will be used to monitor aeration performance at varying locations to assess the performance of the aeration devices. These location types are summarized as follows:

Fixed Monitoring Stations
PDI-4C establishes three fixed CTD monitoring stations in the Pond. These stations and the monitoring/sampling described for PDI-4C will be conducted before, during, and after PDI-15 to assess performance and water quality. Supplemental monitoring and sampling at these fixed stations specifically during the performance of PDI-15 is discussed below. To supplement the water quality data from the fixed stations, an additional, manually operated sonde will be used as discussed below.

Manual Monitoring Locations
Manual monitoring of water quality will be conducted at appropriate locations in the Pond to measure the effective area/distance of the aeration devices. Monitoring includes multi-depth monitoring over the water column to establish profile and confirm CTD monitoring station data.

Water quality entering the Pond at Halls Brook and leaving the Pond at the outlet will be monitored periodically as part of other studies (e.g., SWMP).

3.1.12.5 Startup and Operation Plan

Once site preparations are complete and the aeration equipment is in place, system startup and operation will follow a planned sequence. There are three operating phases for this Aeration Pilot Test: 1) startup; 2) quasi-steady state; and 3) shutdown[15]. These three operating phases are described below.

Startup
Startup may occur under stratified or mixed conditions. If startup occurs during unstratified, oxygenated conditions, the aeration device would simply maintain the existing condition rather than change the water column geochemistry. If startup occurs when the water column is stratified, the sequence for a "soft" startup described below is designed to address concerns related to abrupt changes in the water quality.

The low-speed surface aerator (SolarBee® Units) will be installed initially with the intake tubes in retracted position so that mixing will only occur in the upper 5 ft of the water column. Once the monitored parameters have stabilized, the intake tube will be lowered in 3-ft increments until the final depth is achieved. In the case of the southern setup location, the final depth is generally the water depth that allows aeration of the full water column but does not scour sediment. Whereas, in the northern setup location, the final depth is generally limited to the shallow water depth above the chemocline, and so the water intake will be lowered and the final depth achieved when the chemocline depth is reached. As the system starts up, geochemical data will be closely monitored. The data will be compared to the performance criteria presented below to determine whether the Aeration Pilot Test should continue. The startup sequence is summarized in Table 3.1.12.5-1.

Quasi-Steady State
Once the Pond reaches steady state relative to the aeration device operation, the Aeration Pilot Test will be considered in quasi-steady state mode and system operation will continue. Data will be collected according to the monitoring schedule presented herein.

Shutdown
Two shutdown scenarios are identified: 1) at the conclusion of the Aeration Pilot Test; and 2) for an unanticipated fault or intentional shutdown. In the first case, the two aerators will be shut off and the Pond system allowed to return to ambient conditions. If the system shut down occurs due to a system fault or intentional shutdown (e.g., maintenance, shut down trigger threshold exceeded, etc.), and system re-start is desired, an evaluation will be conducted to determine whether the intake tube needs to be raised and the startup process repeated.

[15] If the system shuts down either through a system fault or intentional shutdown, it may be necessary, depending on the shutdown duration and field conditions, to restart the system in startup mode.

3.1.12.6 Monitoring/Sampling Plan

A combination of field measurements and fixed lab analysis will be used to monitor the pilot test performance (Table 3.1.12.6-1). The use of near-real-time data and visual observations will be used to make adjustments to the test while the test is occurring. The following sections and Tables 3.1.12.6-2 and 3.1.12.6-3 summarize the parameters and monitoring schedule/locations that will be used to assess water quality during the Aeration Pilot Test.

Baseline and Post-pilot Monitoring/Sampling
The principle purpose of the baseline and post-pilot monitoring is to provide a means to evaluate changes in the water chemistry brought about during the Aeration Pilot Test. PDI-4C and the SWMP will establish the baseline and post-pilot water quality within and entering/leaving the Pond, respectively, but additional sampling may be recommended. Parameters not included in PDI-4C and/or SWMP, summarized as follows:

- TSS (total suspended solids)*
- TDS (total dissolved solids)**
- TOC (total organic carbon)**
- DOC (dissolved organic carbon)**
- COD**
- BOD**

Notes: *Add to monitoring at RM1 and RM2 (already performed for SWMP at pond inlets and outlet)
**Add to RM1, RM2, and up to four discrete grab sampling stations [Halls Brook, Pond outlet, and AAD and ROW No. 9 (if flowing)

Analysis for these additional parameters will be performed during one event in each of the baseline and post-pilot phases. The CTD sensor stations established in PDI-4C will be operated during the test as well.

Test Phase Monitoring/Sampling
The purpose of the test phase monitoring and sampling program is to collect sufficient data to assess the net changes to water quality during the test. The program includes a combination of fixed and manually operated profiling with a water quality sonde and sampling and fixed lab analysis. The manually operated sonde will be used at various locations/distances from the aeration equipment to evaluate the effectiveness of the aeration device(s). The water quality monitoring locations are presented above. Table 3.1.12.6-1 provides a detailed description of the monitoring and sampling plan associated with the test phase of the pilot test. As noted, sampling activities conducted for PDI-15 will be coordinated with PDI-4C to eliminate redundant sampling and analysis.

Microbiological Sampling/Testing
Ammonia and benzene transformation occurs through various biologically-mediated reactions (e.g., ammonia nitrification to nitrite by Nitrosomonas, ammonia to dinitrogen gas by anammox). A baseline microbiological test program is described in PDI-4B. Molecular biological tools (MBTs) will be used to determine what microorganisms exist and what processes microbes use to degrade ammonia and benzene during/following the pilot test to evaluate gross changes (if any) from baseline event (see PDI-4B). This information promotes greater understanding of the dominant ammonia and benzene degradation pathways. Microbiological monitoring will be conducted during the test to look for gross changes in the composition of the biological community. The proposed microbiological monitoring consists of sampling two media, as follows:

- **Surface Water**: At the north station, a water sample will be collected in the interval above the chemocline, below the chemocline, and at the chemocline (i.e., at the interface between the two compartments). Water will be passed through a 0.2 micron filter to collect the particulate fraction. Particulates will be analyzed using qPCR techniques similar to sediment samples below.

- **Sediment**: A surface sediment sample will be collected from the north monitoring station. The sediment sample will be analyzed using qPCR for functional genes related to AOB, nitrite-oxidizing bacteria (NOB), and anaerobic ammonia oxidation bacteria (anammox). The sediment sample at the microbial testing location will also be analyzed for arsenic in the baseline and post-pilot monitoring event.

The monitoring program is further described in RDWP Attachment 1 Microbiological Monitoring.

3.1.12.7 Performance Monitoring Criteria

These performance metrics will be used as action levels to trigger changes to the Aeration Pilot Test, including temporary shutdown, if conditions warrant. To be considered a viable approach, the aeration system must be capable of approaching the surface water standards presented in the SOW (parameters noted in Table 3.1.12.7-1 with **). As such, the surface water standards represent the first tier of performance measures for the aeration test and approach.

3.1.12.8 Contingency Planning

In the unlikely event that certain adverse conditions such as significant increases in turbidity, arsenic, benzene, or ammonia concentrations or other deleterious conditions occur in the upper layer of the water column, a contingency plan is included as Attachment C3.

3.1.13 PDI-16: Cofferdam Simulation Pilot Test

The primary objective of PDI-16: Cofferdam Simulation Pilot Test is to evaluate the hydrodynamic effects of a cofferdam on the chemocline and surface water flows within the HBHA Pond. Particular interest will be on whether or not a cofferdam for the primary treatment cell may potentially cause the chemocline to rise and how this may be considered in the final design. An additional purpose of this PDI will be to evaluate the surface water forces on the flexible curtain-style cofferdams[16].

3.1.13.1 Investigation Approach and Methods

PDI-16 will be completed to simulate the cofferdam installation to encompass a portion of the pond within the full extent of the primary treatment cell, as contemplated in the SOW. The test will be completed north of the Halls Brook inlet to eliminate challenges posed by variable flows (e.g., stormflows) emanating from Halls Brook. To the extent a storm does occur during the test, the impact of such an event on the chemocline behind the curtain will be evaluated.

- Operate the barrier simulation for a duration to be determined based on the schedule/timing of RDWP approval and other ongoing PDIs. We anticipate warmer weather will be the best period to evaluate the chemocline rising behind the curtain given the low surface water flows, limited rainfall/infiltration, intensity of stratification during this season, and safer monitoring conditions than the winter months, for example. In addition, it is desirable to simulate the affect a barrier/curtain may have on the accumulation of dense water and rise of the chemocline over an extended time period. However, given the schedule limitations and potential seasonal limitations, to ensure the cofferdam simulation pilot test is thorough, and to avoid having

[16] Note: During the remedial design, AASHTO Design Specifications or other appropriate method for determining stream pressure loading will be used, consistent with standard engineering practice and factoring in the cofferdam's proposed materials of construction, orientation to flow, and/or other relevant design considerations as appropriate. Given the pilot test of a flexible curtain to simulate a flexible cofferdam concept, the nature of the evaluation of surface water forces on the pilot tested curtain will be more qualitative (e.g., observation of anchorage requirements).

PDI-16 interfere with other PDIs, it may be necessary for PDI-16 to extend beyond the submittal of the 30% design. Pending the performance observed and to the extent possible, the barrier may be installed for a period overlapping the Aeration Pilot Test (PDI-15) to observe any contributory effects, as described in more detail in the RDWP text.

- Conduct water column profiling manually on both sides of the barrier to assess the stratification and chemocline elevation. See monitoring/sampling plan summarized below.

Field procedures may be modified if necessary based on field conditions.

3.1.13.2 Preparation, Materials and Setup Procedures

The following outlines the sequence of procedures to be followed to execute the test, beginning with site preparation.

- **Site Preparation Activities:** Prior to testing the barrier, site preparation activities will be implemented, including the following major tasks:
  - Establish fixed buoys for monitoring stations
  - Conduct baseline monitoring (see below)
- **Materials:** The cofferdam simulation test will be performed using materials similar to those used for silt controls (silt curtain baffles). A schematic of the simulated cofferdam barrier is provided on Figure 3.1.13.2-1. As shown, the barrier uses a ballast chain(s) along the base of the curtain (which is a standard approach used for silt curtains). In this application, the weighted chain is anticipated to settle into the loose, floc-like sediment bed to establish the seal. Monitoring will be performed downstream of the barrier to evaluate flow under or through the barrier. If the ballast chain is unsuccessful, other measures will be evaluated and applied, as appropriate, considering field conditions, timing constraints, the apparent root cause of problems observed (if any), and other relevant considerations. This flexible curtain system is suitable for pilot testing the general approach. However, this curtain is generally not applicable to a winter iced-in condition, unless modified (modifications that are not readily implemented for a pilot test of the approach). Consequently, this type of curtain for PDI-16 will be run during warmer periods to test the general concept.
- **Barrier Setup:** The barrier will be set in place using the manufacturers recommended procedures. Setup procedures are described in the associated SOP (see Attachment C1).

3.1.13.3 Monitoring/Sampling Plan

Water quality monitoring immediately adjacent to the barrier allows assessment of the potential chemocline buildup behind the simulated primary treatment cell barrier. To accomplish this work, we anticipate a combination of manual, real-time measurements of conventional field parameters with a sonde and sampling of the water column on a reduced frequency. The monitoring/sampling is as summarized below and in Tables 3.1.13.3-1 and 3.1.13.3-2. Figure 3.1.13.3-1 shows the layout plan for the pilot test.

Water Quality Monitoring Locations: Water quality monitoring will be conducted using two types of monitoring station setups (fixed CTD monitoring stations and a manually-operated sonde):

- Fixed Monitoring Stations: PDI-16 will use the monitoring station set up for PDI-4C. Figure 3.2.2.3-1 shows the approximate location of the fixed stations. The fixed stations will collect data at the interval described in PDI-4C and store data for retrieval and data reduction on a periodic basis. To supplement the water quality data from the fixed stations, an additional, manually operated sonde will be used as further discussed below.

- Manual Monitoring Locations: A manually-operated sonde will be used to periodically collect supplemental water quality data along the alignment of the barrier, as well as at RM1 within the cofferdam simulation area. The manually operated sonde will be used to evaluate the consistency of the chemocline elevation across either side of the curtain. Depth intervals for profiling will generally be every 50 cm (reduced to 25 cm intervals when approaching the chemocline) beginning near the water surface and extending to near the sediment-water interface.

Field Parameters and Manual Monitoring Frequency
The CTD sensor monitoring stations set up for PDI-4C at RM1, RM2, and RM3 will be used; these stations include CTD sensors configured as described in Section 3.2.2.3. The manually operated sonde will be a full-spectrum sonde, providing the following conventional water quality parameters: ammonia (via ion-selective probe), DO, pH, ORP, conductivity, temperature, and turbidity. The manually-operated sonde will be performed at the RM1 CTD station, as well as well as at two locations (flexible location) along the barrier setup alignment (one each either side of the barrier). We estimate that manual field water quality monitoring will be conducted: immediately before the barrier deployment, and post deployment on days 1, 2, 5, 7, and weekly until week 4 (the initial manual monitoring frequency). Thereafter, monitoring and sampling will be conducted on a monthly basis or as needed to calibrate the water quality sondes. If there is a storm event (> 1 inch in 24 hours) during the test, monitoring will revert to the initial manual monitoring frequency to assess the potential disruption of the chemocline caused by increased inflows, unless no storm impacts are observed during prior storm events of equal or greater magnitude experienced during PDI-16.

Sample Depth Intervals
Samples will be collected at the fixed monitoring station at RM1. The purpose of this sampling and analysis is to correlate the field measurements with chemical data. The sample depths at the fixed monitoring stations will be as per PDI-4C. See PDI-4C for a description of the CTD sensor layout at the fixed monitoring station.

Sampling and Laboratory Analysis/Frequency
Water samples will be obtained from the locations and depths noted above. The frequency of this sampling will be as follows: immediately before the barrier deployment (via PDI-4C), and post deployment on day 2, 7, and weekly through week 4 (initial sampling frequency). Thereafter, sampling will be conducted on a monthly basis per PDI-4C. Similar to the monitoring schedule for field parameters, if there is a storm event, the sampling sequence will revert to the initial sampling frequency, unless no storm impacts are observed during prior storm events of equal or greater magnitude experienced during PDI-16. Discrete surface water grab samples will be collected using a peristaltic pump, filtered with a 0.45 micron filter (dissolved arsenic only), placed in proper glassware, and transported under chain of custody procedures to Alpha Analytical Labs for the following analyses:

- Ammonia
- Benzene
- Arsenic - total and dissolved

Note: If other PDIs are ongoing at the time of this work, and the monitoring/sampling activities are similar, the laboratory analysis and field water quality profiling will be coordinated if possible to avoid duplicating activities.

3.2 WHP In-situ Enhanced Bioremediation

3.2.1 PDI-9: West Hide Pile Investigations and Assessment

The goals of this PDI are to:

- Obtain sufficient data to assess if the potential human health and ecological risk(s) near the WHP, EHP and contiguous wetlands are unacceptable, particularly with respect to the benzene plume beneath the WHP
- Assess the potential for enhanced biodegradation of benzene, if it is determined risk(s) to human health and ecological receptors exist and ICs can not address the estimated risks
- Perform additional studies, as necessary, to refine and/or reduce risks if unacceptable estimates of human health and/or ecological risk are determined

3.2.1.1 PDI-9A - West& East Hide Pile Investigations and Assessment

A. Investigation Approach and Methods

The following general steps will be followed for PDI-9A:

- **Step 1** - Sampling and analysis of groundwater (from WHP wells), shallow groundwater (piezometers), surface water and bulk sediment (from the Lower South Pond) will be completed.
- **Step 2A (HH)** - If COC concentrations are below the human health (HH) screening thresholds, no further action will be required with respect to human health. If concentrations exceed the HH screening thresholds, then an evaluation of whether ICs can mitigate the HH risk will be conducted. If ICs apply, then ICs will be pursued; otherwise, Step 3 described below will be performed.
- **Step 2B (ECO)** - If COC concentrations in media are below applicable ecological screening thresholds, no further action will be required. If applicable concentrations exceed the screening thresholds, then Step 3 will be performed.
- **Step 3** - If Step 2A/2B show exceedances of screening thresholds, then EPA will conduct the applicable supplementary risk characterization. Additional groundwater investigation and characterization may also be required in the vicinity of the WHP (PDI-9B).

The risk screening Performance Criteria for both human health and ecological receptors are presented in the following table:

Media	Ecological Risk	Human Health Risk[1]
Sediment	Arsenic: 300 mg/kg Lead: 600 mg/kg Chromium: 1000 mg/kg Benzene: Modified EqP	Arsenic: 300 mg/kg Lead: 600 mg/kg Chromium: 1000 mg/kg
Surface Water	Arsenic: 150 ug/L Benzene: 46 ug/L Ammonia: NRWQC (2009)	Arsenic: N/A[1] Benzene: N/A[1] Ammonia: N/A[1]

[1]N/A: Contribution to human health risk anticipated to be negligible for the anticipated recreational wading scenario.

The data collection sequence for samples obtained for the WHP Investigation and Assessment will be groundwater (WHP), shallow groundwater (Lower South Pond), followed by surface water and finally sediment.

The following field sampling procedures will be used for media that will be sampled for PDI-9. Three groundwater wells will be developed using direct push technology (methods presented in Section 3.1.2.1) on the eastern side of the WHP. These wells will, to the extent practicable, replicate former wells RX-18 and RX -19 (Figure 3.1.2.2-1). One additional well, located on the southwestern side of the WHP, will also be installed. A minimum of seventeen (17) locations in Lower South Pond (Figure 3.2.1.1-1) will also be sampled (see Tables 3.2.1.1-1 and 3.2.1.1-2). The following describes how each media will be sampled:

- **Shallow Groundwater**: At each location (Figure 3.2.1.1-1) shallow groundwater will be obtained from a slotted 2½" PVC piezometer fitted with a dedicated sintered glass filter attached to silicon sample tubing. Piezometers will be positioned three feet from the shoreline and screened within the 3 to 4 ft sediment depth interval. The water level inside and outside of the piezometers will also be measured, which will allow the determination of hydrostatic water levels to identify if groundwater is discharging from the WHP and/or EHP into the Lower South Pond. Shallow groundwater will be measured for arsenic (total and dissolved), benzene, ammonia, nitrogenous species (TKN, NO3/NO2), suspended solids (total and dissolved) and organic carbon (total and dissolved). Conventional parameters (DO, pH, temperature, specific conductivity, ORP) will be measured using a portable multiprobe.
- **Surface water**: Aliquots will be obtained at half the surface water depth for at least six locations using a Kemmerer sampler. Lower South Pond is fairly shallow and therefore vertical profiling, if applicable, would only be limited to one or two of the deep locations. If the maximum water depth does not exceed 6 ft, then it will be assumed the incremental precision needed to obtain vertical profiling data cannot be met, and therefore vertical profiling will not be required. Samples will be analyzed for arsenic (total and dissolved), benzene, ammonia, nitrogenous species (TKN, NO3/NO2), suspended solids (total and dissolved) and organic carbon (total and dissolved). Conventional parameters (DO, pH, temperature, specific conductivity, ORP) will be measured using a portable multiprobe.
- **Sediment**: grab samples will be obtained using a Petite Ponar dredge. Sediment will also be analyzed for grain size, arsenic, chromium, lead, benzene, ammonia, nitrogenous species (TKN, NO3/NO2), and total organic carbon. Enough sediment will be obtained to split the sample, preserve a portion with 70% ethanol, and archive if benthic macroinvertebrate taxonomy might be needed.

With the exception of two deep water locations, surface water and sediment will be sampled in the vicinity of the mini-piezometers. Water quality parameters (pH, temperature, DO, conductivity, ORP, and turbidity) will be measured in the field. Additional sediment sample will also be obtained so that a portion can be sieved, preserved with 70 % ethanol, labeled and archived should benthic macroinvertebrate metrics be needed in the near future.

3.2.1.2 PDI-9B - WHP Enhanced Bioremediation Studies

Surface and shallow groundwater data will be compared to the applicable risk-based standards (above) for benzene, arsenic, and ammonia. Collection of additional samples may be necessary if Performance Standards are exceeded (e.g., for benzene) and an in situ enhanced bioremediation system needs to be evaluated for the WHP. Should surface and shallow groundwater samples be below the applicable standards, but benzene concentrations are identified in bulk sediment, benzene concentrations will be normalized using sediment total organic carbon concentrations and compared to Equilibrium Partitioning (EqP) criteria for VOCs (calculated using a modified EPA EqP methodology for VOCs). Benzene does not bioconcentrate or bioaccumulate in freshwater species and critical body burden thresholds for narcosis would need to be met to incur ecological risk.

The selected remedy for In-Situ Enhanced Bioremediation included oxidant injection to increase oxygen levels within the WHP and address benzene in groundwater through the aerobic biological degradation, as well as arsenic and ammonia contamination in groundwater through precipitation and reversing reducing conditions which contribute to contaminant migration. Sampling and analysis methods for evaluation of enhanced bioremediation may include installation of a groundwater monitoring well, groundwater sampling, and characterization of indigenous microbes. Methods and locations of additional data collection would be specified in an addendum to this FSP and the QAPP.

3.2.1.3 PDI-9C Additional Actions to Address Unacceptable Risk(s)

The goal of PDI-C is to perform additional studies, as necessary, to refine and/or reduce risks if unacceptable estimates of human health and/or ecological risk are determined. The scope of PDI-9C will be developed, with EPA input, if additional actions are necessary. The details of any scope will be provided in an addendum to the RDWP, subject to EPA approval.

3.3 Removal and Restoration of Near Shore Sediments from the Wells G&H Wetland and CBCA

3.3.1 PDI-2: Wells G&H and CBCA Wetlands Sediment Dredging/Excavation

The goals of this PDI will be to:

- Delineate areas to be dredged based on 1) accessibility and 2) arsenic concentration in sediment exceeding 300 mg/kg in the Wells G&H wetland and exceeding 230 mg/kg in the CBCA wetland along the bog irrigation channels
- Determine geotechnical properties to establish design requirements for construction staging, equipment access, material handling, and wetlands sediment dewatering
- Determine preliminary waste characteristics of sediment for preliminary evaluation of disposal option(s)

3.3.1.1 Investigation approach

PDI-2 will include collection of samples to support delineation of the lateral limits of accessible sediments requiring dredging/excavation. EPA has designated areas requiring dredging in the ROD as shown in Figures 3.3.1.1-1 and 3.3.1.1-2. The limits of dredging/excavation will extend 30 ft from the shoreline (generally east west orientation). The purpose of sampling conducted as part of PDI-2 will be to determine the horizontal limits of sediments requiring dredging/excavation along the edge of the shoreline (generally in the north-south orientation). Sampling will only be completed in areas that meet the definition as accessible. The ROD states …. *Accessible sediments were defined in Appendix 6A of the March 2005 MSGRP RI as areas with mild to moderate vegetation, generally shallow (i.e., less than two feet) and slow moving surface water, and gradual banks with few, if any, physical barriers present (e.g., fencing or other access obstacles).*

During this PDI, data will also be collected to characterize arsenic in sediments with depth, and support the civil engineering design for construction staging, equipment access, and the dredging/excavation design for material handling, dewatering, and disposal planning.

3.3.1.2 Sampling and Analysis Methods

Approximately 27 locations will be sampled within the wetland areas using 2-ft piston and/or ballcheck corers. Alternatively, a sharpened serrated piston core barrel or a Russian Peat Corer may be necessary to cut through fibrous peat layers in order to obtain full, undisturbed 4-to-5-ft sediment cores. The best method for obtaining cores will be determined in the field by trial and error at the initial sampling

locations. Soil/sediment cores will be sectioned into 0 to 0.5 ft, 0.5 to 1.5 ft, and subsequent 1-ft depth horizons to the bottom of the core. Composite samples from these sections will be analyzed first for arsenic, and potentially benzo(a)pyrene. Benzo(a)pyrene, with a Performance Standard of 4.9 mg/kg, will only be analyzed in delineation samples for which arsenic concentration is below the applicable Performance Standard. Samples collected from depths greater than 2.5 ft will initially be placed on hold, with analysis of arsenic, and possibly benzo(a)pyrene, pending results of the samples collected from ground surface to 2.5 ft below ground surface (bgs). Wetland sediment samples will be stored frozen to extend holding times up to 1 year, so that analyses for arsenic and benzo(a)pyrene will not be compromised by holding time exceedances. Wetland sediments are expected to have greater than 30 % solids content, and should not require freeze drying.

Although wetland sediments are not expected to require a dewatering design, they are may warrant some solidification to facilitate handling, transportation, and disposal. Four bulk composite samples (two from Wells G&A, two from CBCA, minimum of 5 gallons each) will be collected (by piston core or other means) from more than one sample location where the Performance Standard is exceeded for solidification testing to determine the effect of different solidifying agents on the sediment from the wetland areas. The goal of this testing will be to determine what solidifying agents and weights of agents will improve handling and disposal properties of the sediment. Solidification testing is performed on the homogenized sediment removing only the very largest particles prior to the test. The testing will include the use of quick lime, Portland cement, and other agents that may be readily available in the Boston metro area. Test procedures are described in Section 3.1.1.2.

In addition, effluent from settling of wetland sediment within each 5-gal container will be sampled for analysis of arsenic to determine the need for designing wastewater treatment. It is anticipated that the dredging design will include returning dewatering effluent from settling to the wetlands, with or without treatment as determined by sampling up to four (4) effluent samples for the following analytes:

- Dissolved Arsenic
- Particulate Arsenic (measured as the difference between total and dissolved)

Sediment geotechnical characterization of four samples (two from Wells G&H, two from CBCA) of the top 2 ft of wetland soil/sediment (the extent of delineation) will include the following parameters:

- Water content
- Grain size (sieve and hydrometer)
- Atterberg limits
- Organic content (loss on ignition)
- Specific gravity

Two of the four (4) samples composited for geotechnical testing will also be subsampled for preliminary RCRA waste disposal characterization:

- TCLP Metals
- Corrosivity
- Reactivity
- Ignitability
- Paint Filter Test

The weight bearing capacity of wetlands soil/sediment for construction equipment accessibility will be evaluated via a two-step process. First, a peat probe (steel rod) will be manually advanced adjacent to the areas of concern to measure the penetration resistance and depth to refusal. Next, depending on the variability observed in the probing study, one soil boring will be performed in each (2 borings total) of the

main remediation areas (the Wells G & H Wetland and CBCA Wetland). Test borings will be completed in each area using hollow stem augers. Standard drilling methods may be used to evaluate strength of the sediments (e.g., standard penetration test (SPT), field torvane). Sampling and analysis methods for wetland soil/sediment collected for PDI-2 are summarized in Tables 3.3.1.2-1 and 3.3.1.2-2.

Wetland conditions will be surveyed and photo-documented to provide information for wetlands restoration planning.

3.4 Institutional Controls

3.4.1 PDI-12: Soil and Groundwater Institutional Controls

Pursuant to the requirements of the SOW, Institutional Controls (ICs) will be implemented to prevent contact with contaminated media such as groundwater, surface and subsurface soil, and sediments, as well as to ensure that components of the remedy can and will be maintained to ensure long term performance of their stated objectives. There is a broad range of ICs that may be applicable to these various components ranging from easements and covenants to deed notices and advisories. The purpose of this task will be to evaluate the applicability of this full range of IC options for the Industri-plex OU2 remedy with regard to exposure pathways to be controlled, assess the compliance of particular IC mechanisms with MassDEP and EPA guidance and policy, and prepare a description to be included in the 30% Design Submission of how recommended ICs will meet the performance objectives of the remedy.

Consistent with the selected remedy in the ROD and SOW, institutional controls shall be designed and implemented to:

- Control risks from exposures to contaminated surface soils (0 to 3 ft bgs) and subsurface soils (3 to 15 ft bgs)
- Control risks from exposures to contaminated groundwater
- Control risks from exposures to contaminated deeper interior wetland sediments
- Ensure the remedy remains protected and establishes permanent access

In addition, the selected remedy describes institutional controls studies and an Institutional Control Plan. Institutional controls studies are necessary to evaluate the most appropriate form(s) of Institutional Controls for the various components of the remedy, which includes coordination with various stakeholders (representatives from EPA, MassDEP, settling defendants, city officials, landowners, etc.). Information gathered from the institutional controls studies would be applied to the draft Institutional Controls Plan required under the 95% and 100% Remedial Design.

ICs shall be designed to be consistent with EPA's publication "Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups" (OSWER 9355.0-74 FS-P, cited in EPA's Administrative Record Compendium of Guidance Documents). ICs may be established in the form of a Grant of Environmental Restriction and Easement, running with the land. Any such Institutional controls for which a request to MassDEP to serve as grantee is anticipated shall also be consistent with EPA and MassDEP guidance documents and regulatory requirements, including any model forms/documents applicable to ICs (e.g., Grant of Environmental Restriction and Easement). EPA, in consultation with MassDEP, shall approve of the form, design and implementation of each IC remedy component.

The first step of this PDI will be to delineate the type of ICs that may be needed to restrict contact with soils, groundwater, or deeper interior wetland sediments above clean-up standards as identified in the ROD. Based on the list of likely exposure pathways established in the ROD, suitable use restrictions to prevent exposures via those pathways can be developed into a basis for establishing appropriate ICs.

Subsequently, data from other studies will be used to establish the physical limits of the areas in which ICs need to be implemented (e.g., caps, groundwater contaminant plumes, subsurface sediments).

Other PDIs which will also provide data for the delineation of these physical limits include:

- PDI-3: Groundwater data will be collected within both OU2 and OU1 site boundaries that will be used in evaluating the need for ICs
- PDI-10: Groundwater and surface water data will be collected along surface water channels that will be used in evaluating the need for ICs

Long term security and protection from damage to ensure long term efficiency and enforceability, if applicable, will be considered in the development of ICs. In addition, several survey and land-ownership-related studies will be carried out to provide data necessary for the evaluation of the most appropriate IC alternatives and to promote their eventual implementation, including:

- Survey information for all parcels likely to be impacted by ICs to delineate either property boundaries where entire parcels will be subject to ICs and/or restricted areas within parcels when only a portion of that parcel will be subject to the IC
- Examination of property titles and related title examination work for such properties

These data will assist in the evaluation of the classes of ICs potentially suitable for OU2 including controls which fall into one or more of the categories identified in relevant EPA guidance documents including; (i) government controls (state and/or local land use controls such as zoning restrictions, ordinances, building restrictions, etc.); (ii) proprietary controls (easements, covenants); and (iii) informational devices (i.e., deed notices and advisories); and (iv) EPA enforcement and permit tools with IC components, although such do not appear to be applicable at this time. The various IC options within each of these categories judged to be potentially relevant upon initial screening will be assessed as to their consistency with and practicality for the overall demands of the remedy. . Experience gained at Industri-plex OU1 will be applied to this evaluation, and consideration will be given to the extent (if any) that Industri-plex OU2-related ICs require the modification of Industri-plex OU1-related ICs. This analysis will also evaluate whether the “layering” or sequencing of different forms of ICs may be appropriate.

PDI-12 data collection efforts and coordination related to ICs are divided into the following categories:

- PDI-12A: Soil IC Delineation;
- PDI-12B: Groundwater IC Delineation;
- PDI-12C: Remedy Monitoring, Protection and Permanent Access
- PDI-12D: IC Studies.

3.4.1.1 PDI-12A: Soil IC Delineation

ICs will be established to restrict contact with surface and subsurface soils with concentrations above the Performance Standards to ensure the long-term effectiveness and protectiveness of response actions performed at the Site. One area where ICs may be implemented is the former Lake Mishawum lakebed (FLM) area, which historically received runoff and was filled before the construction of the HBHA Pond. This PDI will build upon existing data, and is designed to collect additional soil data from various vertical intervals to fill any RI data gaps and further delineate the extent of surface soils (0 to 3 ft bgs) and subsurface soils (3 to 15 ft) contamination in the FLM area requiring institutional controls.

A. Investigation Approach and Methods

The goal of PDI-12A will be to identify properties or portions of properties within the boundary of FLM that have measured arsenic concentrations greater than 50 mg/kg in surface and/or subsurface soils (Figure 3.4.1.1-1). A higher soil standard, however, may be possible through the implementation of bioavailability studies (as described in the ROD). ICs will be implemented on property parcels that exceed the performance standard of 50 mg/kg. A higher standard may be supported through the use of EPA's Region 8 bioavailability strategy for arsenic, which recommends the same relative bioavailability factor for arsenic in soil that was obtained in the MSGRP Human Health Risk Assessment.

A brief synopsis of each step of the FLM investigation is presented below:

- Boring Locations: Soil borings will be collected within the footprint of FLM (Figure 3.4.1.1-1). Location preference will lean toward industrial properties (approximately seven) within this footprint. A boring will be taken on the north, east, south, and west portions of each industrial property. Because ICs may not be limited to private property, other soil borings may be located on non-industrial lands (e.g., landscaped or grassy areas, easements, etc.). To complete the FLM ICs for arsenic in soil, we estimate approximately 40 supplemental soil boring locations will be required.
- Sample Collection Method: Soil samples will be collected using Geoprobe™ direct push technology. Sampling will terminate based on visual stratigraphy, i.e., when the bottom of the FLM sediment bed is encountered, which is estimated to be less than 15 ft below ground surface. The bottom of the FLM sediment bed will be defined by the presence of peat deposits.
- Soil Sample Analysis: Four 4-ft sections will be taken at each soil boring location (Tables 3.4.1.1-1 and 3.4.1.1-2). Soil from 0 to 3 ft will be homogenized and an aliquot of this sample will then be analyzed for arsenic. Soil from 3 to 15 ft will also be homogenized and an aliquot will be analyzed for arsenic. Following analysis, soil samples will be archived to insure enough soil can be sub-sampled for a bioavailability study, if necessary.
- Where elevated arsenic is detected in soil in FLM, groundwater profiling will be completed to assess impacts to groundwater as described in PDI-12B.

3.4.1.2 PDI-12B: Groundwater IC Delineation

ICs will be established on select properties to restrict contact with groundwater exhibiting concentrations above the Performance Standards. This PDI will build upon existing data, and collect additional groundwater data to further delineate the extent of groundwater contamination requiring ICs. In areas where groundwater contamination exceeds the cleanup standards in the SOW Section IV.A.1 (i.e. Arsenic at 150 ug/L [parts per billion, or ppb], Benzene at 4 ug/L, Ammonia at 4,000 ug/L, 1,2-Dichloroethane at 2 ug/L, Trichloroethene 1 ug/L, and Naphthalene at 5 ug/L), ICs will be imposed to restrict drinking water, industrial process water, or other purposes (such as water for a commercial car wash facility and groundwater encountered during excavation activities). The Performance Standards presented in the SOW as applicable to groundwater on OU2 are summarized in Table 1.2.2-1 of the RDWP.

To assess the limits of groundwater contamination requiring ICs, PDI-12B will rely on groundwater data collected in numerous PDIs including:

- PDI-3 Groundwater Investigation
- PDI-9 West Hide Pile Investigations and Assessment
- PDI-10 Impermeable Caps
- PDI-14 Ammonia Background Investigation

As mentioned previously in PDI-12A, additional groundwater profiling will be completed in the vicinity of the FLM where elevated arsenic concentrations are observed in soils, or where historical data indicate

groundwater contamination exists. The exact location of the groundwater profiling locations in the FLM area will be determined by the observed concentrations in soil. However Figure 3.4.1.1-1 shows fifteen proposed groundwater profiling locations in the vicinity of FLM to supplement the groundwater investigations proposed in other PDIs to evaluate the need for ICs to restrict contact with groundwater exhibiting concentrations above the Performance Standards.

A. Investigation Approach and Methods

Former Lake Mishawum
Groundwater profiling in the vicinity of FLM (see Figure 3.4.1.1-1 will be completed using direct push technology (DPT) driving a groundwater sampling tool (e.g., GeoProbe™ groundwater profiler, Waterloo Profiler™) and low-flow sampling methods to the extent feasible. Groundwater samples would be collected from the water table to the top of bedrock or to a total depth of approximately 30 ft, whichever is less, at 10-ft increments. Therefore at each location, groundwater samples will be collected at approximately 5 to 10 ft (water table), 15 to 20 ft (near the depth of the bottom of FLM) and 25 to 30 ft or refusal, whichever is encountered first.

- Groundwater samples will be submitted to a fixed laboratory for analysis of the following parameters:
  - Total and Dissolved arsenic
  - VOCs (including benzene, 1,2-dichlorethane, trichloroethene, and naphthalene)
  - Total ammonia

Filtered samples (0.45-micron) will be collected for dissolved arsenic analysis and unfiltered samples will be collected for total arsenic, VOCs and ammonia.

Sampling and analysis methods are summarized in Tables 3.4.1.2-1 and 3.4.1.2-2.

Industri-plex OU2
In addition to groundwater investigations described above for PDI-12B, numerous PDI's (PDI-3, -9, -10) will be collecting groundwater data that will also be used to identify properties or portions of properties within Industri-plex OU2 that require ICs for groundwater. Figure 3.4.1.2-1 assimilates all of the proposed groundwater sampling (PDI-3, PDI-9, PDI-10, PDI-12) described in this FSP. Refer to the appropriate FSP sections for additional detail on proposed investigation approaches for the individual PDIs. The groundwater data collected at the locations shown on this Figure will be used as the basis for assessing the need for ICs and will be also be used to assess background ammonia conditions (PDI-14) at the Site.

3.4.1.3 PDI-12C: Remedy Monitoring, Protection and Permanent Access

This PDI will consider ICs to ensure that any remedial components constructed as part of the selected remedy are not disturbed or otherwise compromised by any other use or activity. Remedial components may include monitoring wells throughout the site, covers or caps over contaminated soil areas, or low-head cofferdams or other structures installed in the HBHA Pond as part of the remedy. In addition, this PDI will evaluate ICs necessary to ensure that permanent access is obtained to all components of the remedy. While details of the final remedy, including environmental monitoring plan and operations and maintenance plan, will not be well understood until the 95% and 100% designs, the potential forms of ICs to protect the remedy and ensure access need to be considered early in the design process.

3.4.1.4 PDI-12D: IC Studies

This PDI studies and evaluates the estimated duration, long-term effectiveness and enforceability of various forms of ICs, including but not limited to deed restrictions, easements, regulatory action, zoning ordinances, and/or other legal and/or administrative measures, either individually or applied in combination on an individual property. The evaluation will take into consideration all relevant EPA and MassDEP guidance documents and regulatory requirements, including any available model forms/documents applicable to ICs. As part of this PDI, representatives from various stakeholders (e.g., EPA, MassDEP, settling defendants, city officials, landowners) will be established as a working group to discuss and further evaluate various forms of the ICs applicable for the various media (soils, groundwater and deeper interior wetland sediments) and long-term remedy protection, monitoring and access. Information gathered and/or recommendations formed from these working group studies will be considered further in the draft Institutional Controls Plan required under the 95% and 100% Remedial Design.

4.0 SCHEDULE

The conceptual PDI schedule (Figure 4-1) demonstrates the anticipated timeframes and interdependencies of the individual PDIs outlined in this document. The schedule generally assumes the RDWP will be approved of by 24 May 2010. It should be noted that this schedule will change to incorporate comments, revisions, access limitations, and further development of PDI's.

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4. Koerner, G.R. and Koerner, R.M. 2005. "Geotextile Tube Assessment Using a Hanging Bag Test." Geotextiles and Geomembranes. Vol 24, Issue 2, pp 129-137.

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TABLE 2-1
SUMMARY OF TASKS BY PRE-DESIGN INVESTIGATION
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Task No.	Task	Relevant Standard Operating Procedures (SOPs)	PDI-1	PDI-2	PDI-3	PDI-4A	PDI-4B	PDI-4C	PDI-5	PDI-6	PDI-9	PDI-10	PDI-11	PDI-12A	PDI-12B	PDI-15	PDI-16
1	Sediment Sampling	OP3004- Sediment Sampling OP1008- Operations Over, Near or on Water	x	x			x				x						
2	Bathymetric Survey (incl. debris)	OP1008- Operations Over, Near or on Water	x														
3	Peat Probing	OP2030- Direct Push Borings OP2000- Monitoring Field Explorations	x														
4	Accessibility Survey	OP1008- Operations Over, Near or on Water		x													
5	Wetland Peat Probing and Soil Boring	OP1008- Operations Over, Near or on Water OP2030- Direct Push Borings OP2000- Monitoring Field Explorations		x													
6	Groundwater Profiling Using DPT and Low Flow Sampling	OP3010- Groundwater Sampling OP3011- Groundwater Sampling Using Direct Push Technology OP3012- Low Stress/Low Flow Groundwater Sampling Procedure			x										x		
7	Groundwater Sampling	OP3010- Groundwater Sampling OP3012- Low Stress/Low Flow Groundwater Sampling Procedure			x						x	x			x		
8	Groundwater Sampling from barge	OP3010- Groundwater Sampling			x												
9	Drive Point Piezometer Installation	OP2021- Piezometers			x						x	x					
10	Water Level Measurement	OP3008- Manual Water Level Measurement Procedure			x						x	x			x		
11	Monitoring Well Development	OP3009- Monitoring Well Development Procedure			x						x	x			x		
13	Surface Water Sampling	OP3007- Surface Water Sampling OP3012- Low Stress/Low Flow Groundwater Sampling Procedure				x	x	x			x	x				x	x
14	Surface Water Screening with full spectrum sonde	OP3012- Low Stress/Low Flow Groundwater Sampling Procedure				x	x	x			x	x				x	x
15	Fluorescent Dye Tracer Study	OP1008- Operations Over, Near or on Water OP3007- Surface Water Sampling				x											
16	Meteorological Monitoring	OP1008- Operations Over, Near or on Water						x									
17	Tank Treatability Study	OP3007- Surface Water Sampling OP3023- Air Sample Collection with Tedlar Bags							x								
18	Deep Soil Borings	OP2005- Test Borings OP 1002- Drilling Safety								x				x			
19	Soil Borings and Sampling	OP2005- Test Borings OP2030- Direct Push Borings OP 1001- Excavation and Trenching Safety OP 1002- Drilling Safety								x			x	x			
20	Monitoring Field Explorations	OP2000- Monitoring Field Explorations			x					x	x	x	x	x	x		
21	Identification and Description of Soils in the Field	OP2001- Identification and Description of Soils in the Field Using Visual-Manual Methods								x			x	x			
22	Surficial Soil Sampling	OP3003- Surficial Soil Sampling OP3003A- Addendum to Surficial Soil Sampling								x			x	x			
23	Subsurface (Pond) Sampler and Instrumentation Deployment and Collection	OP1008- Operations Over, Near or on Water	x					x								x	x

NOTES

1. Additional tasks include surveying, test pits, hand sampling, etc.

2. In some cases, PDI series are listed in place of individual subparts.

TABLE 2-2
SAMPLE SUMMARY BY PRE-DESIGN INVESTIGATION
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference (Preperation Method)	No. of Samples[1]	PDI-1	PDI-2	PDI-3A	PDI-3B	PDI-4A	PDI-4B	PDI-4C	PDI-5	PDI-6A	PDI-6B	PDI-6C	PDI-9A	PDI-10	PDI-11	PDI-12A	PDI-12B	PDI-15	PDI-16
GW	Total Alkalinity	SM 2320/SOP/07-22	**108**			8					100										
GW	Biological Oxygen Demand	SM 5210/ SOP/07-13	**6**			6															
SW			**196**								140									56	
GW	Chemical Oxygen Demand	SM 5220/ SOP/07-16	**6**			6															
SW			**196**								140									56	
GW	Dissolved Organic Carbon	EPA 9060/ SOP/07-24	**17**												17						
SW			**213**								140				17					56	
GW	Ferrous Iron (Fe^{2+})	Hach Method 8146	**462**			74				120	140									128	
GW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	**187**			74	33								17	18			45		
SOIL			**8**									4	4								
SED			**17**												17						
SW			**483**	9						120	140				17	18				144	35
GW	Nitrogen, Nitrate (NO_3^-)	SM 4500/ SOP/07-26	**91**			74									17						
SED			**17**												17						
SW			**421**							120	140				17					144	
GW	Nitrogen, Nitrite (NO_2^-)	SM 4500/ SOP/07-26	**91**			74									17						
SED			**17**												17						
SW			**421**							120	140				17					144	
GW	Nitrogen, Total Kjeldahl (TKN)	SM 4500 / SOP/07-15	**91**			74									17						
SED			**17**												17						
SW			**421**							120	140				17					144	
SW	Phosphate, Ortho	SM 4500/SOP/07-34	**40**								40										
SW	Phosphorous, Total	SM 4500/SOP/07-35	**40**								40										
GW	Solids, Total Dissolved	SM 2540 / SOP/07-28	**17**												17						
SW			**137**								64				17					56	
GW	Solids, Total Suspended	SM 2540 / SOP/07-29	**17**												17						
SW			**455**							120	206				17					112	
GW	Sulfate (SO_4^{2-})	EPA 9038 / SOP/07-21	**8**			8															
GW	Total Organic Carbon	EPA 9060 / SOP/07-24 / W-028	**17**												17						
SED			**17**												17						
SW			**73**												17					56	
GW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	**187**			74	33								17	18			45		
SW			**616**	9	4					120	206				17	18				207	35
SED	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3050B/ SOP/05-07)	**167**	69	81										17						
SOIL			**143**									4	14				45	80			
SW		EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	**616**	9	4					120	206				17	18				207	35
GW			**187**			74	33								17	18			45		
SED	Chromium, Total	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	**17**												17						
SED	Lead, Total	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	**17**												17						
SED	Iron, Total	EPA 6010 / SOP/06-01	**69**	69																	
GW		EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	**74**			74															
SW			**388**							120	140									128	

TABLE 2-2
SAMPLE SUMMARY BY PRE-DESIGN INVESTIGATION
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference (Preperation Method)	No. of Samples[1]	PDI-1	PDI-2	PDI-3A	PDI-3B	PDI-4A	PDI-4B	PDI-4C	PDI-5	PDI-6A	PDI-6B	PDI-6C	PDI-9A	PDI-10	PDI-11	PDI-12A	PDI-12B	PDI-15	PDI-16
GW	VOCs including Benzene and/or 1,2-DCA, TCE, Naphthalene	EPA 8260/SOP/03-03	**187**			74	33								17	18			45		
SED			**17**												17						
SOIL			**8**									4	4								
SW			**483**	9						120	140				17	18				144	35
SED	Benzo(a)pyrene	EPA 8270C / SOP 03-06 (EPA 3540C/3546/SOP/02-04/12[2])	**81**		81																
SED	Corrosivity	EPA 9040B/9045C/ SOP/07-11	**5**	3	2																
SED	Ignitability	EPA 1030 / SOP/07-60	**5**	3	2																
SED	Paint Filter Test	EPA 9095A / SOP/07-70	**5**	3	2																
SED	Reactivity	EPA 7.3 / SOP/07-37	**5**	3	2																
SED	TCLP Metals	EPA 1311	**5**	3	2																
SED	Water Content	ASTM D2216	**17**	8 to 13	4																
SOIL			**18**									5	5	8							
SED	Grain Size	ASTM D6913 and D422	**34**	8 to 13	4										17						
SOIL			**16**									5	5	6							
SED	Atterberg Limts	ASTM D4318	**17**	8 to 13	4																
SOIL			**18**									6	6	6							
SED	Loss on Ignition	ASTM D2974/ GLP 121	**17**	8 to 13	4																
SED	Specific Gravity	ASTM D859	**17**	8 to 13	4																
SOIL			**8**									3	3	2							
SED	Large Diameter Settling Test	USACE EM 1110-2-5027	**3**	3																	
SED	API Filtrate Loss Test	API 13A & 13B (ASTM D5981)	**3**	3																	
SED	Hanging Tube Test	see FSP text	**3**	3																	
SED	Solidification Agent Testing	see FSP text	**7**	3	4																
SED	qPCR	MI	**5**						3											2	
SW			**21**						9		8									4	
SW	phospholipid fatty acid (PLFA)	MI	**8**								8										
SOIL	CIU Triaxial	ASTM D4767	**9**									3	3	3							
SOIL	1-D Consolidation	ASTM D2435	**3**									1	1	1							
SOIL	Visual Manual ID	ASTM D2488	**24**									8	8	8							
SW	Percent absorbance (FDT)	Procedures in FSP Attachment C3	**160**					160													
GAC Packets	Percent absorbance (FDT)	Procedures in FSP Attachment C3	**216**					216													
AIR	Benzene	GC VPSOP [H&A]	**13**								13										
AIR	Benzene	Method TO-15/ SOP/A-001[3]	**4**								4										
AIR	Ammonia by Anasorb	Galson Analytical Anasorb	**13**								13										

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.
[2] -Prior to sample preparation for BaP analysis, soil and sediment samples will be inspected. Samples exhibiting greater than 50% moisture content or the presence of artifacts (concrete or metal fragments/shavings) and/or high petroleum product content (i.e tar or oil impacted soils) be prepared using SOP/02-04 (soxhlet extraction).
[3] - All samples will be analyzed by GC VPSOP (H&A) with 25% of these samples analyzed by EPA Method TO-15 (Alpha) for confirmation.

Parameter	Matrix	Sample Volume/Weight	Containers (Number, size[1] & type)	Preservation Requirements	Holding Time[2]	Analytical Laboratory
Total Alkalinity	GW	100 mL	125 mL HDPE	4 ± 2ºC	14 days	Alpha Analytical, Inc
	SW	100 mL	125 mL HDPE	4 ± 2ºC	14 days	Alpha Analytical, Inc
Biological Oxygen Demand	GW	300 mL	1 L HDPE	4 ± 2ºC	24 hr	Alpha Analytical, Inc
	SW	300 mL	1 L HDPE	4 ± 2ºC	24 hr	Alpha Analytical, Inc
Chemical Oxygen Demand	GW	20 mL	250 mL glass	H_2SO_4	28 days	Alpha Analytical, Inc
	SW	20 mL	250 mL glass	H_2SO_4	28 days	Alpha Analytical, Inc
Dissolved Organic Carbon	SW	150 mL	250 mL glass	H_2SO_4	28 days	Alpha Analytical, Inc
Nitrogen, Ammonia (NH_3)	GW	500 mL	1 L amber glass	H_2SO_4	28 days	Alpha Analytical, Inc
	SED	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SOIL	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SW	500 mL	1 L amber glass	H_2SO_4	28 days	Alpha Analytical, Inc
Nitrogen, Nitrate (NO_3^-)	GW	50 mL	125 mL HDPE	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SED	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SW	50 mL	125 mL HDPE	4 ± 2ºC	48 hr	Alpha Analytical, Inc
Nitrogen, Nitrite (NO_2^-)	GW	50 mL	125 mL HDPE	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SED	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SW	50 mL	125 mL HDPE	4 ± 2ºC	48 hr	Alpha Analytical, Inc
Nitrogen, Total Kjeldahl (TKN)	GW	500 mL	1 L amber glass	H_2SO_4	28 days	Alpha Analytical, Inc
	SED	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	48 hr	Alpha Analytical, Inc
	SW	500 mL	1 L amber glass	H_2SO_4	28 days	Alpha Analytical, Inc
Phosphate, Ortho	SW	50 mL	125 mL HDPE	4 ± 2ºC	48 hr	Alpha Analytical, Inc
Phosphorous, Total	SW	100 mL	125 mL glass	H_2SO_4	28 days	Alpha Analytical, Inc
Solids, Total Dissolved	SW	1000 mL	1 L HDPE	4 ± 2ºC	7 days	Alpha Analytical, Inc
Solids, Total Suspended	SW	1000 mL	1 L HDPE	4 ± 2ºC	7 days	Alpha Analytical, Inc
Sulfate (SO_4^{2-})	GW	50 mL	125 mL HDPE	4 ± 2ºC	28 days	Alpha Analytical, Inc
Total Organic Carbon	SED	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	14 days	Alpha Analytical, Inc
	SW	150 mL	250 mL amber glass	H_2SO_4	28 days	Alpha Analytical, Inc
	GW	150 mL	250 mL amber glass	H_2SO_4	28 days	Alpha Analytical, Inc
Arsenic, Dissolved	GW	100 mL	250 mL HDPE	HNO_3	180 days	Alpha Analytical, Inc
	SW	100 mL	250 mL HDPE	HNO_3	180 days	Alpha Analytical, Inc
Arsenic, Total	GW	100 mL	250 mL HDPE	HNO_3	180 days	Alpha Analytical, Inc
	SED	2 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	180 days	Alpha Analytical, Inc
	SOIL	2 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	180 days	Alpha Analytical, Inc
	SW	100 mL	250 mL HDPE	HNO_3	180 days	Alpha Analytical, Inc
Chromium, Total	SED	2 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	180 days	Alpha Analytical, Inc
Lead, Total	SED	2 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	180 days	Alpha Analytical, Inc
Iron, Total	GW	100 mL	250 mL HDPE	HNO_3	180 days	Alpha Analytical, Inc
	SW	100 mL	250 mL HDPE	HNO_3	180 days	Alpha Analytical, Inc
Benzene* 1,2-Dichloroethane Trichloroethene Naphthalene	GW	40 mL	3-40 mL VOA vials	HCl	14 days	Alpha Analytical, Inc
	SED	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	14 days	Alpha Analytical, Inc
	SOIL	10 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	14 days	Alpha Analytical, Inc
	SW	40 mL	3-40 mL VOA vials	HCl	14 days	Alpha Analytical, Inc
	AIR	1L	1L Tedlar bag	Store in dark, 15-25ºC, Protect from <10ºC & > 30ºC	3 days	Alpha Analytical, Inc
Benzo(a)pyrene	SED	20 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	7 days	Alpha Analytical, Inc
	SED	20 g	4 oz glass jar w/ 33% Headspace	Frozen >-20 C ; <-10 C	365 days	Alpha Analytical, Inc
Corrosivity	SED	20 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	ASAP (24 hr)	Alpha Analytical, Inc
Ignitability	SED	100 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	14 days	Alpha Analytical, Inc
Paint Filter Test	SED	100 g	4 oz glass jar w/Teflon lined lid	None	N/A	Alpha Analytical, Inc
Reactivity (cyanide & sulfide)	SED	20 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	7 days	Alpha Analytical, Inc
TCLP for Metals	SED	100 g	4 oz glass jar w/Teflon lined lid	4 ± 2ºC	14 days	Alpha Analytical, Inc
Water Content	SED	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
	SOIL	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
Grain Size	SED	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
	SOIL	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
Atterberg Limits	SED	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
	SOIL	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
Loss on Ignition	SED	20 - 500 g	8 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
Specific Gravity	SED	50 - 100 g	4 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
	SOIL	50 - 100 g	4 oz glass jar w/Teflon lined lid	NA	NA	Haley & Aldrich, Inc
Large Diameter Settling Test	SED	57 L	3 X 19 L (5 gal) HDPE	NA	NA	Hard Hat Services
API Filtrate Loss Test	SED	1.5 L	3 X 500 mL HDPE	NA	NA	Hard Hat Services
Hanging Tube Test	SED	95 L	5 X 19 L (5 gal) HDPE	NA	NA	Hard Hat Services
Solidification Agent Testing	SED	1.5 L	3 X 500 mL HDPE	NA	NA	Hard Hat Services
CIU Triaxial	SOIL	Shelby Tube	3 X 3.5 cu. Inch	NA	NA	Geotesting Express
1-D Consolidation	SOIL	Shelby Tube	3 X 3.5 cu. Inch	NA	NA	Geotesting Express
Visual Manual ID	SOIL	Shelby Tube	3 X 3.5 cu. Inch	NA	NA	Geotesting Express
Phospholipid Fatty Acid (PFLA)	SW	2-3 L	1 L HDPE	4 ± 2ºC	24-48 hr	Microbial Insights
DNA (qPCR)	SED	50-100 g	8 oz glass jar w/Teflon lined lid	4 ± 2ºC	24-48 hr	Microbial Insights
	SW	2-3 L	1 L HDPE	4 ± 2ºC	24-48 hr	Microbial Insights
Ammonia	AIR	Recorded during sample collection	Anasorb tube, SKC Catalog no. 226-29	NA	29 days	Galson Laboratories

Note:
* Benzene is the only VOC that will be sampled for air.
[1] - It is acknowledged that in some instances, where a large amount of moisture is present, additional or larger glass jars will be used to provide sufficient sample volume.
[2]- Holding time is determined from the time of sample collection, not when samples are received by the analytical lab.

TABLE 3.1.1.2-1
PDI-1 HBHA POND SEDIMENT DREDGING
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
HBHA Pond	SD-1 through SD-23	Sediment	Floc	Arsenic, Total Iron	Delineation of noncompliant (i.e. Arsenic exceeding) sediment deposits within HBHA Pond for the purpose of dredge design
HBHA Pond	SD-1 through SD-23	Sediment	Sludge	Arsenic, Total Iron	
HBHA Pond	SD-1 through SD-23	Sediment	Sand	Arsenic, Total Iron	
HBHA Pond grid	5 to 10 samples	Sediment	Composite Dredge Layer	Water content, grain size, Atterberg limits, organic content, specific gravity	Noncompliant samples will be tested for Geotechnical properties for dredging and material handling design
Non Compliant Cells	3 composite samples	Sediment	Dredge layer	Large-diameter settling test, API Filtrate Loss Test, Hanging Tube Test, Solidification Agent Testing, TCLP Metals, Corrosivity, Reactivity, Ignitability, Paint Filter Test, Water content, grain size, specific gravity, organic content, Atterberg limits	De-watering design and Waste Characterization for disposal
De-watering Effluent	9 treatability tests	Aqueous Effluent	N/A	Dissolved Arsenic, Total Arsenic, Benzene, Ammonia	Evaluate need for effluent treatment

TABLE 3.1.1.2-2
PDI-1 HBHA POND SEDIMENT DREDGING
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	9
SW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	9
SED	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3050B/ SOP/05-07)	69
SW		EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	9
SED	Iron, Total	EPA 6010 / SOP/06-01 (EPA 3050B/ SOP/05-07)	69
SW	Benzene	EPA 8260/ SOP/03-03	9
SED	Corrosivity	EPA 9040B/9045C/ SOP/07-11	3
SED	Ignitability	EPA 1030 / SOP/07-60	3
SED	Paint Filter Test	EPA 9095A / SOP/07-70	3
SED	Reactivity	EPA 7.3 / SOP/07-37	3
SED	TCLP Metals	EPA 1311	3
SED	Water Content	ASTM D2216	8 to 13
SED	Grain Size	ASTM D6913 and D422	8 to 13
SED	Atterberg Limits	ASTM D4318	8 to 13
SED	Loss on Ignition	ASTM D2974/ GLP 121	8 to 13
SED	Specific Gravity	ASTM D4318	8 to 13
SED	Large Diameter Settling Test	USACE EM 1110-2-5027	3
SED	API Filtrate Loss Test	API 13A & 13B (ASTM D5981)	3
SED	Hanging Tube Test	Procedures in FSP PDI-1 Text	3
SED	Solidification Agent Testing	Procedures in FSP PDI-1 Text	3

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.2.1-1
PDI-3A GROUNDWATER DISCHARGE EVALUATION TO HBHA POND
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
North-South Transects along Eastern and Western Edges of HBHA Pond Extending South of known limits of contamination	7	Groundwater	5-10 ft	Ammonia, arsenic (dissolved and total), benzene, 1,2-dichloroethane, trichloroethane, naphthalene, total iron, ferrous iron, nitrate/nitrite, and TKN plus sulfate, BOD, COD, and alkalinity from multiple depths of two profiling locations	Groundwater plume delineation/characterization of geochemistry
	7	Groundwater	15-20 ft		
	7	Groundwater	25-30 ft/refusal		
Within HBHA Pond	9	Groundwater	min 2 ft into sand underlying recent sediments in the Pond	Ammonia, arsenic (dissolved and total), benzene, 1,2-dichloroethane, trichloroethane, naphthalene, total iron, ferrous iron, nitrate/nitrite, and TKN plus sulfate and alkalinity from multiple depths of two profiling locations	Groundwater plume delineation/characterization of geochemistry
Within HBHA Pond	up to 4	Groundwater	min. 2 ft into sediment	Ammonia, arsenic (dissolved and total), benzene, 1,2-dichloroethane, trichloroethane, naphthalene, total iron, ferrous iron, nitrate/nitrite, and TKN	To support long term monitoring of groundwater discharge into HBHA Pond
Along HBHA Pond shoreline	5 couplets	Groundwater	shallow well 15 ft depth, deep well 30 ft depth	Ammonia, arsenic (dissolved and total), benzene, 1,2-dichloroethane, trichloroethane, naphthalene, total iron, ferrous iron, nitrate/nitrite, and TKN	Evaluate seasonal fluctuations in groundwater discharge

TABLE 3.1.2.1-2
PDI-3A GROUNDWATER DISCHARGE EVALUATION TO HBHA POND
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
GW	Total Alkalinity	SM 2320/ SOP/07-22	8
GW	Biological Oxygen Demand	SM 5210/ SOP/07-13	6
GW	Chemical Oxygen Demand	SM 5220/ SOP/07-16	6
GW	Nitrogen, Ammonia (NH3)	SM 4500/ SOP/07-14	74
GW	Nitrogen, Nitrate (NO3-)	SM 4500/ SOP/07-26	74
GW	Nitrogen, Nitrite (NO2-)	SM 4500/ SOP/07-26	74
GW	Nitrogen, Total Kjeldahl (TKN)	SM 4500 / SOP/07-15	74
GW	Sulfate (SO_4^{2-})	EPA 9038 / SOP/07-21	8
GW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/SOP/05-05)	74
GW	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	74
GW	Iron, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	74
GW	Ferrous Iron (Fe2+)	Hach Method 8146	74
GW	VOCs including Benzene, 1,2-DCA, TCE, Naphthalene	EPA 8260/ SOP/03-03	74

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.2.2-1
PDI-3B SITEWIDE GROUNDWATER PLUME INVESTIGATION
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Several transects between the EHP and WHP and HBHA Pond	30 locations	Groundwater	5 ft below water table	Arsenic (total and dissolved), benzene, 1,2-dichloroethane, trichloroethane, naphthalene, and ammonia	Evaluate the stability of the groundwater plume
Between WHP and HBHA Pond	3 locations	Groundwater	shallow well 10-20 ft depth, deep well 25-35 ft depth	Arsenic (total and dissolved), benzene, 1,2-dichloroethane, trichloroethane, naphthalene, and ammonia	locations where groundwater contamination was known to exist previously

TABLE 3.1.2.2-2
PDI-3B SITEWIDE GROUNDWATER PLUME INVESTIGATION
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
GW	Nitrogen, Ammonia (NH3)	SM 4500/ SOP/07-14	33
GW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	33
GW	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	33
GW	VOCs including Benzene, 1,2-DCA, TCE, Naphthalene	EPA 8260/ SOP/03-03	33

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.3.1-1
PDI-4A ESTIMATING RESIDENCE TIMES
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix[1]	Depth (units)	Analytical Parameter	Site Location Rationale
Transect "A" (west)	A1	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "A" (midchannel)	A2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "A" (east)	A3	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "B" (west)	B1	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "B" (midchannel)	B2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "B" (east)	B3	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "C" (west)	C1	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "C" (midchannel)	C2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "C" (east)	C3	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "D" (west)	D1	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "D" (midchannel)	D2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "D" (east)	D3	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "E" (west)	E1	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "E" (midchannel)	E2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "E" (east)	E3	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "F" (west)	F1	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Transect "F" (midchannel)	F2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.

TABLE 3.1.3.1-1
PDI-4A ESTIMATING RESIDENCE TIMES
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix[1]	Depth (units)	Analytical Parameter	Site Location Rationale
Transect "F" (east)	F2	GAC Matrix	1 below chemocline; 2 above chemocline	Percent absorbance (FDT)	Quantation of FDT at a particular location and depth w/in HBHA.
Mouth of Hall's Brook	ISCO-1	Surface Water	~6"	Fluorescent dye measurement	Evaluate Hall's Brook inlet water for concentration of post-release FDT.
HBHA Outlet	ISCO-2	Surface Water	~6"	Fluorescent dye measurement	Evaluate Hall's Brook outlet water for concentration of post-release FDT.
HBHA Wetland Culvert at Mishawum Road	ISCO-3	Surface Water	~6"	Fluorescent dye measurement	Evaluate Hall's Brook wetland water for concentration of post-release FDT.

[1] - GAC = granular activated carbon packet; FDT = fluorescent dye tracer compound

TABLE 3.1.3.1-2
PDI-4A ESTIMATING RESIDENCE TIMES
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SW	Percent absorbance (FDT)	Procedures in FSP Attachment C3	160
GAC Packets	Percent absorbance (FDT)	Procedures in FSP Attachment C3	216

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.3.2-1
PDI-4B COC TRANSFORMATION PROCESSES
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
North, Central, South monitoring stations in HBHA Pond	RM-1,RM-2, RM-3	Sediment	up to 1 ft	qPCR- AOB, NOB, anammox, total eubacteria	Microbiological monitoring of sediments
North, Central, South Portions of HBHA Pond	RM-1,RM-2, RM-3	Surface Water	Below chemocline	qPCR- AOB, NOB, anammox, total eubacteria	Microbiological monitoring of surface water
	RM-1,RM-2, RM-3	Surface Water	Above chemocline		
	RM-1,RM-2, RM-3	Surface Water	At chemocline		

TABLE 3.1.3.2-2
PDI-4B COC TRANSFORMATION PROCESSES
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SED	qPCR	MI	3
SW		MI	9

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.3.3-1
PDI-4C SURFACE WATER PROFILING
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
RM1	RM1	Surface Water	at same depths as CTD sensors as discussed in FSP	Ammonia, nitrate, nitrite, TKN, benzene, arsenic (total and dissolved), total iron, ferrous iron, total suspended solids	Program designed to collect data regarding variability/sensitivity of chemocline in the natural setting Samples collected on a periodic basis as described in the FSP
RM2	RM2	Surface Water	at same depths as CTD sensors as discussed in FSP	Ammonia, nitrate, nitrite, TKN, benzene, arsenic (total and dissolved), total iron, ferrous iron, total suspended solids	Program designed to collect data regarding variability/sensitivity of chemocline in the natural setting Samples collected on a periodic basis as described in the FSP

TABLE 3.1.3.3-2
PDI-4C SURFACE WATER PROFILING
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SW	Nitrogen, Ammonia (NH3)	SM 4500/ SOP/07-14	120
SW	Nitrogen, Nitrate (NO3-)	SM 4500/ SOP/07-26	120
SW	Nitrogen, Nitrite (NO2-)	SM 4500/ SOP/07-26	120
SW	Nitrogen, Total Kjeldahl (TKN)	SM 4500 / SOP/07-15	120
SW	Nitrogen, Total Organic	Calc from NH3 & TKN	120
SW	Solids, Total Suspended	SM 2540 / SOP/07-29	120
SW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	120
SW	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	120
SW	Iron, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	120
SW	Ferrous Iron (Fe2+)	Hach Method 8146	120
SW	Benzene	EPA 8260/ SOP/03-03	120

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.4.3-1
PDI-5 TANK TREATABILITY STUDIES
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Pump intake above the chemocline	Pump inlet above chemocline	Surface Water	N/A	Arsenic (total and dissolved), TSS	Quality at pump inlet above the chemocline
Pump intake below the chemocline	Pump inlet below chemocline	Surface Water	N/A	Arsenic (total and dissolved), TSS	Quality at pump inlet below the chemocline
Aeration Test - Tank 1 (mixture)	Influent and Effluent	Surface Water	N/A	Aeration Test: Ammonia, TKN, Nitrite, Nitrate, BOD5, COD, TSS, Total Arsenic, Dissolved Arsenic, Total Iron, Ferrous Iron, Benzene	Tanks contain a mixture of water from above and below the chemocline.
Aeration Test - Tank 2 (mixture)	Effluent	Surface Water	N/A		
Aeration Test - Tank 3 (mixture)	Effluent	Surface Water	N/A		
Aeration Test - Tank 4 (mixture)	Effluent	Surface Water	N/A		
Aeration Test - Tank 1 (a)	Influent and Effluent	Surface Water	N/A	Aeration Test: Ammonia, TKN, Nitrite, Nitrate, BOD5, COD, TSS, Total Arsenic, Dissolved Arsenic, Total Iron, Ferrous Iron, Benzene	Tanks contain water from above the chemocline.
Aeration Test - Tank 2 (a)	Effluent	Surface Water	N/A		
Aeration Test - Tank 3 (a)	Effluent	Surface Water	N/A		
Aeration Test - Tank 4 (a)	Effluent	Surface Water	N/A		
Settling Tank	Settling Tank	Surface Water	4 sample ports along side	Arsenic (total and dissolved), total suspended solids, total dissolved solids	Evalute settling rate for arsenic
Bio. Test, No Nutrients - Tank 1 (a)	Influent and Effluent	Surface Water	N/A	Bio Test, No Nutrients: Ammonia, TKN, Nitrite, Nitrate, BOD5, COD, TSS, Total Arsenic, Dissolved Arsenic, Total Iron, Ferrous Iron, Benzene (with qPCR - AOB, NOB, anammox for Tank 1 and one test vessel), Total Alkalinity	Tanks contain water from above the chemocline.
Bio. Test, No Nutrients - Tank 2 (a)	Effluent	Surface Water	N/A		
Bio. Test, No Nutrients - Tank 3 (a)	Effluent	Surface Water	N/A		
Bio. Test, No Nutrients - Tank 4 (a)	Effluent	Surface Water	N/A		
Bio. Test, No Nutrients - Tank 1 (m)	Influent and Effluent	Surface Water	N/A	Bio Test, No Nutrients: Ammonia, TKN, Nitrite, Nitrate, BOD5, COD, TSS, Total Arsenic, Dissolved Arsenic, Total Iron, Ferrous Iron, Benzene (with qPCR - AOB, NOB, anammox for Tank 1 and one test vessel), Total Alkalinity	Tanks contain a mixture of water from above and below the chemocline.
Bio. Test, No Nutrients - Tank 2 (m)	Effluent	Surface Water	N/A		
Bio. Test, No Nutrients - Tank 3 (m)	Effluent	Surface Water	N/A		
Bio. Test, No Nutrients - Tank 4 (m)	Effluent	Surface Water	N/A		
Bio. Test, With Nutrients - Tank 1 (a)	Influent and Effluent	Surface Water	N/A	Bio Test, With Nutrients: Ammonia, TKN, Nitrite, Nitrate, BOD5, COD, TSS, Total Arsenic, Dissolved Arsenic, Total Iron, Ferrous Iron, Benzene, Total Phosphorus, Orthophosphate (with qPCR - AOB, NOB, anammox for two test vessels), Total Alkalinity	Tanks contain water from above the chemocline.
Bio. Test, With Nutrients - Tank 2 (a)	Effluent	Surface Water	N/A		
Bio. Test, With Nutrients - Tank 3 (a)	Effluent	Surface Water	N/A		
Bio. Test, With Nutrients - Tank 4 (a)	Effluent	Surface Water	N/A		
Bio. Test, With Nutrients - Tank 1 (m)	Influent and Effluent	Surface Water	N/A	Bio Test, No Nutrients: Ammonia, TKN, Nitrite, Nitrate, BOD5, COD, TSS, Total Arsenic, Dissolved Arsenic, Total Iron, Ferrous Iron, Benzene (with qPCR - AOB, NOB, anammox for two test vessels), Total Alkalinity	Tanks contain a mixture of water from above and below the chemocline.
Bio. Test, With Nutrients - Tank 2 (m)	Effluent	Surface Water	N/A		
Bio. Test, With Nutrients - Tank 3 (m)	Effluent	Surface Water	N/A		
Bio. Test, With Nutrients - Tank 4 (m)	Effluent	Surface Water	N/A		
All Test Tanks	Headspace	Air	N/A	Ammonia and benzene	Evaluate presence of ammonia and/or benzene in headspace as part of mass balance

a = Water from above the chemocline
m = Mixture of water from above and below the chemocline

TABLE 3.1.4.3-2
PDI-5 TANK TREATABILITY STUDIES
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SW	Total Alkalinity	SM 2320/SOP/07-22	100
SW	Biological Oxygen Demand	SM 5210/ SOP/07-13	140
SW	Chemical Oxygen Demand	SM 5220/SOP/07-16	140
SW	Dissolved Organic Carbon	EPA 9060/ SOP/07-24	140
SW	Nitrogen, Ammonia (NH3)	SM 4500/ SOP/07-14	140
SW	Nitrogen, Nitrate (NO3-)	SM 4500/ SOP/07-26	140
SW	Nitrogen, Nitrite (NO2-)	SM 4500/ SOP/07-26	140
SW	Nitrogen, Total Kjeldahl (TKN)	SM 4500 / SOP/07-15	140
SW	Phosphate, Ortho	SM 4500/ SOP/07-34	40
SW	Phosphorous, Total	SM 4500/ SOP/07-35	40
SW	Solids, Total Dissolved	SM 2540 / SOP/07-28	64
SW	Solids, Total Suspended	SM 2540 / SOP/07-29	206
SW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	206
SW	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	206
SW	Iron, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	140
SW	Ferrous Iron (Fe2+)	Hach Method 8146	140
SW	Benzene	EPA 8260/ SOP/03-03	140
SW	qPCR	MI	8
SW	phospholipid fatty acid (PLFA)	MI	8
AIR	Benzene	GC VPSOP [H&A]	13
AIR	Benzene	Method TO-15/ SOP/A-001[2]	4
AIR	Ammonia	Galson Analytical Anasorb	13

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.
[2]Headspace samples will be analyzed in the field using Draeger tubes and a photoionization detector (PID); QC samples will be submitted for GC analysis at Haley & Aldrich (with a 25% subset sent to Alpha Analytical for TO-15 analysis) and ammonia by anasorb analysis at Galson Analytical.

TABLE 3.1.5.1-1
PDI-6A HBHA-4 COFFERDAM AND STORM FLOW BYPASS
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
PSC-1	Each sample identified by boring and depth	Soil	0-40 ft	Undisturbed tube samples if fine grained soils are encountered for geotechnical lab strength testing and 1-d consolidation testing	SPT samples would be collected at 5 ft intervals with additional samples collected as required to define the fill natural soil interface. Location is along alignment of proposed sheet pile structure. Depth of exploration is approximately the maximum depth a sheet pile structure might have to be driven.
PSC-2		Soil	0-40 ft		
PSC-3		Soil	0-40 ft		
PSC-4		Soil	0-40 ft		
PSC-5		Soil	0-40 ft		
PSC-6		Soil	0-40 ft		Location of flow bypass structure
PSC-7		Soil	0-50 ft		Location of sensitive structures which may be affected by construction
4 of the 7 borings listed above	Each sample identified by boring and depth	Soil	5-10 ft	Total arsenic, ammonia, benzene	To establish contamination levels at this depth; to facilitate proper handling and safety procedures in the geotechnical testing lab
TP1	Each sample identified by pit No., depth and a sketch showing location	Soil	1 ft below water table	Bulk soil samples for geotechnical testing depending on soil types encountered (index testing, triaxial strength testing)	Shallow foundation design and soil disposal characterization
TP2		Soil	1 ft below water table		
TP3		Soil	1 ft below water table		

TABLE 3.1.5.1-2
PDI-6A HBHA-4 COFFERDAM AND STORM FLOW BYPASS
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SOIL	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	4
SOIL	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	4
SOIL	VOCs including Benzene and/or 1,2-DCA, TCE, Naphthalene	EPA 8260/ SOP/03-03	4
SOIL	Water Content	ASTM D2216	5
SOIL	Grain Size	ASTM D6913 and D422	5
SOIL	Atterberg Limits	ASTM D4318	6
SOIL	Specific Gravity	ASTM D854	3
SOIL	CIU Triaxial	ASTM D4767	3
SOIL	1-D Consolidation	ASTM D2435	1
SOIL	Visual Manual ID	ASTM D2488	8

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.5.2-1
PDI-6B HALLS BROOK STORM BYPASS/HOLDING DISSIPATION SYSTEMS
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
TP-4 through TP-8	Each sample identified by boring and depth	Soil	1 ft below water table	Total Arsenic	Soil management considerations
W-1	Each sample identified by boring and depth	Soil	0-40 ft	Undisturbed tube samples if fine grained soils are encountered for geotechnical lab strength testing; Total arsenic, ammonia, benzene	Location is along alignment of proposed overflow wier structure or extended Halls Broko Bypass
W-2		Soil	0-40 ft		
W-3		Soil	0-40 ft		
W-4		Soil	0-40 ft		
PSC-7*	PSC-7	Soil	0-50 ft	Additional samples of soil from fills, organic layers, or fines susceptible to the influence of vibration will be recovered for geotechnical testing	Located between the railroad tracks and the sewer line easements; will be used to help assess the general stability of the railroad embankment and what effect the proposed construction might have on the railroad tracks

*Note that PSC-6, PSC-7, TP-1, TP-2 and TP-3 from PDI-6A are linked to the decision making process for this Pre Design Investigation.

TABLE 3.1.5.2-2
PDI-6B HALLS BROOK STORM BYPASS/HOLDING DISSIPATION SYSTEMS
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SOIL	Nitrogen, Ammonia (NH3)	SM 4500/ SOP/07-14	4
SOIL	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	14
SOIL	VOCs including Benzene and/or 1,2-DCA, TCE, Naphthalene	EPA 8260/ SOP/03-03	4
SOIL	Water Content	ASTM D2216	5
SOIL	Grain Size	ASTM D6913 and D422	5
SOIL	Atterberg Limits	ASTM D4318	6
SOIL	Specific Gravity	ASTM D854	3
SOIL	CIU Triaxial	ASTM D4767	3
SOIL	1-D Consolidation	ASTM D2435	1
SOIL	Visual Manual ID	ASTM D2488	8

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.5.3-1
PDI-6C AAD & BECO DRAINWAY STORM ENERGY DISSIPATION SYSTEMS
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
AAD Inlet-1	Each sample identified by boring and depth	Soil	0-40 ft	SPT at 5 ft interval with up to 4 undisturbed tube samples if fine grained soils encountered for analysis of geotechnical strength testing; up to 4 extra SPT samples will be taken per hole to delineate fill/natural soil interface	Location is in area of AAD inlet
AAD Inlet-2	Each sample identified by boring and depth	Soil	0-40 ft		Location is in area of AAD inlet
AAD Inlet-3	Each sample identified by boring and depth	Soil	0-40 ft		Location is in area of AAD inlet
BECO Inlet-1	Each sample identified by boring and depth	Soil	0-40 ft	SPT at 5 ft interval with up to 4 undisturbed tube samples if fine grained soils encountered for analysis of geotechnical strength testing; up to 4 extra SPT samples will be taken per hole to delineate fill/natural soil interface	Location is in area of BECO Drainway inlet
BECO Inlet-2	Each sample identified by boring and depth	Soil	0-40 ft		Location is in area of BECO Drainway inlet

TABLE 3.1.5.3-2
PDI-6C AAD AND BECO DRAINWAY STORM ENERGY DISSIPATION SYSTEMS
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SOIL	Water Content	ASTM D2216	8
SOIL	Grain Size	ASTM D6913 and D422	6
SOIL	Atterberg Limits	ASTM D4318	6
SOIL	Specific Gravity	ASTM D854	2
SOIL	CIU Triaxial	ASTM D4767	3
SOIL	1-D Consolidation	ASTM D2435	1
SOIL	Visual Manual ID	ASTM D2488	8

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.6.1-1
SWMM5 MODEL INPUT INFORMATION
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Storm Water Monitoring Station	Data Type	Time Interval between Measurements	Measurement Dates	Source	Comments
SW-01-TT	Flow	5 minutes	10/17/2008 - 08/31/2009	ROUX ISCO SAMPLERS	Water Levels recorded by Isco samplers, and flows calculated based on newly developed rating curves on 09/22/2009.
SW-02-TT	Flow	5 minutes	10/17/2008 - 08/31/2009	ROUX ISCO SAMPLERS	Water Levels recorded by Isco samplers, and flows calculated based on newly developed rating curves on 09/22/2009.
SW-04-TT	Flow	5 minutes	10/25/2008 - 08/31/2009	ROUX ISCO SAMPLERS	Water Levels recorded by Isco samplers, and flows calculated based on newly developed rating curves on 09/22/2009.
SW-2-IP	Flow	5 minutes	10/17/2008 - 08/31/2009	ROUX ISCO SAMPLERS	Water Levels recorded by Isco samplers, and flows calculated based on newly developed rating curves on 09/22/2009.
SW-03-TT	Water Level	5 minutes	09/01/2009 - 09/25/2009 10/25/2009 - 11/30/2009	ROUX ISCO SAMPLERS	
SW-01-TT	Rainfall	5 minutes	10/21/2008 - 08/29/2009	ROUX ISCO SAMPLERS	
SW-02-TT	Rainfall	5 minutes	11/05/2008 - 08/29/2009	ROUX ISCO SAMPLERS	
SW-04-TT	Rainfall	5 minutes	10/25/2008 - 08/29/2009	ROUX ISCO SAMPLERS	
SW-2-IP	Rainfall	5 minutes	10/21/2008 - 08/29/2009	ROUX ISCO SAMPLERS	
SW-03-TT	Rainfall	5 minutes	09/01/2009 - 09/25-2009 10/25/2009 - 11/30/2009	ROUX ISCO SAMPLERS	

TABLE 3.1.7.1-1
PDI-8 HYDRODYNAMIC MODELING HBHA POND
COMPARISON OF MODEL TECHNICAL ATTRIBUTES
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Criteria	ELCOM-CAEDYM	FLOWMOD	EFDC	CE-QUAL-W2
Commercially available	X		X	X
Applicable to density-stratified flows	X		X	X
Can simulate three-dimensional hydrodynamic patterns (and associated velocities) within pond including side inflows	X	X	X	
Can be used to evaluate shear stress on sediments over submerged weir				
Can be used to evaluate potential disturbance to the chemocline	X		X	X
Can be used to assess the circulation patterns and evaluate extent of mixing from aeration devices	X	X	X	

Notes:
Table taken from the ELCOM-CAEDYM description report provided by FlowScience on 5 May 2008.

TABLE 3.1.8.1-1
PDI-10 IMPERMEABLE CAPS
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Along surface water channels upgradient of HBHA Pond	18 locations	Groundwater	just below gw table	total/dissolved arsenic, benzene, and ammonia	Understand relationship between SW and GW near NBSD
Along surface water channels upgradient of HBHA Pond	18 locations	Surface Water	grab	total/dissolved arsenic, benzene, and ammonia	Understand relationship between SW and GW near NBSD

TABLE 3.1.8.1-2
PDI-10 IMPERMEABLE CAPs
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
GW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	18
SW			18
GW	Arsenic, Dissolved	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	18
SW			18
GW	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	18
SW			18
GW	Benzene	EPA 8260/ SOP/03-03	18
SW			18

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.9.1-1
PDI-11 PERMEABLE CAPS
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Along Northern Shoreline of HBHA Pond in the vicinity of BECO ROW No. 9	S1 through 15	Soil	0-0.5 ft	Total arsenic	Determine extent of arsenic soil contamination
Along Northern Shoreline of HBHA Pond in the vicinity of BECO ROW No. 9	S1 through 15	Soil	0.5-1.5 ft bgs	Total arsenic	Determine extent of arsenic soil contamination
Along Northern Shoreline of HBHA Pond in the vicinity of BECO ROW No. 9	S1 through 15	Soil	1.5-3.0 ft bgs	Total arsenic	Determine extent of arsenic soil contamination

TABLE 3.1.9.1-2
PDI-11 PERMEABLE CAPS
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SOIL	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3050B/ SOP/05-07)	45

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.12.2-1
PDI-15 AERATION TECHNOLOGY COMPARISON AND SCREENING
FIELD SAMPLING PLAN
INDUSTRI-PLEX SITE OU2
WOBURN, MASSACHUSETTS

Background: The technologies identified in the following table include those technologies most commonly associated with aeration or oxygenation of natural water bodies, man-made reservoirs, or tanks (e.g., water treatment plants). The purpose of the table is to screen and identify technologies for pilot testing in the HBHA Pond (PDI-15). However, the technologies listed in the following table are assumed to be installed in the Pond itself and function as an oxygen delivery mechanism; systems on the market that combine these techniques and a fixed film media (i.e., a bioreactor) are not the subject of this table, and have been considered as part of other PDIs (e.g., PDI-5: Tank Treatability Studies). Principal considerations relevant to the screening of these technologies relate to the following attributes of the Pond or other site limitations: 1) soft, fine-grained sediment bed; 2) approximately 4.6 acres in area; 3) maximum water depth of approximately 16 ft; 4) flood storage loss must be minimized; 5) avoid disturbing sediments. The screening outcome presented in the following table is intended to summarize the aeration technology type(s) warranting further evaluation and consideration for pilot testing in PDI-15.

Category	Technology Type	Description	Select Manufacturers and Model Number[1]	Screening Rationale	Screening Outcome[2]
Diffused Air	Jet Diffuser	Header piping delivers compressed air and water to diffuser head that combines the two fluids and discharges the mixture into the water column. Uni-, bi-, or multi-directional jet diffusers available.	Mixing Systems, Inc.: Jet Aerator (www.jetaerators.com)	■ Tanks and other process equipment for activated sludge treatment most common application for technology ■ Would require the installation of base platforms within the Pond to physically attach and support equipment at appropriate water elevation ■ Requires more capital equipment and infrastructure (blower and pump) compared to other technologies ■ Significant disturbance of the water column anticipated due to aggressive nature of jetting technique, therefore not appropriate as a stand alone option	Eliminate

TABLE 3.1.12.2-1
PDI-15 AERATION TECHNOLOGY COMPARISON AND SCREENING
FIELD SAMPLING PLAN
INDUSTRI-PLEX SITE OU2
WOBURN, MASSACHUSETTS

Category	Technology Type	Description	Select Manufacturers and Model Number[1]	Screening Rationale	Screening Outcome[2]
Diffused Air (Cont.)	Surface Aspirating Aerator	Inclined propeller, motor and shaft that draws in air at the hub above the water line and discharges air and water mixture into the water, where the propeller turbulence shears and disperses the bubbles and enhances oxygen transfer	Aeromix: Aquatornado™ Surface Aspirating Aerator (www.aeromix.com/Tornado) Aeration Industries International, Inc.: AIRE-O_2® (www.aireo2.com/pdf)	■ Has been used in ponds (e.g., aquaculture and to create aerated "cap" for ice management) ■ Operation injects air and moves air-water mixture to distribute oxygen bubbles ■ Can be operated all year ■ Works on floating pontoons that adjust with water level ■ Propeller/shaft angle adjustable to control depth of influence for mixing ■ Multiple units work together to enhance distribution and mixing of DO ■ Angled bubble dispersion increases hang time for oxygen transfer	Retain
	Fine or Coarse Bubble Aerator	Disk- or linear tubing-shaped device with perforations of varying size. Materials of construction vary. Compressed air delivered from on-shore compressor through header piping and bubbled through submerged diffusers.	■ Vertex : *Air 3XL* (www.vertexwaterfeatures.com) ■ Siemens: *DualAir*® Fine Bubble Diffuser System (in ceramic or membrane) (www.usfilter.com) Aeromix: Cyclone™ Coarse & Cyclone II Fine Bubble Diffusers (www.aeromix.com/Cyclone) ■ Aeromix: Aeromix® Diffused Air System (www.aeromix.com/Diffusedair)	■ Commonly utilized for pond aeration ■ Would require the installation of base platforms within the Pond to physically attach and support diffusers at appropriate water elevation, hence does not self-adjust to varying water surface ■ Density (number) of diffusers vary according to target application (WWTP on dense grid, pond aeration typically uses fewer aeration disks) ■ Maintenance requires removal of the submerged diffusers, although mechanical components (blower) mounted on shore ■ Installation in relatively shallow water depths may limit oxygen transfer efficiency and area of influence	Eliminate

TABLE 3.1.12.2-1
PDI-15 AERATION TECHNOLOGY COMPARISON AND SCREENING
FIELD SAMPLING PLAN
INDUSTRI-PLEX SITE OU2
WOBURN, MASSACHUSETTS

Category	Technology Type	Description	Select Manufacturers and Model Number[1]	Screening Rationale	Screening Outcome[2]
Mechanical	High or low speed, vertical axis mechanical aerators	Vertical axis mixer pulls water up and, depending on flow rate, configuration, exit velocity, may or may not spray the water out onto the water surface	■ SolarBee®: Solar-powered, Low-speed surface aerator with adjustable intake Model SB10000v12 (www.solarbee.com)	■ Commonly utilized for pond aeration, including applications involving aeration caps in wastewater treatment lagoons ■ Lifts water from depth (variable) to surface to mix interval and enhance oxygen transfer ■ Mounted on floats that adjust with the water surface ■ Horizontal position established using anchors ■ Intake height on SolarBee® Model adjustable ■ Operates solar power, as well as from the power grid	Retain
			Conventional Low- or High-speed mixing systems used in WWTP: – Aeromix: Twister™ Low Speed Surface Aerator (www.aeromix.com/Twister) – Aeromix: Typhoon™ High Speed Surface Aerator (www.aeromix.com/Typhoon)	■ Commonly utilized for WWTP operation ■ Pulls water up through intake cone (conventional units do not use adjustable intake tube) and projects water outward as droplets for oxygen transfer ■ Mounted on floats that adjust with the water surface ■ Horizontal position established using anchors ■ Do not typically use intake pipe ■ Conventional configuration may potentially induce flow/sediment from depth; therefore, not applicable.	Eliminate
	Horizontal axis mechanical aerators	Similar in principle to vertical axis mixer although the mixer axis is horizontal and uses disks or paddles attached to rotating shaft to agitate the water.	■ Aeromix: Monsoon™ Horizontal Surface Aerator (www.aeromix.com/Monsoon) PMSL: AERO-BRUSH™ Brush Rotor (www.philamixers.com)	■ Commonly utilized in WWTP (oxidation ditches or channel aeration) ■ Not commonly applied in natural ponds	Eliminate

TABLE 3.1.12.2-1
PDI-15 AERATION TECHNOLOGY COMPARISON AND SCREENING
FIELD SAMPLING PLAN
INDUSTRI-PLEX SITE OU2
WOBURN, MASSACHUSETTS

Category	Technology Type	Description	Select Manufacturers and Model Number[1]	Screening Rationale	Screening Outcome[2]
Waterfall	Fountain	Sprays water into the air to enhance oxygen transfer. Multiple fountain spray geometries available.	■ Aeromix: Fountain Aerator (www.aeromix.com/Fountain)	■ Commonly employed for aesthetic improvement in stagnant ponds ■ The geometry of the HBHA Pond limits efficient application of technology since the device tends to aerate the radius surrounding the fountain and system does not enhance dispersion	Eliminate
	Cascade Waterfall	Simple waterfall over weir onto rocks or similar to disturb and aerate water. Depending on configuration, may include pumps to raise the head before the waterfall.	■ Variable	■ Commonly employed stream morphology enhancement to improve re-aeration ■ No moving parts or equipment to maintain unless pumps and related appurtenances involved ■ Generally low maintenance of weir depending on materials of construction ■ Relatively low re-aeration compared to other mechanical or diffused air systems ■ Requires increase in water elevation to create fall, which results in loss of flood storage volume. Hence, technology not applicable to the HBHA Pond.	Eliminate[3]

TABLE 3.1.12.2-1
PDI-15 AERATION TECHNOLOGY COMPARISON AND SCREENING
FIELD SAMPLING PLAN
INDUSTRI-PLEX SITE OU2
WOBURN, MASSACHUSETTS

Category	Technology Type	Description	Select Manufacturers and Model Number[1]	Screening Rationale	Screening Outcome[2]
Other	Oxygen delivery: oxygen/super-oxygen technologies	Encompasses a variety of technologies that deliver pure oxygen gas (using mechanism such as diffused air) and other "custom" devices capable of delivering high DO levels	■ Bubble plume oxygenation (w/ pure O_2) ■ ECO_2: Speece Cone (Contact Chamber oxygenation) ■ Others	■ Typically applied to large-scale hypolimnetic aeration projects for stratified lakes or reservoirs, including cases where stratification is to be maintained and DO deficits warrant water quality improvement ■ Bubble plume "oxygenation" increases DO levels by bubbling in pure oxygen gas, which dissolves in the water column as the bubbles rise due to buoyancy. DO is dispersed via natural or induced currents. These systems have been applied to some large, deep lakes. For lakes where thermal stratification is to be maintained, bubble size and injection depth ideally designed so that bubble disappears before encountering thermocline. Due to shallow depths of the HBHA Pond, not likely to be a candidate technology. ■ Speece Cone system typically uses a submerged cone wherein water is pumped into the top of the cone using a submersible pump and pure oxygen gas is injected inside the cone. Result is high DO levels on account of pure oxygen addition and high hydrostatic pressures at deep water depth. Superoxygenated water is distributed through diffuser pipe(s). Submerged Speece cone concept is to maintain thermal stratification while raising DO. Maintenance drawback is that liquid pump is submerged. In deep water application, DO levels can be raised higher (DO > 50 mg/L) due to the combined atmospheric and hydrostatic head at depth. Shallow depth of the HBHA Pond reduces applicability of this technology.	Eliminate

TABLE 3.1.12.2-1
PDI-15 AERATION TECHNOLOGY COMPARISON AND SCREENING
FIELD SAMPLING PLAN
INDUSTRI-PLEX SITE OU2
WOBURN, MASSACHUSETTS

Category	Technology Type	Description	Select Manufacturers and Model Number[1]	Screening Rationale	Screening Outcome[2]

Notes:
1. Not an exhaustive list of technology vendors. Other vendors may be considered.
2. General technology type retained (or eliminated) from further consideration for PDI-15: HBHA Pond Mixing/Aeration Pilot Test. Other scenarios evaluated in PDI-5 (Tanks Treatability Studies), may use one of the above methods/devices in the unit operation tested/evaluated [e.g., bubble diffusers for the volatilization test (see PDI-5)].
3. Cascading waterfalls or stream riffles to enhance aeration may be appropriate in other areas, such as, but not limited to, Halls Brook discharge into the HBHA Pond, downstream of the Pond, or other areas, as appropriate.
4. “WW” = wastewater
5. “WWTP” = wastewater treatment plant
6. “DO” = dissolved oxygen

TABLE 3.1.12.5-1
PDI-15 HBHA POND AERATION PILOT TEST
STARTUP SEQUENCE FOR LOW-SPEED SURFACE AERATION DEVICES
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

Startup Sequencing		
Time from Start	**Criteria**	**Action**
Mixing the 0-5 ft Layer Start RC-S and RC-N in progression *14 hours total**	Parameter stabilization[3]	Lower intake tube 3 ft
Mixing the 5-8 ft Layer See Note 1 *5 hours total**	Parameter stabilization[3]	Lower intake tube 3 ft
Mixing the 8-11 ft Layer See Note 1 *2.5 hours total**	Parameter stabilization[3]	Lower intake tube 3 ft (or to the target maximum depth at the circulator location)

Notes:
1. Start RC-S, then RC-N in progression
2. * = Time to exchange three volumes (at the relevant depth profile) based on the pond geometry (volume by depth) and combined flow rate of 20,000 gpm (2 units at 10,000 gpm each). Time for other layer based on the approximate volume in that interval, which varies by depth due the pond bottom shape.
3. In addition to the estimated mixing duration for each layer, the intake will not be lowered until the parameters (DO, T, conductivity, ORP, and NH_4^+) have stabilized and DO is 2.0 mg/L or greater

TABLE 3.1.12.6-1
PDI-15 HBHA POND AERATION PILOT TEST
SURFACE WATER MONITORING PROGRAM
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

Parameter	Method	Frequency of Monitoring/Sampling (During Task 2 and 3, Following the Baseline Monitoring Phase)		
		Profiling Locations RM1 & RM2 (2 Depths, Note 1)	Profiling Locations RM1, RM2 & RM3 (5 Depths, Note 2)	Discrete Grab Sampling Stations HB, AAD, ROW9, Pond OF (Grab, Note 3)
DO	Field Instrument (Sonde) (Note 2)	Hourly	Daily	Daily
Temperature				
Turbidity				
pH				
ORP				
Conductivity				
Ammonia				
Iron (ferrous)	Field (Hach)	Daily (Week 1) Weekly (Week 2+)	None	Weekly
Ammonia	Fixed Lab (Note 8)	Daily (Week 1) Weekly (Week 2+)	None	Daily (Week 1) Weekly (Week 2+)
Nitrate				
Nitrite (Note 7)				
TKN (org. nitrogen)				
Benzene		Daily (Week 1) Weekly (Week 2+)	None	Daily (Week 1) Weekly (Week 2+)
Arsenic (total and dissolved)		Daily (Week 1) Weekly (Week 2+)	Bi-weekly	Daily (Week 1) Weekly (Week 2+)
Iron (total)		Daily (Week 1) Weekly (Week 2+)	None	Weekly
TSS		Weekly	None	Weekly
TDS		Bi-weekly	None	Bi-weekly
TOC		Bi-weekly	None	Bi-weekly
DOC		Bi-weekly	None	Bi-weekly
BOD		Bi-weekly	None	Bi-weekly
COD		Bi-weekly	None	Bi-weekly
Micro-biological Monitoring	Note 4	RM1 Only 2 Events - End of Test A and End Test B (Post-pilot) (Note 10)	None	None

Abbreviations: Halls Brook (HB); Atlantic Avenue Drainway (AAD), Right-of-Way No. 9 (ROW9), and Pond Outfall (Pond OF); Total Kjeldahl Nitrogen (TKN).
Notes:
1. Approximately 3± ft (100± cm) below water (above the chemocline) and 9± ft (300± cm) below water (below the chemocline).
2. Approximately sampled at 0 ft (0 cm), 3 ft (100 cm), 6 ft (200 cm), 9 ft (300 cm), and 12 ft (350-400 cm) below water.
3. Single depth, discrete grab surface water sample location.
4. Detailed descriptions of microbiological monitoring analyses are summarized in the RDWP/FSP text.
5. Includes filtered (dissolved) arsenic samples in surface water.
6. It is assumed that the sampling will continue when Test B begins (i.e., the sampling frequency does not reset to the beginning).
7. Nitrite is commonly short-lived in the environment, and thus is anticipated to be present at low or non-detect concentrations; if nitrite is repeatedly non-detect at all monitoring stations in the initial event, a combined nitrate/nitrite analyses will be conducted to reduce the analytical expense.
8. Analytical Methods for this list of parameters is provided in QAPP.
9. To the extent other PDIs are ongoing collecting these data, the programs will be coordinated to reduce redundant sampling and analysis.
10. Baseline microbial testing addressed in PDI-4B.

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TABLE 3.1.12.6-2
PDI-15 HBHA POND AERATION PILOT TEST
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
RM1	RM1	Surface Water	3, 9 ft	Ammonia, Nitrate, Nitrite, TKN, Benzene, Arsenic (total and dissolved), Iron(total and ferrous), TSS, TDS, TOC, DOC, BOD, COD	Monitor effect of aeration pilot test on analytical parameters above/below chemocline
	above, at, and below chemocline	Surface Water	above, at, and below chemocline	Microbiological Monitoring	
RM2	RM2	Surface Water	3, 9 ft	Ammonia, Nitrate, Nitrite, TKN, Benzene, Arsenic (total and dissolved), Iron(total and ferrous), TSS, TDS, TOC, DOC, BOD, COD	Monitor effect of aeration pilot test on analytical parameters above/below chemocline
RM-1	RM-1	Surface Water	0, 3, 6, 9, 12 ft	Arsenic (total and dissolved)	Monitor effect of aeration pilot test on analytical parameters across water column
RM-2	RM-2	Surface Water	0, 3, 6, 9, 12 ft	Arsenic (total and dissolved)	Monitor effect of aeration pilot test on analytical parameters across water column
RM-3	RM-3	Surface Water	0, 3, 6, 9, 12 ft	Arsenic (total and dissolved)	Monitor effect of aeration pilot test on analytical parameters across water column
HB	HB	Surface Water	Grab	Ammonia, Nitrate, Nitrite, TKN, Benzene, Arsenic (total and dissolved), Iron(total and ferrous), TSS, TDS, TOC, DOC, BOD, COD	Monitor analytical parameters at inlets
AAD	AAD	Surface Water	Grab	Ammonia, Nitrate, Nitrite, TKN, Benzene, Arsenic (total and dissolved), Iron(total and ferrous), TSS, TDS, TOC, DOC, BOD, COD	Monitor analytical parameters at inlets
ROW9	ROW9	Surface Water	Grab	Ammonia, Nitrate, Nitrite, TKN, Benzene, Arsenic (total and dissolved), Iron(total and ferrous), TSS, TDS, TOC, DOC, BOD, COD	Monitor analytical parameters at inlets
Pond Outlet	Pond Outlet	Surface Water	Grab	Ammonia, Nitrate, Nitrite, TKN, Benzene, Arsenic (total and dissolved), Iron(total and ferrous), TSS, TDS, TOC, DOC, BOD, COD	Monitor effects of aeration pilot test on analytical parameters at pond outlet
RM1	Sediment	Sediment		Microbiological Monitoring	

TABLE 3.1.12.6-3
PDI-15 HBHA POND AERATION PILOT TEST
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SW	Biological Oxygen Demand	SM 5210/ SOP/07-13	56
SW	Chemical Oxygen Demand	SM 5220/ SOP/07-16	56
SW	Dissolved Organic Carbon	EPA 9060/ SOP/07-24	56
SW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	144
SW	Nitrogen, Nitrate (NO_3^-)	SM 4500/ SOP/07-26	144
SW	Nitrogen, Nitrite (NO_2^-)	SM 4500/ SOP/07-26	144
SW	Nitrogen, Total Kjeldahl (TKN)	SM 4500 / SOP/07-15	144
SW	Solids, Total Dissolved	SM 2540 / SOP/07-28	56
SW	Solids, Total Suspended	SM 2540 / SOP/07-29	112
SW	Total Organic Carbon	EPA 9060 / SOP/07-24/W-028	56
SW	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	207
SW	Arsenic, Dissolved	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	207
SW	Iron, Total	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	128
SW	Ferrous Iron (Fe2+)	Hach Method 8146	128
SW	Benzene	EPA 8260/ SOP/03-03	144
SW	qPCR	MI	4
SED	qPCR	MI	2

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.1.12.7-1
PDI-15 HBHA POND AERATION PILOT TEST
PERFORMANCE MONITORING CRITERIA
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

Parameter	Performance Criteria	Comments/Rationale
DO	> 2 mg/L on average in the upper 5 ft of the water column	If DO levels remain below 2 mg/L in upper 5 ft of the water column for an extended period of time (e.g. >12 hours) ecological receptors could become distressed. The criteria only applies to the upper 5 ft of the water column because at greater depths there is often little DO under current conditions.
Arsenic**	< 0.150 mg/L at the outlet of the pond	Increases in arsenic concentrations may also be indicative of oxidation of sulfide deposits and subsequent release of arsenic.
Ammonia**	NRWQC criterion (variable) at the outlet of the pond	The NRWQC is pH and temperature dependent.
Benzene**	< 0.046 mg/L at the outlet of the pond	Benzene will be monitored and used to assess performance
Ecological impacts	Observed fish kill	If a fish kill is observed, the aerators will be shut down while the cause is evaluated.
Turbidity	> 150 NTUs at the outlet of the pond	Turbidity has been seen at levels approaching or exceeding 200 NTU near the chemocline. Turbidity in excess of 150 NTU may indicate solids potentially containing arsenic are migrating downstream and the impeller will be shutdown until the source of arsenic concentrations of the water and suspended solids can be determined. If the arsenic analysis indicates that the arsenic concentration is well below 150 µg/L under turbid conditions, then the aerators may be turned back on.

TABLE 3.1.13.3-1
PDI-16 COFFERDAM SIMULATION PILOT TEST
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
RM1	RM1	Surface Water	0 ft (0cm) 3 ft (100cm) 6 ft (200 cm) 9 ft (300 cm) 12 ft (350-400cm)	Ammonia, Benzene, Arsenic (total/dissolved)	Observe effect of Curtain on chemocline

TABLE 3.1.13.3-2
PDI-16 COFFERDAM SIMULATION PILOT TEST
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	35
SW	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	35
sw	Arsenic Dissolved	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	35
SW	VOCs including Benzene and/or 1,2-DCA, TCE, Naphthalene	EPA 8260/ SOP/03-03	35

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.2.1.1-1
PDI-9A WHP & EHP INVESTIGATION AND ASSESSMENT
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Lower South Pond	17 locations	Surface water	1/2 of total depth	Benzene,ammonia, nitrate/nitrite, TKN, total/dissolved arsenic, TSS, TDS, TOC, DOC	Improve understanding of contaminants associated with WHP, EHP and contiguous wetlands
Lower South Pond	17 locations	Sediment	0 - 6"	Grain size, ammonia, nitrate/nitrite, TKN, TOC, total arsenic, benzene, chromium, lead	Improve understanding of contaminants associated with WHP, EHP and contiguous wetlands
Lower South Pond	17 locations	Groundwater	screened within the 3 to 4 ft sediment depth interval	Benzene,ammonia, nitrate/nitrite, TKN, total/dissolved arsenic, TSS, TDS, TOC, DOC	Improve understanding of contaminants associated with WHP, EHP and contiguous wetlands

TABLE 3.2.1.1-2
PDI-9A WHP & EHP INVESTIGATION AND ASSESSMENT
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
GW	Dissolved Organic Carbon	EPA 9060/ SOP/07-24	17
SW			17
GW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	17
SED			17
SW			17
GW	Nitrogen, Nitrate (NO_3^-)	SM 4500/ SOP/07-26	17
SED			17
SW			17
GW	Nitrogen, Nitrite (NO_2^-)	SM 4500/ SOP/07-26	17
SED			17
SW			17
GW	Nitrogen, Total Kjeldahl (TKN)	SM 4500 / SOP/07-15	17
SED			17
SW			17
GW	Solids, Total Dissolved	SM 2540 / SOP/07-28	17
SW			17
GW	Solids, Total Suspended	SM 2540 / SOP/07-29	17
SW			17
GW	Total Organic Carbon	EPA 9060 / SOP/07-24/W-028	17
SED			17
SW			17
GW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	17
SW			17
GW	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	17
SW			17
SED		EPA 6010 / SOP/06-01 (EPA 3050A/ SOP/05-07)	17
GW	Benzene	EPA 8260/ SOP/03-03	17
SED			17
SW			17
SED	Grain Size	ASTM D6913 and D422	17
SED	Chromium	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	17
SED	Lead	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	17

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.3.1.2-1
PDI-2 WELLS G&H AND CBCA WETLANDS SEDIMENT DREDGING/EXCAVATION
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Target areas based on accessibility	27	Sediment	0-0.5	Arsenic, *benzo(a)pyrene	Define extent of dredge/excavation area
	27	Sediment	0.5-1.5	Arsenic, *benzo(a)pyrene	Define extent of dredge/excavation area
	27	Sediment	1.5-2.5	Arsenic, *benzo(a)pyrene	Define extent of dredge/excavation area
	27	Sediment	1 ft intervals to bottom of core	Archive, may be analyzed for arsenic, *benzo(a)pyrene	Define extent of dredge/excavation area
Dredge areas	2 locations in Wells G&H	Sediment	up to 2 ft	Water content, grain size Atterberg limits, organic content, Specific gravity, Solidification Agent Testing	Weight Bearing Capacity
	2 locations in CBCA	Sediment	up to 2 ft	Water content, grain size Atterberg limits, organic content, Specific gravity, Solidification Agent Testing	Weight Bearing Capacity
Dredge areas	1 Composite in Wells G&H	Sediment	Up to 2 ft	TCLP Metals, Corrosivity, Reactivity, Ignitability, Paint Filter Test	Waste characterization for disposal
	1 Composite in CBCA	Sediment	Up to 2 ft	TCLP Metals, Corrosivity, Reactivity, Ignitability, Paint Filter Test	Waste characterization for disposal
De-watering Effluent	2 from Wells G&H	Aqueous Effluent	NA	Dissolved Arsenic, Total Arsenic	Evaluate need for effluent treatment
	2 from CBCA	Aqueous Effluent	NA	Dissolved Arsenic, Total Arsenic	Evaluate need for effluent treatment

*Benzo(a)pyrene will only be tested if Arsenic is not in exceedence

TABLE 3.3.1.2-2
PDI-2 WELLS G&H AND CBCA WETLANDS SEDIMENT DREDGING/EXCAVATION
SAMPLING AND ANALYSIS METHODS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]	
SW	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	4	
SW	Arsenic, Dissolved	EPA 6010/ SOP/06-01 (EPA 3005A/ SOP/05-05)	4	
SED	Arsenic, Total	EPA 6010/ SOP/06-01 (EPA 3050B/ SOP/05-07)	81	See Note 2.
SED	Benzo(a)pyrene	EPA 8270C / SOP 03-06 (EPA 3540C/3546/SOP/02-04/12)	81	See Note 2,3.
SED	Corrosivity	EPA 9040B/9045C/ SOP/07-11	2	
SED	Ignitability	EPA 1030 / SOP/07-60	2	
SED	Paint Filter Test	EPA 9095A / SOP/07-70	2	
SED	Reactivity	EPA 7.3 / SOP/07-37	2	
SED	TCLP Metals	EPA 1311	2	
SED	Water Content	ASTM D2216	4	
SED	Solidification Agent Testing	Procedures in FSP PDI-1 Text	4	
SED	Grain Size	ASTM D6913 and D422	4	
SED	Atterberg Limits	ASTM D4318	4	
SED	Loss on Ignition	ASTM D2974/ GLP 121	4	
SED	Specific Gravity	ASTM D859	4	

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.
[2]Additional archived samples may be analyzed based on analytical results.
[3]Prior to sample preparation for BaP analysis, soil and sediment samples will be inspected.
Samples exhibiting greater than 50% moisture content or the presence of artifacts (concrete or metal fragments/shavings) and/or high petroleum product content (i.e tar or oil impacted soils) be prepared using SOP/02-04 (soxhlet extraction).

TABLE 3.4.1.1-1
PDI-12A SOIL IC DELINEATION
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
Seven properties, borings at North, South, East & West of property[1]	Approximately 40 locations TBD in the field	Soil	0-3 ft	Total Arsenic	Determine limits of contamination specified for Institutional Controls
		Soil	3-15 ft	Total Arsenic	

[1] - Each boring will not exceed 15'.

TABLE 3.4.1.1-2
PDI-12A SOIL IC DELINEATOIN
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
SOIL	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3050B/ SOP/05-07)	80

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.

TABLE 3.4.1.2-1
PDI-12B GROUNDWATER INSTITUTIONAL CONTROL DELINEATION
SAMPLING SUMMARY
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

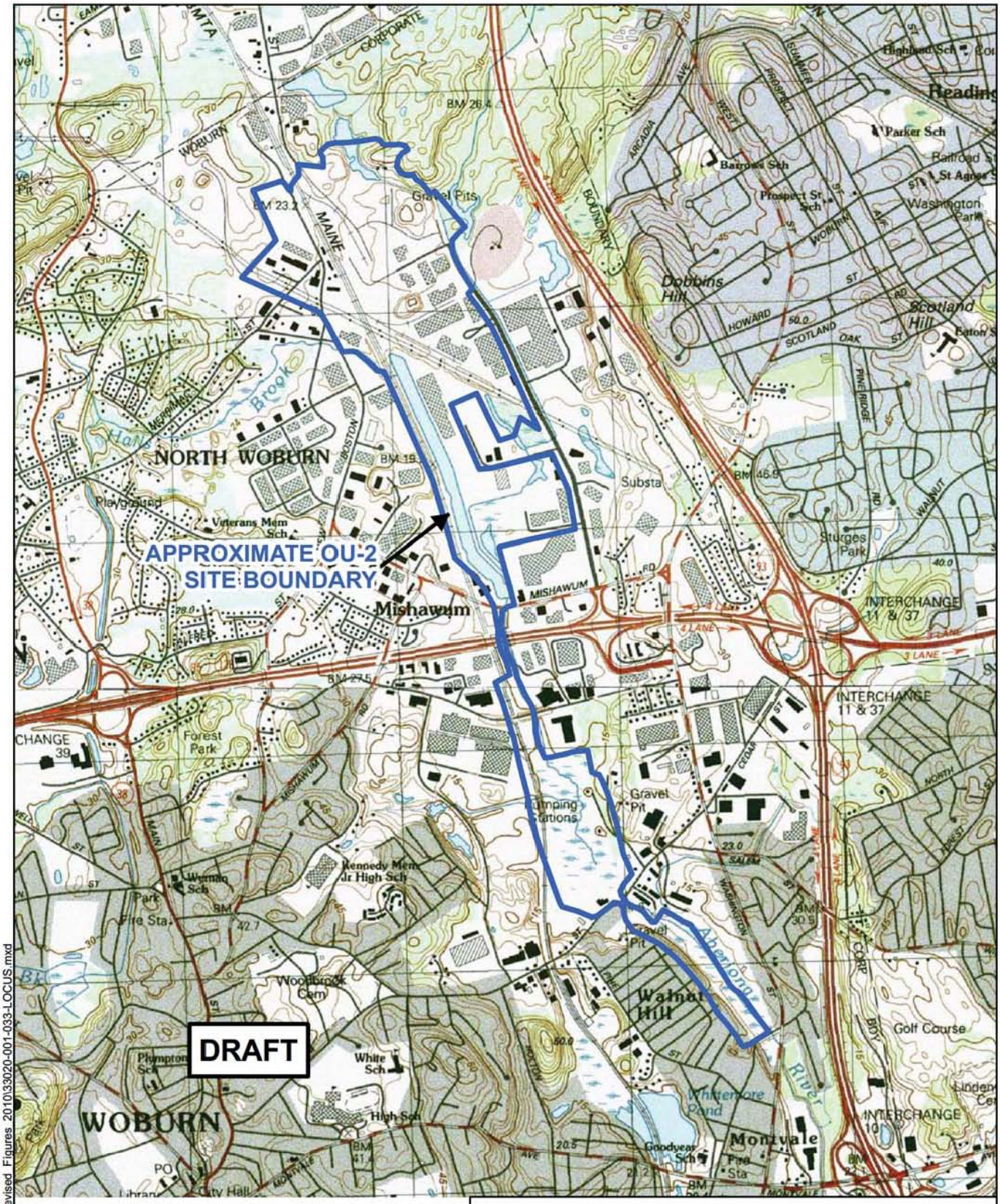
Sampling Location	Sample Location ID Number	Medium/Matrix	Depth (units)	Analytical Parameter	Site Location Rationale
15 Groundwater Profiling Locations along interpreted extent of contamination plume per ROD	15 locations	Groundwater	5-10 ft BGS	dissolved arsenic, total arsenic, ammonia, benzene, trichloroethylene, 1,2-dichloroethane, naphthalene	Determine limits of contamination specified for Institutional Controls
15 Groundwater Profiling Locations along interpreted extent of contamination plume per ROD	15 locations	Groundwater	15-20 ft BGS	dissolved arsenic, total arsenic, ammonia, benzene, trichloroethylene, 1,2-dichloroethane, naphthalene	Determine limits of contamination specified for Institutional Controls
15 Groundwater Profiling Locations along interpreted extent of contamination plume per ROD	15 locations	Groundwater	25-30 ft BGS	dissolved arsenic, total arsenic, ammonia, benzene, trichloroethylene, 1,2-dichloroethane, naphthalene	Determine limits of contamination specified for Institutional Controls

TABLE 3.4.1.2-2
PDI-12B GROUNDWATER INSTITUTIONAL CONTROL DELINEATION
SAMPLING AND ANALYSIS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

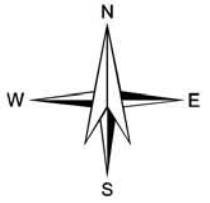
DRAFT

Matrix	Parameter	Analytical Method/ SOP Reference	No. of Samples[1]
GW	Nitrogen, Ammonia (NH_3)	SM 4500/ SOP/07-14	45
GW	Arsenic, Total	EPA 6010 / SOP/06-01 (EPA 3005A/ SOP/05-05)	45
GW	Arsenic, Dissolved		45
GW	VOCs including Benzene and/or 1,2-DCA, TCE, Naphthalene	EPA 8260/ SOP/03-03	45

[1]Total does not include field duplicate samples, which shall be collected at a frequency of 1 per event or every 20 samples.



SITE COORDINATES: 42°30'21"N 71°8'12"W



U.S.G.S. QUADRANGLE: WILMINGTON, MA

HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

LOCUS

SCALE: 1:24,000
MARCH 2011

FIGURE 1-1

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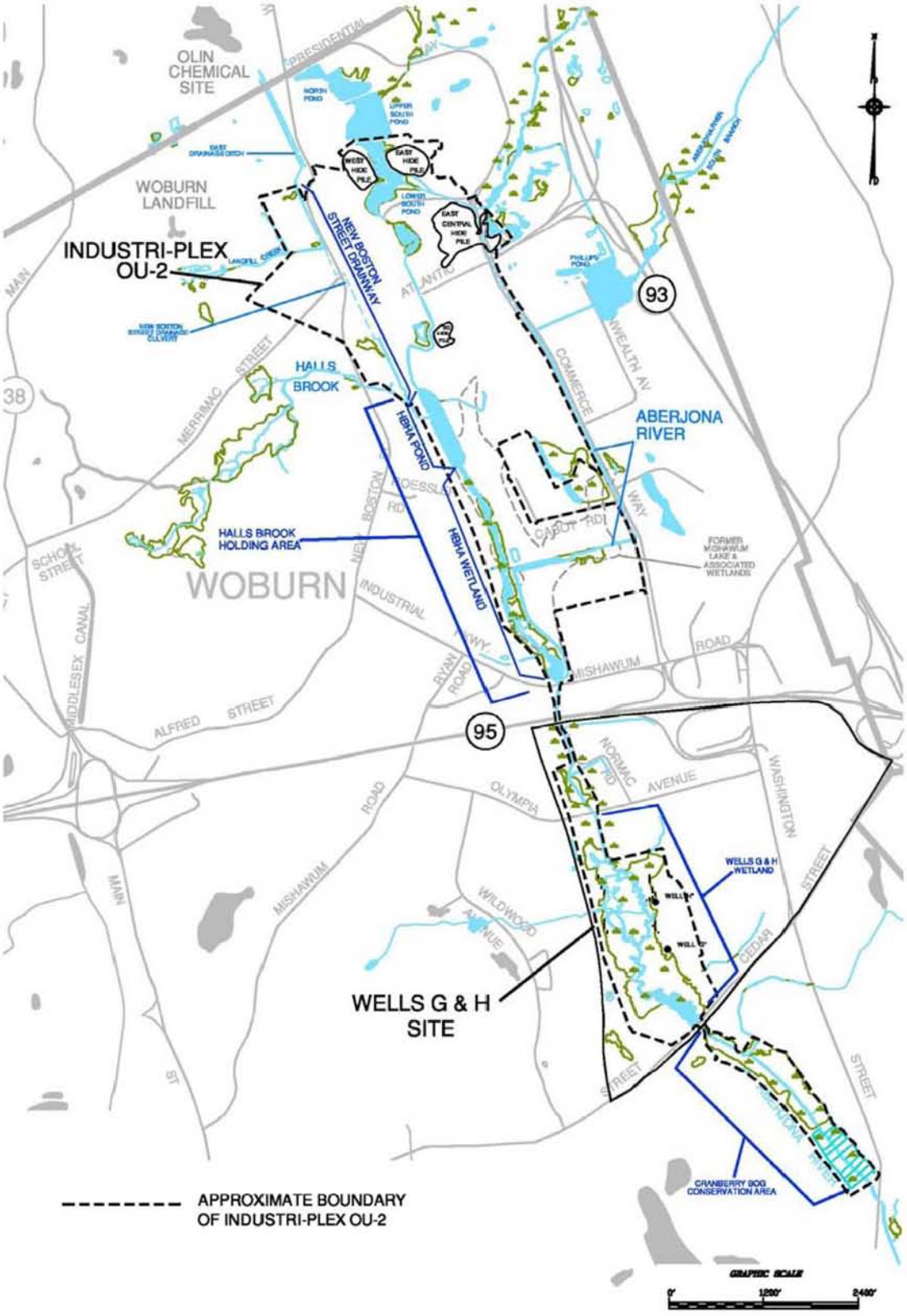

Source: Figure A-3 from the SOW

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

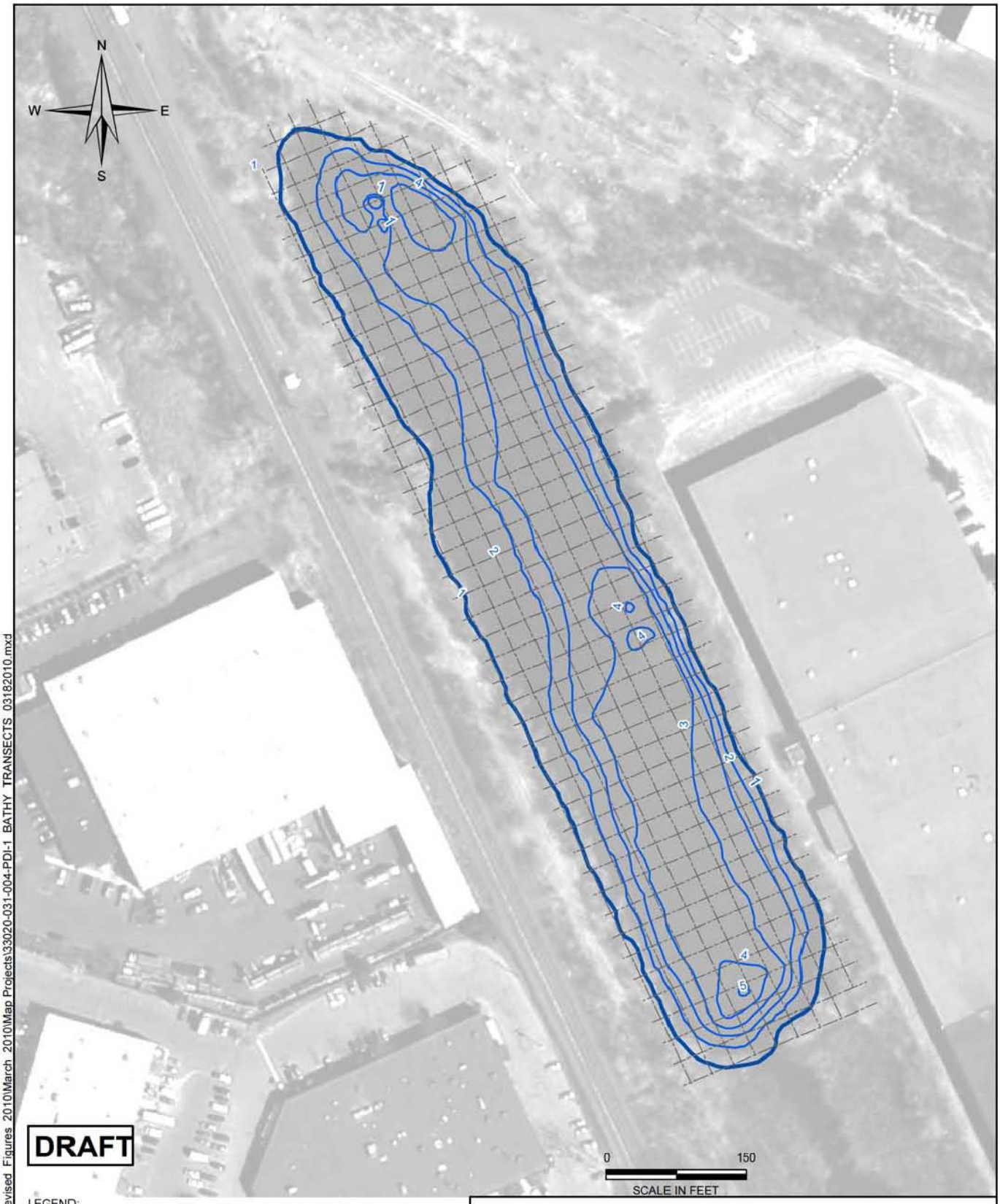
INDUSTRI-PLEX OU2 SITE PLAN

SCALE: NONE
MARCH 2011

FIGURE 1.1-1

DRAFT

G:\33020\030\RDWP\03022011 Figures\Figure ES-1 2010-0316-HAI-OU2SITEPLAN-D.vsd



LEGEND:

25 FT TRANSECTS

EDGE OF WATER

BATHYMETRY (METERS)

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004)

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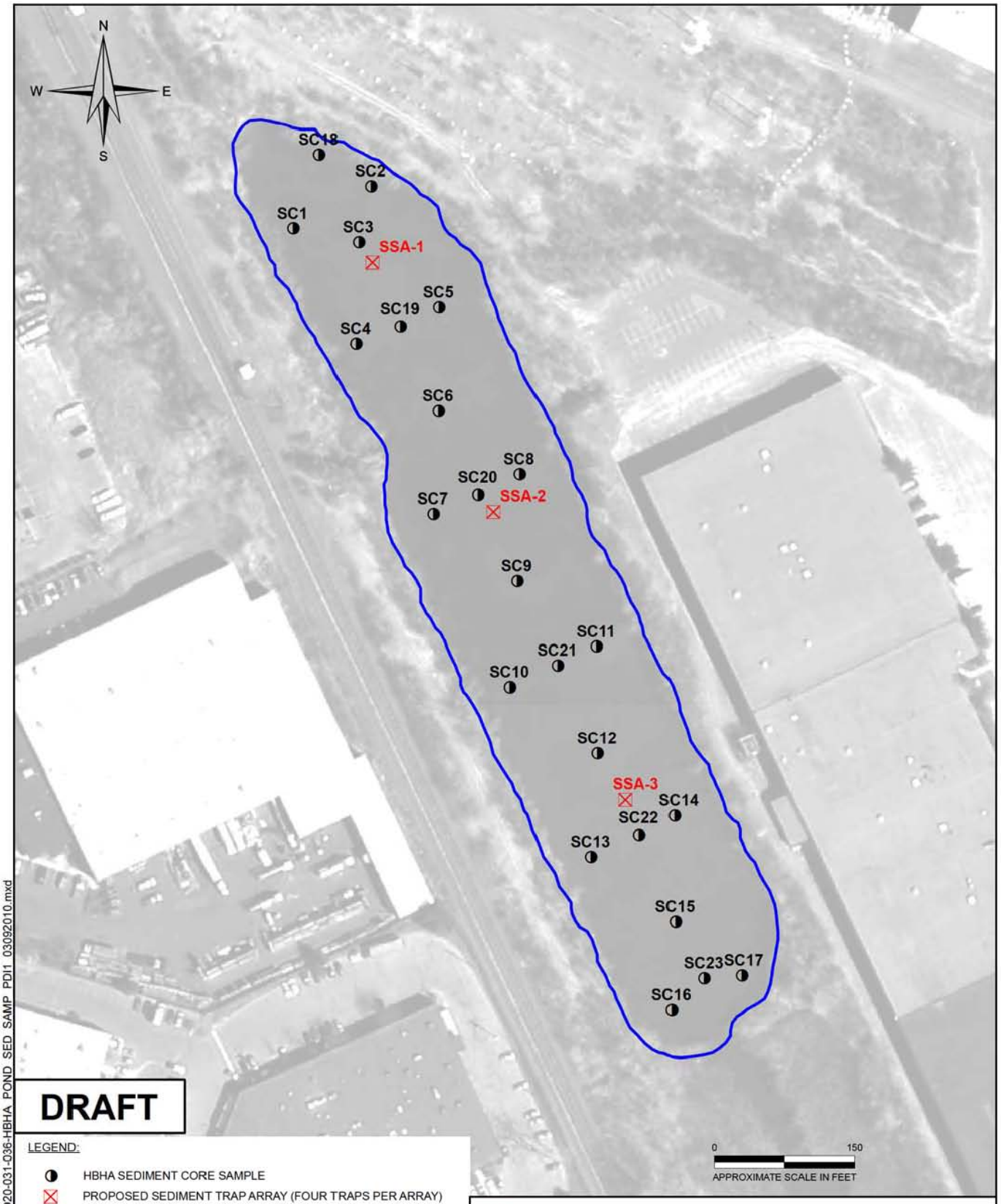
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-1 BATHYMETRY TRANSECTS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.1.1-1

G:\33020\GLOBAL\GIS\MapProjects\Revised Figures 2010\March 2010\Map Projects\33020-031-004-PDI-1 BATHY TRANSECTS 03182010.mxd



DRAFT

LEGEND:

- HBHA SEDIMENT CORE SAMPLE
- PROPOSED SEDIMENT TRAP ARRAY (FOUR TRAPS PER ARRAY)

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. LOCATIONS OF SEDIMENT TRAP ARRAYS CONSIDERED APPROXIMATE. TRAPS WILL BE INSTALLED WHERE THE SOF LAYER THICKNESS IS GREATEST, BASED ON PROBING CONDUCTED AS PART OF PDI-1.

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-1 PROPOSED HBHA POND DREDGING DELINEATION SAMPLE LOCATIONS

SCALE: AS SHOWN
MARCH 2011

3.1.1.1-2

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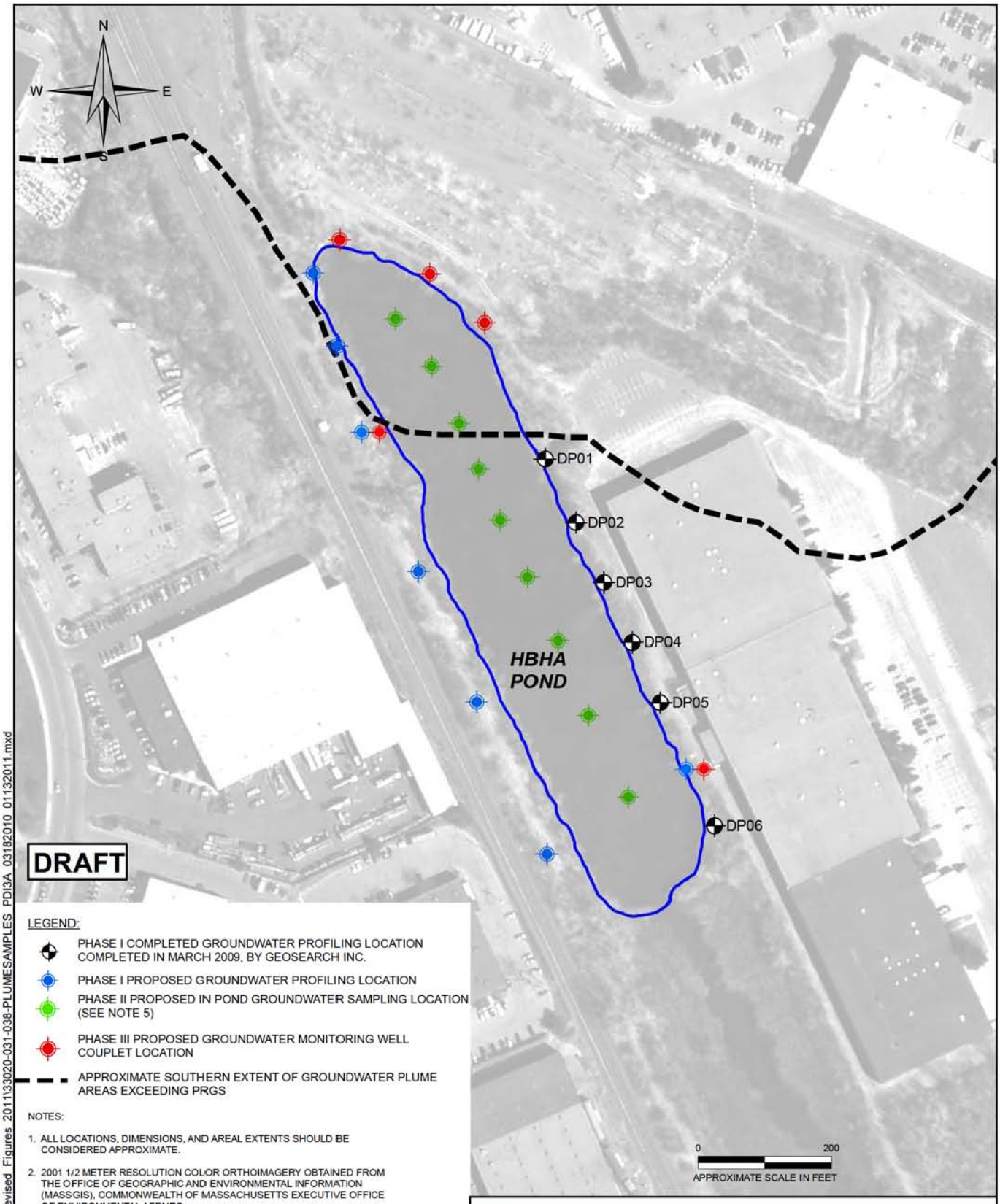

LEGEND:

- PHASE I COMPLETED GROUNDWATER PROFILING LOCATION COMPLETED IN MARCH 2009, BY GEOSEARCH INC.
- PHASE I PROPOSED GROUNDWATER PROFILING LOCATION
- PHASE II PROPOSED IN POND GROUNDWATER SAMPLING LOCATION (SEE NOTE 5)
- PHASE III PROPOSED GROUNDWATER MONITORING WELL COUPLET LOCATION
- APPROXIMATE SOUTHERN EXTENT OF GROUNDWATER PLUME AREAS EXCEEDING PRGS

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. GROUNDWATER PLUME EXTENT DERIVED AND PRESENTED AS A COMPOSITE OF MULTIPLE PARAMETERS SHOWN ON FIGURE BY TETRA TECH NUS, INC., GROUNDWATER PLUME AREAS EXCEEDING PRGS, INDUSTRI-PLEX SITE, WOBURN, MASSACHUSETTS.
4. ACTUAL NUMBER OF MONITORING WELL COUPLETS WILL BE DETERMINED BASED ON PHASE I & II RESULTS.
5. AT THE PHASE II PROPOSED IN-POND GROUNDWATER SAMPLING LOCATIONS, VERTICAL GRADIENT INFORMATION WILL ALSO BE COLLECTED DURING INSTALLATION. FOUR TEMPORARY PIEZOMETERS WILL BE LEFT IN PLACE FOR ADDITIONAL MONITORING OF VERTICAL GRADIENTS. THE LOCATIONS OF THESE TEMPORARY PIEZOMETERS WILL BE DETERMINED BASED ON INITIAL FIELD DATA COLLECTED DURING PHASE I AND PHASE II.

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REMEDIAL DESIGN
INDUSTRI-PLEX SUPERFUND SITE OPERABLE UNIT NO. 2
WOBURN, MASSACHUSETTS

PDI-3A GROUNDWATER PLUME DISCHARGE AREA DELINEATION

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.2.1-1

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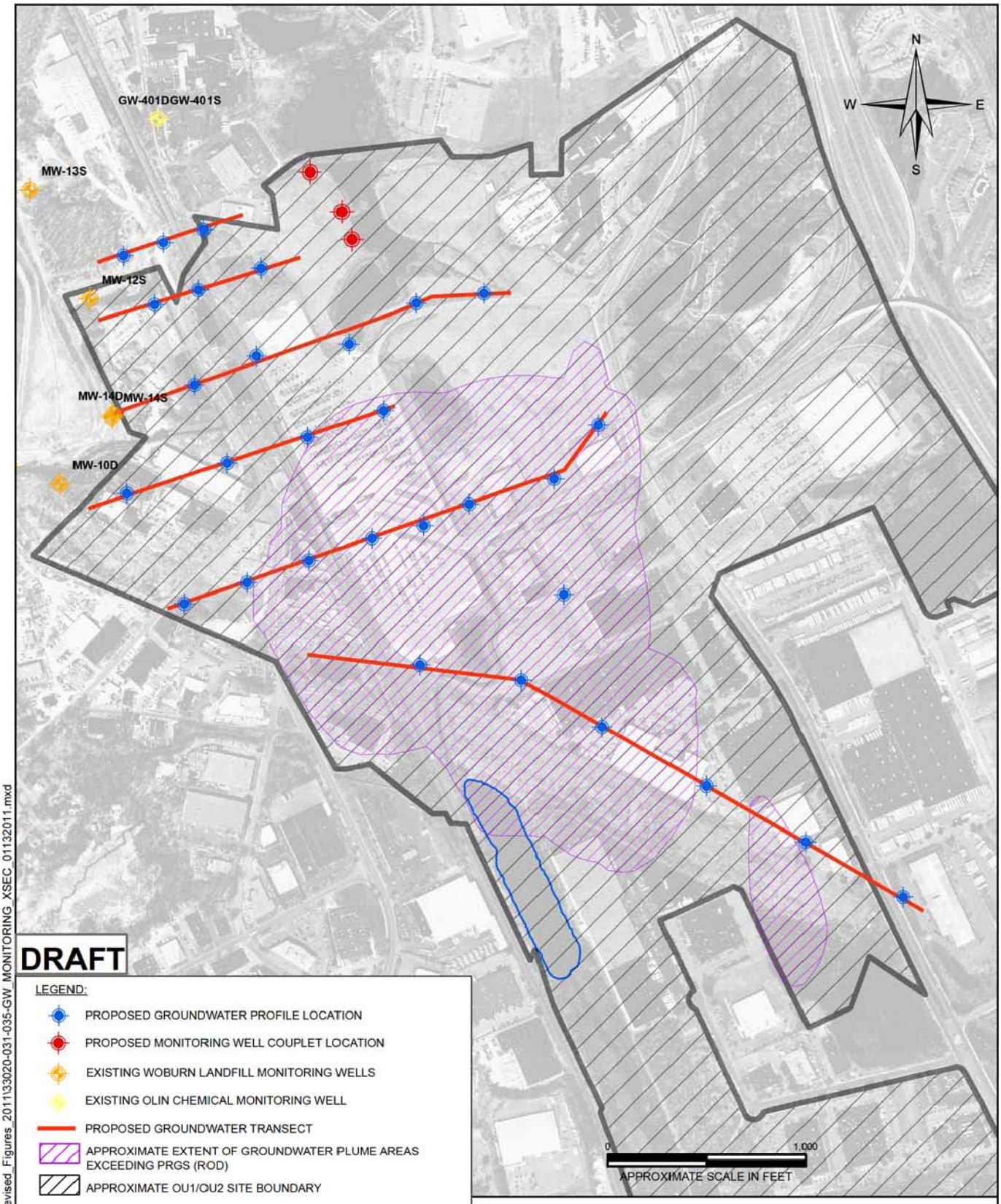

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LEGEND:

- PROPOSED GROUNDWATER PROFILE LOCATION
- PROPOSED MONITORING WELL COUPLET LOCATION
- EXISTING WOBURN LANDFILL MONITORING WELLS
- EXISTING OLIN CHEMICAL MONITORING WELL
- PROPOSED GROUNDWATER TRANSECT
- APPROXIMATE EXTENT OF GROUNDWATER PLUME AREAS EXCEEDING PRGS (ROD)
- APPROXIMATE OU1/OU2 SITE BOUNDARY

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2008 30 CENTIMETER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS),COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. EXISTING MONITORING WELL LOCATIONS PROVIDED BY DDMS ON 11 FEB 2010.
4. LOCATION OF PERMANENT WELLS WILL BE IDENTIFIED FOLLOWING THE EVALUATION OF THE PRE- AND POST-ROD DATA.

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-3B PROPOSED GROUNDWATER SAMPLING TRANSECTS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.2.2-1

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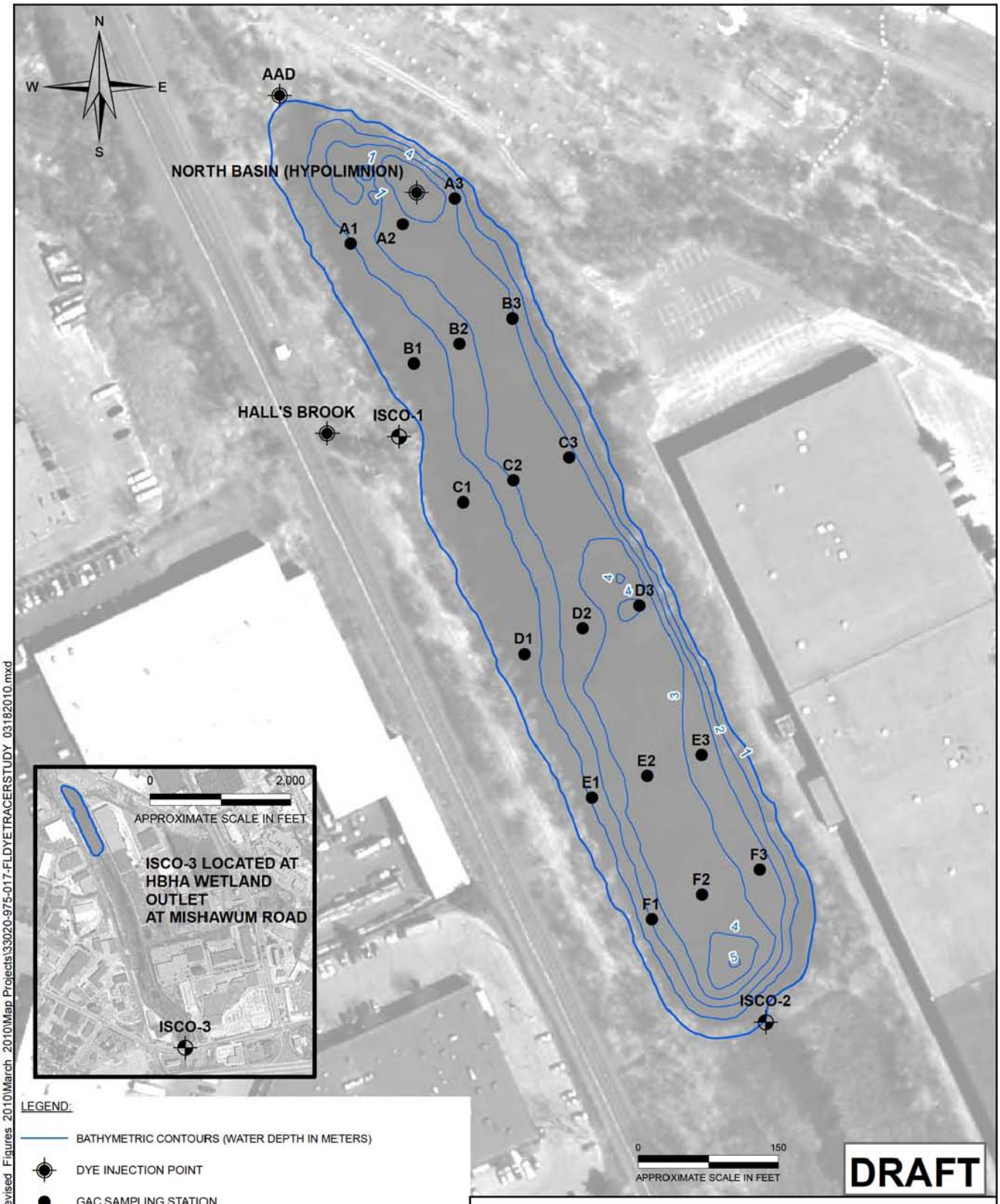

LEGEND:

- BATHYMETRIC CONTOURS (WATER DEPTH IN METERS)
- DYE INJECTION POINT
- GAC SAMPLING STATION
- ISCO SAMPLING STATION

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004).

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INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-4A ESTIMATING RESIDENCE TIMES

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.3.1-1

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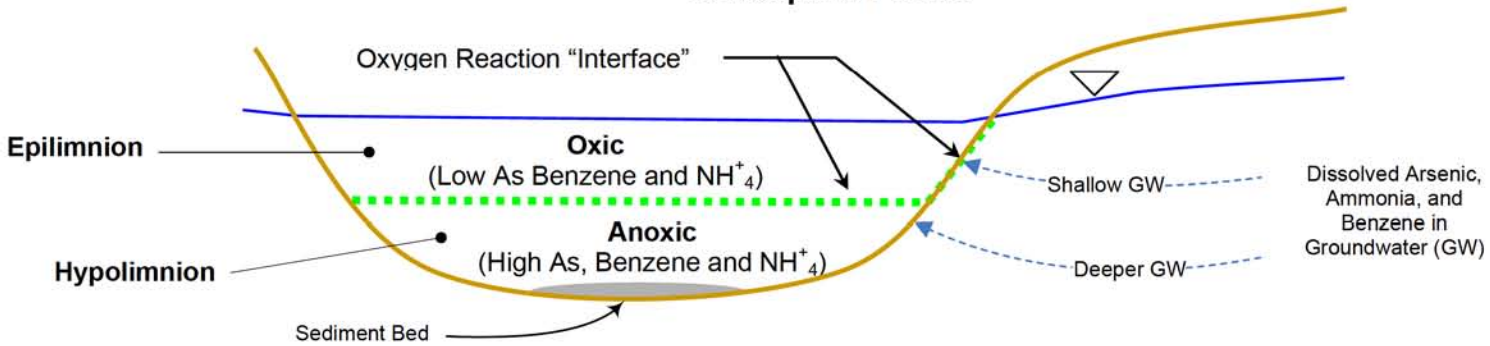
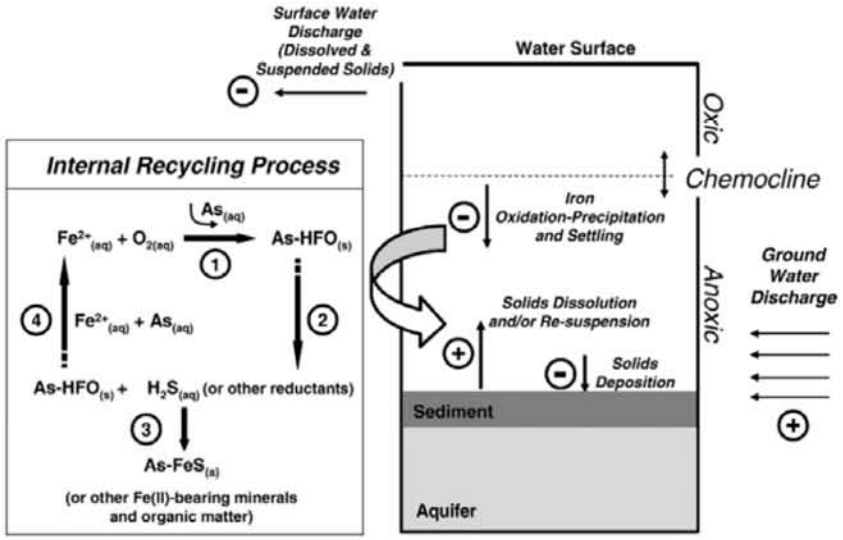
Conceptual Profile



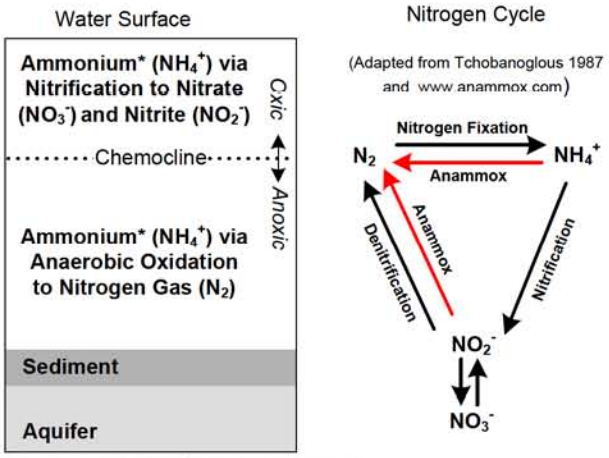
Conceptual Diagrams of Fate and Transformation Scenarios

Arsenic



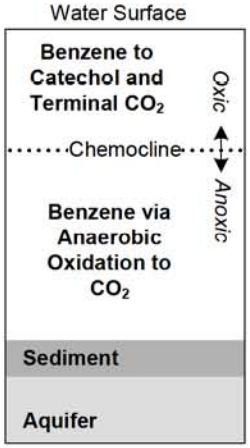
From Ford (2005)

Ammonia



* Ammonium (NH_4^+) likely to be the dominate species present at pH of HBHA Pond

Benzene



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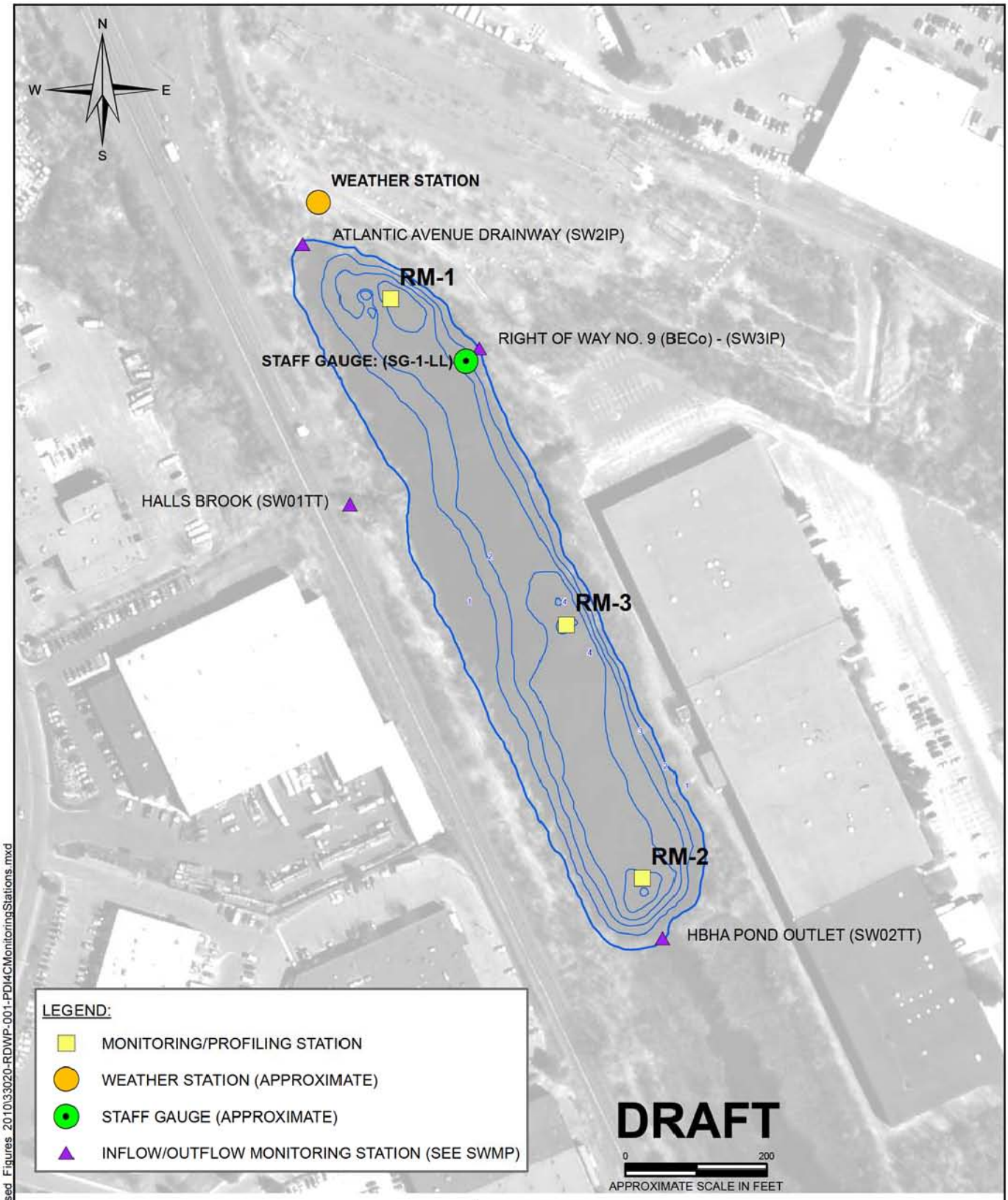
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

CONCEPTUAL PROFILE, FATE AND TRANSFORMATION PATHWAY DIAGRAMS

DRAFT

SCALE: NONE
MARCH 2011

FIGURE 3.1.3.2-1



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NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004)

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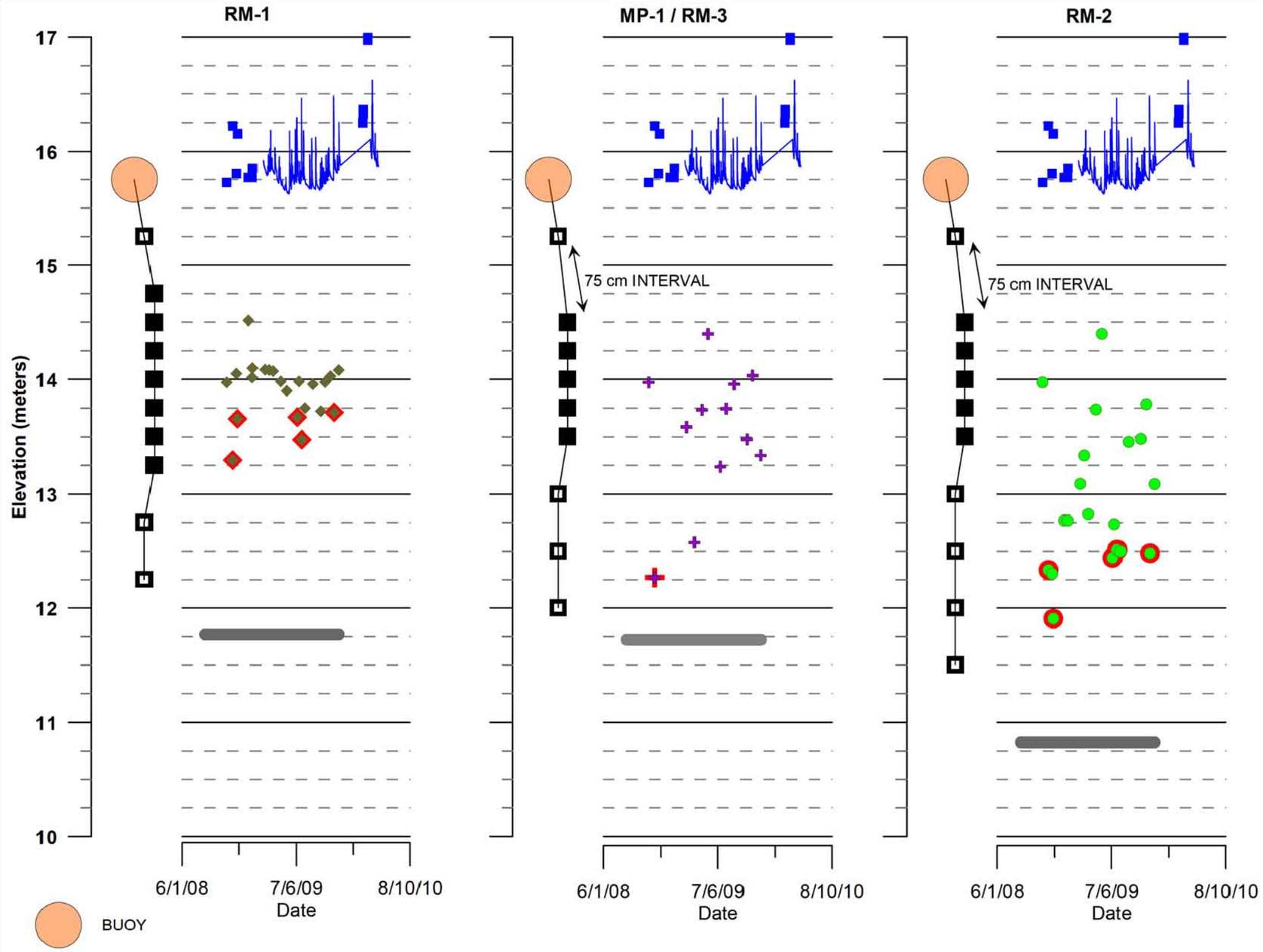
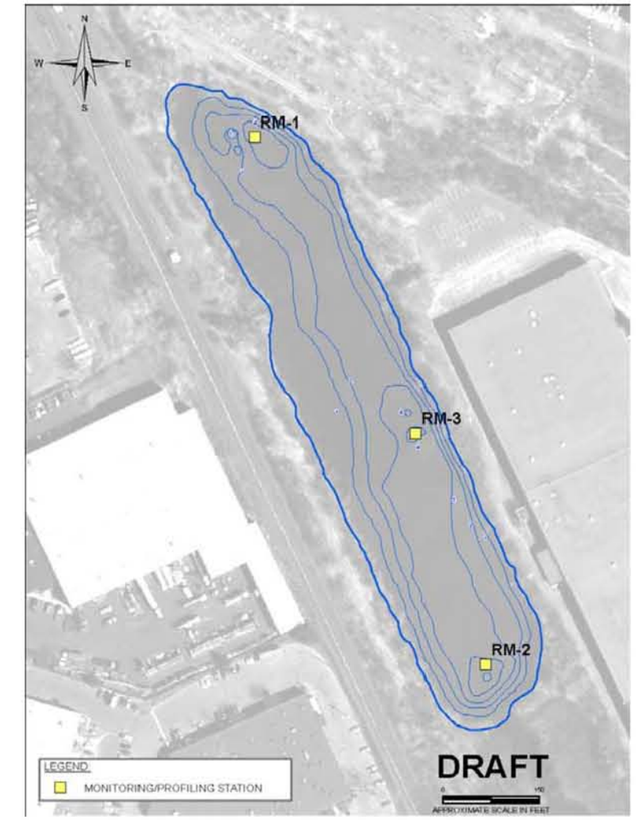
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-4C MONITORING STATIONS AND RELATED LOCATIONS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.3.3-1





LEGEND

- Discrete Water Level Surface Est (See Note 2)
- Time Series Electronic Staff Gauge Reading at SG-1-LL (See Note 2)
- Rough Est of Pond Bottom at Location (See Note 3)
- Rough Est of Chemocline at RM-2
- Rough Est of Chemocline at MP-1
- Rough Est of Chemocline at RM-1
- STORM EVENT

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND SITE FEATURES SHOULD BE CONSIDERED APPROXIMATE.
2. ALL ELEVATION SHOULD BE CONSIDERED ESTIMATED (** STAFF GAUGE DATUM ELEVATION ESTIMATED AND REMAINS TO BE SURVEYED).
3. TOTAL DEPTH ESTIMATE BASED ON MAXIMUM TOTAL DEPTH FIELD MEASUREMENT DURING SERIES OF PROFILING EVENTS.

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-4C CTD SENSOR STATION CONFIGURATION

SCALE: NONE
MARCH 2011

FIGURE 3.1.3.3-2

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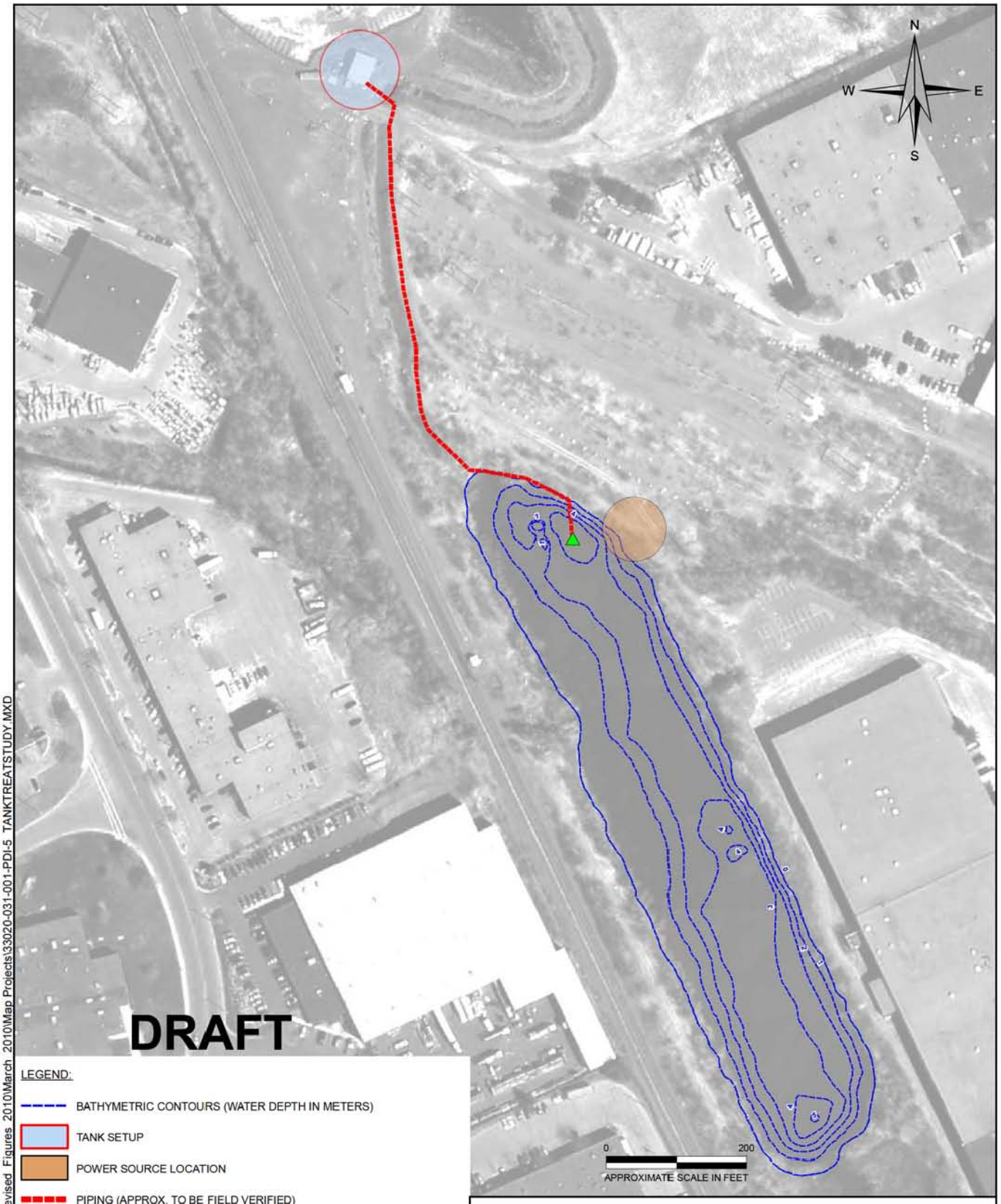

LEGEND:

- BATHYMETRIC CONTOURS (WATER DEPTH IN METERS)
- TANK SETUP
- POWER SOURCE LOCATION
- PIPING (APPROX, TO BE FIELD VERIFIED)
- WATER INTAKE LOCATION

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004).

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-5 TANK TREATABILITY STUDIES
LAYOUT PLAN

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.4.1-1

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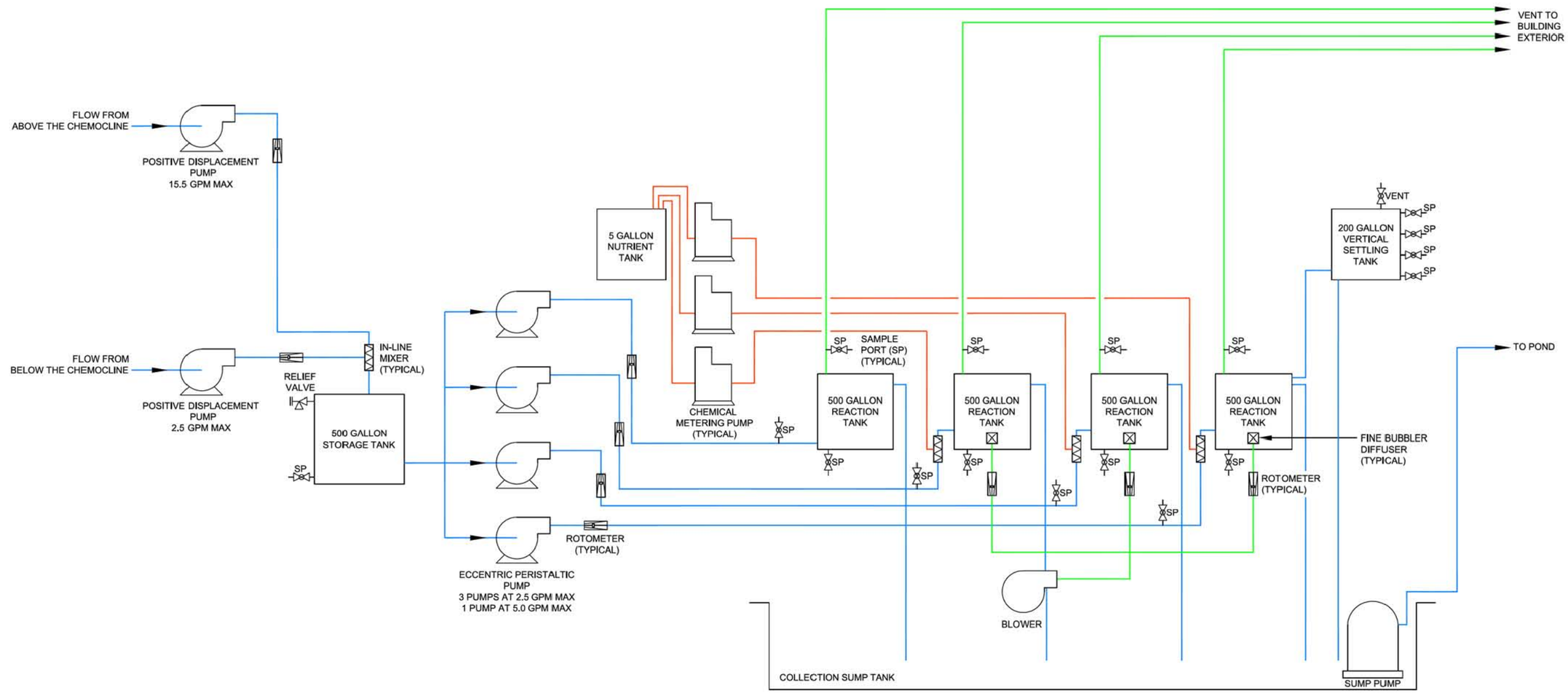

LEGEND:

- INDICATES WATER LINE
- INDICATES AIR LINE
- INDICATES NUTRIENT FEED LINE

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-5 TANK TREATABILITY STUDIES
PROCESS FLOW DIAGRAM

SCALE: NONE
MARCH 2011

FIGURE 3.1.4.1-2

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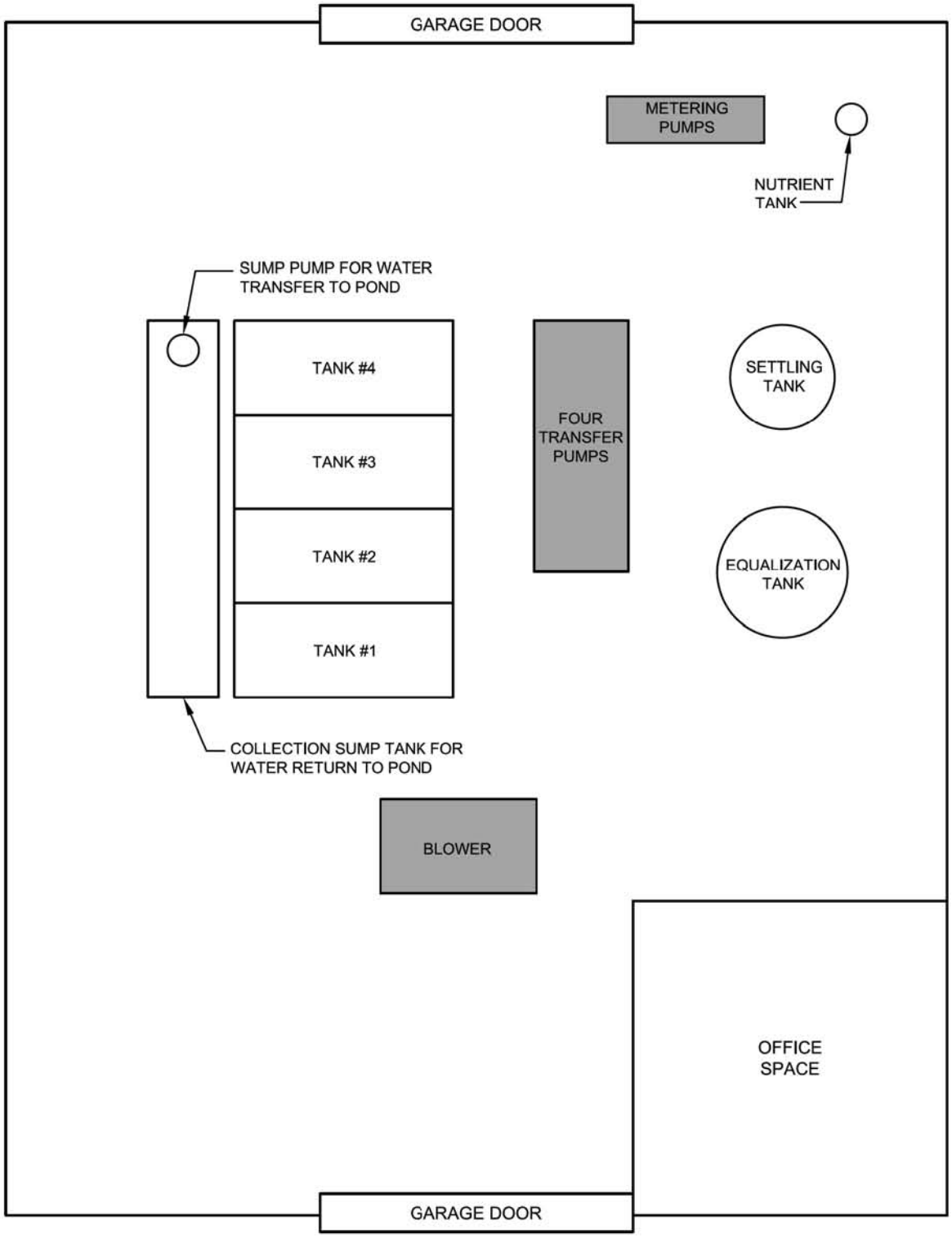

DRAFT

0 2.5 5
SCALE IN FEET

HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-5 BUILDING LAYOUT AND EQUIPMENT SETUP PLAN

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.4.1-3

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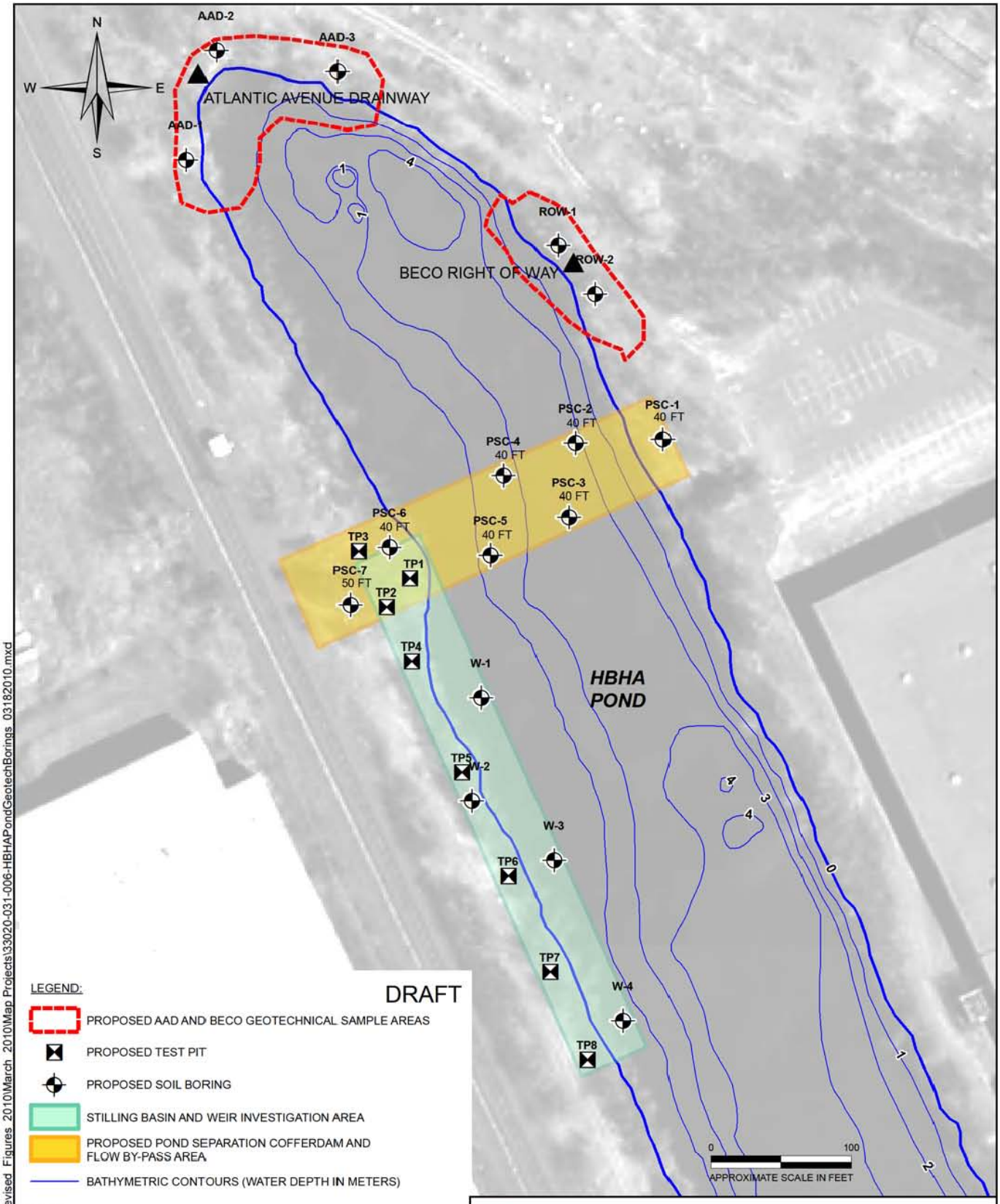

LEGEND:

DRAFT

- PROPOSED AAD AND BECO GEOTECHNICAL SAMPLE AREAS
- PROPOSED TEST PIT
- PROPOSED SOIL BORING
- STILLING BASIN AND WEIR INVESTIGATION AREA
- PROPOSED POND SEPARATION COFFERDAM AND FLOW BY-PASS AREA
- BATHYMETRIC CONTOURS (WATER DEPTH IN METERS)

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. PROPERTY AND EASEMENT BOUNDARIES SHALL BE ESTABLISHED BEFORE WORK.
3. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
4. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004).

HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-6 HBHA POND
GEOTECHNICAL BORINGS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.5.1-1

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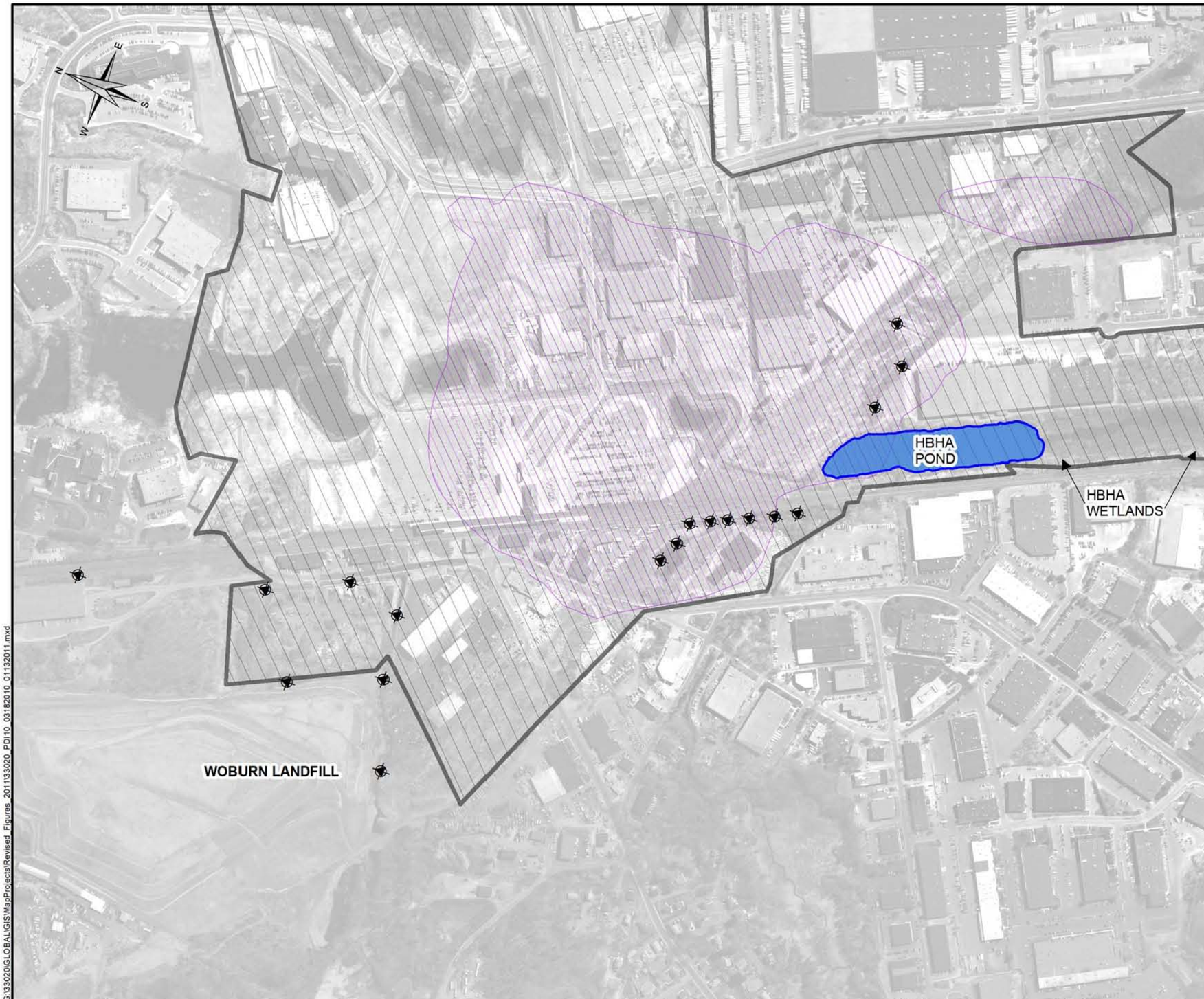

LEGEND:

- PROPOSED TEMPORARY DRIVE POINT PIEZOMETER
- APPROXIMATE OU1/OU2 SITE BOUNDARY
- APPROXIMATE EXTENT OF GROUNDWATER PLUME AREAS EXCEEDING PRGS

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFARIS.
3. GROUNDWATER PLUME EXTENT DERIVED AND PRESENTED AS A COMPOSITE OF MULTIPLE PARAMETERS SHOWN ON FIGURE BY TETRA TECH NUS, INC., GROUNDWATER PLUME AREAS EXCEEDING PRGs, INDUSTRI-PLEX SITE, WOBURN, MASSACHUSETTS.

DRAFT

0 250 500 1000
SCALE IN FEET

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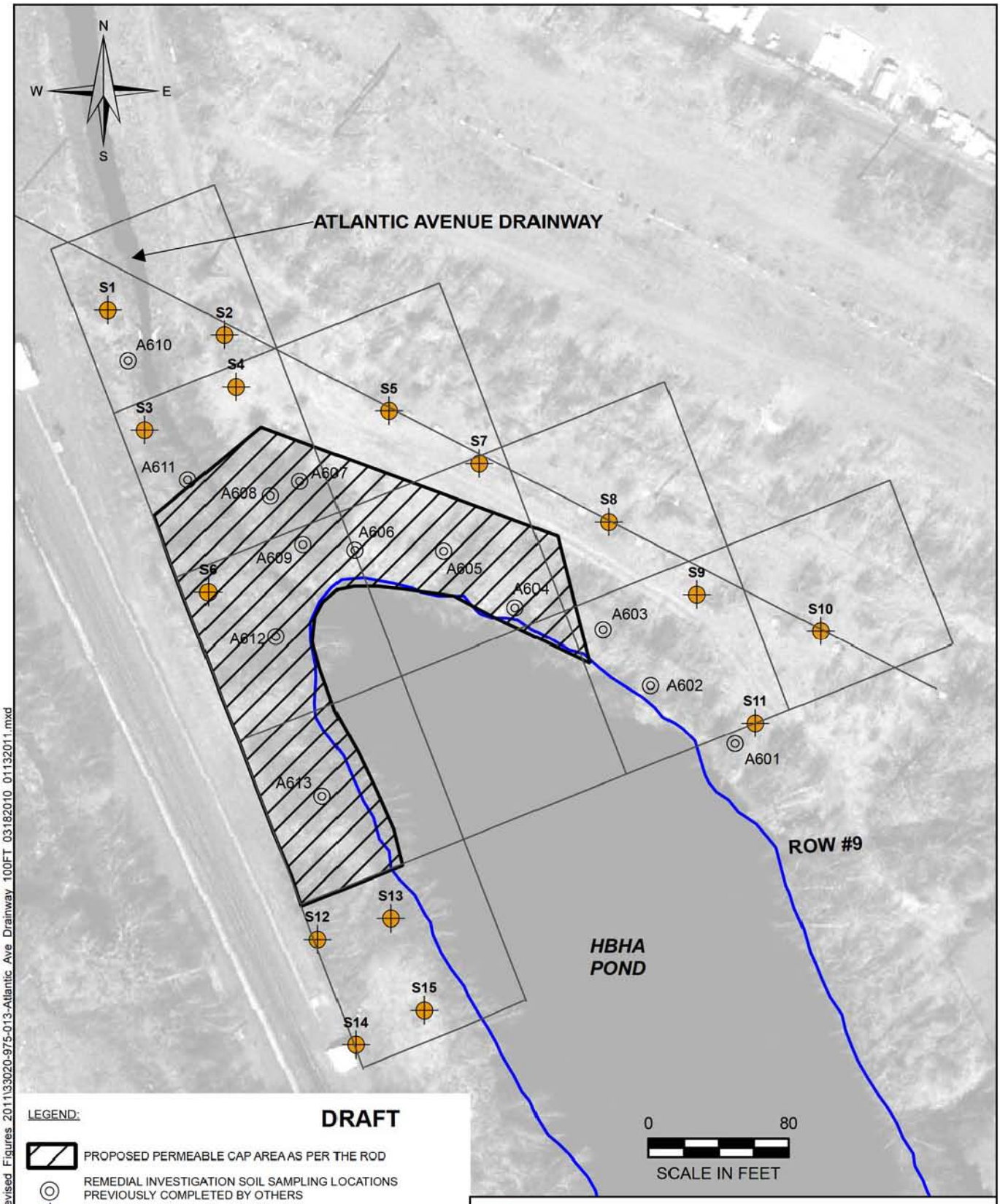
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-10 IMPERMEABLE CAP INVESTIGATIONS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.8.1-1

G:\33020\GLOBAL\GIS\MapProjects\Revised_Figures_2011\33020_PDI10_03182010_01132011.mxd



LEGEND:

DRAFT

PROPOSED PERMEABLE CAP AREA AS PER THE ROD

REMEDIAL INVESTIGATION SOIL SAMPLING LOCATIONS PREVIOUSLY COMPLETED BY OTHERS

PROPOSED SOIL SAMPLING LOCATION

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. PROPERTY AND EASEMENT BOUNDARIES SHALL BE ESTABLISHED BEFORE WORK.
3. 2008 30 CENTIMETER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.

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REMEDIAL DESIGN
INDUSTRI-PLEX OPERABLE UNIT NO. 2
WOBURN, MASSACHUSETTS

PDI-11 PERMEABLE CAP INVESTIGATION

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.9.1-1

G:\33020\GLOBAL\GIS\MapProjects\Revised Figures 2011\33020-975-013-Atlantic Ave Drainway 100FT 03182010 01132011.mxd

LEGEND:

- PROPOSED GROUNDWATER PROFILING LOCATION
- COMPLETED GROUNDWATER PROFILING LOCATION COMPLETED IN MARCH 2009, BY GEOSEARCH INC.
- PROPOSED IN POND GROUNDWATER SAMPLING LOCATION
- PROPOSED GROUNDWATER MONITORING WELL COUPLET LOCATION
- PROPOSED TEMPORARY DRIVE POINT PIEZOMETER AND SURFACE WATER SAMPLING LOCATION
- EXISTING AMMONIA BACKGROUND SURFACE WATER SAMPLING LOCATION
- EXISTING OLIN CHEMICAL SURFACE WATER SAMPLING LOCATION
- EXISTING OLIN CHEMICAL MONITORING WELL LOCATION
- EXISTING WOBURN LANDFILL MONITORING WELL LOCATION
- APPROXIMATE OU1/OU2 SITE BOUNDARY
- APPROXIMATE EXTENT OF GROUNDWATER PLUME AREAS EXCEEDING PRGS (ROD)

NOTES

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFARIS.
3. GROUNDWATER PLUME EXTENT DERIVED AND PRESENTED AS A COMPOSITE OF MULTIPLE PARAMETERS SHOWN ON FIGURE BY TETRA TECH NUS, INC., GROUNDWATER PLUME AREAS EXCEEDING PRGs, INDUSTRI-PLEX SITE, WOBURN, MASSACHUSETTS.
4. ACTUAL NUMBER OF MONITORING WELL COUPLETS WILL BE DETERMINED BASED ON PHASE I & II RESULTS.
5. OLIN CHEMICAL SURFACE WATER SAMPLING AND MONITORING WELL LOCATIONS OBTAINED FROM DDMS, 11 MARCH 2010.
6. WOBURN LANDFILL MONITORING WELL LOCATIONS OBTAINED FROM DDMS, 11 MARCH 2010.

DRAFT

0 300 600 1,200 1,800 2,400 Feet

HALEY & ALDRICH

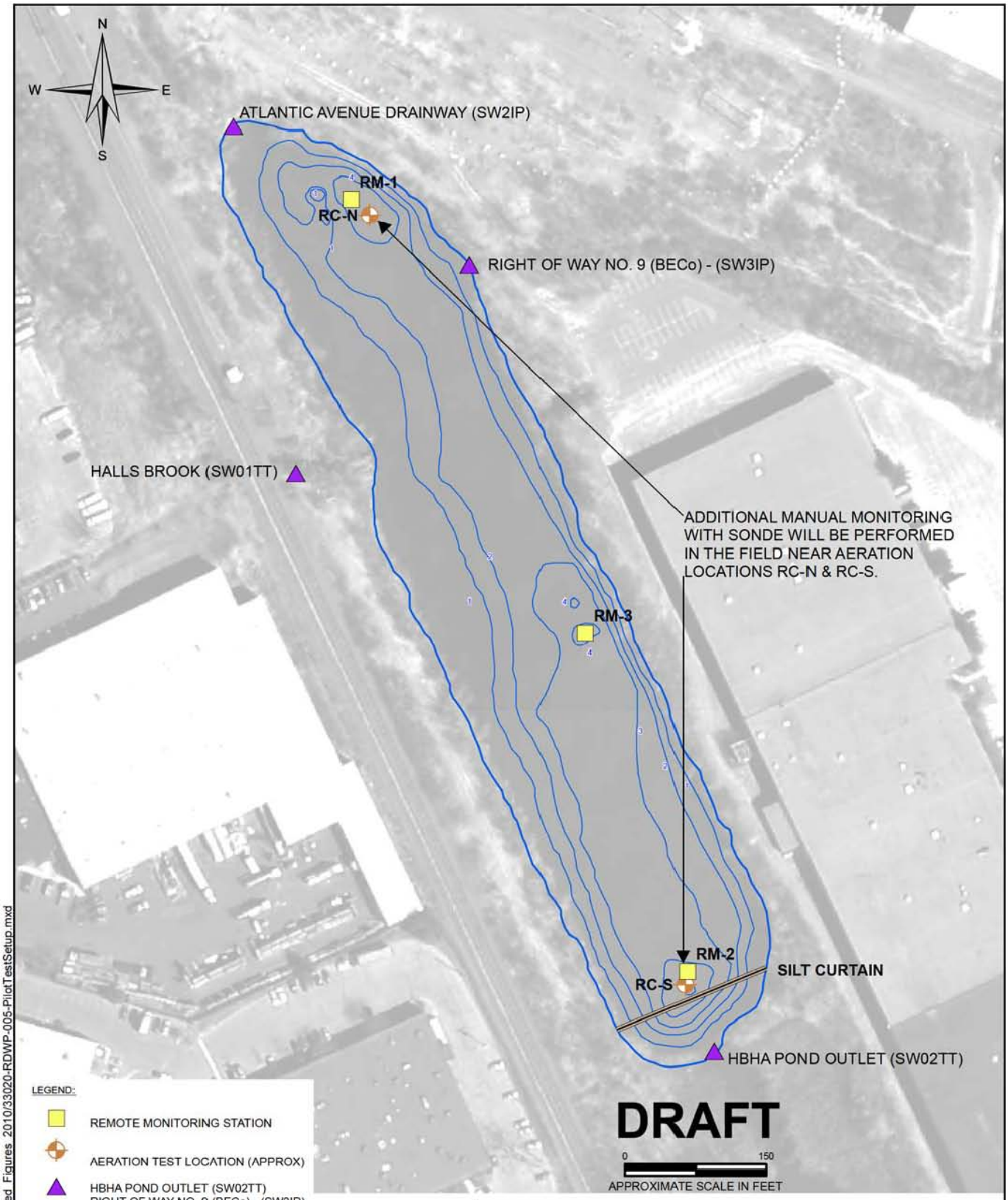
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-14 AMMONIA BACKGROUND SAMPLING LOCATIONS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.11.1-1

G:\33020\GLOBAL\GIS\MapProjects\Revised_Figures_2011\33020_PDI14_03182010_02032011REV2.mxd



LEGEND:

- REMOTE MONITORING STATION
- AERATION TEST LOCATION (APPROX)
- HBHA POND OUTLET (SW02TT)
  RIGHT OF WAY NO. 9 (BECo) - (SW3IP)
  ATLANTIC AVENUE DRAINWAY (SW2IP)
  HALLS BROOK (SW01TT)
- SILT CURTAIN

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004)

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

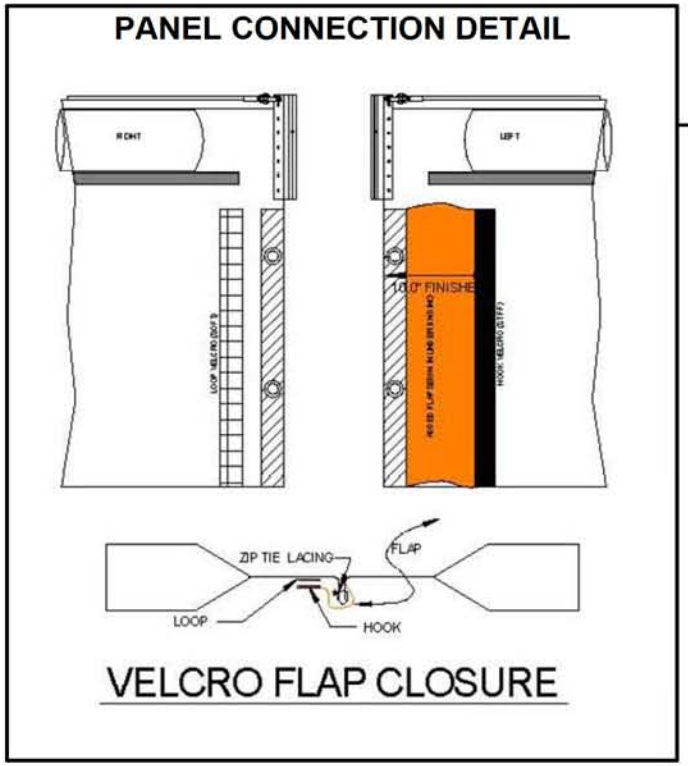
PDI-15 PILOT TEST SETUP PLAN

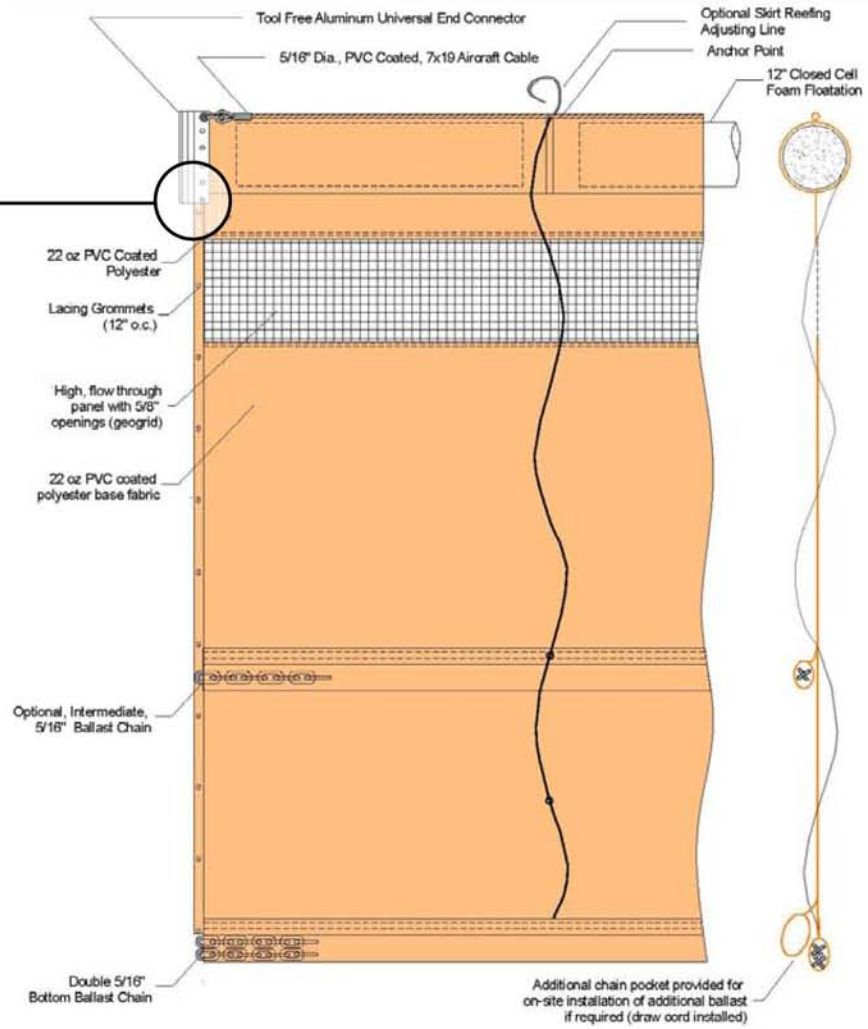
SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.12.4-1

G:/33020/Global/GIS/Map Projects/Revised Figures 2010/33020-RDWP-005-PilotTestSetup.mxd

G:\33020\030\RDWP\03022011 Figures\2010-0312-HAI-RDWP_Curtain_Schematic-D.vsd





NOTES:

1. ADAPTED FROM SCHEMATIC FIGURE PROVIDED BY BROCKTON EQUIPMENT/SPILLDAM, INC. ON 3/10/2010.

2. MINOR ADJUSTMENTS TO BE MADE PRIOR TO FABRICATION OR DURING INSTALLATION BASED ON FIELD CONDITIONS.

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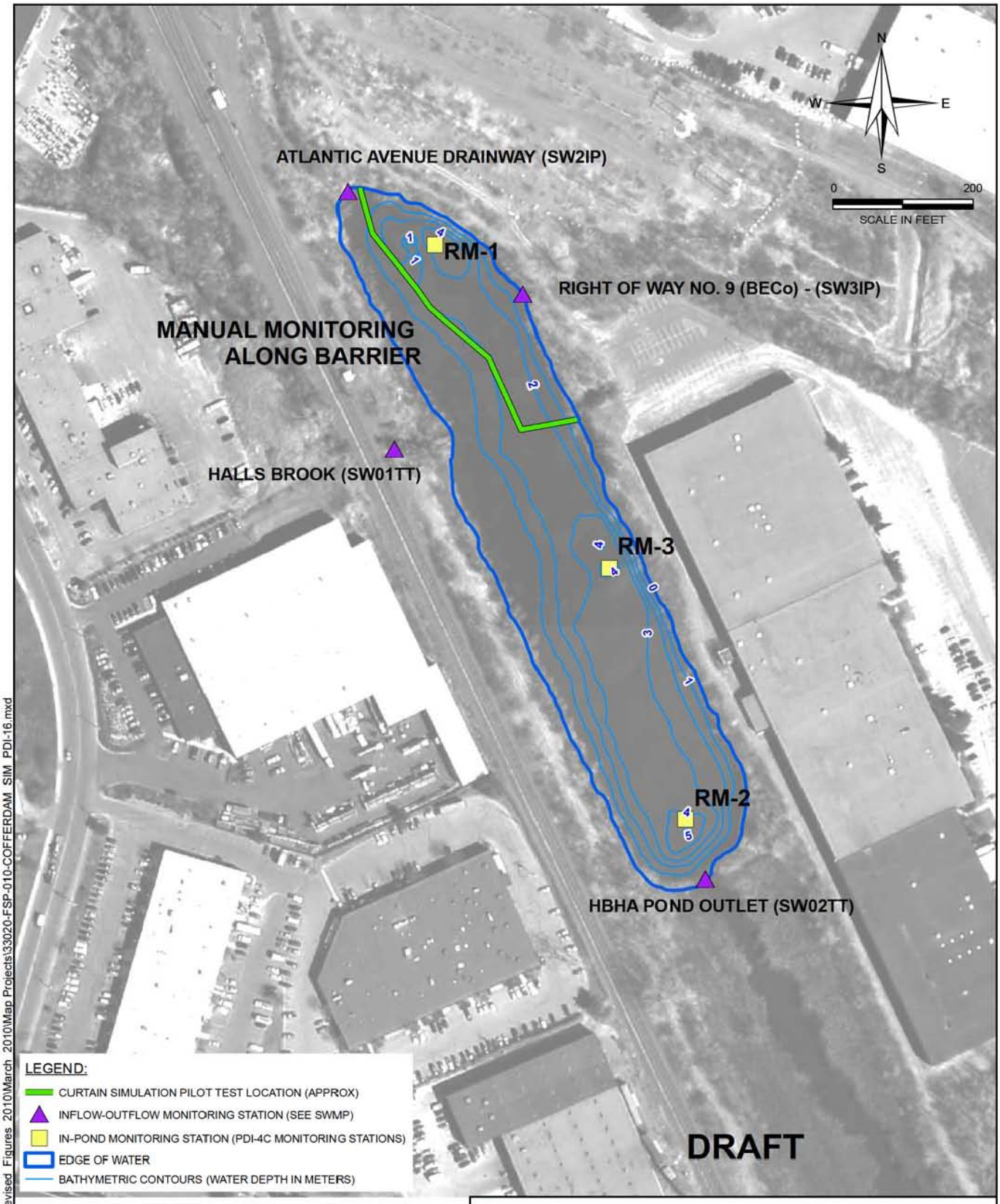
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-16 COFFERDAM SIMULATION
FLEXIBLE CURTAIN SCHEMATIC DETAIL

SCALE: NONE
MARCH 2011

FIGURE 3.1.13.2-1



LEGEND:

- CURTAIN SIMULATION PILOT TEST LOCATION (APPROX)
- INFLOW-OUTFLOW MONITORING STATION (SEE SWMP)
- IN-POND MONITORING STATION (PDI-4C MONITORING STATIONS)
- EDGE OF WATER
- BATHYMETRIC CONTOURS (WATER DEPTH IN METERS)

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. BATHYMETRY TAKEN FROM NATURAL ATTENUATION STUDY (FORD, 2004).

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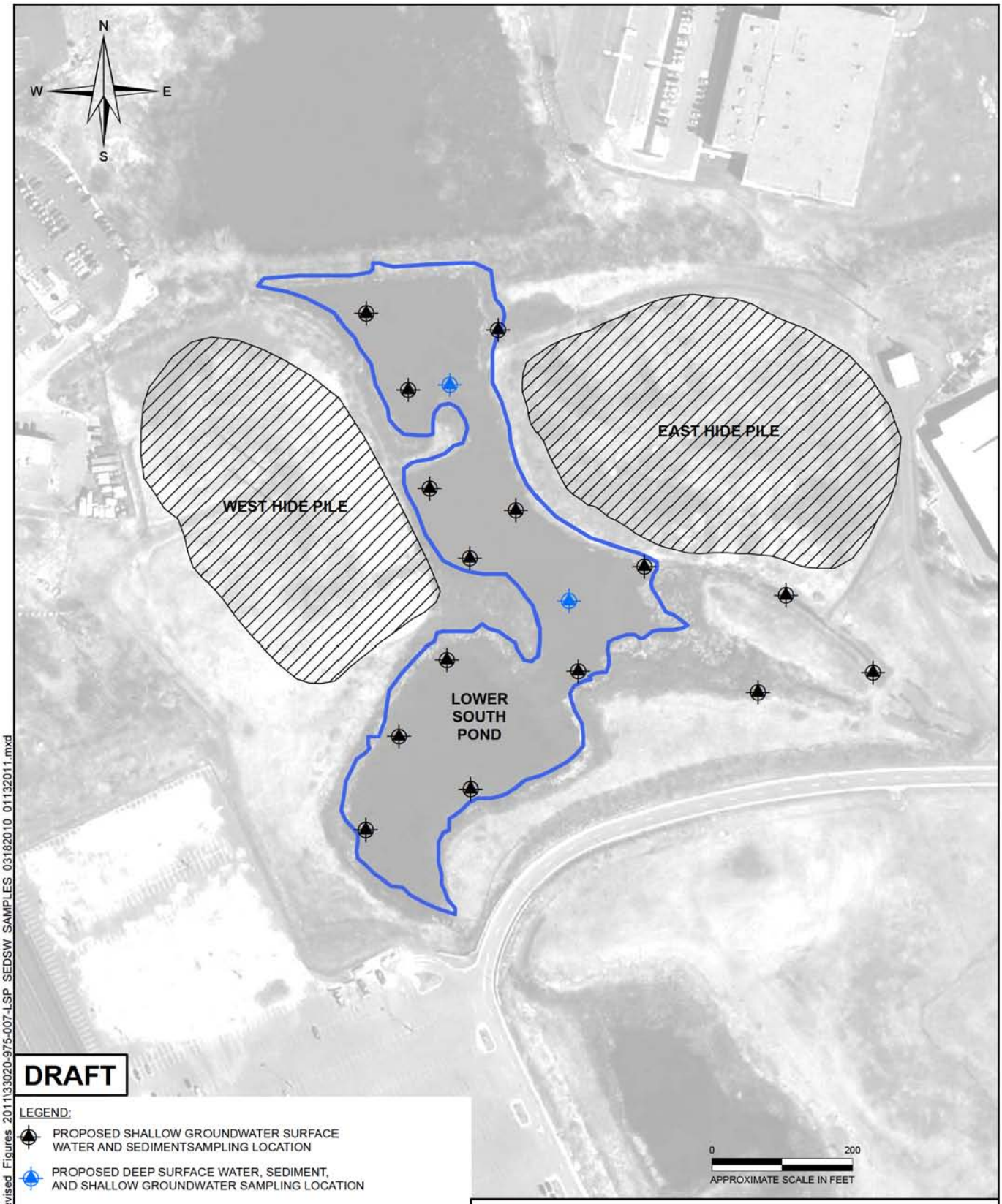
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-16 COFFERDAM
SIMULATION PILOT TEST
LAYOUT PLAN

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.1.13.3-1

G:\33020\GLOBAL\GIS\MapProjects\Revised Figures 2010\March 2010\Map Projects\33020-FSP-010-COFFERDAM SIM PDI-16.mxd



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LEGEND:

- PROPOSED SHALLOW GROUNDWATER SURFACE WATER AND SEDIMENTSAMPLING LOCATION
- PROPOSED DEEP SURFACE WATER, SEDIMENT, AND SHALLOW GROUNDWATER SAMPLING LOCATION

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. WEST HIDE PILE, EAST HIDE PILE, AND LOWER SOUTH POND APPROXIMATED FROM MSGRP REMEDIAL INVESTIGATION REPORT, RI FIGURE 2-5A SURFACE WATER SAMPLE LOCATIONS - REACH 0.

HALEY & ALDRICH

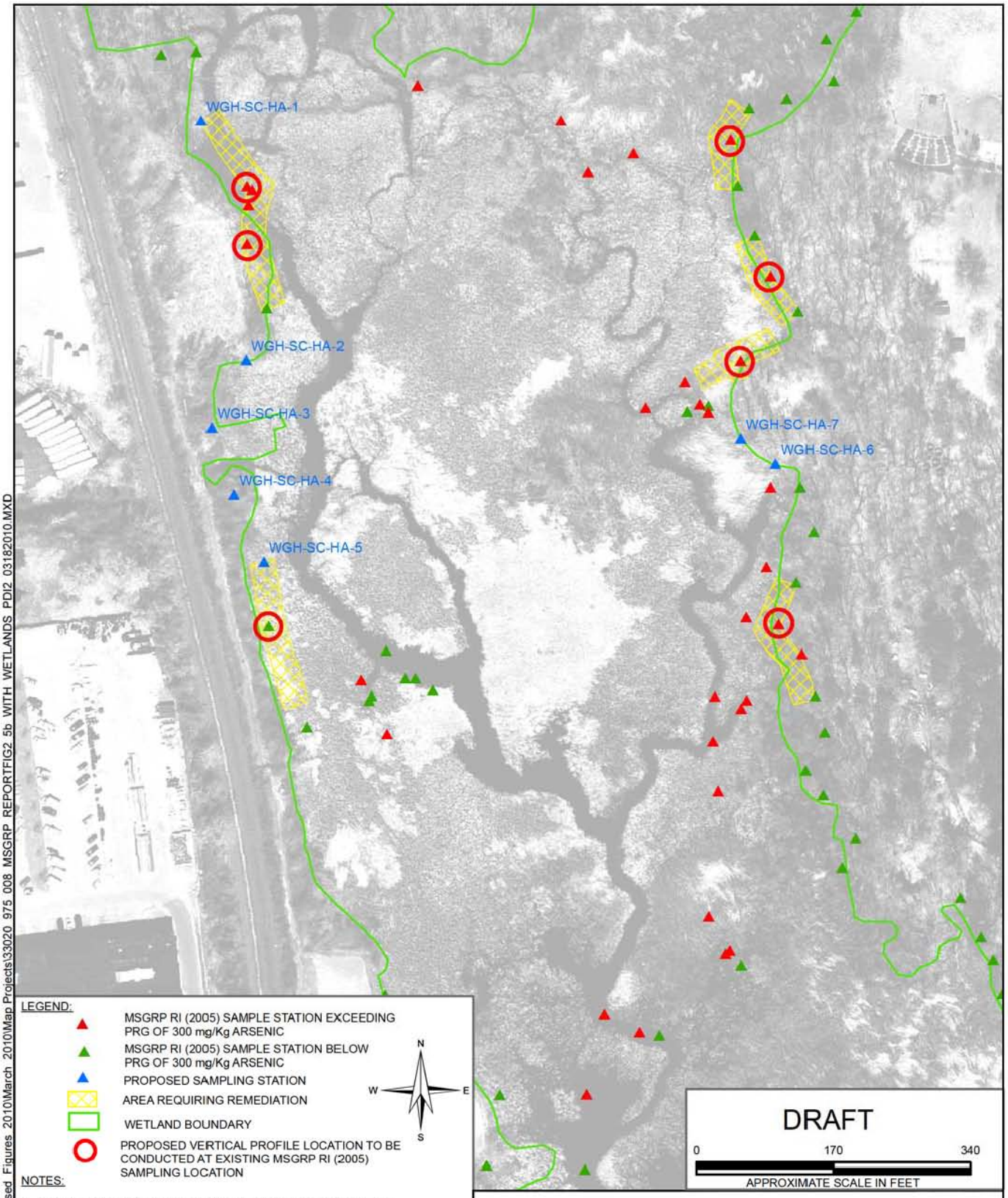
REMEDIAL DESIGN
INDUSTRI-PLEX S SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-9 WEST & EAST HIDE PILE INVESTIGATION

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.2.1.1-1

G:\33020\GLOBAL\GIS\MapProjects\Revised Figures 2011\33020-975-007-LSP SEDSW SAMPLES 03182010 01132011.mxd



LEGEND:

- MSGRP RI (2005) SAMPLE STATION EXCEEDING PRG OF 300 mg/Kg ARSENIC
- MSGRP RI (2005) SAMPLE STATION BELOW PRG OF 300 mg/Kg ARSENIC
- PROPOSED SAMPLING STATION
- AREA REQUIRING REMEDIATION
- WETLAND BOUNDARY
- PROPOSED VERTICAL PROFILE LOCATION TO BE CONDUCTED AT EXISTING MSGRP RI (2005) SAMPLING LOCATION

NOTES:

1. EXISTING LOCATIONS EXPORTED FROM DDMS DATABASE ON 28 JANUARY 2010
2. SEDIMENT SAMPLE LOCATIONS AND WETLAND BOUNDARY SHOWN ON FIGURE 2-7b, "SEDIMENT SAMPLE LOCATIONS-REACH 1 MSGRP REMEDIAL INVESTIGATION REPORT", PREPARED BY TETRA TECH NUS INC. MARCH 2005. WETLAND BOUNDARY DIGITIZED FROM FIGURE.
3. 2008 30 CENTIMETER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MassGIS),COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
4. AREAS REQUIRING REMEDIATION DIGITIZED FROM FIGURE 2-5b "SURFACE SEDIMENT PRG EXCEEDENCE-ARSENIC-REACH 1, MSGRP FEASABILITY", PREPARED BY TETRA TECH NUS INC. DATED 22 APRIL 2005

HALEY & ALDRICH

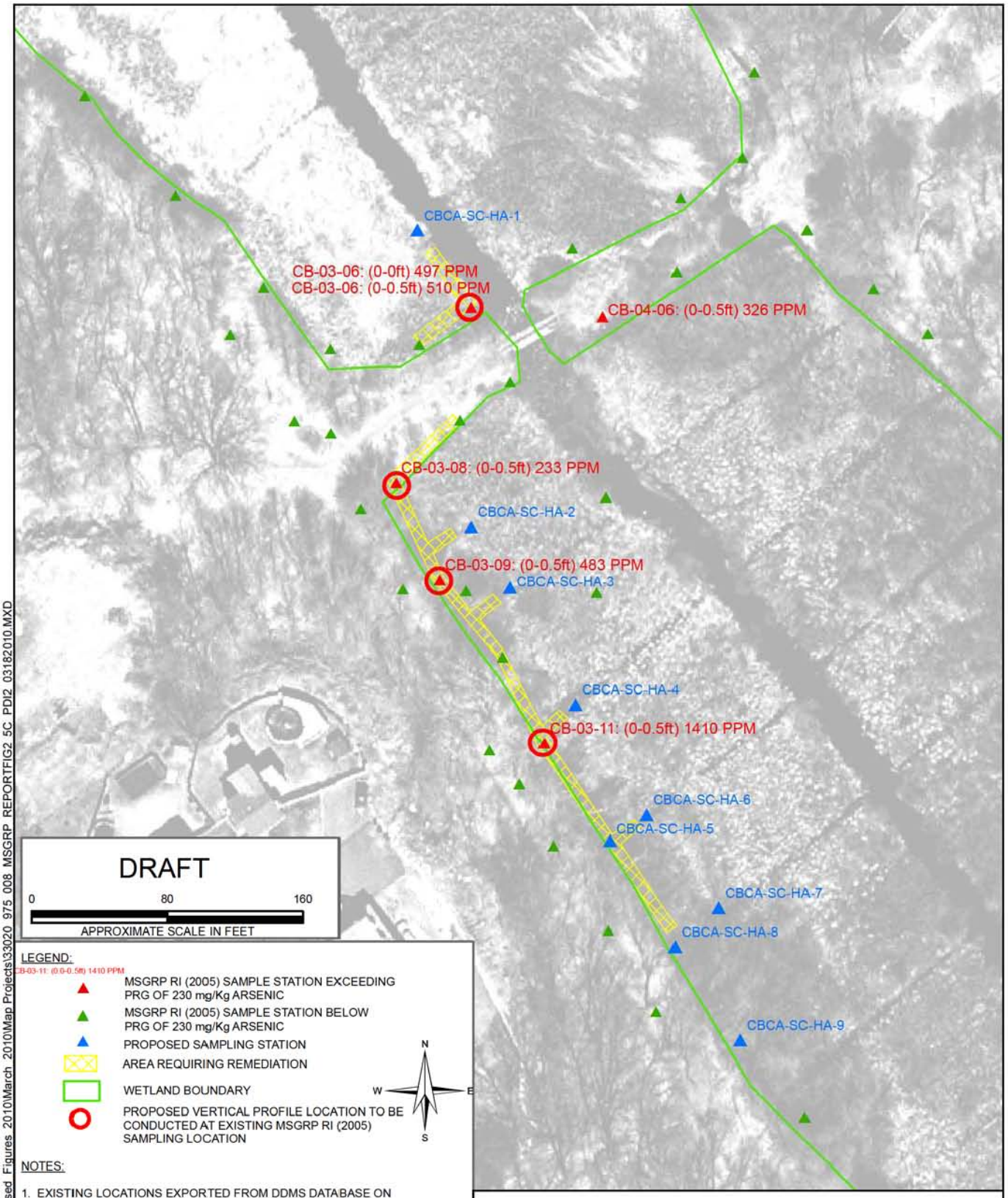
REMEDIAL DESIGN INDUSTRI-PLEX SITE
OPERABLE UNIT NO. 2
WOBURN, MASSACHUSETTS

PDI-2 WELLS G AND H WETLAND
PROPOSED SAMPLING LOCATIONS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.3.1.1-1

G:\33020\GLOBAL\GIS\MapProjects\Revised Figures 2010\March 2010\Map Projects\33020 975 008 MSGRP REPORTFIG2 5b WITH WETLANDS PDI2 03182010.MXD



LEGEND:

CB-03-11: (0-0-0.5ft) 1410 PPM

- MSGRP RI (2005) SAMPLE STATION EXCEEDING PRG OF 230 mg/Kg ARSENIC
- MSGRP RI (2005) SAMPLE STATION BELOW PRG OF 230 mg/Kg ARSENIC
- PROPOSED SAMPLING STATION
- AREA REQUIRING REMEDIATION
- WETLAND BOUNDARY
- PROPOSED VERTICAL PROFILE LOCATION TO BE CONDUCTED AT EXISTING MSGRP RI (2005) SAMPLING LOCATION

N W E S

NOTES:

1. EXISTING LOCATIONS EXPORTED FROM DDMS DATABASE ON 28 JANUARY 2010
2. SEDIMENT SAMPLE LOCATIONS AND WETLAND BOUNDARY SHOWN ON FIGURE 2-7c, "SEDIMENT SAMPLE LOCATIONS-REACH 1 MSGRP REMEDIAL INVESTIGATION REPORT", PREPARED BY TETRA TECH NUS INC. MARCH 2005. WETLAND BOUNDARY DIGITIZED FROM FIGURE.
3. 2008 30 CENTIMETER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MassGIS),COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
4. AREAS REQUIRING REMEDIATION DIGITIZED FROM FIGURE 2-5c "SURFACE SEDIMENT PRG EXCEEDENCE-ARSENIC-REACH 1, MSGRP FEASABILITY", PREPARED BY TETRA TECH NUS INC. DATED 22 APRIL 2005

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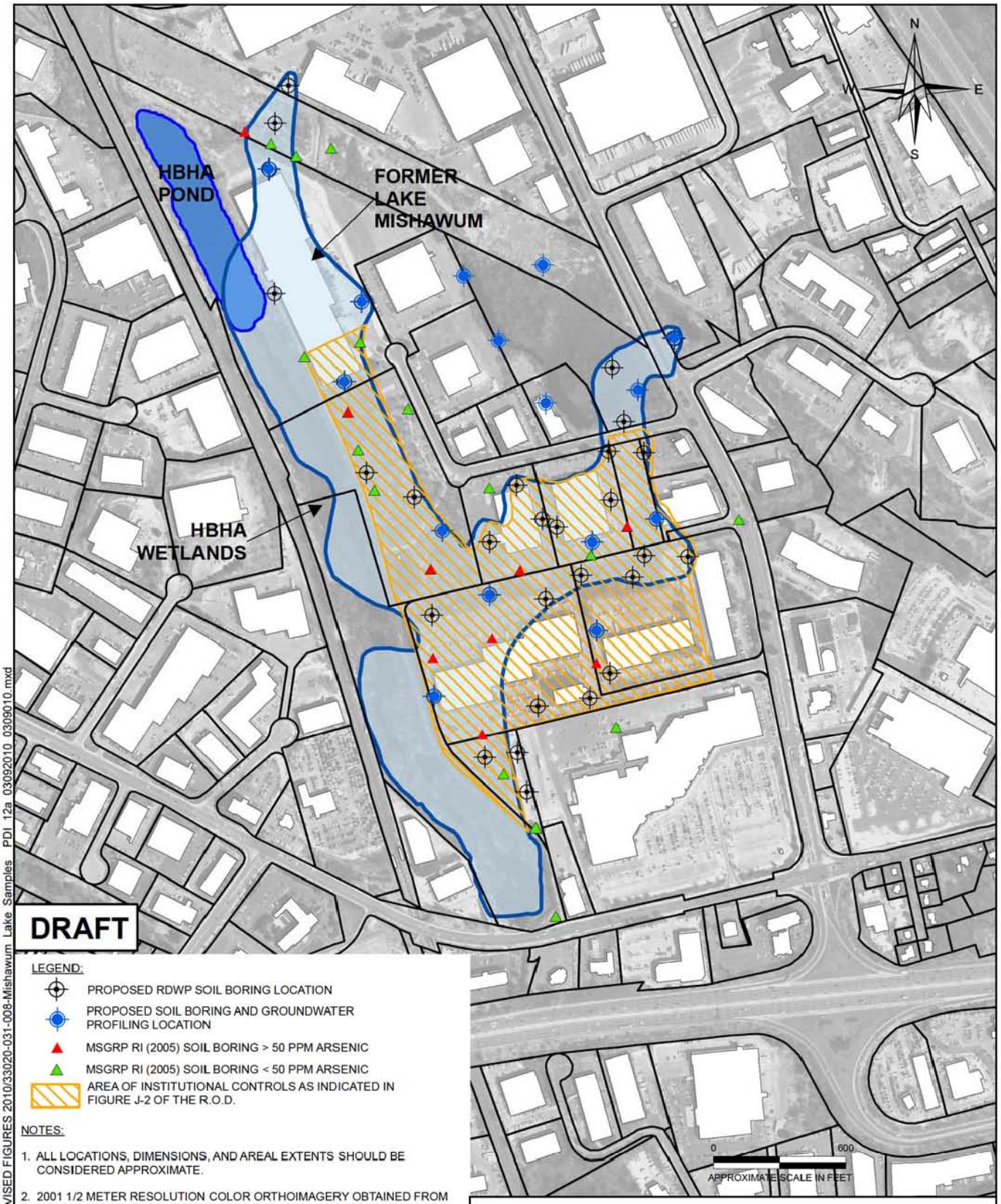
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT NO. 2
WOBURN, MASSACHUSETTS

PDI-2 CRANBERRY BOG CONSERVATION AREA WETLAND SAMPLING LOCATIONS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.3.1.1-2

G:\33020\GLOBAL\GIS\MapProjects\Revised Figures 2010\March 2010\Map Projects\33020_975_008_MSGRP_REPORTFIG2_5C_PDI2_03182010.MXD



DRAFT

LEGEND:

- PROPOSED RDWP SOIL BORING LOCATION
- PROPOSED SOIL BORING AND GROUNDWATER PROFILING LOCATION
- MSGRP RI (2005) SOIL BORING > 50 PPM ARSENIC
- MSGRP RI (2005) SOIL BORING < 50 PPM ARSENIC
- AREA OF INSTITUTIONAL CONTROLS AS INDICATED IN FIGURE J-2 OF THE R.O.D.

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS.
3. FORMER LAKE MISHAWUM APPROXIMATED FROM FIGURE BY TETRA TECH NUS, INC. DATED 14 MARCH 2005 TITLED "SOIL SAMPLING LOCATIONS - REACH 0", FIGURE 2-3A, MSGRP REMEDIAL INVESTIGATION REPORT.
4. LOCATIONS SHOWN ON BUILDINGS WILL BE SHIFTED IN THE FIELD DURING SAMPLING TO THE NEAREST LOCATION WITHIN THE GRID OUTSIDE THE BUILDING FOOTPRINT.
5. BUILDINGS AND PARCEL BOUNDARIES FROM THE CITY OF WOBURN G.I.S.
6. HISTORIC LOCATION DATA EXPORTED FROM DDMS

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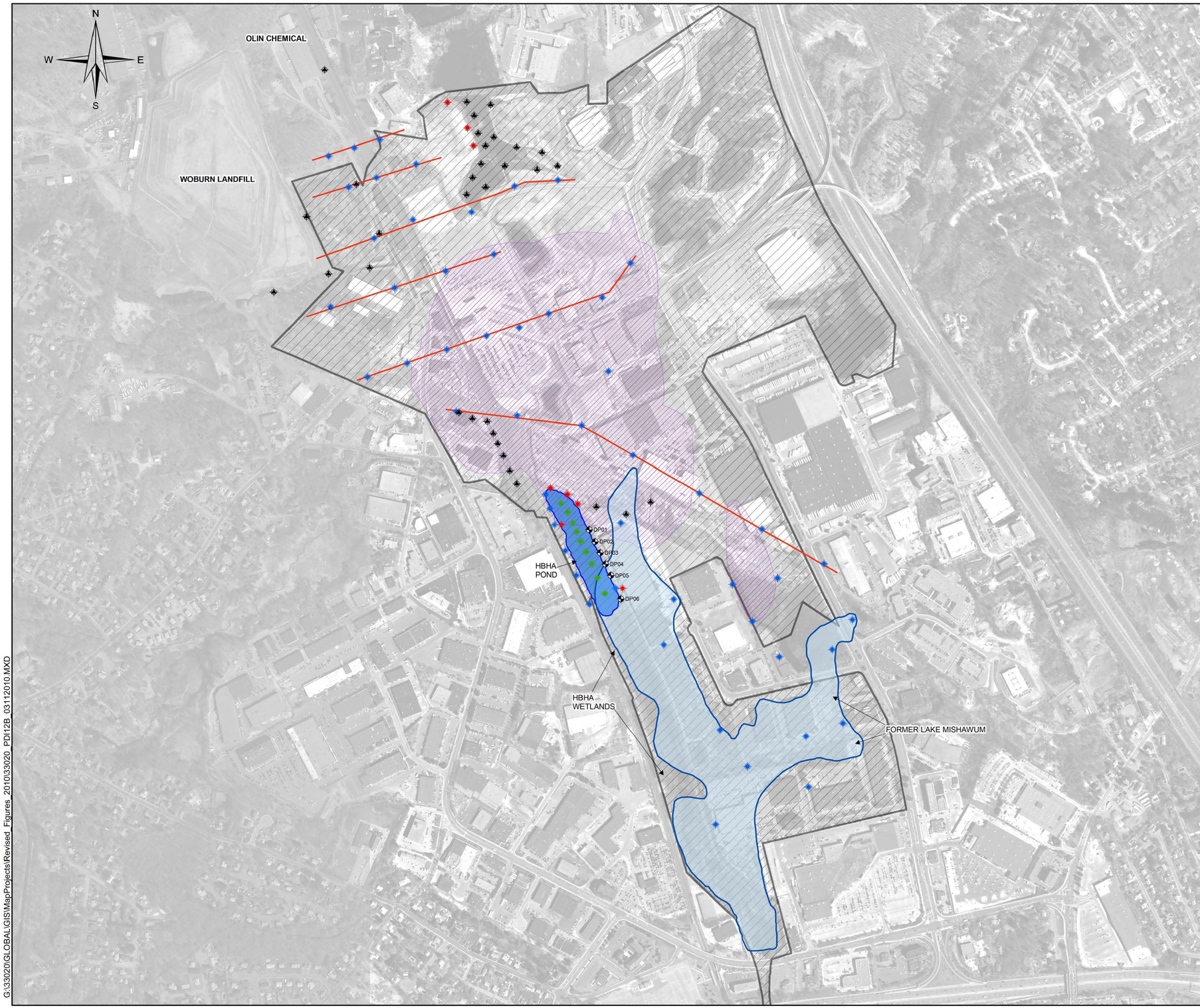
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-12A FORMER LAKE MISHAWUM
SOIL & GROUNDWATER INVESTIGATION

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.4.1.1-1

G:/33020/Global/GIS/Map Projects/REVISED FIGURES 2010/33020-031-008-Mishawum Lake Samples PDI 12a 03092010 0309010.mxd



LEGEND:

- PROPOSED GROUNDWATER PROFILING LOCATION
- COMPLETED GROUNDWATER PROFILING LOCATION COMPLETED IN MARCH 2009, BY GEOSEARCH INC.
- PROPOSED IN POND GROUNDWATER SAMPLING LOCATION
- PROPOSED GROUNDWATER MONITORING WELL COUPLET LOCATION
- PROPOSED TEMPORARY DRIVE POINT PIEZOMETER
- APPROXIMATE OU1/OU2 SITE BOUNDARY
- APPROXIMATE EXTENT OF GROUNDWATER PLUME AREAS EXCEEDING PRGS (ROD)

NOTES:

1. ALL LOCATIONS, DIMENSIONS, AND AREAL EXTENTS SHOULD BE CONSIDERED APPROXIMATE.
2. 2001 1/2 METER RESOLUTION COLOR ORTHOIMAGERY OBTAINED FROM THE OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFARIS.
3. GROUNDWATER PLUME EXTENT DERIVED AND PRESENTED AS A COMPOSITE OF MULTIPLE PARAMETERS SHOWN ON FIGURE BY TETRA TECH NUS, INC., GROUNDWATER PLUME AREAS EXCEEDING PRGs, INDUSTRI-PLEX SITE, WOBURN, MASSACHUSETTS.
4. ACTUAL NUMBER OF MONITORING WELL COUPLETS WILL BE DETERMINED BASED ON PHASE I & II RESULTS.

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0 200 400 800 1,200 1,600 Feet

HALEY & ALDRICH

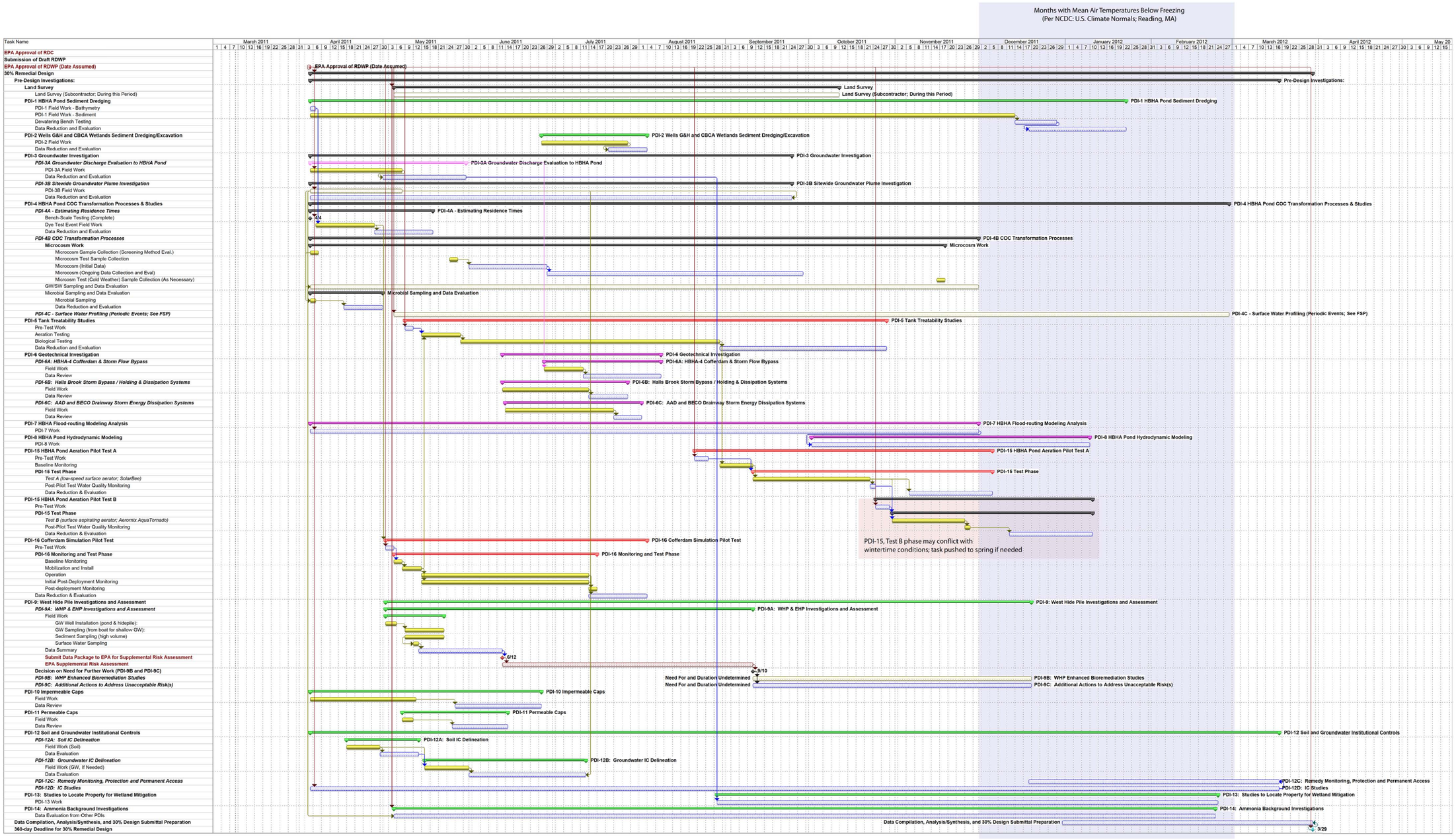
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-12B GROUNDWATER INSTITUTIONAL CONTROL DELINEATION PROPOSED GROUNDWATER SAMPLING LOCATIONS

SCALE: AS SHOWN
MARCH 2011

FIGURE 3.4.1.2-1

G:\33020\GLOBAL\GIS\MapProjects\Revised_Figures_2010\33020_PDI12B_03112010.MXD



NOTES:

1. CPM = CRITICAL PATH METHOD.
2. LINES/ARROWS DEPICT CRITICAL PATH, DEPENDANT TASKS, AND/OR SCHEDULE REQUIREMENTS DESCRIBED IN THE SOW.
3. CPM SCHEDULE IS CONCEPTUAL AND IS DESIGNED TO SHOW DEPENDENCES AND APPROXIMATE DURATIONS; ACTUAL DATES, TIMING, DURATION OF PDI TASKS MAY VARY FROM THIS SCHEDULE.
4. ACTUAL DATES OF SUBMITTAL MAY VARY FROM THIS SCHEDULE BECAUSE IT DEPENDS ON THE DURATIONS OF EPA REVIEW/APPROVAL AND OTHER CONSIDERATIONS.

FUSCIA = TASKS INITIATED UPON RDWP APPROVAL TO COLLECT KEY SITE DATA (PRE-REQUISITE)
GREEN=FLEXIBLE SCHEDULE ELEMENTS
OLIVE=FIELD WORK ITEMS
RED = TIME/SEASON CRITICAL SCHEDULE ELEMENTS
PURPLE = CONTINGENT/MODERATE FLEXIBILITY TASK

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REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PRE-DESIGN INVESTIGATION CPM SCHEDULE

SCALE: NONE
MARCH 2011

FIGURE 4-1

G:\33020\045\PDI Scheduling\Figure 4-1\2011-0309-PDI-schedule.ai

ATTACHMENT C1

Field Sampling Standard Operating Procedures (SOPs)

ATTACHMENT C1
FIELD SAMPLING STANDARD OPERATING PROCEDURES (SOPs)

HALEY & ALDRICH PROCEDURES:

OP1002	Drilling Safety
OP1008	Operations Over, Near, or on Water
OP2000	Monitoring Field Explorations
OP2001	Identification and Description of Soils in the Field Using Visual-Manual Methods
OP2005	Test Borings, Sampling, Standard Penetration Testing (SPT) and Borehole Abandonment
OP2021	Piezometers
OP2030	Direct Push Borings
OP3001	Preservation and Shipment of Environmental Samples
OP3003	Surficial Soil Sampling
OP3003A	Soil Investigation and Sampling Procedures
OP3004	Sediment and Wetland Sediment/Soil Sampling
OP3006	Procedures for Subsurface Soil Sampling for Chemical Analysis
OP3007	Surface Water Sample and Data Collection
OP3008	Manual Water Level Measurement Procedure
OP3009	Monitoring Well Development Procedure
OP3010	Groundwater Sampling
OP3011	Groundwater Sampling Using Direct Push
OP3012	Low Stress/Low Flow Groundwater Sample Collection Procedure
OP3018	Vertical Profiling of Groundwater Using Direct Push Technology
OP3023	Air Sample Collection with Tedlar Bags
OP3026	Chain of Custody
OP3027	Decontamination Procedure
OP3028	Investigation Derived Wastes
OP3029	Field Data Recording
OP3030	Field Instruments – Use and Calibration

Iron, Ferrous, Methods (Associated with HACH D2800)

OZARK UNDERGROUND LABORATORY PROCEDURES:

Procedures and Criteria Analysis of Fluorescein, Eosine, Rhodamine Wt, Sulforhodamine B, and Pyranine Dyes in Water and Charcoal Samplers

OPERATING PROCEDURE: 1002

DRILLING SAFETY

Haley & Aldrich

PREPARATIONS AND APPROVALS

VERSION	AUTHORED/ DATE	REVIEWED/ DATE	REVIEWED/ DATE	REVIEWED/ DATE	APPROVED/ DATE
Ver. 0	CLM/ Dec.	CSO/June 2003	TWN/Sep.2003	JPD/Sep.	SRK/Oct. 2003
Ver. 1	SB/2009				BAW/ 2010

Total Pages: 30

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1.2 Application 3
1.3 Equipment and Supplies 3
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1.3.2 Additional Personnel Protective Equipment (PPE) as Required 4
1.3.3 Required Site Safety Equipment 4
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2.7 Work on the Mast 7
2.8 Hoisting Safety 8
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Haley & Aldrich

1. PURPOSE

This OP defines the responsibilities of Haley & Aldrich staff members and drilling subcontractors with regard to safety during execution of drilling programs as required by governing regulations and standard contractual agreements. In addition, this document provides an outline of safety-related issues and guidance toward safe operations during site investigations with drilling equipment in common practice.

1.1 Discussion

Familiarity with basic drilling safety is an essential component of all drilling projects. Potential hazards related to drilling operations include, but are not limited to encountering underground or overhead utilities, traffic and heavy equipment, hoisting heavy tools, steel impacts, open rotation entanglement, and the use or unexpected encountering of toxic or hazardous substances. While staff members do not operate drilling equipment, they may work in close proximity to operating drilling equipment and may be exposed to many of the same hazards as the drilling subcontractor.

Haley & Aldrich may be held responsible by regulatory agencies and others for personal injuries or property damage as a result of drilling related accidents. It is the responsibility of the staff members to be knowledgeable of, and in conformance with Federal (OSHA) regulations applicable to worker safety and to adhere to company health and safety policies and procedures. Deviation from applicable safety regulations and established guidelines by staff members and subcontractors is not permitted. Failure to adhere to these regulations, policies and procedures is grounds for disciplinary action or termination.

1.2 Application

The following procedures apply to all Haley & Aldrich projects that include mechanical drilling activities where drilling rigs are used for soil and rock drilling, boring advancement, subsurface sample collection, groundwater monitoring well or instrumentation installation, and in-situ testing.

1.3 Equipment and Supplies

A project or site specific Health & Safety Plan (HASP) may be developed to address the particular concerns of a given project. The HASP must always be referred to prior to assembling safety and monitoring equipment in preparation for fieldwork. In the absence of a HASP, field staff must consult with the Project Manager (PM) and the Regional Health & Safety Coordinator (RHSC) for guidance. Refer to form *Subsurface Activity Pre-Field Checklist* on the Health & Safety Homepage for more information.

1.3.1 Standard Required Personnel Protective Equipment (PPE)

- Hard Hat
- Safety Glasses
- Sound Dampeners
- Steel Toe Boots

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- Protective Gloves
- Work Clothing (Denim Blue Jeans or Equivalent, Short or Long Sleeve Shirt)
- Rain Gear
- Reflective Safety Vest
- First Aid Kit/Eye Wash Kit

1.3.2 Additional Personnel Protective Equipment (PPE) as Required

- Tyvek or Saranex Coveralls/Sleeves/Apron
- Latex/Nitrile Inner Gloves/Boot Covers
- Air-Purifying Respirator & Spare Cartridges (Type Varies with Contaminants commonly Type GMC or Type H)
- Personnel Flotation Device (PFD)
- Safety Harness

NOTE: Use of the equipment outlined in Section 1.3.2 requires special training and, in the case of respiratory protective equipment, medical surveillance.

1.3.3 Required Site Safety Equipment

- Fire Extinguishers
- First Aid Kit/Eye Wash Kit
- Traffic Controls (Safety Cones, Lighting & Signs)
- Site Control – Barricades, Caution Tape (Flagging for Exclusion Zones)

NOTE: The Project Manager should coordinate site safety equipment requirements with the drilling contractor to ensure that the proper equipment is available for on-site use.

1.3.4 Required Air Quality Monitoring Equipment

Most environmental fieldwork will have extensive equipment requirements specifically related to the project needs. The following list is a representative list of air quality monitoring equipment that may be used in order to comply with requirements set forth in the HASP or project contract documents. A comprehensive list of environmental equipment and PPE must be developed for each project in coordination with the PM and RHSC prior to the start of the field program.

1.3.4.1 Air Quality Monitoring Equipment

- Photo-Ionization Detector (PID)
- Flame Ionization Detector (FID)
- Organic Vapor Analyzer (OVA)
- Combustible Gas Meter-LEL/O2
- Dust Monitor

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- Multigas Meter
- Gas Pointer
- Draeger Tube Sampling Kit
- Radiation Survey Meter
- Industrial Hygiene Personal Sampling Equipment

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2. PROCEDURE

2.1 Underground Hazards

Haley & Aldrich staff members must ensure that permission has been gained from the property owner to access the property prior to site entry and before marking proposed exploration or drilling locations. On public property the estimated location of utility installations, such as gas, electric, water, sewer, telephone, fuel, or any other underground installation that may be expected to be encountered during drilling work, will be identified by the appropriate authority. Appropriate authorities include client representatives, utility companies, nonprofit organizations (e.g. "Dig-Safe"), and others. A list of all state "utility locators" is posted on the Health and Safety Homepage under "Guidance Documents". Refer to OP 1020 *Work Near Utilities* for specific guidance on clearing underground utilities.

2.2 Overhead Utilities

The masts of exploratory equipment used on-site must be maintained a safe distance from overhead utilities. Typically, these are overhead power lines. The proper, safe distance is dependent upon the voltage carried by the line. Refer to OP 1020 *Work Near Utilities* for the requirements of working near overhead power lines. Other overhead utilities may also be present. Consult the Corporate Health & Safety Manager (CHSM) for additional information related to other overhead utility hazards.

In general, the subcontractor shall note the location of overhead power lines and other overhead electrical sources. Drilling must not occur near these areas unless precautions are taken to prevent contact. Under no circumstances is the drilling rig to be moved with the mast raised. The drilling rig mast must maintain at least 35 feet of clearance from all energized power lines. Power lines can be de-energized or shielded and the drill rig may be grounded when working within the 35-foot clearance distance. Contact the utility company to find out their requirements when working within the 35-foot clearance minimum.

2.3 Subcontractor Safety Requirements

All subcontractors must conform to applicable OSHA regulations governing worker safety including the wearing of hard hats, eye protection, sound protection, suitable work clothing, gloves, steel toe boots and additional PPE such as air-purifying respirators and Tyvek suits as necessary.

All equipment must be designed for the purpose for which it is to be used, maintained in good condition and have current licenses and inspection certificates.

Drillers must be qualified to operate the equipment and experienced in the activities conducted. Certificates of training or applicable licensure must be available upon request. Personnel will conduct themselves in a professional manner and be safety conscious at all times.

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2.4 Setting up and Blocking the Drilling Rig

It is the drilling rig operator's responsibility to ensure that the rig is properly set up. The stability of the drilling rig is critical to assure safe drilling operations. Whenever possible, the operator shall choose a dry, level and reasonably smooth drilling site. The operator shall make sure the rigs emergency brake is engaged and that the wheels which will remain on the ground are chocked. Blocking the rig will help to provide a more stable drilling structure by distributing the weight of the rig evenly. If the rig is equipped with jacks or outriggers, they will be extended from the rig to the ground, raising the rig partially or entirely off the ground. Proper blocking of the rig will prevent differential settling which could result in the rig toppling sideways. Blocks should be placed between the jack swivel and the ground to provide more support area under the pad.

2.5 Operation of the Drilling Rig

Staff members must never operate any of the subcontractor's vehicles or equipment. The drilling subcontractors are solely responsible for the safe operation of the drilling rig and for handling the equipment associated with the drilling. Drillers and staff members must be aware of the location and operation of the drill rig's emergency shut off (kill switch) which cuts the power to the rig in the event of an entanglement. The kill switch must be maintained in working order at all times.

The driller should never leave the controls of the drilling rig while the tools are rotating.

2.6 Precautions Against Entanglement

All staff members who will work in the vicinity of the drilling rig should secure all loose clothing to prevent them from becoming caught in the drilling mechanism. Only employees necessary to run the rig are allowed in close proximity, except during essential sampling and other activities. Personnel will not reach into or near the borehole or the rotating equipment, unless the drilling rig has been shut down. For the same reasons, a long handled shovel or other similar device should be used to clear the drill cuttings away from the borehole and from rotating tools. Hands and/or feet should not be used to clear cuttings.

2.7 Work on the Mast

Drill rig operators shall not climb the mast to conduct repairs if the mast can be lowered. If the mast cannot be lowered to conduct repairs, workers may utilize a ladder or may climb the mast if fall protection, such as a harness and attached lanyard, is available. Fall protection devices, in the form of a harness and lanyard, will be used where workers must climb to 6 feet or greater in height. No one should climb the mast to conduct repairs while the drilling rig is operating.

Workings at heights requirements, as described in the *Operating Procedure Fall Protection (OP1022)*, are applicable during all drilling operations. In the exceptional circumstance that there is a need to climb a drill rig mast, the driller, SSO shall prepare a task RA of the work activity.

The client project manager or the RHSC shall be consulted and the risk evaluated before

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work on the mast may proceed. If the planned activity is agreed to proceed, the rig shall be shut down, locked out and the *Working at Heights Permit* developed. The work at elevation may then proceed.

2.8 Hoisting Safety

Worn or misused cables and rope are potentially the most dangerous pieces of equipment on the drilling rig. When a steel cable or fiber rope breaks under significant tension it has a tendency to snap like a rubber band. Be constantly aware of the condition of all cables and rope being used to hoist drill pipe or other heavy objects. Any cable or rope used for such purposes which has begun to fray, stretch or unravel, or which has a number of breaks in the same strand must be replaced. Use of thumb clips or clevis pins on hoisting hooks is required (see Section 2.8 below). If you do not need to be near the rig during its operation, stay a safe distance away.

2.9 Hot Work

Ignitable vapors from natural sources or from contamination may be encountered during soil borings.

The Primary Source of Ignition (PSI) hot work is not allowed within 35' (10.67m) of an open borehole unless a *Hot Work Permit* is prepared in accordance with the *Hot Work Defined Practice* and:

- Data history shows the borehole is free of flammable vapors.
- The borehole is capped to prevent the entry of sparks.
- Where a borehole is under construction, an approved procedure is used to inert the borehole vapor space.

When there is no data history or ignitable vapors are expected to be present, the boring shall be treated as a Class 1 area, and *Hot Work Permit* requirements shall apply. The Class 1 area shall be a cylinder that is centered on the well, extending 10' (3.05m) in radius and 3' (.9144 m) in height. Drilling and ancillary activity in the Class 1 area shall meet the secondary source of ignition hot work definition. (Refer to the *Hot Work Defined Practice*.)

When ignitable vapors are not expected based on data history, boreholes under construction shall be verified by taking continuous Lower Explosive Level (LEL) readings at the top of the borehole. LEL readings should also be taken from soil cuttings and produced fluids. Readings shall remain below 5 percent of LEL, or mitigations shall be implemented.

Where neither naturally occurring sources of flammable vapor nor flammable vapors from contaminants are present, the boring is not considered a Class 1 area as defined in the *Hot Work Defined Practice*.

Mechanical drilling, when conducted in a Class 1 area, requires a *Hot Work Permit* before any drilling or other ancillary hot work can proceed. (Refer to *Hot Work Defined Practice*.)

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2.10 Equipment Safety Inspections

Drill rig operators are responsible for ensuring rigs are properly inspected. All drilling rigs and related support equipment and vehicles shall be scheduled for a periodic safety inspection. The inspections shall be the responsibility of the owner/operator of the equipment. The inspections shall include, but are not limited to, all hydraulic lines and fittings for wear and damage, all cable systems and pull ropes for damage and proper installation, exhaust systems, brake systems, drill controls, etc. The kill switches must be operable from various locations on the rig and should be tested for proper operation daily before work begins. Certification of inspection may be required from the driller upon request.

The driller in charge shall inspect the rig on a regular basis covering all major systems. If potentially hazardous deficiencies are found during the inspections, the rig may be shut down until the deficiencies are corrected and potential hazards are addressed or repaired. If staff members believe that equipment is unsafe or believe that an imminent hazard exists, staff members should exercise their stop work authority (see OP 1035 *Stop Work Authority*), notify the PM and SSO until the owner/operator can confirm that the rig is safe to operate.

Air compressors and ancillary equipment represent a significant source of energy and hazard.

All components of a compressed air system shall be inspected regularly by qualified and trained members of the workforce. The compressor owner shall check with regulatory agencies or regulations to determine if regulatory-driven inspection of this equipment is required. Operators shall be aware of and utilize the following general safety requirements for compressed air.

Air Receivers

The requirements for air receivers are:

- The maximum allowable working pressures of air receivers shall never be exceeded, except when being tested. Only hydrostatically tested and approved tanks shall be used as air receivers.

- Each air receiver shall be equipped with at least one pressure gauge and an American Society of Mechanical Engineers or equivalent certifying organization safety valve of the proper design.

- A safety (spring-loaded) release valve shall be installed to prevent the receiver from exceeding the maximum allowable working pressure.

Air Distribution Lines

The requirements for air distribution lines are:

- Air lines shall be made of high-quality materials and fitted with secure connections.

- Hoses shall be checked to make sure they are properly connected to pipe outlets before

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use.

- Air lines shall be inspected frequently for defects. Any defective equipment should be repaired or replaced immediately.
- Compressed air lines shall be identified as to maximum working pressures (in psi) by tagging or marking pipeline outlets.
- Whip checks or safety tethers shall be used on both ends of the air line.
- Air lines shall be protected from damage from other equipment.
- Air lines shall not be placed where they will create tripping hazards.

Pressure Regulation Devices

The requirements for pressure regulation devices are:

- Valves, gauges and other regulating devices shall be installed on compressor equipment in such a way that they cannot be made inoperative.
- Air tank safety valves shall be set no less than 15 psi or 10 percent (whichever is greater) above the operating pressure of the compressor. They shall never be set higher than the maximum allowable working pressure of the air receiver.
- Blowoff valves shall be located on the equipment and shall be shielded so that sudden blowoffs will not result in injury or equipment damage.

Air Compressor Operation

The requirements for air compressor operation are:

- Air compressor equipment shall be operated only by authorized and trained personnel.
- The air intake shall come from a clean, outside, fresh air source. Screens or filters can be used to clean the air.
- Air compressors shall never be operated at speeds faster than the manufacturer's recommendations.
- Moving parts that could be hazardous, such as compressor flywheels, pulleys and belts shall be effectively guarded.
- Compressed air shall not be used to clean a member of the workforce.

2.11 General Housekeeping

The work area around the drill area must be kept clean and orderly at all times. Items such as hand tools, rakes, shovels, etc. shall not be left lying on the ground to pose a trip hazard.

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Excess pipe, augers, connections, etc., should be stored in a rack or on the rig and not left lying around the rig. Remove and dispose of empty bags or other containers which have held drilling mud, cement or other dust producing materials.

Preventive measures must be in place to contain all drill fluids and cuttings. Spray, spills and run-off of drilling fluid must be arrested and recovered immediately in order to prevent the escape of potentially contaminated fluids into the environment or to avoid exposing passersby to a potential slipping hazard. During freezing weather salt or sand must be scattered on the ground surface within the work zone and the surrounding area to provide traction against slipping hazards.

2.12 Lightning

Because of the high potential for lightning strike on the mast of a drilling rig, drilling must cease when thunder and lightning storms approach and workers should take shelter away from the rig. If possible, the mast should be lowered prior to the onset of lightning storms. This decision should be a joint decision between staff members and the subcontractor. Typically work should be suspended if lightning is visible in two directions or is estimated to be less than 2 miles away.

2.13 Lighting

Lighting around a drilling operation should be sufficient to provide illumination at all times of at least:

- An average of 5-foot candle (fc) power in the immediate drilling area, with no less than 3-fc power at any point.
- A minimum of 3 fc power on all other walking and working surfaces.

Work shall be suspended until additional lighting is provided should either H&A or the Subcontractor personnel feel that work site lighting is inadequate.

NOTE: The above are minimum OSHA requirements. Under certain circumstances higher lighting values may be warranted.

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3. STAFF MEMBER SAFETY REQUIREMENTS

All staff members must conform to applicable OSHA regulations governing worker safety including the wearing of hard hats, eye protection, sound protection, suitable work clothing, gloves, steel toe boots and additional PPE such as air-purifying respirators and Tyvek suits as necessary.

A fundamental approach to minimizing one's personal risk of exposure to a variety of potential hazards is to plan ahead of the execution of activities and to set up a work space outside the immediate area of drilling or other traffic. The added distance from the drilling activities serves to provide a safety zone from vehicular traffic, falling objects, bursting hoses, vapors and fumes.

Many activities require staff members to enter into close proximity to the drill rig during operation. At such moments one should never become preoccupied or distracted from the drilling operation. Make certain of the drillers next move at all times and be aware of the hazards of hoisted objects falling and open rotation entanglement. Close to the drill rig there is a greater potential for eye damage from hammering steel splintering, bursting hydraulic lines and other solids or fluids associated with either the rotating drill stem or the borehole. Dangerous sound levels are common as well.

There are many visual and audible cues to an imminent hazard around the drill rig and any number of unsafe drilling practices to be aware of such as excessive stacking of drill rods, excessive rotation speeds, lifting overweight objects, and loose ropes, cables or chains near the rotation.

Take care against disrupting the driller's concentration or approaching him when he's hoisting or adjusting feed. Do not allow the drillers to rush their activities and suggest they take a break if frustration is an issue.

Whenever possible, exercise engineering controls to minimize low level exposure to engine or borehole vapors by working up-wind. Exhaust pipe extensions and fans may be necessary to provide adequate ventilation when working in an interior or confined area. Near continuous air quality monitoring in the breathing zone may be required on both environmental and non-environmental projects. Consult with the Project Manager and the RHSC for compound-specific guidelines for detection and the proper response actions according to company policy.

Use latex gloves in order to minimize low level exposure to soils. Use disposable boot covers to prevent small amounts of soil from boots from contaminating your personal vehicle and potentially exposing those you interact with, including your children, to harmful doses of lead or other contaminants.

Setting up exclusion zones around the work area may be necessary to ensure public safety. In some cases this may be done using caution tape and reflective cones or steel drums. Depending upon the hazard it may be necessary to install a temporary chain-link fence around the work area. OP 1046 *Site Control* provides guidance in this area.

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Setting up a decontamination area is a common practice to effectively recover contaminated wash water and materials while decontaminating equipment and PPE. Health and safety protocols are most easily followed when field decontamination practices are properly executed.

For environmental projects, the practical implications of having on hand and utilizing all of the required PPE, decontamination, sampling and monitoring equipment require use of a rented or company-owned vehicle of sufficient capacity and design to adequately transport and effectively access the equipment at the work site. In addition to the above, it may be necessary to have the applicable Material Safety Data Sheets (MSDS) for the various decontamination chemicals and environmental preservatives.

General field safety calls for attention to a variety of factors including physical stress due to extreme heat and cold as well as potential exposure to any number of hazards. Night drilling in urban neighborhoods may present security risks sufficient to warrant a police escort (Refer to OP 1046 *Site Control* for site security assessments). Drilling over water or near water poses special hazards addressed in OP 1008 *Operations Over, Near or On Water* necessitating use of personal flotation devices (PFD) and other safety requirements. Highway projects and large-scale construction sites typically involve working around vehicular traffic (OP 1043 *Site Vehicle Control*) and heavy equipment where high visibility reflective safety vests are necessary. Railway and airport projects may involve a number of special protocols including the use of defined communications and the completion of a specialized training program. Working in and around quarries, deep excavations and tunnels may require use of safety harnesses to guard against falls. Rural and undeveloped areas may present risks from poison ivy, ticks or snakes and limited access to medical attention in the event of an accident.

3.1 Basic Personal Protective Equipment (PPE)

Certain personal protective equipment (PPE) must be worn because of the physical hazards posed by the drilling operation. As a minimum on Haley & Aldrich field projects, hard hats, steel-toed work shoes, and safety eyewear (EPA Level D) must be worn at all times within the vicinity of the mast of the drilling rig. Hearing protection devices, such as ear plugs and ear muffs, shall be worn as required when the noise exposure is 85 dB (A) or greater over an 8-hour workday. Although noise levels vary with the type of drilling equipment utilized, potentially hazardous noise levels are likely to be generated during split spoon sampling and air drilling. Typically, speech at normal conversational levels becomes difficult at 2 to 3 feet when noise levels are in excess of 85 dB (A). Be aware of any additional personal protective equipment that may be required by the client. Though Haley & Aldrich is not responsible for issuing subcontractor PPE or the use of it, we must be diligent of our client's requirements and work closely with our drillers to ensure conformance with the site requirements. All protective equipment shall be provided by respective employer(s).

3.2 Special Precautions for Drilling in Landfills

In addition to the usual physical hazards of drilling, staff members drilling in landfills may experience an increased hazard from methane gas and other decomposition products. Decomposition products of organic materials typically produce very flammable and/or hazardous gases and vapors, which may accumulate in the borehole or in the general work area. To help reduce the hazards due to the presence of these products while drilling in landfills, the following procedures shall be implemented:

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- Smoking, open flames or spark-producing equipment are not permitted within 75 feet of drilling rigs open wells, gasoline-driven pumps, or fuel storage areas.
- Flammable liquids (includes empty/full cans) shall not be stored or left within 50 feet of drilling rigs, pumps, or other related machinery.
- A fire extinguisher shall be located on, or within 10 feet, of any operating drilling rig.
- Equipment engines shall be shut off during fueling.
- Containers used for fuel shall be bonded and grounded during dispensing to prevent the discharge of static electricity.
- Safety fuel cans shall be returned to a designated safe storage area after fueling is completed.
- The drilling rig must be diesel powered and equipped with a spark-arresting muffler.
- Explosive gas concentrations shall be monitored as frequently as possible using a Combustible Gas Indicator (CGI). The frequency of monitoring must be established in the HASP. The meter should be kept near the rig. Results of the monitoring data should be entered on the field log.
- Haley & Aldrich policy requires that all work stop if explosive gases are detected at 10% or greater of the lower explosive limit (LEL) in the hole being drilled or in the work area surrounding the hole. Under such circumstances it may become necessary to inert, ventilate, or flood the borehole with water during drilling to reduce the risk of downhole explosions.

3.3 Special Precautions for Drilling in Contaminated Soils

A HASP must be developed for all drilling operations when environmental contamination is reasonably expected. Follow the requirements of the HASP to safely manage exposure to contaminated soils. In the event environmental contamination is encountered unexpectedly, work must be suspended until the PM and RHSC can be contacted to develop a Site Specific HASP.

All contaminated equipment shall be properly decontaminated prior to leaving the general location of the drilling activities. Improperly decontaminated equipment returned to the Haley & Aldrich storerooms is not permitted. Subcontractors are expected to ensure that there will be no cross-contamination of the property and offsite locations as a result of the sampling event.

3.4 Training

Staff members working in the proximity of an operating drilling rig and the support equipment required should be thoroughly familiar with the operational hazards involved and the applicable work safety regulations. For environmental projects, staff members must have undergone the 40-hour OSHA (HAZWOPER) training and shall read, sign and comply with the provisions of

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the site-specific HASP drafted for the project. For other projects, standard regulations and health and safety precautions must be followed.

In the scope of this procedure a qualified equipment operator (QEO) is an individual who, through experience or training, and with the endorsement of his or her employer, is competent to operate equipment used during drilling operations. The PM shall verify that the QEO is identified in the HASP (or on the client-specific permit) prior to beginning work activity. The PM shall certify that all equipment operators have QEO credentials. Drilling subcontractors shall have a similar level of training to staff members and a HASP when required. Heavy equipment operators in most states must be certified or licensed. If at any time there may be a question about competency in regards to safe operations, the PM should request training records.

3.5 Personal Hygiene Requirements

To help limit the potential for ingestion of contaminants, eating, drinking, chewing, applying cosmetics or smoking is not allowed when working in the immediate vicinity of the drilling rig or in any restricted work areas (i.e., exclusion and decontamination zones). A break area outside the restricted work areas shall be established with a hand and face washing facility. Before eating, drinking, or smoking, all staff members shall thoroughly wash their hands and face.

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4. ROLES & RESPONSIBILITIES

Project Manager (PM)

The PM, or designee shall have specific training and knowledge of the applicable regulations regarding the activities he or she is leading as well as the necessary requirements for protective systems. The PM shall also be knowledgeable, experienced and/or trained and have the ability to identify existing or predictable hazards and has the authority to initiate prompt corrective action. The PM shall be responsible for:

- Ensuring that utility clearance has been properly conducted.
- Assuring that provisions specified in this OP are followed by staff members and the drilling subcontractor.
- Assuring that a HASP is developed for the project if it involves drilling in anticipated or unexpectedly encountered contaminated soils or significant safety hazards.
- Assuring that Haley & Aldrich staff members do not operate or handle the drilling subcontractor's equipment and that they remain clear of the drilling rig when their presence is not necessary.
- Assuring that all required personal protective equipment, for example hard hats, steel-toed shoes, and/or safety glasses are worn within the restricted work areas during the drilling operation. Hearing protection may be required in some instances.

Drilling Subcontractor

The drilling subcontractor is responsible for:

- Provide trained, qualified and competent personnel to operate drilling rigs or comparable equipment. Subcontractors shall provide trained drillers and driller's helpers who meet Haley & Aldrich requirements for drilling. The training shall include a mechanism of verifying employee and Contractor's comprehension of the work process and associated equipment via written test, observation and evaluation by a competent trainer.
  - Refresher training shall be required on a periodic basis. Refresher training in relevant topics shall be required when an individual has been observed to operate machinery in an unsafe manner or involved in an accident or near-miss incident.
- Identifying any overhead and underground utilities/hazards prior to the start of drilling activities and, if necessary, arranging to have electrical lines de-energized prior to the start of drilling. In California, this might be a contractual/work scope responsibility for H&A.
- Making the final decision as to where they feel they can safely drill all borings.

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- Safely operating the drilling rig and handling all equipment associated with the drilling operation.
- Maintaining the drilling rig and equipment in accordance with standard industry practices and safety standards.
- Containing generated material and preventing contamination from being spread as a result of drilling activities.
- Responding to staff members to correct deficiencies related to unsafe conditions or practices.

Staff Members

On-site staff members are responsible for:

- Complying with the provisions of this OP.
- Working in a safe manner.
- Notifying subcontractors/contractors of potentially unsafe conditions and utilizing stop work authority as necessary.
- Notifying the PM or RHSC of any unsafe acts or conditions in the workplace.
- Notifying the PM of any work-related injuries or illnesses that incur during work at the site.
- Conforming with the provisions outlined in applicable site-specific HASPs.

Corporate Health & Safety Manager (CHSM)

The CHSM is responsible for the development, implementation and monitoring of the procedure.

Regional Health & Safety Coordinators (RHSCs)

The RHSCs are responsible for implementing the requirements of the OP and providing support to the PMs and field staff during its implementation.

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5. REFERENCES

OSHA standard, 29 CFR 1910.134, "Respiratory Protection"

OSHA Hazardous Waste Operations and Emergency Response (Hazwoper) standard (i.e., 29 CFR 1910.120)

"Occupational Safety & Health Guidance Manual for Hazardous Waste Site Activities" published by NIOSH/OSHA/USCG/EPA, October 1985

Occupational Health and Safety Regulations (OSHA) and United States Coast Guard (USCG) 29 CFR 1926 Subpart C, General Safety and Health Provisions; 29 CFR 1926 Subpart E, Personal Protective Equipment; 29 CFR 1926.106, Working Over or Near Water; 33 CFR Part 151, Vessels Carrying Oil, Noxious Liquid Substances, Garbage, Municipal or Commercial Waste, and Ballast Water; 46 CFR Parts 25 and 26, Uninspected Vessels

U.S. Environmental Protection Agency Environmental Response Team, Response Engineering and Analytical Contract, Standard Operating Procedure Number 9, Drilling and Monitoring Well Installation at Hazardous Waste Sites, adopted from SOP 2150

BP International, Ltd., Remediation Defined Practice; Ground Disturbance, Appendix D Probing Guideline

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APPENDIX A - RELATED HALEY & ALDRICH PROCEDURES

OP1004	Operation/Calibration of PID Photoionization Detector
OP1005	Operation/Calibration of FID Flame Ionization Detector
OP1006	Operation of Draeger Gas Detector Pump
OP1007	Field Monitoring for Volatile Organics (breathing space-work zone)
OP1008	Operations Over, Near, or On Water
OP1009	Medical Surveillance Program
OP1010	Health and Safety Plans
OP1015	Heat and Cold Stress
OP1016	Recordkeeping and Reporting
OP1020	Work Near Utilities
OP1022	Health and Safety
OP2000	Monitoring Field Explorations

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APPENDIX B - FORMS

Subsurface Activity Pre-Field Checklist

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APPENDIX C - GLOSSARY

Air Drilling
A method of rotary drilling that uses compressed air as its circulation medium to remove cuttings from the borehole.

Bit
The cutting or boring element used in drilling wells. Most bits used in rotary drilling are roller-cone bits. The bit consists of the cutting elements and the circulating element. The circulating element permits the passage of drilling fluid and utilizes the hydraulic force of the fluid stream to improve drilling rates.

Borehole
The hole drilled by the bit. A borehole may have casing in it or may be open (i.e., uncased), or a portion of it may be cased and a portion of it may be open.

Casing
Steel or PVC pipe placed in a well during the drilling process to prevent the wall of the hole from caving in during drilling and after installation.

Cuttings
The fragments of rock and soil dislodged by the bit and brought to the surface in the drilling mud.

Drill Stem
All members in the assembly used for drilling by the rotary method from the swivel to the bit, including the Kelly bar, drill pipe and tool joints, drill collars, stabilizers, and various subsequent items.

Driller
The individual of the drilling company directly in charge of a drilling rig and crew. His/her main duty is operation of the drilling rig and hoisting equipment, but he/she is also responsible for the downhole condition of the well, operation of downhole tools, and pipe measurements.

Drilling Fluid
Circulating fluid, one function of which is to force cuttings out of the borehole and to the surface. While a mixture of clay, water, and other chemical additives is the most common drilling fluid, boreholes can also be drilled using air, gas, or water as the drilling fluid.

Grouting
To fill the annulus between the casing and borehole with liquid slurry of grout (cement or bentonite) and water to support the casing and prevent fluid migration between permeable zones.

Mast
A portable derrick capable of being erected as a unit, as distinguished from a standard derrick, which cannot be raised to a working position as a unit.

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Mud
A liquid fluid that may be used to circulate through the borehole during rotary drilling and work over operations. It functions to bring cuttings to the surface, to cool and lubricate the bit and drill stem, to protect against blowouts by holding back subsurface pressures and to deposit a mud cake on the wall of the borehole to prevent loss of fluids to the formation. The mud used in modern drilling operations is a complex, three-phase mixture of liquids, reactive solids, and inert solids. The liquid phase may be freshwater, diesel, oil, or crude oil and may contain one or more conditioners.

Rig
The mast, drawworks, and attendant surface equipment of a drilling unit.

Rotary Drilling
A drilling method in which a hole is drilled by a rotating bit to which a downward force is applied. The bit is fastened to and rotated by the drill stem, which also provides a passageway through which the drilling fluid is circulated. Additional joints of drill pipe and added as drilling progresses.

Well Head
The equipment installed at the surface of the borehole when a well is installed in the borehole. A well head may include such equipment as the casing head and tubing head.

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APPENDIX D - PROBING GUIDELINE

Overview:

This guidance establishes minimum probing requirements for all personnel involved with ground disturbance activities as defined in this procedure. Staff members and contractors may deem it necessary to have more stringent requirements in place for specific tasks, based on past work experience and hazard assessments.

Definitions:

PPE – Personal Protective Equipment

Poly pipe – plastic pipe (polybutylene)

PVC – Poly Vinyl Chloride (plastic pipe)

General Requirements:

BEFORE conducting probing operations, all personnel shall be familiar with the general requirements for prevention of subsurface facility strikes. All ground disturbance work shall only be conducted upon receipt of a completed Subsurface Clearance Review, which is signed by the designated competent person. In addition, the terms and requirements of the Review MUST be discussed with all involved with the task prior to initiating work.

Procedure/Process:

1. Use caution probing for the following:
   - Probe for steel or polypipe carefully. Probe may penetrate line if excessive force is used.
   - Probe for PVC and fiberglass pipelines with extreme caution. Be aware that some clients may not allow the use a probe for these types of lines.
   - Do not probe electrical lines or fiber optic lines and cables.
2. Probe should be positioned and used directly above the center line of the pipeline.
3. After probing pipeline, note depth then probe to each side of pipeline to insure that the initial probe was an accurate indication of the pipeline.
4. Probe pipeline 25 feet, on each side of dig site and at dig site.

NOTE: If not sure of pipeline material (*i.e.: PVC, poly pipe, fiberglass, and special coated pipelines*) seek additional information before continuing work.

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APPENDIX E - DRILLING METHODS

Drilling Methods

The most commonly used drilling methods are:

- Hollow-stem auger
- Solid-stem auger
- Bucket auger
- Direct- mud rotary
- Reverse-air rotary
- Cable tool

The type of equipment used depends upon the site geology, hydrology, equipment available, and monitoring design. Control of cuttings and other potentially contaminated materials at the drill site may influence drilling method selection. Depending upon equipment availability and site geology, more than one method may be combined to complete a particular monitoring well installation.

Hollow-Stem auger

Hollow-stem auger drilling uses large diameter (up to 14-inch outside diameter [OD]) continuous- flight augers which mechanically excavate drilled materials from the hole. These augers are built with a large (up to 10.25- inch inside diameter [ID]) axial opening to allow access to the bottom of the hole without withdrawing the auger string. The augers act as temporary casing during and at the completion of drilling to facilitate the sampling of sediment and water and the installation of monitoring wells.

Some advantages of hollow-stem auger drilling often make it the preferred method of installing monitoring wells. Hollow-stem auger drilling is relatively rapid, especially in shallow applications in poorly lithified to unlithified sediments. Little or no outside fluid is required in the drilling process. Though a relatively large volume of cuttings are generated, they are normally easily contained. The volume of effluent, resulting from well-development efforts and requiring disposal, is normally lower than with some methods, notably mud rotary. Hollow-stem auger drilling readily supports thin-wall and split-tube sampling in poorly lithified sediments.

Most hollow-stem rigs also support other drilling methods such as mud rotary, solid-stem auger, and coring. Hollow-stem rigs are relatively simple, with few lubricated parts at positions likely to contaminate the test hole or monitoring well.

There are some disadvantages and limitations to the use of the hollow-stem auger method in the construction of monitoring wells. It is limited to drilling in poorly lithified to unlithified sediments and to a maximum depth of about 150 feet. Shallow bedrock or other hard-to-drill materials may reduce this depth significantly. Hollow-stem augers are prone to cross contamination of fluids within the bore hole along the large annular space around the auger tubing. High hydrostatic pressures in the bore hole can cause problems with sand heaving up into the augers during sampling and well- installation procedures. Wide variations in bore-hole

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size, common to auger drilling in poorly cohesive sediments, may complicate effective sealing of the annular space during monitoring-well installation. The design of hollow-stem augers produce an approximately 1- inch thick rind of smeared cuttings which may effectively seal the bore-hole walls in clayey sediments. This rind may interfere with the flow of fluids to the monitoring well.

U.S. Environmental Protection Agency guidelines (U.S. Environmental Protection Agency, 1986, 1987) recommend that hollow-stem auger inside diameters be 3 to 5 inches greater than the outer diameter of well casings to allow effective placement of filter and sealing materials. Ideally, 2-inch diameter monitoring wells should therefore be installed within 5.5 inch ID or larger hollow-stem augers.

Hollow-stem auger drilling is usually appropriate in the more poorly lithified sediments. The method is well suited to drilling in glacial drift. These sediments, however, are composed primarily of sticky bentonitic clays that require a rig which can supply high drill head torque to complete deeper holes. Cretaceous shale, chalk, and sandstone provide for difficult hollow-stem auger drilling but may often be penetrated with larger, more powerful rigs equipped with heavy-duty augers. Sediments containing abundant large boulders may be penetrated only with great difficulty by hollow-stem methods. Other well lithified bedrock units such as well-cemented sediments, igneous and metamorphic rocks preclude hollow-stem drilling.

Solid-Stem auger

Solid-stem auger drilling uses continuous- flight augers which mechanically cut and continuously transport cuttings to the land surface. Augers are available in diameters of 3 to 14 inches.

Augers used for monitoring-well construction must be of sufficient diameter (about 3 to 5 inches larger in diameter than the monitoring well OD) to allow effective placement of well filter and sealing materials.

Solid-stem augering has a number of advantages. It produces a moderate amount of easily contained cuttings; little or no fluid is required in the drilling process. The entire surface area of the augers is easily accessible, facilitating complete and simplified decontamination. Thin wall and split barrel soil sampling operations are supported. Smaller rigs than used in hollow-stem auger drilling may be used, simplifying decontamination, site maneuvering and often incurring lower costs. These rigs drill relatively rapidly, especially in shallow applications. Solid-stem rigs are relatively simple, with few lubricated parts at positions likely to contaminate the test hole or monitoring well. Rigs capable of supporting this method are available throughout the U.S.

Solid-stem auger drilling has some disadvantages. It is prone to cross contamination of fluids in the bore hole along the large annular space around the auger. Like hollow-stem augers, the design of these augers produce an approximately 1-inch thick rind of smeared cuttings which may effectively seal the bore-hole walls in clayey sediments. This rind may interfere with the flow of fluids to the monitoring well. Solid-stem augers must be removed from the hole before any soil sampling or well installation can commence. The method is, therefore, generally limited to stable earth materials which will not collapse when the augers are removed from the hole.

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Saturated silts, sands and gravels, and materials below those sediment types are not suited to monitoring-well construction by this drilling method. Soil sampling during solid-stem auger drilling is labor intensive, especially in deeper holes because the augers must be removed from the hole during each sampling procedure. Workers are also more likely to contact contaminated materials and equipment during this repeated large scale handling of down-hole equipment.

Solid-stem auger drilling is generally restricted to the more cohesive, yet poorly lithified sediments. The method is well suited to drilling in glacial tills. These sediments are composed primarily of sticky-bentonitic clays that require high rotary head torque to cut and transport cuttings from deeper holes. Cretaceous shale, chalk, and sandstone provide for difficult auger drilling but may often be penetrated with larger, more powerful auger rigs and heavy-duty augers. Sediments containing abundant large boulders may be penetrated only with great difficulty by solid-stem auger methods. Other well lithified bedrock units preclude solid-stem auger drilling.

Bucket auger

Bucket auger drilling uses a rotating cylindrical bucket with cutting blades mounted on a hinged bottom to repeatedly cut and lift sediments from the hole, much like the operation of a common post hole auger. Bucket-auger rigs may be equipped to drill holes from 10 to 60 inches in diameter. Bore holes for monitoring wells drilled are commonly 12 inches in diameter. Bucket-auger rigs are capable of drilling to about 100 feet in depth.

Bucket augering requires little or no fluid in the drilling process. The entire surface of the drilling tools is easily accessible, allowing complete and simplified decontamination. Though normal soil sampling tools are not usually supported, samples from the drilling process are adequate for most purposes and easily located as to position within stratigraphy of the hole. A variation of bucket-auger drilling available fashioned after the California Stovepipe method, advances casing during the drilling process. This variation greatly limits the potential for cross contamination of fluids within the bore hole. Bucket-auger rigs are relatively simple, with few lubricated parts at positions likely to contaminate the test hole or monitoring well.

They are capable of quite rapid drilling rates. Bucket-auger rigs are available at throughout the U.S.

Disadvantages of bucket augering include the production of a large volume of cuttings and fluids (when operating within the saturated zone). When water-tight casing is not advanced concurrent with drilling, cross contamination of fluid-bearing intervals is likely. Bucket augering is generally limited to poorly lithified but cohesive sediments, but may continue even into sand and gravel if the hole is cased concurrent with the drilling process, or the hole is kept full of water.

Even moderately lithified sediments usually are too resistant for bucket-auger rigs to penetrate. Bucket augering is generally restricted to the more cohesive, yet unlithified sediments. The method is well suited to drilling in glacial tills. Cretaceous shale, chalk, and sandstone are difficult to impossible to drill using the bucket-auger method. Sediments containing abundant large boulders preclude bucket-auger drilling.

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Direct-Mud Rotary

In the direct- mud rotary method, the borehole is advanced by rapid rotation of a drill bit mounted upon the end of drill rods. The bit cuts and breaks the material at the bottom of the hole into small pieces (cuttings). The cuttings are removed by pumping drilling fluid (water, or water mixed with bentonite or other fluid enhancers) down through the drill rods and bit and up the annulus between the bore hole and the drill rods. The drilling fluid also serves to cool the drill bit and stabilize the borehole walls, to prevent the flow of fluids between the borehole and surrounding earth materials, and to reduce cross contamination between aquifers.

Direct- mud rotary drilling offers a number of advantages. It is a very fast and efficient means of drilling. Efficient rigs can produce several hundred feet of hole per day. The direct-mud rotary method can reach to several thousand feet in depth and create hole diameters to greater than 48 inches. The method is adaptable to a wide range of geologic conditions. Only exceptionally large, poorly stabilized boulders or karst (cavernous) conditions are unsuited for direct-mud rotary drilling. Direct- mud rotary rigs are widely available throughout the U.S. Sediment sampling is broadly supported in direct- mud rotary drilling: standard split-barrel and thin-wall sampling are available in poorly lithified materials while a broad range of coring apparatus are supported for consolidated rock. Hydrologic conditions have little effect upon direct- mud rotary drilling; operations are usually unhindered by the presence of ground water. Direct- mud rotary drilling readily supports the telescoping of casings to successively smaller sizes to isolate drilled intervals and to protect lower geologic units from contamination by previously drilled, contaminated upper sediments.

Direct- mud rotary drilling has some inherent disadvantages for monitoring-well installation. If the drilling mud is not carefully engineered, drill fluids may invade permeable zones, compromising the validity of subsequent monitoring well samples from those intervals. The mud cake necessary for hole stability will usually interfere to some unknown extent by ionic exchange with the analysis of monitoring well water samples (U.S. Environmental Protection Agency, 1991). Organic compounds that are commonly added to drilling fluids may also interfere with chemical and physical tests on sediment samples. Poorly engineered drill fluids may produce difficult-to-remove mud cakes that inhibit the flow of fluids to the well. Relatively large volumes of cuttings and drilling fluids may provide containment problems and must be disposed of properly. At sites being monitored for hydrocarbons, inherently complex rotary rigs may introduce grease and oil to the monitoring system. Mud pumps, water swivels, rotary drives, rod connections, and drill- fluid components all may contribute hydrocarbons inadvertently to the system, despite the best decontamination/degreasing efforts. When water or other materials are introduced to the drill hole, those materials must be sampled and analyzed as control samples.

Despite these problems, direct- mud rotary drilling may sometimes be the best available alternative, especially for deep wells or wells completed into well lithified rocks. When direct-mud rotary methods are used, hole diameters should be 3 to 5 inches larger than the outer diameter of the well casings to allow effective placement of filter and sealing materials. Two inch diameter monitoring wells should therefore be installed within 5.5- inch diameter or larger holes.

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Direct- mud rotary drilling is well suited to most geologic conditions. Only areas prone to lost circulation such as karstic limestones and boulder formations such as found along high- gradient stream valleys are beyond the capabilities of direct-mud rotary drilling.

Reverse-Air Rotary

The reverse-air rotary method operates by the same general principles as direct- mud rotary except that compressed air is pumped down the drill rods and returns with the drill cuttings up through the annulus. The reverse-air rotary method is best suited to drilling in relatively stable to consolidated formations. Casing is sometimes used to prevent caving in poorly consolidated formations.

Reverse-air rotary drilling is a very fast and efficient means of drilling. Rigs that are properly equipped and staffed can drill several hundred feet of hole per day. The reverse-air rotary method can reach to several thousand feet in depth and create hole diameters up to approximately 17 inches. Reverse-air rotary rigs are unrestrained by karst (cavernous) terrain.

Sediment sampling is supported both in poorly lithified materials (by split-barrel samplers) and in consolidated rock (by coring). Reverse-air rotary drilling supports the telescoping of casings to successively smaller sizes to isolate drilled intervals and protect lower geologic units from contamination by previously drilled contaminated upper sediments. Reverse-air rotary rigs are sometimes fitted with a casing driver to overcome bore hole instability problems in unconsolidated sediments. When so equipped, reverse-air rotary rigs minimize the potential for interaquifer contamination. Reverse-air rotary rigs are available throughout the U.S.

Reverse-air rotary drilling presents some disadvantages. In contaminated formations, the use of high-pressure air may pose a significant hazard to the drill crew due to rapid transport of contaminated material up the bore hole during drilling. Large volumes of hazardous gases may be discharged at the surface, posing an immediate hazard to the drill crew and others in the vicinity. Introduction of air to ground water could interfere with chemical analyses primarily by oxidation and by vigorous agitation and mixing. Concentrations of volatile contaminants are very likely to be reduced in ground water adjacent to holes drilled using the reverse-air rotary method. The air discharged from air compressors normally contains finely atomized lubricating oil. To help prevent this oil from contaminating monitoring well drill holes, compressor discharge filters must be installed (and maintained during regular intervals) on rigs used to drill monitoring wells. Air-discharge samples should be collected as reference samples for future comparison where hydrocarbon contamination is being studied. These samples are a necessity in applications where lubrication of down-the-hole hammers or other tools is essential. The use of foam additives to aid cuttings removal can also introduce organic contaminants into the monitoring system. These should be avoided, but where necessary, samples of the foaming agent must be taken as reference samples.

Cuttings above the water table are usually very fine and hard to interpret. Also, the drying effect of the air in the annulus may reduce or eliminate any natural moisture in the cuttings, thereby masking low yield water producing zones. Conversely, when high- yield aquifers are encountered, large volumes of water may be produced during drilling, a definite disadvantage if the water is contaminated and requires special handling and disposal.

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When reverse-air rotary methods are used, hole diameters should be 3 to 5 inches larger than the outer diameter of the well casings to allow effective placement of filter and sealing materials. Two- inch diameter monitoring wells should therefore be installed within 5.5- inch diameter or larger holes.

Cable Tool

Cable-tool drilling involves chipping and cutting earth materials by lifting and dropping a heavy, solid chisel-shaped bit, suspended on a steel cable from a truck- mounted rig. Steel casing is often used to keep the hole open during drilling in unstable materials. Casing is also used to isolate potentially contaminated strata.

In the context of monitoring-well drilling, the cable-tool method is unrestricted as to depth, diameters, and ability to penetrate geologic materials. The method is well suited to drilling both below and above the water table. Small volumes of easily contained cuttings are produced. Little or no outside drilling fluids are normally needed, and fluids which are used are primarily to facilitate cuttings removal by a bailer or sand pump.

Detection and isolation of thin fluid bearing intervals and ease of well development is unsurpassed by any other drilling technique. Excellent sediment samples are obtainable. Successively smaller casing may be easily telescoped within previously installed casing to avoid carrying shallow contaminated materials into lower stratigraphic units. Sampling of soil and water during drilling and the installation of monitoring equipment is easily accomplished during cable-tool drilling. Cable-tool rigs are extremely simple with few lubricated parts at positions likely to contaminate the test hole or monitoring well. Some cable-tool rigs are dual purpose, also supporting rotary-drilling techniques. The primary disadvantage of cable-tool drilling is its relatively slow rate of penetration. Cable tool drilling rates range from as low as 10 feet per day to rarely over 100 feet per day in glacial drift. Cable-tool rigs are becoming relatively rare. Only a few may be found.

Sufficient annular space should be maintained between drilling casing and monitoring-well casing to allow effective placement of filter and sealing materials. Test holes or steel casing around the well casings should be 3 to 5 inches greater in diameter than the monitoring-well casings. Two-inch diameter monitoring wells should therefore be installed within a 5.5-inch diameter or larger test hole or drilling casing.

Cable-tool drilling is applicable throughout the U.S. in all geologic and hydrologic conditions.

Direct Push

Direct push technology includes several types of drilling rigs and drilling equipment which advances a drill string by pushing or hammering without rotating the drill string. While this does not meet the proper definition of drilling, it does achieve the same result — a borehole. Direct push rigs include both cone penetration testing (CPT) rigs and direct push sampling rigs such as a PowerProbe or Geoprobe. Direct push rigs typically are limited to drilling in unconsolidated soil materials and very soft rock.

CPT rigs advance specialized testing equipment (such as electronic cones), and soil samplers using large hydraulic rams. Most CPT rigs are heavily ballasted (20 metric tons is typical) as a

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counter force against the pushing force of the hydraulic rams which are often rated up to 20 kN. Alternatively, small, light CPT rigs and offshore CPT rigs will use anchors such as screwed-in ground anchors to create the reactive force. In ideal conditions, CPT rigs can achieve production rates of up to 250–300 meters per day.

Direct push drilling rigs use hydraulic cylinders and a hydraulic hammer in advancing a hollow core sampler to gather soil and groundwater samples. The speed and depth of penetration is largely dependent on the soil type, the size of the sampler, and the weight and power the rig. Direct push techniques are generally limited to shallow soil sample recovery in unconsolidated soil materials. The advantage of direct push technology is that in the right soil type it can produce a large number of high quality samples quickly and cheaply, generally from 50 to 75 meters per day. Rather than hammering, direct push can also be combined with sonic (vibratory) methods to increase drill efficiency.

Sonic (Vibratory) Drilling

A sonic drill head works by sending high frequency resonant vibrations down the drill string to the drill bit, while the operator controls these frequencies to suit the specific conditions of the soil/rock geology. Vibrations may also be generated within the drill head. The frequency is generally between 50 and 120 hertz (cycles per second) and can be varied by the operator.

Resonance magnifies the amplitude of the drill bit, which fluidizes the soil particles at the bit face, allowing for fast and easy penetration through most geological formations. An internal spring system isolates these vibrational forces from the rest of the drill rig.

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OPERATING PROCEDURE: OP1008

OPERATIONS OVER, NEAR, OR ON WATER

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP1008

OPERATIONS OVER, NEAR, OR ON WATER

1. PURPOSE

To ensure that Haley & Aldrich, Inc. staff members are aware of safe operations when working over, near, or on water bodies that are applicable to worker safety and pollution prevention rules and regulations.

1.1 Background

Haley & Aldrich conducts work activities that require staff members to work on vessels or land-based activities over, near, or on water. Worker safety, equipment approval, and pollution prevention regulations for these operations must conform to a variety of Federal and State regulations depending on the water body, equipment used, and nature of the operation. This Haley & Aldrich procedure has been developed in accordance with certain Occupational Safety and Health Administration (OSHA) and United States Coast Guard (USCG) rules.

Projects involving fieldwork near bodies of water must be evaluated by the Project Manager (PM), Local Health and Safety Coordinator (LHSC), and/or the Corporate Health and Safety Manager (CHSM) for potential hazards to employees.

1.2 Application

This procedure applies to Haley & Aldrich, Inc. (H&A) projects and activities while working over, near or on water. The information and requirements within this procedure apply to navigable and non-navigable waterways. The actual determination of whether or not a given project or activity will fall within the requirement of this procedure will be made by the Project Manager with the Local Health and Safety Coordinator providing assistance. If there is a question about applicability, the Corporate Health and Safety Manager will determine applicability.

2. EQUIPMENT & SUPPLIES

- Head protection
- Hearing protection
- Eye and face protection
- Chemical Resistant Clothing

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- Respiratory protection
- Safety harness, lifelines and lanyards
- USCG approved lifejacket, personal flotation device (PFD) or buoyant work vest
- A 30 – inch diameter ring buoy with 90 feet of line for emergency rescue operations.
- At least one lifesaving skiff or boat immediately available for rescues.
- For activities where personnel must board a vessel, an appropriate ramp, gangway, ladder or Jacobs ladder must be available.
- Appropriate illumination for activities that will occur at night or in reduced visibility. OSHA requires a minimum of five foot-candles measured in the working area.
- A first aid kit shall be available on site or on the vessel.
- No hazardous material in bulk (> 55 U.S. gallons) shall be carried on board a vessel unless the vessel has been inspected and certified for that purpose by the USCG.
- Appropriate fire fighting equipment shall be provided on any vessel. Work areas shall be marked with safety signs as required.
- No plastics or other garbage shall be discharged overboard from any vessel. Any garbage that accumulates shall undergo proper disposal.

Equipment must be kept in good working condition and worn properly at all times.

3. PROCEDURE

3.1 Project Evaluation

Project Managers are responsible for insuring that his/her projects with activities over, near, or on water meets the minimum requirements discussed in this procedure. It is the responsibility of the PM to enlist the assistance of the LSHC if the contractor providing appropriate field services is not familiar with USCG or OSHA worker safety, equipment requirements, or pollution prevention responsibilities related to water safety.

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3.2 General Requirements

Haley & Aldrich projects that require staff members to work near or over bodies of water (over 3 ft. deep) must develop a site-specific health and safety plan (HASP), regardless of the type of work that is being performed. This includes geotechnical and environmental related work activities and, in particular, includes drilling and sampling work from boats, barges, and jack-up rigs. Health and Safety Plan templates can be obtained from the Health and Safety Homepage on the Company Intranet.

When working on a vessel, such as a barge, Haley & Aldrich Staff Members must conduct a visual inspection of the vessel to determine whether the items listed below are present. In the event that an item listed is not present, contact the Project Manager and inform him/her that one is not available on the vessel. Project Managers are expected to communicate OSHA requirements to the responsible party and to ensure that our subcontractors, such as drillers, have a health and safety plan for their staff on the site.

Staff Members shall never work alone when working on a vessel. One or more additional Haley & Aldrich staff member(s) or one or more contractor representative(s) shall be present at all times.

It is the responsibility of the staff members on the site in consultation with the PM to determine whether the water and weather conditions are safe for work activities. Consideration shall be made based on water velocity, water temperature, degree of recreational and commercial use, adverse weather (wind, heavy rain, fog, snow, etc.), and unknown structures and hazards below the water.

Vessels shall have the appropriate navigational equipment, emergency lights, and running lights.

3.3 Reporting of an Oil or Chemical Spill

In the event of an oil or chemical spill into U.S. waters, the entity that owns or operates the vessel shall make a report immediately to the National Response Center (1-800-424-8802). The Incident Report Number shall be entered in the daily field log to forestall any subsequent questions about a failure to notify.

In the event of a spill, immediate steps shall be taken to stop the source of the discharge and to clean up and mitigate environmental damages. Major spills are not in the scope of H&A work activities. Staff members must have advanced training and certification to respond to spills on the water.

The PM shall be notified of spill or release incidents. In the event of any significant pollution incident, the PM shall notify the, LHSC, CHSM, and the Operational Leader from their business unit.

3.4 Uninspected Vessel Operations

If an uninspected vessel is used, the PM shall ensure that the vessel is suitable for its intended service prior to commencing field activities. The vessel shall be examined and made structurally sound by the contractor before commencing any work. If there are any questions regarding the vessels condition, a marine surveyor should be used identify deficiencies.

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In the event a H&A staff member believes that the vessel is unsafe for use, he/she shall contact the PM immediately to discuss the situation and their concerns.

3.5 Inspected Vessel Operations

In a large number of cases, the type of work H&A performs will not require the use of an inspected vessel. If an inspected vessel is used for the field activities, the contractor providing the vessel shall be responsible for ensuring that the vessel has and maintains the appropriate vessel inspection certification. The contractor shall ensure that personnel operating the vessel have the appropriate licenses and certificates. The contractor shall provide the PM with an appropriate Oil Spill Prevention Certificate of Financial Responsibility prior to the commencement of field activities.

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APPENDIX A
REFERENCES

- Occupational Health and Safety Regulations (OSHA) and United States Coast Guard (USCG) 29 CFR 1926 Subpart C, General Safety and Health Provisions; 29 CFR 1926 Subpart E, Personal Protective Equipment; 29 CFR 1926.106, Working Over or Near Water; 33 CFR Part 151, Vessels Carrying Oil, Noxious Liquid Substances, Garbage, Municipal or Commercial Waste, and Ballast Water; 46 CFR Parts 25 and 26, Uninspected Vessels

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP1022 Health and Safety
- OP2000 Monitoring Field Explorations

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APPENDIX C
FORMS

None required

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APPENDIX D
GLOSSARY

- **Inspected Vessels.** The US Coast Guard determines whether a vessel operating in the U.S. must be inspected by an evaluation of its intended service, the vessels length and the intended area of operation (ocean; lakes, bays or sounds; rivers, etc.). If the contractor providing the vessel is unsure of the inspection status, the owner/operator of the vessel shall refer to 46 Code of Federal Regulations Table 24.05-1(a). Questions should be directed to the local USCG Marine Safety Office.

- **Barge.** Any water transportable vessel not equipped with means of self-propulsion.

- **Uninspected Vessels.** All vessels indicated in Column 6 of 46 CFR Table 24.05-1(a).

- **Garbage Discharge -** 33 CFR 151.67 prohibits the discharge of plastic or garbage mixed with plastic into the sea or the navigable waters of the United States. "Plastic" and "garbage" are defined in 33 CFR 151.05.

- **National Response Center -** The U.S. National Response System is the federal government's mechanism for emergency response to discharges of oil and releases of chemicals. The National Response Center is the communications hub of the National Response System. Its 24-hour phone number is (1-800-424-8802)

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OPERATING PROCEDURE: OP2000

MONITORING FIELD EXPLORATIONS

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP2000

MONITORING FIELD EXPLORATIONS

1. PURPOSE

Exploratory test borings, probes and test pits represent important sources of subsurface information relating to geologic conditions and site suitability fundamental to environmental site assessment and geotechnical engineering design recommendations. The following procedure is an outline of the field staff responsibilities while monitoring subsurface exploration methods utilized by Haley & Aldrich Inc. (H&A) to obtain the best possible data for geologic characterization, laboratory testing and subsequent engineering evaluations and environmental assessment.

2. EQUIPMENT & MATERIALS

2.1 Standard Required Equipment

Required		Additional as Required	
1.	Proposal (signed by Client)	20.	First Aid Kit
2.	Site Plan	21.	Cellular Phone
3.	Contract with Subcontractor (pay items)	22.	Health & Safety Plan
4.	Exploration Criteria/Specifications	23.	Respirator & Tyvek Suit
5.	Field Book	24.	Laptop Computer
6.	Clipboard	25.	Camera & Film
7.	Logs & Forms	26.	Field Procedures
8.	Office Supplies (pencils & markers)	27.	Maps and References
9.	Engineer's Scale	28.	Sample Bags & Jars with Labels
10.	6 ft. Ruler	29.	Survey Stakes/Paint/Flagging
11.	100 ft. Measuring Tape	30.	Shovel
12.	Hand Lens, magnifying	31.	Geologist's Pick
13.	Pocket Knife	32.	Flashlight
14.	Hard Hat	33.	Roadway Box Key/Socket Wrench
15.	Safety Glasses	34.	Water Level Indicator
16.	Sound Dampeners	35.	Hand Level
17.	Steel Toe Boots	36.	Brunton Compass
18.	Protective Gloves	37.	Pocket Penetrometer
19.	Rain Gear	38.	Torvane

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2.2 Required Environmental Equipment

Most environmental fieldwork will have extensive equipment requirements and supplies specifically related to the project needs. The following list is a representative list of equipment classed as type-specific groups. A comprehensive list of equipment and materials must be developed for each project in coordination with the Project Manager (PM) and Health & Safety (H&S) Coordinator prior to the start of the field program.

1. Personal Protection Equipment (PPE)
   - Air Purifying Respirator & Cartridges (Type GMC-Type H)
   - Latex/Nitrile Inner Gloves/Boot Covers
   - Tyvek/Saranex Coveralls/Sleeves/Apron

2. Decontamination Equipment and Supplies
   - Decontamination Kit
     - 5 gallon bucket
     - 5 gallon water jug
     - alconox detergent
     - brushes & paper towels
     - methanol/hexane/deionized water
   - Decontamination Tub
   - Absorption Pads
   - Polyethylene Sheeting
   - Polyethylene Trash Bags

3. Air Quality/Headspace Monitoring Equipment
   - Photo-Ionization Detector (PID)
   - Flame Ionization Detector (FID)
   - Organic Vapor Analyzer (OVA)
   - Combustible Gas Meter-LEL/O2
   - Dust Monitor
   - Multigas Meter-HCn/Methane/H2S
   - Gas Pointer
   - Draeger Tube Sampling Kit
   - Radiation Survey Meter

4. Soil Sampling Equipment and Supplies
   - Hand Auger
   - Soil Core Sampler
   - Shovel/Trowel/Remote Sampler
   - Stainless Steel Bowl
   - Aluminum Foil
   - Tongue Depressors
   - Sample Bags/Laboratory Glassware & Labels
   - Cooler & Ice Blocks

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5. Water Sampling Equipment and Supplies
   - Water Level Indicator
   - Oil/Water Interface Probe
   - Centrifugal Pump-Volume
   - Submersible Pump-Low Flow
   - Peristaltic Pump & Silicone Tubing
   - Purge Pump & DC Supply
   - Waterra® Tubing/Foot Valves/Filters
   - Stainless Steel/Teflon Bailers & Rope
   - Remote Sampler
   - Water Testing Equipment
     - Flow Cell (pH, temperature, conductivity, DO, turbidity, ORP and salinity)
     - Dissolved Oxygen (DO) Meter
     - Oxidation-Reduction Potential (ORP) Meter
     - Turbidity Meter
     - Downhole Temperature/Resistivity/Conductivity/Salinity Meter
     - pH/ Turbidity/DO/ Temperature/Resistivity/Conductivity/Salinity Meter
   - Laboratory Glassware & Labels
   - Cooler & Ice Blocks

2.3 Additional Equipment, Specialized Instrumentation, Materials & Company Vehicles

Company-wide, Haley & Aldrich maintains an array of equipment, vehicles and specialized instrumentation for a broad variety of uses in addition to the selected equipment listed above. Additional equipment, vehicles and materials may be rented or purchased as needed with the approval of the project manager. Project equipment needs should be addressed proactively so that interoffice allocation can take place. It is recommended that the field staff familiarize themselves with the use, function and availability of all types of equipment standard to the industry. The following list is representative of the additional equipment currently available but is not intended to be a comprehensive list.

1. Survey Instrumentation
   - Theodolite/Transit/ Level & Rod
   - Global Positioning System (GPS)

2. Subsurface Locating Equipment
   - Ground Penetrating Radar (GPR)
   - Metal Detector
   - Magnetometer

3. Air-Soil-Water Quality/Analytical Equipment
   - Gas Chromatograph (GC)
   - TPH Analyzer
   - Infrared Oil Analyzer
   - Radiation Survey Meter
   - Oxidation-Reduction Potential Meter (ORP)

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4. Geotechnical Equipment & Instrumentation
   - Vane Shear Test Equipment
   - Vibrating Wire Piezometer Equipment
   - Pressuremeter Testing Equipment
   - Seismograph Equipment
   - Inclinometer Equipment
   - Nuclear Moisture-Density Gauge
   - Sound Level Meter

5. Hydrogeologic Equipment & Instrumentation
   - Datalogger/Levelogger Hardware & Software
   - Stream Flow Gauge & Equipment

6. Photographic Equipment
   - Video Camera
   - Digital Camera
   - 35mm Camera

7. Communication Equipment
   - Cellular Telephone
   - Satellite Telephone
   - Two-Way Radio

8. Computer Hardware & Software

2.4 Billing Equipment & Materials

Equipment and materials are billed to the project as used on a daily or per item basis. Completion of equipment usage and billing forms and submission of original receipts for items purchased or rented is required in order to charge the project for reimbursement.

3. PROCEDURE

3.1 Preliminary Preparations

3.1.1 Project Briefing

Prior to the beginning of an exploration program all field staff should attend a project briefing with the project manager and office staff involved in the proposed project. At this time a file folder for the field activities should be created for the purpose of containing all relevant project information including: copies of the original proposal, site and utility plans, contract documents and drawings, applicable regulations, exploration and sampling criteria, site contacts, phone numbers of team members, health

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and safety (H&S) plans, log and report forms and any other related documents or references. The field folder should be organized and maintained such that all documents likely to be useful for the completion of field activities by others are readily available in the event of personnel changes.

During the project briefing each team member should become thoroughly familiar with the overall scope of the project in addition to the task items and individual requirements of the work plan. Development of an outline of the specific activities envisioned and a review of the details concerning each task may facilitate the formulation of alternate approaches to field methods as well as the creation of action, materials and equipment lists.

Field staff should review all existing applicable information that relates to site geology and possess detailed familiarity and understanding of the contract specifications in order that knowledgeable field decisions can be made. Field staff should be experienced in all of the various field exploration procedures, instrumentation installation and sampling techniques required for the project. Requests for training, guidance or assistance should be made by the field staff as needed. Haley & Aldrich, Inc. fosters a supportive environment where all staff are encouraged to share knowledge and experiences with each other.

3.1.2 Health & Safety

Safety in the workplace is a prime concern of Haley & Aldrich, Inc. on all projects. It is essential that field personnel understand and comply with all regulations governing worker safety in the field including applicable OSHA guidelines. Certain projects will require the field staff to attend a Health & Safety briefing due to specific occupational safety concerns. The nature of these concerns will be addressed by a site specific Health & Safety Plan. It is the responsibility of the project manager to notify the field staff of the existence of the Health & Safety Plan, however all field staff are encouraged to inquire with the Project Manager and with the Health & Safety Coordinator directly to avoid any possible oversight. Safety awareness and safe work practices are the responsibility of the field staff at all times and on all projects whether or not site or task specific guidelines are in existence. In the event of an accident, exposure or if unexpected contamination is encountered, the Project Manager and the Health & Safety Coordinator must be contacted immediately. Standard H&A safety recommendations for subsurface explorations are provided OP1001 Excavation and Trenching Safety and OP1002 Drilling Safety.

3.2 Duties and Responsibilities

3.2.1 General

The principal reason for providing Haley & Aldrich field representation is to assure that the field data being collected is accurate and of the type necessary to properly evaluate the site geologic conditions for use in the subsequent engineering analyses and environmental assessment.

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3.2.2 Supervision of Subsurface Exploration Programs

Each subsurface exploration program carried out under H&A supervision is designed to accommodate the specific requirements of a given project. Subsurface exploration programs routinely include the excavation of test pits and the drilling of test borings with associated instrumentation installation, special testing and sampling requirements. Modifications to the fieldwork criteria, sampling and testing are often made during the execution of the subsurface exploration program as the accumulated geologic data and test results are interpreted. For this reason it is essential that all records are current and complete and that uncertainties are identified for resolution. Field staff are responsible for maintaining communication with the project manager and logistical coordination of the field effort within the workscope and budgetary limits.

3.2.3 Verification of Subsurface Exploration Techniques and Services

It is the role of H&A field staff to verify that instrumentation installation, subsurface sampling and testing methods are in conformance with applicable approved standards and specifications and to document conditions and results. Performance of sampling and testing is commonly conducted with subcontractor support and equipment. It is the responsibility of the H&A field staff to verify that proper equipment and techniques are employed and to obtain measurements and make observations independently. H&A field staff are responsible for complete field logging of groundwater, soil and bedrock conditions, the maintenance of accurate test records and field exploration location sketches, and ensuring proper instrumentation installation, sample preservation and handling. In addition, payment for services rendered on behalf of the client is commonly handled with H&A providing a daily field report (DFR) including an accurate breakdown of the work activities and itemized costs on a daily basis. Subcontractor pay items and method of payment are defined in their contract.

3.2.4 Right of Access

Prior to site entry, Haley & Aldrich staff members must ensure that permission has been gained from the property owner to access the property.

3.2.5 Layout and Utility Clearance

Prior to the start of any subsurface exploration all proposed locations must have utility clearance from all appropriate agencies and utility owners. Utility owners typically do not enter private properties. If there are particular concerns regarding utilities on private property, arrangements can be made with a private utility locating service. Prior to contacting any utility agency or service all proposed exploration locations must first be clearly marked in the field either with white paint or staked and white flagged. Additional colors can be used to highlight the location if the ground is snow covered. Alternate locations should be laid out in areas of suspected utilities. H&A requires the subsurface exploration subcontractor to obtain the utility clearance within the terms of the contract or services agreement. H&A field staff should verify with the driller/test pit contractor that the utilities have been cleared and obtain the clearance number prior to the start of subsurface explorations. Pre-excavation

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may be necessary in areas of closely spaced utilities either by hand, vacuum, or other means. Additional guidance is provided in OP1003 Utility Clearance.

3.2.6 Site Safety and Subcontractor Briefing

At the start of fieldwork, H&A field staff should coordinate a site briefing to review the schedule and workscope with all subcontractors involved with the project. This briefing should include a review of the equipment and material needs, exploration criteria and priority, testing and sampling specifics, pay items, site conditions, environmental concerns, known or suspected contamination, H&S information, decontamination requirements, site restoration and waste disposal issues, a site walkover and utility check. While it is the subcontractor's responsibility to obtain the utility clearance, the field representative should pay attention to the utility plans as well as surface manifestations of utilities involving manholes or catch basin grates, and gate or roadway boxes. Distance to overhead utilities must be considered as well. Observations of potential conflicts with utilities should be addressed with the subcontractor for their consideration.

3.2.7 Exploration Monitoring

3.2.7.1 General

Haley & Aldrich field staff should become familiar with the technical details and suitability of all exploration equipment and methods. Test borings are the most common method employed by H&A to obtain high quality data on subsurface conditions. Unsampled probes can be used in a limited capacity to document overburden thickness. Specialty equipment is routinely used in sampled probes for environmental sampling. Test pits are preferred for surficial geological mapping and to document fill or overburden thickness. In addition to these typical exploration methods a variety of special testing techniques and instrumentation installations may supplement the subsurface exploration program. Specific H&A procedures must be consulted for details relating to special testing, sampling and instrumentation installation.

3.2.7.2 Exploration Equipment and Use

Exploration equipment selection is based upon a detailed understanding of the capabilities of the equipment with regard to the anticipated site geological conditions. In addition, the particular project needs may necessitate or preclude certain techniques and equipment. During the initial site walkover or layout, equipment access is considered and the type of exploration method is determined. Relatively small drill rigs are routinely used for overburden sampling, bedrock coring and groundwater monitoring well installations on a variety of projects. Larger pneumatic-percussive well rigs are used for drilling aquifer test and production wells. Excavation equipment may be preferred for initial surficial geologic mapping and to provide access prior to drilling. Various probe equipment may be considered for preliminary estimation of overburden thickness. Access to a water supply must be arranged for cased test borings and rock coring. Shallow water conditions and potentially liquefaction-susceptible soils preclude the use of augers. Bedrock monitoring wells must be cored in sufficient diameter to

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allow sand pack and seals. Enclosed areas may necessitate alternate fuels or low overhead equipment. Ecologically sensitive areas may require non-petroleum-based hydraulics or lightweight equipment. Many factors affect the equipment selection resulting in some trade-off in performance, cost and reliability of data.

3.2.7.3 Test Boring Techniques

A. *Cased Borings* - Cased borings are the primary method of obtaining high quality overburden samples and for penetration to bedrock prior to rock coring. The drill casing (pipe) is typically advanced in 5 ft. increments either by driving or spinning and then is washed out with an axially discharging tricone rollerbit pumping water or drill slurry from the recirculation tub. Upon flushing, the rollerbit is removed and a splitspoon sampler is fixed to the drill string (rods), lowered to the bottom of the borehole and driven into the undisturbed soils below the bottom of the casing. The procedure is repeated until the termination depth criterion is reached or bedrock is encountered. Common casing inside diameter (I.D.) ranges from 3 inch to 6 inch depending upon conditions and criteria. Rollerbits are sized to fit inside the casing with approximately 1/16 to 1/8 in. clearance. Typically boreholes are started with 5 or 6 in. I.D. casing fitted with a hard-shoe or drive-shoe in the lead (bottom) section. The casing is driven and splitspoon sampling is conducted at 5 ft. intervals (standard sampling) until an obstruction is encountered or the casing is seated into material such as clay that will maintain itself uncased. In the event of an obstruction the rollerbit or a buttonbit may be used to advance through the obstruction. In some cases the obstruction may break or a boulder-buster may be successfully employed and the casing is advanced. In other cases the next smaller diameter casing will be telescoped down the borehole and advanced through the hole in the obstruction created by the buttonbit. In the event that material such as clay that will maintain itself uncased is encountered, the open hole is extended as deep as possible. The borehole may be maintained by a bentonite or polymer slurry (mud rotary drilling). Casing fitted with a spin-shoe (econoshoe) is advanced by drilling in a similar manner to rollerbit advancement. Slurry or water is pumped down the casing to cool the bit and flush away the drill solids. Prior to splitspoon sampling the rollerbit must be lowered down the borehole and the spun casing must be drilled out in the same fashion as with driven casing. Spun or driven casing must be seated into the top of the bedrock in order to achieve an effective seal prior to rock coring.

B. *Mud Rotary Drilling* - Mud rotary drilling typically is conducted in deeper overburden borings and on projects where there are special concerns for soil sample integrity or particularly soft soils. Various products are used to make drill mud depending upon conditions and project requirements. Some mud is bentonite-silica based (heavy mud), some are compatible with saline conditions for ocean drilling, and some polymers are biodegradable for use in boreholes intended for environmental groundwater monitoring well installation. In all cases, mud drilling requires that a positive head be maintained in the casing at all times to stabilize the borehole. The practice is to fit a bypass line to

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the recirculation circuit that can be easily used to fill the casing as the rollerbit is being withdrawn. Use of a mud balance is required under certain circumstances to ensure sample integrity at the bottom of the borehole. The specific gravity to maintain in the drill mud will be specified on these projects.

C. *Auger Borings* - Hollow stem augers (HSA) are an effective and fast method for drilling shallow borings in softer soils above the water table without introducing water or drill slurry. Hollow stem augers are preferred for environmental studies where continuous soil sampling and minimization of potential cross contamination due to the use of drilling fluids is desired. Hollow stem augers and solid stem augers are also used as shallow probes. Auger flights are typically 5 ft. in length and are commonly 3.5 to 4.25 in. I.D. The lead section is fitted with a cutter head upon which are fixed several hardened, replaceable teeth. Using a center plug fixed to the bottom of the rods, hollow stem augers are typically advanced by drilling to the desired depth whereupon the center plug is replaced by the splitspoon and driven below the bottom of the lead section. Disturbance below the bottom of the augers due to the cutter head is typically substantial and heave is common at the bottom of the borehole due to the piston like effect of the center plug during removal. As such, augers are not favored for test borings on many geotechnical projects where high quality samples and penetration resistance data are required.

D. *Splitspoon Sampling and the Standard Penetration Test (SPT)* - The typical method for obtaining representative samples and a measure of the penetrative resistance of soils in test borings is by means of the Standard Penetration Test (SPT). This is accomplished utilizing a hollow tube splitspoon sampler assembly attached to the drill rods and driven into the soils at the bottom of the borehole at regular intervals. Splitspoon samplers are manufactured in various sizes with the most commonly used being 1 3/8 in. I.D. (2 in. O.D.) and having an interior sample chamber length of 24 in. (approximately 36 in. overall length). Once lowered to the sampling depth, the sampler is typically driven 24 in. into the soils with a 140 lb. hammer freely-falling over a 30 in. drop and the number of blows (SPT blowcount) required for each 6 in. of penetration is recorded. The penetrative resistance in blows per foot obtained from the summation of the blowcounts from 6 in. to 18 in. is referred to as the “N-value”. Terminology for density of granular soils and consistency of cohesive soils has been correlated to N-values. When performed properly the SPT provides useful data for determination of the geotechnical behavior of soils and engineering design in addition to representative remolded soil samples for geological interpretation.

E. *Bedrock Coring* - Bedrock coring is conducted in cased borings to obtain accurate detail of the bedrock properties and high quality samples for laboratory testing. A wide variety of rock core equipment is available and rock coring techniques vary greatly depending upon the driller, rock type, equipment and many other factors. Observations related to drilling activities are a primary focus during rock coring including bit weight, feed restriction, head speed, engine speed and gear, pump volume, water loss

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and fluid return, core rate, drilling halts, jamming, rapid advances, equipment defects, bit type, bit wear, core barrel type, core barrel adjustment. For all projects it is essential that accurate measurements be made when determining the depth of the bedrock surface from drill action or SPT and that detailed observations are recorded concerning the effects noted and the procedures executed upon encountering bedrock. Coring should begin at the minimum depth below the bedrock surface required to seat the casing in order to document the bedrock condition in the uppermost zone where typically fracturing and weathering transitions are greatest. Core hole depth must be verified following each run to account for lost core. When necessary, logging should be broken down into a two step process beginning with sample preservation, labeling and recording of a simple description including recovery and RQD measurements followed by detailed logging of individual features and properties as time and conditions permit.

F. *Observation Well Installation* - Groundwater observation or monitoring wells are commonly installed in completed test borings as a means obtaining accurate stabilized groundwater readings essential to engineering design, and hydrogeologic modeling. In addition, permanent observation or monitoring well installations provide for continual long-term sampling for environmental analyses. A wide variety of material types and sizes are employed depending upon the intended use. Typical observation or monitoring wells installations consist of 2 in. I.D. PVC pipe with a machine slotted screen section backfilled with filter sand and sealed with bentonite within the desired stratum or zone. Solid riser sections above the sealed zone may be grouted or backfilled with a variety of materials depending upon the project needs and finished at the ground surface with either a flush-mount roadway box or with a protective casing such as a guard pipe and padlock for undeveloped sites. Careful attention to the placement of screens, backfill and seals is required and accurate depth measurements must be recorded during installation. Initial well development may occur immediately upon completion in order set the sand pack and remove the effects of drill fluids from the formation waters.

3.2.7.4 Probes

A. *Unsampled Probes* - The term probe has historically referred to the advancement of a solid drill bit or rod by various means without sampling in order to estimate potential soft sediment thickness and refusal or obstruction depths. Small diameter rods advanced by hand have been useful in determining minimum peat and organic thickness in wetlands. Mechanical advancement of solid stem augers with conventional drilling equipment and pneumatic-percussive air track drilling are routinely used to supplement or replace test borings in areas of known shallow bedrock. Direct-push methods include simple rod assemblies to sophisticated electro-piezocone mechanisms. The principle advantage to conducting probes is that a great deal of data points can be rapidly obtained to create detailed contours of the desired surface or stratum. Implicit in the conduct of non-instrumented unsampled probes is that variations in drill action

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or rod advance is used to estimate strata changes. Acoustic listening devices placed within a saturated bedrock well near an air track rig will enhance the listener's ability to hear the pneumatic-percussive bit encounter bedrock. Primary among the disadvantages to conducting probes is the uncertainty resulting from relying strictly upon drill action without a hard data sample. Close proximity probes in zones of shallow refusal and repeated probes adjacent to those terminated on suspected obstructions help boost confidence and define aberrations. Secondary among the disadvantages to conducting probes is the inaccuracy inherent in the measurement of an often rapidly moving reference point as the drill advances through obstructions or variable zones into progressively more competent bedrock. Solid stem augers with conventional drilling equipment are slow to progress through dense soils and may be defeated by boulders but can be advanced below the water table without problems. Pneumatic-percussive air track drilling will rapidly advance through dense soils, boulders and bedrock but is inhibited below the groundwater table by borehole collapse and particularly when the air evacuation is suspended as rods are added to the drill string. Depending upon site conditions and termination depth, dozens of probes may be conducted in a single day. As such, horizontal and vertical control should be established at each probe location separate from the probe effort in order to obtain the most use from the rig time and to maximize the accuracy of the data.

B. *Sampled Probes* - Small diameter hand augers, soil plugs and manual soil cores are routinely used for surface soil sampling for rudimentary site reconnaissance, environmental sampling and hydric soils mapping. Direct-push and percussive or vibration driven soil core equipment preferred for shallow environmental sampling ranges in size from small diameter hand held units to vehicle mounted machinery capable of obtaining soil cores within polycarbonate liners 3.6 in. I.D. by 8 ft. length. As with any uncased borehole, additional soil cores may be obtained until the termination depth criterion is reached or sample integrity is compromised due to borehole collapse. Care must be exercised in establishing collapsed or resampled zones when documenting direct-push samples or soil cores.

3.2.7.5 Test Pits

Test pits are an extremely economical and effective way to rapidly characterize shallow subsurface conditions. Test pits are particularly useful for surficial geologic mapping, determining fill thickness and content, contouring shallow bedrock conditions and in determining oversized (cobble and boulder) percentages. Small backhoes with an approximately ¼ cubic yard bucket capacity are capable of excavating test pits up to 12 ft. depth in most materials and can be used with minimal site damage. Larger excavators with an approximately ¾ cubic yard bucket capacity are capable of excavating test pits up to 16 to 20 ft. depth and can be used to construct access for drill rigs on difficult sites. Given sufficient area, excavators can safely enter the excavation and extend the test pit indefinitely. During test pit excavation careful consideration must be given to potential bearing surface disturbance within proposed structures. In addition, care must be taken to minimize other site impacts

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requiring costly restoration including damage to trees, pavement, curbing, landscaping and utilities.

3.2.7.6 Environmental Sampling & Monitoring

Environmental sampling combined with discrete field screening of soil and groundwater for contaminants is routinely conducted during the performance of subsurface explorations. In addition, continuous monitoring of air quality within the work zone or at the project site may be required to address H&S concerns. Potential contaminants and sources may be identified in the initial stage of project planning and prior arrangements made for PPE, monitoring, sampling and laboratory analysis.

To minimize the risk of cross-contamination typical environmental sampling programs work from known or suspected clean areas toward areas of known or suspected contamination. Contamination encountered unexpectedly may present serious exposure risks to field personnel without proper PPE and monitoring instrumentation, particularly if the contamination is gross or unidentified. In the event unexpected contamination is encountered, all fieldwork should be suspended and the area evacuated immediately until the Project Manager and the Health & Safety Coordinator can be contacted so that H&S and sampling guidelines can be developed.

A. *Decontamination Procedures & Waste Management* - Standard equipment decontamination practices may include the establishment of a decontamination area such that decontamination fluids are collected and properly stored for disposal. Typically a location within the site is chosen away from sensitive or occupied zones and a decontamination pad is created within a bermed area using polyethylene sheeting. A high-pressure steam cleaner is used to wash all equipment prior to each exploration and wastewater is pumped into adjacent drums. Splitspoons and hand sampling tools are scrubbed between samples at the exploration location using a detergent (water and alconox) solution rinsed with control (tap) water followed by a solvent (methanol) rinse, wiped with a paper towel and rinsed with deionized water before being allowed to air dry. Hexane may be needed for removal of heavy petroleum, grease and coal tar. Decontamination waste, sample residue and drill cuttings are typically drummed, labeled and staged onsite for proper disposal.

B. *Environmental Soil Sampling* - Environmental soil samples obtained for chemical analyses are collected in surface samples and by using many of the techniques employed in typical subsurface explorations with special attention given to decontamination procedures. Preservation, handling and glassware for environmental soil samples varies considerably depending upon several factors including the type and degree of contamination, the analytical method to be conducted, the analytical laboratory being used and the governing regulations. In addition, the depth and location of samples may be strictly controlled under agency guidelines. Documentation of volatile organic compounds (VOC) in the soil through headspace screening is required in order to provide real-time guidance in the field to direct the sampling.

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Clean 8 oz. jars are partially filled with newly obtained soils and covered with aluminum foil and allowed to stabilized prior to screening with a photoionization detector (PID). The presence of metals in soils is not associated with odors, while coal tar, fuels and solvents are often easily distinguished. Particular attention is given to discoloration or odors noted, however it is company policy to avoid fumes and odors at all times. Soils collected from a discrete zone should be homogenized and a representative portion placed into laboratory glassware and labeled. Analytical samples are kept in a cooler with ice blocks and a Chain of Custody form is maintained until transfer to the analytical laboratory.

C. *Environmental Water Sampling* - Groundwater monitoring (observation) wells must undergo an initial well development following installation and prior to sampling. This is intended optimize well function and to produce formation-derived groundwater samples and valid analytical testing results. Groundwater sampling from existing monitoring wells for chemical analyses involves initially gauging the static groundwater level and the well depth in order to determine the well volume. Waterra® footvalves and tubing, bailers, submersible pumps or peristaltic pumps may be used to purge a minimum of three well volumes in order to minimize well effects. Turbidity, conductivity, resistivity, salinity, dissolved oxygen, oxidation-reduction potential, temperature and pH are recorded periodically after purging and groundwater parameters must be stable prior to sampling. Low-flow groundwater sampling is required for certain analyses to be valid. In such cases, variable speed submersible pumps are used at extremely slow rates to minimize drawdown and turbidity. Sampling of surface waters or open-body water at depth may be done with remote or variable depth, bottle-type samplers. Preservation, handling and glassware for environmental water samples varies considerably depending upon several factors including the type and degree of contamination, the analytical method to be conducted, the analytical laboratory being used and the governing regulations.

4.2.7.7 Special Testing, Sampling and Instrumentation

H&A utilizes a wide variety of well established and state-of-the-art soil, rock and groundwater testing procedures and instrumentation to supplement many subsurface exploration programs. Among the methods and techniques routinely used are fixed-piston tube sampling, vane shear testing, pressuremeter testing, permeability testing, water pressure (packer) testing in rock, inclinometer installation, multiposition borehole extensometers (MPBX) installation and aquifer (pump) testing. Prior to attempting an unfamiliar technique H&A field staff must review all related procedures and consult experienced personnel. Outside support or training that may be necessary to perform new procedures shall be sought with project manager approval. Notes and references obtained should be retained for potential development into new operating procedure.

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APPENDIX A
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- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6001-96, “Standard Guide Direct Push Water Sampling for Geoenvironmental Investigations.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D4700-91, “Standard Guide for Soil Sampling from the Vadose Zone.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.11.04, D4547-98, “Standard Guide for Sampling Waste and Soils for Volatile Organics.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5903-96, “Standard Guide for Planning and Preparing for a Ground-Water Sampling Event.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6089-97, “Standard Guide for Documenting a Ground-Water Sampling Event.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D4750-87, “Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.11.04, D4448-01, “Standard Guide for Sampling Groundwater Monitoring Wells.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6452-99, “Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations.”

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- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6517-00, “Standard Guide for Field Preservation of Ground-Water Samples.”

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1001 Excavation and Trenching Safety
- OP1002 Drilling Safety

- OP2001 Identification & Description of Soils in the Field Using Visual-Manual Methods
- OP2002 Identification & Description of Rock in the Field Using Visual-Manual Methods

- OP2005 Test Borings, Sampling, Standard Penetration Testing (STP) and Borehole Abandonment

- OP2020 Groundwater Monitoring (Observation) Well Installation, Development and Abandonment
- OP2026 Exploratory Test Pits
-
- OP2030 Direct Push Borings

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APPENDIX C
FORMS AND EXAMPLES

C.1 Forms

All Haley & Aldrich field forms are maintained on the server at K:\techproc\sop\Forms. The following is a list of selected current forms available for use in routine field exploration programs.

Site Investigations

- Form 2024 Site Investigation Form

Test Borings

- Form 2004 Subcontractor Quantities For Test Borings
- Form 2029 Sampling Labels - Geotechnical
- Form 2003 Test Boring Daily Field Report
- Form 2001 Test Boring Reports
- Form 2002 Core Boring Reports
- Form 2028 Geotechnical Sample Receiving Form

Observation (Monitoring) Wells

- Form 2007 Observation Well Installation Form
- Form 2013 Well Decommissioning Report
- Form 3006 Monitoring Well Development Report
- Form 2021 Groundwater Monitoring Report

Test Pits

- Form 2006 Test Pit Logs
- Form 2028 Geotechnical Sample Receiving Form

Test Probes

- Form 2022 Test Probe Report
- Form 2023 Test Probe Summary
- Form 2025 Vibracore Report

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Environmental Sampling

- Form 1010 Headspace Screening Report
- Form 3001 Sampling Labels – Environmental
- Form 3002 Chain of Custody Electronic
- Form 3003 Chain of Custody Field
- Form 3004 Sampling Record
- Form 3005 Groundwater Sampling Record

C.2 Examples

The following examples of selected completed forms are intended to provide guidance in the standard documentation conventions practiced by H&A.

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SITE INVESTIGATION FORM

PROJECT _____ **H&A FILE NO.** _____
LOCATION _____ **PROJECT MGR.** _____
CLIENT _____ **FIELD REP** _____
CONTRACTOR _____ **DATE** _____

SITE ACCESS
☐ Paved ☐ Gravel ☐ Trails ☐ None ☐ Water ☐ Inside ☐ Other _____

ENTRANCE
☐ Enclosed ☐ Gate/Keys Comments: _____

EXPLORATION EQUIPMENT
☐ Truck Rig ☐ ATV Rig ☐ Skid Rig ☐ Tripod ☐ Geoprobe ☐ Other _____
☐ Backhoe ☐ Bobcat ☐ Excavator ☐ Sm Excavator ☐ Barge ☐ Other _____
☐ Chainsaw ☐ Haybales ☐ Plywood ☐ 4WD Vehicle ☐ Other _____

WATER SUPPLY AVAILABLE
☐ Hydrant ☐ Tap ☐ River/Lake ☐ None

ELECTRIC AVAILABLE:
☐ Yes ☐ No

TOPOGRAPHY
☐ Low Lying ☐ Level ☐ Sloping ☐ Cliffs ☐ Mountains ☐ Other _____

PHYSIOGRAPHY
☐ Bedrock ☐ Till Upland ☐ Valley Floor ☐ Flood Plain ☐ Coastal Plain ☐ Other _____
☐ Wetlands ☐ Tidal Marsh ☐ Estuarine ☐ Lakes/Ponds ☐ Outwash Plain ☐ Other _____
☐ Developed ☐ Filled Land ☐ Paved ☐ Landscaped ☐ Other _____

DRAINAGE
☐ Rivers ☐ Streams ☐ Rills ☐ Canals ☐ Ditches ☐ Culverts ☐ Other _____

ESTIMATED GROUNDSURFACE ELEVATION: _____ ft

ESTIMATED GROUNDWATER DEPTH/ELEVATION: _____ ft

WOODED
☐ Heavily ☐ Partially ☐ Sparsely ☐ Comments: _____

VEGETATION
☐ Brush ☐ Grass ☐ None ☐ Comments: _____

BEDROCK OUTCROPS
LOCATION: _____
TYPE: _____

SOIL EXPOSURES
LOCATION: _____
TYPE: _____

EXISTING STRUCTURES
☐ Buildings ☐ Warehouse ☐ Slabs ☐ Bridges ☐ Foundations ☐ Other _____

UNDERGROUND STORAGE TANKS
☐ Yes ☐ No

VISIBLE EVIDENCE OF CONTAMINATION
☐ Drums ☐ Staining ☐ Site history ☐ Unauthorized dumping ☐ Other _____

OVERHEAD UTILITIES
LOCATION: _____
TYPE: _____

UNDERGROUND UTILITIES
LOCATION: _____
TYPE: _____

COMMENTS: _____

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SITE INVESTIGATION FORM

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	

SITE SKETCH

North Arrow

OVERALL DESCRIPTION AND REMARKS:	LEGEND
	Scale: 0

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SUBCONTRACTOR QUANTITIES FOR TEST BORINGS

Form #2005

Project	**File No.**
Location	**Date**
Contractor	**Project Manager**

No.	Description	Unit	Quantity
I	**MOBILIZATION/DEMOBILIZATION**		
1	Mob/Demob of Truck rig w/ OSHA-trained crew within 100 miles of contractor yard*	ea	
2	Mob/Demob of Skid rig with OSHA-trained crew within 100 miles of contractor yard*	ea	
3	Mob/Demob of Bomb/ATV rig with OSHA-trained crew within 100 miles of contractor yard*	ea	
4	Mob/Demob of Geoprobe rig w/ OSHA-trained crew within 100 miles of contractor yard*	ea	
II	**DRILLING - FOOTAGE RATE**		
5	3-in. dia. cased overburden drilling (0-100 ft.) with no sampling	lf	
6	cased overburden drilling (0-100 ft.) with standard 5-ft. interval sampling	lf	
7	cased overburden drilling (0-100 ft.) continuous sampling	lf	
8	4-in. dia. cased overburden drilling (0-100 ft.) with no sampling	lf	
9	cased overburden drilling (0-100 ft.) with standard 5-ft. interval sampling	lf	
10	cased overburden drilling (0-100 ft.) continuous sampling	lf	
11	4-¼ in. dia. hollow stem auger overburden drilling (0-100 ft.) with no sampling	lf	
12	hollow stem auger overburden drilling (0-100 ft.) w/ standard 5-ft. interval sampling	lf	
13	hollow stem auger overburden drilling (0-100 ft.) continuous sampling	lf	
14	NX rock core via double-tube core barrel (includes bit wear)	lf	
15	HX rock core via double-tube core barrel (includes bit wear)	lf	
16	Extra split spoon samples (for footage rates only)	ea	
17	3-in. undisturbed tube samples	ea	
18	Standby Time for rig and crew/Decon of equipment	hr	
III	**DRILLING - DAY RATE**		
19	Truck mounted drill rig with OSHA-trained crew	day	
20	Truck mounted drill rig with OSHA-trained crew (overtime rate)	hr	
21	Skid rig with OSHA-trained crew	day	
22	Skid rig with OSHA-trained crew (overtime rate)	hr	
23	Bomb/ATV drill rig with OSHA-trained crew	day	
24	Bomb/ATV drill rig with OSHA-trained crew (overtime rate)	hr	
25	Geoprobe rig with OSHA-trained crew	day	
26	Geoprobe rig with OSHA-trained crew (overtime rate)	hr	
27	NX rock core via double-tube core barrel (includes bit wear for day rates)	lf	
28	HX rock core via double-tube core barrel (includes bit wear for day rates)	lf	
29	Geoprobe push samples liners (4' section)	ea	
IV	**OBSERVATION WELL INSTALLATION**		
30	1-in. dia. piezometer (Sch 40 PVC) installed	lf	
31	2-in. dia. well (Sch 40 PVC) installed (slotted and screened)	lf	
32	4-in. dia. well (Sch 40 PVC) installed (slotted and screened)	lf	
33	Standard 4-in. dia. roadway box	ea	
34	Standard 8-in. dia. roadway box	ea	
35	5 ft. protective guard pipe with padlock (4-in. diameter)	ea	
V	**ADDITIONAL ITEMS**		
36	Utility Clearance	ea	
37	Permits - Determined on a job to job basis	ls	
38	State Police Detail	hr	
39	Laborer	hr	
40	Chain Saw	day	
41	Steam Cleaner with Generator	day	
42	Upgrade Crew Personnel Protection to Level "C"	hr	
43	55 gal. soil/water drum	ea	
44	Borehole Grouting (4-in. diameter)	lf	
45	Sand	bag	
46	Concrete	bag	
47	Cold Patch	bag	
48			
49			
VI	**COMMENTS**		

Driller Signature _____ **Date** _____

Geologist Signature _____ **Date** _____

WHITE - FIELD SERVICE MANAGER **CANARY** - CONTRACTOR **PINK** - PROJECT MANAGER

Form 2004

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

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Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

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Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

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Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

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Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Boring ID:	File Number:
Sample Interval:	Project:
Depth:	PM:
Recovery:	Blow Counts:
Collected By:	/ / /
Comments:	

HALEY & ALDRICH

TEST BORING DAILY REPORT

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MANAGER	
CLIENT		FIELD REPRESENTATIVE	
CONTRACTOR		DATE	
DRILLER		DFR NUMBER	
TYPE OF RIG(S)		NUMBER OF RIGS	

SUBCONTRACTOR'S TIME ON SITE

Rig Type	Arrived	Left Site	Lunch/Other	Downtime	Standby Time	Total Billable Hours

HALEY & ALDRICH'S TIME ON SITE

Field Representive(s)	Arrived	Left Site	Lunch/Other	Paperwork	Travel Time	Total Billable Hours

WORK PRODUCTION TO DATE

Boring No.	Type of Drilling	Over Burden (lf)	Rock Core (lf)	Obstr. Drilling	Total Footage (lf)	Tubes Samples	Extra Split Spoons*	Misc. (Wells etc.)	Materials Encountered (Type and Depth Range)

STATUS OF TOTAL PRODUCTION

Unsampled	Continuos	Standard	Inside Dia.	Boring Footages: Item	Today	Total to Date	Estimate	% Complete	Additional pay Items	Today	Total to Date
									Observation Wells I.D. (ft)		
									Roadway Boxes (ea)		
				H.S.A.					Guard Pipes (ea)		
				Casing					Steamer and Generator (day)		
				Casing					Grout (lf)		
				Casing					Undisturbed Tube Samples (ea)		
				Uncased					Extra Split Spoons (ea)*		
				Rock Core					55 Gallon Drums (ea)		
				Geoprobe					Police Details (hr)		
									Stand by Time (hr)		

No. of Borings Completed	Remaining	Rig-Days to Date	Remaining

SYMBOLS

B 2-1/2 inch Standard	**A** 4 inch Hollow Stem Auger	**Z** Probes of Soundings	**T** 2 inch Shelby Tube	**Y** Pressure Test
N 3 inch Standard	**W** Water Borings	**C** Rock Core	**V** Vane Shear Test	**S** Observation Well
H 4 inch Standard	**X** Continuous Sampling	**U** 3 inch Piston Tube	**P** Permeability Test	

* Extra split spoon samples are for footage contracts only.

HALEY & ALDRICH

TEST BORING DAILY REPORT

REMARKS

HALEY & ALDRICH

TEST BORING REPORT

BORING NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft.	Datum	Boring Location

Item	Casing	Sampler	Core Barrel
Type			
Inside Diameter (in.)			
Hammer Weight (lb.)			
Hammer Fall (in.)			

Rig Make & Model: ☐ Truck ☐ Tripod ☐ Cat-Head; ☐ ATV ☐ Geoprobe ☐ Winch; ☐ Track ☐ Air Track ☐ Roller Bit; ☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☐ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☐ None

Casing Advance: Type Method Depth

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary

Overburden (Linear ft.) _____
Rock Cored (Linear ft.) _____
Number of Samples _____

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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TEST BORING REPORT

BORING NO.

Page of

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel		Sand			% Fines	Field Test			
								% Coarse	% Fine	% Coarse	% Medium	% Fine		Dilatancy	Toughness	Plasticity	Strength

NOTES:

FILE NO.

BORING NO.

*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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HALEY & ALDRICH

CORE BORING REPORT

BORING NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft	Datum	Boring Location

Item	Casing	Sampler	Core Barrel
Type			
Inside Diameter (in)			
Hammer Weight (lb)			
Hammer Fall (in)			

Rig Make & Model

- ☐ Truck
- ☐ ATV
- ☐ Track
- ☐ Skid
- ☐ Tripod
- ☐ Geoprobe
- ☐ Air Track
- ☐ _____
- ☐ Cat-Head
- ☐ Winch
- ☐ Roller Bit
- ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut

Casing: ☐ Driven ☐ Spun

Drill Mud: ☐ Bentonite ☐ Polymer ☐ None

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Sample ID

- O Open End Rod
- T Thin Wall Tube
- U Undisturbed Sample
- S Split Spoon Sample
- G Geoprobe

Well Diagram

- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (Linear ft.)	
Rock Cored (Linear ft.)	
Number of Samples	

BORING NO.

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HALEY & ALDRICH

CORE BORING REPORT

BORING NO.

Page of

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks

FILE NO. BORING NO.

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HALEY & ALDRICH

GEOTECHNICAL SAMPLE RECEIVING REPORT

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**PROJECT ENGR.**	
DELIVERED BY		**DATE**	

TYPE OF SAMPLE

SOIL:

Jar Samples _____ box(es)

Undisturbed Tube Samples:
Outside Diameter: ☐ 3-in. ☐ 2-in. _____ tube(s)

*** Bag Samples _____ bag(s)

*** 5-gal. Bucket Samples _____ bucket(s)

ROCK CORE:

Boxes: _____ box(es)

Other: _____ sample(s)

OTHER: _____

HAZARDOUS MATERIALS? ☐ Yes ☐ No

CONTAMINANTS (please list major contaminants)

If geology/pre-construction project, fill out Section A - If Con-Mon project, fill out Section B.

A:

Box No.	Exploration No.	Sample No.(s) From - To	Depth From - To	Remarks {if multiple types of samples, list type, (e.g., jars, tube, bag, rock)}

B:

Explor. No.	Sample No.	Depth Range (ft)	Sample Description (USCS or geologic unit)	Sample Source (on-site, Contractor Pit, etc.)	Proposed Use (see below)

For "Proposed Use" try to use the term from the specifications (e.g., structural fill, common fill, dense graded, State Highway Spec. No., etc.)

Notes: _____

*** ANY BAG/BUCKET SAMPLE WHICH HAS NOT HAD TESTING ASSIGNED AFTER 3 WEEKS OF RECEIVING WILL BE AUTOMATICALLY DISPOSED OF UNLESS THE LABORATORY MANAGER IS GIVEN PRIOR WRITTEN NOTIFICATION OF THE NEED TO RETAIN THE SAMPLE.

To be completed by lab personnel:

Sample received by: _____ Boxes Labeled? ☐ Yes ☐ No

STORAGE LOCATION:

☐ Geotechnical Laboratory ☐ Storage Room / Shelf Location: _____

☐ Humid Room ☐ Other: _____

HALEY & ALDRICH

GEOTECHNICAL SAMPLE RECEIVING REPORT

PROJECT	MAXIM OFFICE PARK	H&A FILE NO.	11111-030
LOCATION	BOSTON, MASSACHUSETTS	PROJECT MGR.	S. KRAEMER
CLIENT	BOSTON ARCHITECTS, INC.	PROJECT ENGR.	M. LALLY
DELIVERED BY	JOE SAND	DATE	03/14/02

TYPE OF SAMPLE

SOIL:

Jar Samples 2 box(es)

Undisturbed Tube Samples:
Outside Diameter: ☐ 3-in. ☐ 2-in. 2 tube(s)

*** Bag Samples 3 bag(s)
*** 5-gal. Bucket Samples ____ bucket(s)

ROCK CORE:

Boxes: 2 box(es)

Other: ____ sample(s)

OTHER: ____

HAZARDOUS MATERIALS? ☐ Yes ☑ No

CONTAMINANTS (please list major contaminants)

If geology/pre-construction project, fill out Section A - If Con-Mon project, fill out Section B.

A:

Box No.	Exploration No.	Sample No.(s) From - To	Depth From - To	Remarks {if multiple types of samples, list type, (e.g., jars, tube, bag, rock)}
1	B-01	S01 - S19	-	jars
1	B-02	S01 - S04	-	jars
2	B-02	S05 - S14	-	jars
-	B-01	U1	58.0 - 60.0	tube R=24
-	B-02	U1	68.0 - 70.	tube R=22
1	B-01	C01 - C03	-	rock core
-	TP-01	B01	5.0 - 9.0	ziplock bag

B:

Explor. No.	Sample No.	Depth Range (ft)	Sample Description (USCS or geologic unit)	Sample Source (on-site, Contractor Pit, etc.)	Proposed Use (see below)
TP-04	B01	8.5 - 10.7	Glacial Till	on-site	Common Fill
-	S12	n/a	Brown silty sand	Joe's Borrow Pit, Stoughton, MA	Structural Fill

For "Proposed Use" try to use the term from the specifications (e.g., structural fill, common fill, dense graded, State Highway Spec. No., etc.)

Notes: ____

*** ANY BAG/BUCKET SAMPLE WHICH HAS NOT HAD TESTING ASSIGNED AFTER 3 WEEKS OF RECEIVING WILL BE AUTOMATICALLY DISPOSED OF UNLESS THE LABORATORY MANAGER IS GIVEN PRIOR WRITTEN NOTIFICATION OF THE NEED TO RETAIN THE SAMPLE.

To be completed by lab personnel:

Sample received by: ____ Boxes Labeled? ☐ Yes ☐ No

STORAGE LOCATION:

☐ Geotechnical Laboratory ☐ Storage Room / Shelf Location: ____

☐ Humid Room ☐ Other: ____

HALEY & ALDRICH

OBSERVATION WELL INSTALLATION REPORT

Well No.

Boring No.

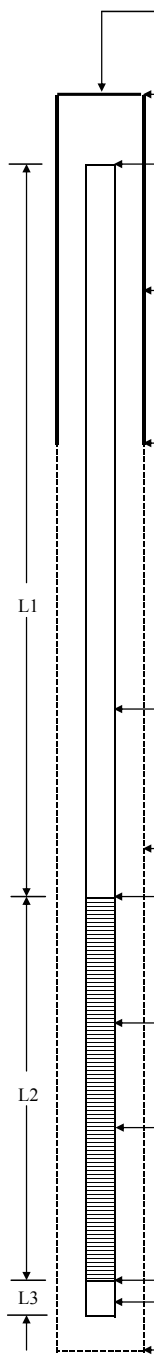
PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE INSTALLED	
DRILLER		WATER LEVEL	

Ground El. _____ ft
El. Datum _____

Location _____

☐ Guard Pipe
☐ Roadway Box

SOIL/ROCK CONDITIONS	BOREHOLE BACKFILL



Type of protective cover/lock _____

Height/Depth of top of guard pipe/roadway box above/below ground surface _____ ft

Height/Depth of top of riser pipe above/below ground surface _____ ft

Type of protective casing: _____
- Length _____ ft
- Inside Diameter _____ in

Depth of bottom of guard pipe/roadway box _____ ft

Type of Seals	Top of Seal (ft)	Thickness (ft)
Concrete		
Bentonite Seal		

Type of riser pipe: _____
- Inside diameter of riser pipe _____ in
- Type of backfill around riser _____

Diameter of borehole _____ in

Depth to top of well screen _____ ft

Type of screen _____
- Screen gauge or size of openings _____ in
- Diameter of screen _____ in

Type of backfill around screen _____

Depth of bottom of well screen _____ ft

Bottom of Silt trap _____ ft

Depth of bottom of borehole _____ ft

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

_____ ft + _____ ft + _____ ft = _____ ft
Riser Pay Length (L1) + Length of screen (L2) + Length of silt trap (L3) = Pay length

COMMENTS: _____

Form 2007

HALEY & ALDRICH

MONITORING WELL DEVELOPMENT REPORT

Well No.

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE	
ELEVATION SUBTRAHEND			

Estimated Volume of Water Lost During Drilling: _____ gallons

Comments: _____

Depth to Water Before Development: _____ feet

Comments: _____

Depth to Well Bottom Before Development: _____ feet

Comments: _____

Turubitiy of Water Before Development: _____ NTU

Comments: _____

Volume of Water Removed: _____ gallons

Comments: _____

Method of Removal (bailing, pumping): _____

Comments: _____

Depth to Well Bottom After Development: _____ feet

Comments: _____

Depth to Water After Development: _____ feet

Comments: _____

Turubitiy of Water After Development: _____ NTU

Comments: _____

HALEY & ALDRICH

GROUNDWATER MONITORING REPORT

OW/PZ NUMBER

Page of

PROJECT

LOCATION

CLIENT

CONTRACTOR

ELEVATION SUBTRAHEND

H&A FILE NO.

PROJECT MGR.

FIELD REP.

DATE

Date	Time	Elapsed Time (days)	Depth of Water from Ground Surface	Elevation of Water	Remarks	Read By

Form 2021

HALEY & ALDRICH

TEST PIT LOG

Test Pit No.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	
EQUIPMENT		WEATHER	

Ground El. _____ ft. Location _____
El. Datum _____

Groundwater depths/entry rates (in./min.):

Depth (ft.)	Sample ID	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (Color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength

Obstructions:

Remarks:

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:
at depth _____ ft.
measured after _____ hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24		=	
over 24		=	

Test Pit Dimensions (ft.):
Pit Depth _____
Pit Length X Width _____

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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HALEY & ALDRICH

ENVIRONMENTAL TEST PIT LOG

Test Pit No.

Page of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	
EQUIPMENT		WEATHER	

Ground El. ft.
El. Datum

Location

Groundwater depths/entry rates (in./min.):

Depth (ft.)	Sample ID	PID Reading (ppm.)	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (Color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength

Obstructions:

Remarks:

Bucket Decontamination Method:

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth ft.
measured after hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24		=	
over 24		=	

Test Pit Dimensions (ft.):

Pit Depth
Pit Length X Width

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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HALEY & ALDRICH

TEST PROBE REPORT

PROBE NO.

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	
EQUIPMENT		DRILLER	

Rig Type:		**TOP OF ROCK BASED ON:**	Datum
Diameter of Hole:		☐ Rate of Penetration ☐ Acoustic Device	Ground El.
Drill Bit type:		☐ Driller's Opinion ☐ Other	Water El.
Drill Bit O.D.:		DEPTH TO TOP OF SOUND ROCK	Location:

Scale In Feet	Cutting Description and Remarks

HALEY & ALDRICH

TEST PROBE SUMMARY

Page of

PROJECT ______ H&A FILE NO. ______
LOCATION ______ PROJECT MGR. ______
CLIENT ______ FIELD REP ______
CONTRACTOR ______ DATE ______
EQUIPMENT ______ DRILLER ______

Probe Type ______

Probe No.	Location	Ground Surface Elevation	Depth to Water (ft)	Depth Probed		Soil Strata Description	Remarks
				From (ft)	To (ft)		

HALEY & ALDRICH

VIBRACORE REPORT

Probe No.

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		GEOLOGIST	
CONTRACTOR		DATE	
EQUIPMENT		CHECKED BY	

Depth (ft)	Sketch	Visual Description
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Recovery			
Section	Tube Length	Sample Length	Total Weight

Top:

Bottom:

Notes:

Soil identification based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

Remarks:

HALEY & ALDRICH

HEADSPACE SCREENING REPORT

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
INSTRUMENT		DATE SAMPLED	
DATE CALIBRATED (1)	LAMP (eV)	DATE SCREENED	
AMBIENT TEMPERATURE	CALIBRATED BY	SCREENING LOC.	

Exploration	Sample Number	Depth (ft)	Sample Description	Sample Reading (ppm)(2)	Back-Ground Reading (ppm)(2)	Remarks	GC(3)	Containers			
								Drill Jar			

1. Instrument calibrated to the manufacturer standard.
2. ppm represents concentration of detectable volatile gaseous compounds in parts per million of air.
3. Sample assigned for gas chromatograph screening.

Sampled and relinquished by:	Received by:	Relinquished by:	Received by:
Sign:	Sign:	Sign:	Sign:
Print:	Print:	Print:	Print:
Firm:	Firm:	Firm:	Firm:
Date: Time:	Date: Time:	Date: Time:	Date: Time:

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Date:	Analysis:
Time:	Preservative:
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Comments:	

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Form 3001

HALEY & ALDRICH

Haley & Aldrich, Inc.
465 Medford St.,
Suite 2200,
Boston, MA 02129-1400

CHAIN OF CUSTODY RECORD

Phone (617) 886-7400
Fax (617) 886-7700

Page of

H&A FILE NO.		LABORATORY		DELIVERY DATE	
PROJECT NAME		ADDRESS		TURNAROUND TIMI	
H&A CONTACT		PROJECT MANAGER		DELIVERY DATE	

Sample No.	Date	Time	Depth	Type	Container Size	No. of Containers	Analysis Requested	Preservatives	Comments - (special instructions, precautions, additional method numbers, etc.)

Sampled and Relinquished by	Received by	PRESERVATION KEY	Sampling Comments
Sign	Sign	A Sample chilled	
Print	Print	B Sample filtered	
Firm	Firm	C NaOH	
Date Time	Date Time	D HNO_3	
Relinquished by	**Received by**	E H_2SO_4	
Sign	Sign	F HCL	
Print	Print	G Methanol	
Firm	Firm	H Sodium Bisulfate	
Date Time	Date Time	I	
Relinquished by	**Received by**	**Evidence samples were tamperd with?** YES NO	
Sign	Sign	**If YES, please explain in section below.**	
Print	Print		
Firm	Firm		
Date Time	Date Time		

WHITE - Laboratory **CANARY** - Project Manager **PINK** - Haley & Aldrich Laboratory **GOLDENROD** - Haley & Aldrich Contact

Form 3002

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Form 3002

HALEY & ALDRICH
Haley & Aldrich, Inc.
465 Medford St.,
Suite 2200,
Boston, MA 02129-1400

CHAIN OF CUSTODY RECORD

Phone (617) 886-7400
Fax (617) 886-7600

Page of

H&A FILE NO.		LABORATORY		DELIVERY DATE	
PROJECT NAME		ADDRESS		TURNAROUND TIME	
H&A CONTACT		CONTACT		PROJECT MANAGER	

Sample No.	Date	Time	Depth	Type	VOA	ABNs PAH only	Metals RCRA (8) PP(13)	Pesticides PCBs	VPH Full Suite C-ranges only	EPH Full Suite C-ranges only	TPH (specify)	TCLP (specify)	Reactivity Ignitability Corrosivity				Number of Containers	Comments (special instructions, precautions, additional method numbers, etc.)

Sampled and Relinquished by	Received by
Sign	Sign
Print	Print
Firm	Firm
Date Time	Date Time
Relinquished by	**Received by**
Sign	Sign
Print	Print
Firm	Firm
Date Time	Date Time
Relinquished by	**Received by**
Sign	Sign
Print	Print
Firm	Firm
Date Time	Date Time

LIQUID												
												VOA Vial
												Amber Glass
												Plastic Bottle
												Preservative
												Volume
SOLID												
												VOA Vial
												Amber Glass
												Clear Glass
												Preservative
												Volume

Sampling Comments

Evidence samples were tampered with? YES NO

If YES, please explain in section below.

PRESERVATION KEY

A Sample chilled	**C** NaOH	**E** H_2SO_4	**G** Methanol
B Sample filtered	**D** HNO_3	**F** HCL	**H** Sodium Bisulfate

WHITE - Laboratory **CANARY** - Project Manager **PINK** - Haley & Aldrich Laboratory **GOLDENROD** - Haley & Aldrich Contact

Form 3003

WATER AND WASTEWATER METHODS

Analysis Description	Method No.	Preservative	Solid Sample Volume/Container	Liquid Sample Volume/Container	Holding Time
Alkalinity	310	Cool 4° C	N/A	250 mL HDPE	14 days
Amenable Cyanide	Std. Mth. 412 F.	pH>12 NaOH, Cool 4° C	N/A	1 L HDPE	14 days
Ammonia	350	pH<2 H2SO4, Cool 4° C	N/A	1 L HDPE	28 days
Base/Neutral & Acid Extractables	625	Cool 4° C	N/A	1 L Amber	7 days Ext/40 days Analyze
Biochemical Oxygen Demand (BOD)	405.1	Cool 4° C	N/A	2 L HDPE	48 hours
Chemical Oxygen Demand (COD)	410	pH<2 H2SO4, Cool 4° C	N/A	125 mL HDPE	28 days
Chloride	300.0, 325	None Required	N/A	125 mL HDPE	28 days
Chromium, Hexavalent	3500D, 218.4/5	None Required	N/A	1 L HDPE	24 hours
Fluoride	300.0, 340	None Required	N/A	500 mL HDPE	28 days
Hardness, Total (as CaCO3)	130	pH<2 H2SO4, Cool 4° C	N/A	250 mL HDPE	6 Months
Nitrate	300.0, 352.1	Cool 4° C	N/A	250 mL HDPE	48 Hours
Nitrite	300.0, 354.1	Cool 4° C	N/A	125 mL HDPE	48 Hours
Orthophosphate	300.0, 365	Filter, Cool 4° C	N/A	125 mL HDPE	48 Hours
PCBs	608	Cool 4° C	N/A	1 L Amber	7 days Ext/40 days Analyze
Pesticides	608	Cool 4° C	N/A	1 L Amber	7 days Ext/40 days Analyze
Physiologically Available Cyanide	MADEP draft	pH>12 NaOH, 4° C	N/A	1 L HDPE	14 days
Priority Pollutant Metals (13 Metals)	200.7/AA, 200 Series	pH<2 HNO3, 4° C	N/A	1 L HDPE	28 days (Hg), 6 mos. (others)
Purgeable Halocarbons & Aromatics	601/602	pH 2 HCl, Cool 4° C	N/A	40 mL Glass Vial	14 days
RCRA Metals (8 Metals)	200.7/AA, 200 Series	pH<2 HNO3, 4° C	N/A	1 L HDPE	28 days (Hg), 6 mos. (others)
Sulfate	300.0, 375	Cool 4° C	N/A	250 mL HDPE	28 days
Sulfide	376	pH>9 NaOH, Zn Acetate, Cool 4° C	N/A	1 L HDPE	7 days
Sulfite	377.1	None Required	N/A	125 mL HDPE	Analyze Immediately
Total Cyanide	335	pH>12 NaOH, Cool 4° C	N/A	1 L HDPE	14 days
Total Dissolved Solids (TDS)	209	Cool 4° C	N/A	250 mL HDPE	7 days
Total Organic Carbon (TOC)	415	pH<2 HCl or H2SO4, Cool 4° C, Dark	N/A	40 mL Amber	28 days
Total Organic Halogen (TOX)	506	pH<2 HNO3, 4° C	N/A	1 L Amber	check with lab
Total Phenolics	420.1	pH<2 H2SO4, Cool 4° C	N/A	1 L Amber	28 days
Total Phosphorus	365	pH<2 H2SO4, Cool 4oC	N/A	125 mL HDPE	28 days
Total Solids (TS)	160.3	Cool 4° C	N/A	250 mL HDPE	7 days
Total Suspended Solids (TSS)	160.2	Cool 4° C	N/A	250 mL HDPE	7 days
Volatile Organics	624	pH 2 HCl, Cool 4° C	N/A	40 mL Glass Vial	14 days
Weak and Dissociable Cyanide	Std. Mth. 412 H.	pH>12 NaOH, Cool 4° C	N/A	1 L HDPE	14 days
DRINKING WATER ANALYSIS					
Volatile Organics	502.2 or 524.2	pH 2 HCl, Cool 4° C	N/A	40 mL Glass Vial	14 days
MICROBIOLOGY					
Fecal Coliform	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours
Standard Plate Count	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours
Total Coliform	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours
Yeast and Mold	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours

SOIL/SEDIMENTS/WATER

Analysis Description	Method No.	Solids (S) / Liquids (L) Preservative	Solid Sample Volume/Container	Liquid Sample Volume/Container	Holding Time
Acid Extractables/Base/Neutral Extractables	8270	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Amenable Cyanide	-	S: 4° C / L: pH>12 NaOH, 4° C	4 oz. CWM	1 L HDPE	14 days
Chromium, Hexavalent	3060A/7196	S/L: Cool 4° C	8 oz. CWM	1 L HDPE	24 hours
Extractable Hydrocarbons	8015B	S: Cool 4° C / L: pH<2 HCl, 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Herbicides	8150	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Non-Halogenated Organics	8015B	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. CWM	40 mL Glass Vial	14 days
PAH (low level)	8310 or GC/MS SIM	S/L: Cool 4° C	8 oz. AWM	1 L Amber	7 days Ext/40 days Analyze
Paint Filter Liquids Test	9095	S: Cool 4° C	8 oz. CWM	1 L Amber	Analyze ASAP
PCBs	8082	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Pesticides	8081	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Physiologically Available Cyanide	MADEP draft	S: 4° C / L: pH>12 NaOH, 4° C	4 oz. CWM	1 L HDPE	14 days
Priority Pollutant Metals(13 Metals)	6010&7000	S: 4° C / L: pH<2 HNO3, 4° C	8 oz. CWM	1 L Amber	28 days (Hg), 6 mos. (others)
RCRA Metals (8 Metals)	6010&7000	S: 4° C / L: pH<2 HNO3, 4° C	8 oz. CWM	1 L Amber	28 days (Hg), 6 mos. (others)
Total Cyanide	9010	S: 4° C / L: pH>12 NaOH, 4° C	4 oz. CWM	1 L HDPE	14 days
Volatile Hydrocarbons	8015B	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. CWM	40 mL Glass Vial	14 days
Volatile Organics	8260B, 8021	S: methanol/$NaHSO_4$, 4° C / L: pH<2 HCl, 4° C	4 oz. CWM	40 mL Glass Vial	14 days
RCRA HAZARDOUS WASTE CHARACTERIZATION					
Corrosivity (pH only)	SW846-7.2	S: Cool 4° C	4 oz. CWM	check with lab	Analyze ASAP
Ignitability/Flashpoint	SW846-7.1	S: Cool 4° C	4 oz. CWM	check with lab	Analyze ASAP
Reactivity (CN-/S2-)	SW846-7.3	S: Cool 4° C	4 oz. CWM	check with lab	Analyze ASAP
TCLP (RCRA 8) Metals (check for mercury)	1311	S: Cool 4° C	16 oz. CWM	check with lab	6 mos. Ext/6 mos. Analyze
TCLP Pesticides/Herbicides	1311	S: Cool 4° C	16 oz. CWM	check with lab	14 days Ext/40 days Analyze
TCLP Semivolatiles	1311	S: Cool 4° C	16 oz. CWM	check with lab	14 days Ext/40 days Analyze
TCLP Volatiles	1311	S: Cool 4° C	8 oz. CWM	check with lab	14 days Ext/14 days Analyze
HYDROCARBON OIL & GREASE ANALYSIS					
MADEP EPH Method	MADEP REV. 0	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. Amber	1 L Amber	S:7 days Ext / L:14 days Ext
MADEP EPH Method (C-Ranges only)	MADEP REV. 0	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. Amber	1 L Amber	S:7 days Ext / L:14 days Ext
MADEP VPH Method	MADEP REV. 0	S: methanol, 4° C / L: pH<2 HCl, 4° C	40 mL+2 oz. CWM.	40 mL Glass Vial	S: 28 days / L: 14 days
MADEP VPH Method (C-Ranges only)	MADEP REV. 0	S: methanol, 4° C / L: pH<2 HCl, 4° C	40 mL+2 oz. CWM.	40 mL Glass Vial	S: 28 days / L: 14 days
MADEP EPH Method - with selected PAHs (including acenaphthene, naphthalene, 2-methylnaphthalene, and phenanthrene	MADEP REV. 0	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. Amber	1 L Amber	S:7 days Ext / L:14 days Ext
Petroleum Identification	ASTM D3328				
Quantitative (include Chromatograms		S: Cool 4° C / L: pH<2 H_2SO_4, 4° C	4 oz. CWM	1 L Amber	S: 7 days / L: 28 days
Total Petroleum Hydrocarbons (Infrared	418.1	S: Cool 4° C / L: pH<2 H_2SO_4, 4° C	4 oz. CWM	1 L Amber	S: 7 days / L: 28 days

AIR METHODS

Analysis Description	Method No.	Preservative	Sample Volume/Container		Holding Time
Volatile Organic Compounds	EPA T01/T02	tubes: 4° C; Tedlar Bags: dark	N/A	N/A	tube: 14 days; bag: 72 hours
Volatile Organic Compounds	EPA T014	check with lab	N/A	N/A	can: 14 days; bag: 72 hours
VPH in air	EPA T01/T02	tubes: 4° C; Tedlar Bags: dark	N/A	N/A	tube: 14 days; bag: 72 hours
VPH in air	EPA T014	check with lab	N/A	N/A	can: 14 days; bag: 72 hours

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HALEY & ALDRICH

SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

Weather _____ **Temperature** _____

Ground surface Conditions ☐ Dry ☐ Wet ☐ Damp ☐ Standing Water ☐ Snow (_____in) ☐ Other_____

Comments _____

SOIL SAMPLING AND SURFACE WATER SAMPLING INFORMATION

Sample No.	Location	Depth (ft)	Time	Sample Description	Sampling Device	Cleaning Prodedure	Container Type

General Comments: (ie: field filtrations, persons communicated with at site, etc.)

Form 3004

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GROUNDWATER SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

GROUNDWATER SAMPLING INFORMATION

Well No.							
Water Depth (ft)							
Time							
Product							
Depth Of Well (ft)							
Inside Diameter (in)							
Standing Water Depth (ft) (1)							
Volume Of Water In Well (gal)							
Purging Device							
Volume of Bailer/Pump Capacity							
Cleaning Procedure							
Bails Removed/ Volume Removed							
Time Purging Started							
Time Purging Stopped							
Sampling Device							
Cleaning Procedure							
TIME SAMPLES TAKEN	VOA						
	ABN						
	Metals						
PARAMETERS	Color						
	Odor						
	pH						
	Conductivity						
	Turbidity						
	Dissolved Oxygen						
	Temp, ^{0} C						
	Salinity						

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

1. Standing Water Depth = Depth of Well - Water Depth

Form 3005

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TEST BORING REPORT

BORING NO. B 7 (OW)

PROJECT	Greenspace Development	**H&A FILE NO.**	27921-000
LOCATION	18 Riverside Road, Boston Massachusetts	**PROJECT MGR.**	S.R. Kraemer
CLIENT	Ecologic Investments	**FIELD REP.**	C.S. Osgood
CONTRACTOR	Guild Drilling Co., Inc.	**DATE STARTED**	13-Feb-01
DRILLER	Charlie O'Donnel	**DATE FINISHED**	14-Feb-01

Elevation 23.3 ft. **Datum** Boston City **Boring Location** See sketch on reverse of form.

Item	Casing	Sampler	Core Barrel
Type	NW	S	NV2
Inside Diameter (in.)	3	1.385	2
Hammer Weight (lb.)	300	140	
Hammer Fall (in.)	24	30	

Rig Make & Model CME 75

- [x] Truck
- [ ] ATV
- [ ] Track
- [ ] Skid
- [ ] Tripod
- [ ] Geoprobe
- [ ] Air Track
- [ ] _____
- [x] Cat-Head
- [ ] Winch
- [x] Roller Bit
- [ ] Cutting Head

Hammer Type
- [x] Safety
- [ ] Doughnut
- [ ] Automatic

Drilling Mud
- [x] Bentonite
- [ ] Polymer
- [ ] None

Casing Advance — Type Method Depth: NW Driven 29.0 ft.

Drilling Notes: Flushed slurry prior to coring.

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0																	
	10		0.0			SP-SM	Medium dense brown poorly graded SAND with silt (SP-SM),				20	70	10				
	12	S1					mps 2 mm, distinctly stratified, fines partially organic, no odor, dry.										
	15	21"															
	20		2.0		2.0		-ALLUVIUM-										
	11		2.0			SP	Dense brown poorly graded SAND (SP), mps 25 mm, no odor, dry.	5	5	20	30	35	5				
	15	S2															
	16	10"															
	17		4.0				-ALLUVIUM-										
					4.5												
5																	
	WOR		5.0				Very soft, dark brown ORGANIC SOILS with sand (OL/OH), trace					25	75	S	M	H	VH
	WOR	S3				OL/OH	seashell fragments and particles, soil mps 0.5 mm, strong										
	WOH	24"					organic odor, moist.										
	WOH		7.0				-ORGANIC DEPOSIT-										
					8.0												
							Note: Drilling fluid returning medium to fine sand from 8.0 ft. to										
							10.0 ft. Drilling fluid color change to yellow red at 8.5 ft.										
							-PROBABLE MARINE DEPOSIT-										
					10.0												
10																	
	3		10.0			CH	Stiff yellow brown fat CLAY (CH), trace fine sand, mps 0.5 mm,						100	N	M	H	
	6	S4					apparently laminated with frequent fine sand partings and										
	6	22"					possible organic fibers, no odor, moist.										
	6		12.0				-MARINE DEPOSIT-										
					13.5												
							Note: Drill action indicates gravel below 13.5 ft.										
15																	
	12		15.0			CL	Very stiff yellow brown to gray sandy lean CLAY with gravel (CL),	5	10	10	10	15	50	S	M	M	
	14	S5					mps 35 mm, distinct disrupted laminae in discrete zones, coarse										
	15	17"					fraction consists of well rounded igneous and igneous and										
	19		17.0				metamorphic lithologies, no odor, moist.										
							-GLACIOMARINE DEPOSIT-										
					18.0												
							Note: Drill action and total loss of drilling fluid indicates gravel										
					19.0		and cobbles from 18.0 ft. to 19.0 ft.										
							Very dense gray silty SAND (SM) , mps 15 mm, very well bonded,										
20																	
	21	S6	20.0			SM	coarse fraction consists partly of platy argillite fragments, no odor, moist.		10	15	20	30	25	R			
	25	10"	21.0		21.0		-GLACIAL TILL-										
	33	S6A	21.0			ML	Very dense gray SILT (ML), mps <0.1 mm, no structure, no odor,						100	R		N	
	34	7"	22.0				dry.										
							-RESIDUAL SOIL-										
							Note: Drilling advanced smoothly from 21.0 ft. to 25.0 ft.										
					25.0		PROBABLE TOP OF DECOMPOSED BEDROCK 25.0 FT.										
25																	
	53		25.0				Very dense gray highly to completely weathered ARGILLITE.										
	28	S7					Possible extremely thin relect bedding subparallel to strong										
	39	5"					low angle foliation. Sample is generally well bonded and consists										
	35		27.0				of very soft angular fragments and particles which are easily										
							crushed with finger pressure.										
							-DECOMPOSED BEDROCK-										
							Note: Drill action indicates stratum change at 28.5 ft.										
					28.5		TOP OF "SOUND" BEDROCK 28.5 FT.										
							SEE SHEET 2 FOR CORE BORING REPORT										
30																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
13-Feb-01	15:30	0	29.0	29.0	2.0
14-Feb-01	7:00	15.5	29.0	29.0	6.2
14-Feb-01	15:00	1.0	39.5	39.5	10.4

Sample ID
- O Open End Rod
- T Thin Wall Tube
- U Undisturbed Sample
- S Split Spoon Sample
- G Geoprobe

Well Diagram
- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (Linear ft.)	29.5
Rock Cored (Linear ft.)	10.0
Number of Samples	S7 C2

BORING NO. B 7 (OW)

Field Tests Dilatancy: R - Rapid S - Slow N - None Plasticity: N - Nonplastic L - Low M - Medium H - High
Toughness: L - Low M - Medium H - High Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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CORE BORING REPORT

BORING NO. **B 7 (OW)**

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks
								SEE SHEET 1 TEST BORING REPORT FOR OVERBURDEN DETAILS.
							21.0	TOP OF RESIDUAL SOIL 21.0 FT.
								Note: Advanced borehole with rollerbit and splitspoon and drove NW casing through residual soil from 21.0 ft. to 25.0 ft.
					Residual Soil			-RESIDUAL SOIL-
25							25.0	TOP OF DECOMPOSED BEDROCK 25.0 FT.
					High to Complete			Note: Advanced borehole with rollerbit and splitspoon and drove NW casing through decomposed bedrock from 25.0 ft. to 28.5 ft.
								-DECOMPOSED BEDROCK-
							28.5	TOP OF "SOUND" BEDROCK 28.5 FT.
								Note: Seated NW casing at 29.0 ft. Advanced borehole with rollerbit to 29.5 ft. without sampling prior to coring.
30		29.5	56"		Slight			C1: Moderately hard, slightly weathered, gray, aphanitic ARGILLITE. Bedding extremely thin to very thin, generally low angle (30-35 degrees). Foliation low angle, commonly subparallel to bedding. Cleavage well developed along bedding/foliation planes where coincident.
	6				Mod.			Cleavage joints very close to close 29.5 -31.0 ft. and close below 32.5 ft. smooth-planar,
	3	C1			High			slightly oxidized, occasionally calcite-infilled, tight. High angle to vertical joints moderately
					Mod.			close, rough-undulatory, pyritized or highly oxidized and decomposed with silt infilling, open.
	5							Soft, moderately to highly weathered zone 31.0-32.5 ft. associated with extremely close,
					Slight			moderately dipping, slickensided-planar shears intersecting bedding plane and high angle features.
	6							Note: Partial water loss below 31.0 ft.
		34.5	24"	40%				Note: Lost core assumed 31.7-32.0 ft.
35	6	34.5	60"	100%				C2: Similar to bottom of run C1 except cleavage joints close to moderately close. High angle to vertical joints absent. Occasional thin zone of extremely close, extremely thin, moderately
	7							dipping to high angle (50-60 degrees) calcite stringers. Occasional calcite-healed low angle joint.
	6	C2			Slight			-CAMBRIDGE FORMATION-
	6						38.0	
	8							Lithology change at 38.0 ft. to hard, slightly weathered, dark gray to black, fine grained to aphanitic DIABASE. Single high angle joint at 38.7 ft. rough-stepped, slightly oxidized, tight.
		39.5	54"	90%				
40	8							BOTTOM OF EXPLORATION 39.5 FT.

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TEST PIT LOG

Test Pit No. **TP-1**

Page 1 of 1

PROJECT	New England Hospital	H&A FILE NO.	10715-205
LOCATION	Boston, Massachusetts	PROJECT MGR.	M.X. Haley
CLIENT	PFT Associates	FIELD REP	C. S. Osgood
CONTRACTOR	J. Marchese & Sons Const.	DATE	07-Jan-02
EQUIPMENT	CAT 416 Rubber Tire Extendahoe 0.24 cu.yd. bucket capacity	WEATHER	Mostly Clear 20s

Ground El.	36.3 ft.	Location	West of Pedestrian Tunnel	Groundwater depths/entry rates (in./min.):
El. Datum	NGVD			7.8 ft. Steadily

Depth (ft.)	Sample ID	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (density/consistency, color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
				Dark brown silty SAND (SM), mps 5 mm, organic odor, moist.		5	5	10	45	40	R			
	0.5		SM	Fines largely organic.										
				-LOAM FILL-										
		1.3												
2	S3			Yellow brown to olive brown sandy fat CLAY (CH), trace roots, clinker fragments,	5	5	5	10	15	60	N	M	H	
			CH	cinder particles and fragments, clay pipe fragments, metal wire, asphalt fragments.										
				10% cobbles, <5% boulders, mps 30 in., no odor, moist.										
				-FILL-										
4	4.0			Note: Poured concrete foundation wall on east side of test pit from 0.0 -4.4 ft.										
	4.0													
				Note: Poured concrete foooting 4.4-5.4 ft.										
6	S2													
8	8.0	8.0												
	8.0			Yellow brown fat CLAY (CH), trace fine sand. mps 0.5 mm, no odor, dry.					5	95	N	M	H	
	S1		CH	Appartantly laminated with frequent fine sand partings and possible organic fibers.										
	9.0			-MARINE DEPOSIT-										
10														
		11.0												
				Yellow brown to gray sandy lean CLAY (CL) with gravel. mps 35 mm,	5	10	10	10	15	50	S	M	L	
			CL	Distinct disrupted laminae in discrete zones. Coarse fraction consists of well-rounded										
				igneous and metemorphic lithologies.										
12	12.0	12.0		-GLACIOMARINE DEPOSIT-										
				Note: Possible stratum change to gray lean CLAY with sand (CL) below 12.0 ft.										
				Coarse fraction apparantly less abundent.										
				-MARINE DEPOSIT-										
				BOTTOM OF EXPLORATION 13.5 FT.										
14														

Obstructions:

Remarks:
Note: Bag samples S1-S3 obtained for potential mechanical analysis from depths indicated.

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth	13.2	ft.
measured after	0.1	hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24	1	=	1.8
over 24	1	=	8.2

Test Pit Dimensions (ft.):

Pit Depth	13.5
Pit Length X Width	9.0 x 6.0

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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ENVIRONMENTAL TEST PIT LOG

Test Pit No. **TP 214**

PROJECT	Mirror Lake Watershed Study	**H&A FILE NO.**	28675-309
LOCATION	Essex, Massachusetts	**PROJECT MGR.**	D.H. Gevalt
CLIENT	Citizens Advisory Partnership	**FIELD REP**	C.S. Osgood
CONTRACTOR	Stanley Lynde Const. Co., Inc.	**DATE**	19-Jul-02
EQUIPMENT	Case 580 rubber tire backhoe - 1/4 cu. yd. bucket	**WEATHER**	Thunderstorms 90's

Ground El.	74.5 ft.	**Location**	N 2,089,041.101	**Groundwater depths/entry rates (in./min.):**
El. Datum	NGVD		E 801,444.238	None

Depth (ft.)	Sample ID	PID Reading (ppm.)	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (density/consistency, color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions,	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
					Note: Ground surface strewn with boulders. Numerous depressions indicating										
					subsurface voids noted.										
	1.5				15% coarse to fine sand, 15% cinder fragments and particles, 10% unidentifiable, white										
					ash-like material, 10% fines (largely organic), 10% coarse to fine gravel, 10% wood										
2					(manufactured and treated), 5% glass fragments, 5% metal strips and wire, 5% charcoal										
	S2	15.9			5% plastic sheeting (possibly polyethelene bags), 5% brick particles, 5% clay pipe										
					fragments. Matrix generally dark brown to gray in color with pockets of white and red.										
					15% boulders, 15 % cobbles. Maximum particle size 36 inches.										
	2.5				Distinct decomposed gasoline odor, possible faint napthalene odor. Visible irridescent										
					sheen on moist solids 4.6 to 5.2 ft.										
4					-FILL-										
	4.6														
	S1	140			Note: Bedrock surface smooth and flat, consisting of very hard to hard, slightly										
	5.2		5.2		weathered, light gray to pink, coarse to fine grained granite. Single high angle joint noted.										
					REFUSAL ON BEDROCK 5.2 FT.										
6															
8															

Obstructions:

Remarks:

Note: Sample S1 submitted for laboratory chemical analysis.

Note: Field monitoring of breathing zone and headspace screening conducted using an hNU 11.7 ev. PID.

Bucket Decontamination Method: Steam cleaned

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth NE ft.

measured after 0.75 hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24	6.0	=	18.0
over 24	1.0	=	33.0

Test Pit Dimensions (ft.):

Pit Depth	5.2
Pit Length X Width	10.5 x 4.3

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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Form #3008

APPENDIX D
CHECKLISTS

D.1 Field Monitoring Checklist

D.1.1 Preliminary Preparation

A. Project Briefing
B. Field Project File and Document Assembly
- Proposal
- Contract Documents
- Locus, Site & Utility Plans
- Exploration Criteria
- Subcontractor Agreement
- Site and Project Contacts
- Forms
  - DFR
  - Subcontractor Quantities
  - Test Boring Report
  - Core Boring Report
  - Observation Well Installation Form
  - Test Pit Log
  - Special Testing / Instrumentation Forms
  - COC
  - Equipment Usage and Billing Form
  - Sample Receiving Form

C. H&S Briefing
- H&S Plan

D. Equipment Request and Assembly

D.1.2 Onsite Duties

A. Site Walkover and Subcontractor Utility and Safety Briefing
B. Exploration Program Review
- Exploration Layout
- Site Conditions Sketch
- Preliminary Surficial Geologic Map
- Exploration Monitoring
  - Equipment Inventory
  - Exploration Layout & Utility Check
  - Field Logging Soil & Rock
  - Water Level Measurements
  - Production and Budget Quantities
  - Sample Handling & Transport
  - Instrumentation & Testing Records
  - As-Built Sketches & Exploration Locations

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D.1.3 Follow Up & Summary

- Proof Logs and Test Reports
- Finalize DFR and Subcontractor Quantities
- Sample Receiving and Disposition
- Equipment Return and Billing
- Exploration Program Summary
- Final Site & Geological Conditions Summary
- Geologic Profiles

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OPERATING PROCEDURE: OP2001

IDENTIFICATION AND DESCRIPTION OF SOILS IN THE FIELD USING VISUAL-MANUAL METHODS

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.0	MPD, SAN, CSO: 5-02	SAN: 5-02	EBK: 5-02	STP/6-1-03	SRK/7-1-03
Ver. 0.1	CSO: 1-13-03				

Total Pages: 53

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OPERATING PROCEDURE: OP2001

IDENTIFICATION AND DESCRIPTION OF SOILS IN THE FIELD USING VISUAL-MANUAL METHODS

1. PURPOSE

This procedure provides methods of identifying soils in a field or office setting using visual examination and simple manual tests. Soil identification produces a Group Symbol and a Group Name for each soil identified. The Group Names and Group Symbols are based on the Unified Soil Classification System (USCS) described in ASTM Standard D2487. It is important to note that this method produces a **SOIL IDENTIFICATION** based on simple observations and does not produce a SOIL CLASSIFICATION. Soil classifications are determined using ASTM D2487 and require laboratory test results which may not be available for every project.

Additional descriptive information is also determined for each soil reviewed. The description includes soil properties such as color, consistency, odor, etc.

Haley & Aldrich (H&A) personnel are to use the techniques in OP2001 to identify and describe all soil samples from any source. The nature of this soil identification procedure makes it adaptable to various types of geologic terrain and provides a high degree of reproducibility and understanding among geoscience professionals everywhere.

IMPORTANT NOTE: It is not necessary to follow all of the methods in this procedure for every sample. Soils which appear similar can be grouped together based on one or two samples completely identified and described. Similar samples can be identified as the same soil based on performing only a few of the identification and descriptive procedures.

2. EQUIPMENT & SUPPLIES

	Required		Optional
1.	Knife, pocket	7.	Penetrometer, pocket
2.	Ruler, engineer's 6 ft. folding	8.	Torvane, pocket
3.	Scale, engineer's	9.	Color chart, Munsell's
4.	Marker, indelible, black	10.	Sieves
5.	Logs & Forms	11.	Test tube
6.	Lens, hand, magnifying	12.	Camera & film
		13.	Jars, sample with labels
		14	HCl (one part 10N HCl to three parts water

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3. PROCEDURE

3.1 Introduction to Soil Identification and Description

The Haley & Aldrich soil identification and description procedures follow the visual-manual procedure outlined in ASTM D2488. Two distinct tasks are required. First the soil is identified based on percentage of grain-size constituents. This process produces a Group Name and Group Symbol for the soil. Secondly, the soil is described. The additional descriptive information includes properties such as color, density or consistency, odor, structure, and geologic origin.

The Group Names and Group Symbols used to identify soils are determined using the flow charts shown in Figures 1 and 2. The Group Names and Group Symbols generated by this procedure are based on the Unified Soil Classification System. It is important to point out again that the soil Group names and Group Symbols determined using OP2001 and ASTM D2488 do not constitute a soil classification. When precise classification of soils is required for engineering purposes, the laboratory procedures outlined in ASTM D2487 must be used.

Soil identification is divided into three broad categories: **coarse grained** soils, for which the proportion and gradation of the components are most significant; **fine grained** soils, for which the degree of plasticity and dry strength are the controlling factor; and **organic** soils. Frequently, coarse grained and fine grained soils will occur in combination.

Soil identification is limited to soil particles smaller than 3 inches in size.

At the initiation of project planning, the Project Manager, Project Engineer or Scientist, and field personnel determine any project-specific requirements for soil identification and description. Project requirements may dictate the use of a different identification system. Different identification methods are permitted if our client requires them. Although identification systems vary to some degree, the procedural aspects of making the underlying observations and describing the soils encountered generally remain the same.

3.2 Definition of Soil Components

Soil Component	Size Range and Sieve Size	
OVERSIZED PARTICLES:		
Boulders	> 12 in.	>305 mm
Cobbles	3 in. to 12 in.	75.0 mm to 305 mm
COARSE GRAINED PARTICLES:		
Gravel:		
coarse Gravel	3 in. to 3/4 in.	75.0 mm to 19.0 mm
fine Gravel	3/4 in. to No. 4 (3/16")	19.0 mm to 4.75 mm
Sand:		
coarse Sand	No. 4 (3/16") to No.10 (1/13")	4.75 mm to 2.00 mm
medium Sand	No. 10 (1/13") to No. 40 (1/60")	2.00 mm to 0.42 mm
fine Sand	No. 40 (1/60") to No. 200	0.42 mm to 0.075 mm
FINE GRAINED PARTICLES:		
Silt:	< No. 200	< 0.075 mm
Nonplastic to very slightly plastic Little or no dry strength		
Clay:	< No. 200	< 0.075 mm
Plastic Considerable dry strength		

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Two other terms are frequently used to broadly describe and define soil behavior:

- Cohesive Soil

  A soil that when unconfined has considerable dry strength when air-dried and that has considerable cohesion when submerged.

- Noncohesive or Cohesionless Soil

  A soil that when unconfined has little or no strength when air-dried and that has little or no cohesion when submerged.

3.3 Sampling

The sample used for soil identification should be representative of the stratum from which it was obtained. All samples should be carefully identified by File No., Exploration No., Sample No., recovery, depth, source, etc.

Soil identification procedures are generally based on a very small quantity of the stratum sampled. Larger particle sizes included in a sample may misrepresent the true proportion of such sizes in a given stratum due to their greater individual weight. Furthermore, in test borings where a split-spoon sampler is utilized, size limitations (2 in. O.D. by 1-3/8 in. I.D.) preclude the ability to recover representative samples in soil strata with significant percentages of gravel and larger size components. Care must be exercised in the field when identifying and describing soils. Care is also required when selecting a representative sample for preservation and possible laboratory testing.

ASTM D2488 defines the minimum amount of soil required for identification and description. The minimum amount required is based on the maximum particle size observed in the soil. However, in many cases it is not possible to obtain the required amount of soil. Therefore, the following table should be used as a guide. Wherever possible, an employee should base his or her soil identification and description on an amount of soil equal to or greater than the minimum amount of soil required in the following table. As a general rule it should be assumed that all split-spoon samples of soils containing coarse gravel do not meet the required sample size. In addition, all jar samples of soil containing particles larger than coarse sand may not meet the required sample size.

Maximum Particle Size			Minimum Specimen Size (estimated in dry weight)	
No. 4	(5 mm)	coarse sand	100 g	(0.25 lb)
3/8 in.	(10 mm)	fine gravel	200 g	(0.5 lb)
¾ in.	(19 mm)	fine gravel	1.0 kg	(2.2 lb)
1.5 in.	(38 mm)	coarse gravel	8.0 kg	(18 lb)
3 in.	(75 mm)	coarse gravel	60.0 kg	(132 lb)

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3.4 Soil Identification

Detailed methods used to identify soil are presented below.

3.4.1 Preliminary Identification

The first step in the soil identification process is the preliminary identification of the soil. At this step, it will be determined if the soil will be considered a fine grained soil or a coarse grained soil. To do this, the percentage of each soil component must be estimated.

3.4.1.1 Fine Grained Soil:

If it is estimated that the soil consists of 50 percent or more fines (particles that are finer than a No. 200 sieve), the soil will be identified as either a SILT or a CLAY using Figure 1.

3.4.1.2 Coarse Grained Soil:

If it is estimated that the soil contains less than 50 percent fines (particles that are finer than a No. 200 sieve), the soil will be identified as either a GRAVEL or a SAND using Figure 2.

3.4.1.3 Organic Soils:

If it is estimated that the soil consists of enough organic particles to influence the soil properties, see Section 3.4.5 and Figure 1.

3.4.2 Methods for Identifying Soil

The following items must be determined to identify a soil:

3.4.2.1 Percent of Gravel, Sand, and Fines

Estimate and note the percentage of gravel, sand, and fines. Estimate percentages to the nearest 5 percent. The percentages of gravel, sand, and fines should equal 100 percent.

3.4.2.2 Percent of Oversized Particles

Estimate and note the percentage, if any, of boulders and cobbles. Estimate percentages, relative to the total volume observed, to the nearest 5 percent.

Methods of estimating the percentages of various soil components are found in APPENDIXD.

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3.4.3 Identification of Coarse Grained Soils

If the soil to be identified contains more than 50 percent coarse grained material it will be identified as a SAND or a GRAVEL. If a coarse grained soil contains no more than 5 percent fines, it is not necessary to determine the characteristics of the fines. Proceed to Section 3.5 and 3.6.

If the sample contains more than 5 percent fines, proceed to Section 3.4.4 below, Identification of Fine Grained Soil Fractions.

3.4.4 Identification of Fine Grained Soil Fractions

The identification of fine grained soil is determined using a combination of four manual tests: dilatancy, toughness, plasticity, and dry strength. It may not be necessary to perform all four tests to determine the identity of a soil. Figure 3a, Sample Identification Procedure Chart, and 3b, Summary of Test Characteristics, are used as guides for identifying fines.

Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dilatancy, toughness, plasticity, and dry strength tests.

To identify the fine grained fraction of a soil, ASTM D2488 requires that particles larger than the No. 40 be removed from the sample. However, with some soils it may be impractical to remove medium and coarse sand from a sample in the field. In such a case, it should be noted on the log and a best estimate made.

Contaminated soils may also pose a problem for fine grained soil identification. Gloves should be worn whenever contaminated fine grained soils are identified in the field. In some cases, contaminants present in the soil (such as coal tar or gasoline) make manual testing impractical, unreliable or unsafe. In such a case, it should be noted on the log and a best estimate made.
Additional comments on contaminated soil are found in Section 3.8.

3.4.4.1 Tests for Fine Grained Soil

A. *Dilatancy* - Dilatancy is the expansion of soil when subjected to a shearing deformation or, more simply, describes the soil's reaction to hand shaking.

From the specimen, select enough material to mold into a ball about 1/2 in. (13 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria listed below. The appearance of water on the surface of the specimen

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resembles a glossy, "liver-like" consistency. When then squeezed, the water and gloss disappears from the surface. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

B. *Toughness* - Toughness is the consistency of the soil near its plastic limit.

On the basis of observations made during the plasticity test, describe the toughness of the material as low, medium, or high in accordance with the criteria below.

Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll a 1/8 in. (3 mm) thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

C. *Plasticity* - Plasticity is the property of soil which allows it to be deformed beyond the point of recovery without cracking or appreciable volume change. The plasticity of soil is determined manually by observing how it behaves when it is rolled into a thread, the degree of cohesiveness at the plastic limit, and the general range of moisture contents over which the soil remains in a plastic state.

The test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms. Attempt to roll the soil into a thread about 1/8 in. (3 mm) in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation. If the sample is too dry, add water.

Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. (3 mm). The thread will crumble at a diameter of 1/8 in. (3 mm) when the water content in the soil is near the plastic limit. Note the pressure required to roll

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the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles.

Note the plasticity of the soil as nonplastic, low, medium, or high in accordance with the criteria listed below.

Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8 in. (3 mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

D. *Dry Strength* - Dry strength describes the crushing characteristics of a dry soil crumb under finger pressure.

Select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary. From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/2 in. (13 mm) in diameter. Allow the test specimens to dry in air or sun, or by artificial means as long as the temperature does not exceed 140° F (60°C). If the test specimen contains natural dry lumps, those that are about 1/2 in. (13 mm) in diameter may be used in place of the molded balls. (The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.)

Test the strength of the dry balls or lumps by crushing between the fingers. The dry strength increases with increasing plasticity. Note the strength as none, low, medium, high, or very high in accordance with the criteria listed below.

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Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand. The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (HCl) (see Appendix G).

3.4.4.2 Identifying the Fine Grained Fraction

Decide whether the fine grained soil fraction is an *inorganic* or an *organic* fine grained soil (see 3.4.5). If inorganic, follow the steps listed below using Table 1 as a guide.

Identify the fine grained soil fraction as a *silt*, ML, if the soil has slow to rapid dilatancy, low toughness, no to low plasticity, and no to low dry strength.

Identify the fine grained soil fraction as an *elastic silt*, MH, if the soil has no to slow dilatancy, low to medium toughness and plasticity, and low to medium dry strength. These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

Identify the fine grained soil fraction as a *lean clay*, CL, if the soil has no or slow dilatancy, medium toughness and plasticity, and medium to high dry strength.

Identify the fine-grained soil fraction as a *fat clay*, CH, if the soil has no dilatancy, high toughness and plasticity, and high to very high dry strength.

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TABLE 1 - Identification of Inorganic Fine Grained Soils from Manual Tests

Soil Symbol	Dilatancy	Toughness	Plasticity Designation	Dry Strength
ML	Slow to rapid	Low or thread cannot be formed	Non-plastic	None to low
MH	None to slow	Low to medium	Low	Low to medium
CL	None to slow	Medium	Medium	Medium to high
CH	None	High	Highly	High to very high

3.4.5 Organic Soils

Organic soils are those soils that contain sufficient organic matter to significantly affect the engineering properties or usage of the soil. Topsoil, peat and organic silt are typical examples. Peaty diatomaceous earth is a common organic soil found at the lower stratum of peat bogs. Fibrous peats may be found in both fresh-water (bogs) and marine settings. Organic clays are common in some sections of the country. Certain types of anthropogenic fills contain significant percentages of organic matter.

- Identification of Organic Fine Grained Soils - Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties (see Figure 1). Organic soils usually have a gray, dark gray brown to black color and may have an "earthy" or hydrogen sulfide odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air-dried. Organic soils frequently contain carbonate shell fragments, silica tests (diatoms) or woody, fibrous matter, although the presence of these materials is not an exclusive indicator of organic soils. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy or elastic. In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

- Identification of Peat - A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT.

Because organic soils can exhibit some of the characteristics of inorganic clay soils, they may be differentiated by the following criteria:

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- Inorganic Clay Soils - Any color may be expected. For more plastic clays, appreciable effort is required to pull the material apart. The broken pieces show the structure standing on end from the pulling. For high plasticities, the smear has a shiny, waxy appearance.

- Organic Soils – Gray, dark gray, black and various shades of brown are characteristic colors. Fresh organic soils, particularly marine peats and silts, commonly have a strong odor of hydrogen sulfide and heating the sample will intensify the odor. Less effort is required to pull fine grained non-fibrous organic soils apart than in the case of inorganic fine grained soil, and a clean break is generally formed. The smear, although smooth, is very dull and appears silty. Fibrous structure is, of course, an obvious identifying property. Organic silts respond positively to the dilatancy test. Organic soils customarily have very low shear strength in their natural state. Organic clays may be very difficult to identify visually without supplemental laboratory testing.

3.4.6 Identifying Soil

Proceed to section 3.5 and 3.6 to determine a Group Symbol and Group Name.

3.5 Determining the Group Symbol

Based on the properties of the soil, determine the Group Symbol using Figure 1 for fine grained soil and for organic soil, or Figure 2 for coarse grained soil.

If a soil has properties that do not distinctly place it into a specific group, Borderline Symbols may be used. A Borderline Symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. **Borderline Symbols** should not be confused with **Dual Symbols** such as GP-GM (well graded GRAVEL with silt) or SW-SC (well graded SAND with clay). A Dual Symbol is two symbols separated by a dash and represents a standard identification group.

3.6 Determining the Group Name

Based on additional observations, determine a Group Name using Figure 1 for fine grained soil and for organic soil, or Figure 2 for coarse grained soil.

3.6.1 Fine Grained Soil

If the fine grained soil is estimated to have 15 to 25 percent sand or gravel, or both, the words “with sand” or “with gravel” (whichever is more predominant) shall be added to the Group Name. For example: “lean CLAY with sand, CL” or “SILT with gravel, ML” (see Fig. 1. If the percentage of sand is equal to the percentage of gravel, use “with sand.” If the soil is estimated to have 30 percent or more sand or gravel, or both, the adjectives “sandy” or “gravelly” shall be added to the Group Name. Add the word “sandy” if there appears to be more sand than gravel. Add the word “gravelly” if there appears to be more gravel than sand. For example: “sandy lean CLAY, CL”, “gravelly fat CLAY, CH”, or “sandy SILT, ML” (see Fig. 1). If the percentage of sand is equal to the percent of gravel, use “sandy.”

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3.6.2 Coarse Grained Soil

1. The soil is a *GRAVEL* if the percentage of gravel is estimated to be more than the percentage of sand. The soil is a *SAND* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

2. The soil is a *clean GRAVEL* or *clean SAND* if the percentage of fines is estimated to be 5 percent or less.

3. Identify the soil as a *well graded GRAVEL*, GW, or as a *well graded SAND*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

4. Identify the soil as a *poorly graded GRAVEL*, GP, or as a *poorly graded SAND*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

5. Identify the soil as a *clayey GRAVEL*, GC, or a *clayey SAND*, SC, if the percentage of fines is estimated to be 15 percent or greater, and the fines are clayey as determined by the procedures in Section 3.4.4.

6. Identify the soil as a *silty GRAVEL*, GM, or a *silty SAND*, SM, if the percentage of fines is estimated to be 15 percent or greater, and the fines are silty as determined by the procedures in Section 3.4.4.

7. If the soil is estimated to contain 10 percent fines, give the soil a dual identification using two Group Symbols. The first Group Symbol corresponds to a clean gravel or sand (GW, GP, SW, SP) and the second Group Symbol corresponds to a gravel or sand with fines (GC, GM, SC, SM). The Group Name corresponds to the first Group Symbol plus the words “with clay” or “with silt” to indicate the plasticity characteristics of the fines. For example: “well graded GRAVEL with clay, GW-GC” or “poorly graded SAND with silt, SP-SM” (see Fig. 2). If the specimen is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse grained constituent, the words “with gravel” or “with sand” are added to the Group Name. For example: “poorly graded GRAVEL with sand, GP” or “clayey SAND with gravel, SC” (see Fig. 2).

3.7 Soil Description

Appropriate descriptive information is also recorded. The twelve categories of descriptive information are listed below.

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3.7.1 Required Descriptive Information

3.7.1.1 Density

The density of cohesionless or granular soils is determined by the Standard Penetration Test. The density of a soil based on the Standard Penetration Test is obtained from the following table:

Standard Penetration Test (SPT) N-Value (Blows per foot)	Density
0 - 4	Very loose
5 - 10	Loose
11 - 30	Medium dense
31 - 50	Dense
Over 50	Very dense

3.7.1.2 Consistency

The consistency of cohesive soils is determined in one of two ways. The preferred method of determining consistency in the field is based upon undrained strength as determined by a Torvane, pocket penetrometer or Field Vane shear test. In general, however, consistency is determined by the Standard Penetration Test (SPT), ASTM Designation D 1586, performed in test borings. The SPT consists of counting the number of blows of a 140 pound hammer freely falling 30 inches while driving a 2 inch O.D. split spoon sampler 18 inches into the soil. The number of blows is recorded for each 6 inches of penetration for an 18 inch drive. The first 6 inches of penetration are discounted and the number of hammer blows required to drive the sample over the 6 to 18 inch range of sampler penetration is termed the standard penetration resistance (N). Cable or wire-winch attached weights are unacceptable for determining STP.

The scale used for the consistency of a soil is presented in the following table:

Approximate Undrained Shear Strength (tsf)	Standard Penetration Test N-Value (Blows/foot)	Consistency
Below 0.13	0 - 2	Very soft
0.13 to 0.25	3 - 4	Soft
0.25 to 0.5	5 - 8	Medium stiff
0.5 to 1.0	9 - 15	Stiff
1.0 to 2.0	16 - 30	Very stiff
Over 2	Over 30	Hard

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If required, the ASTM procedure for determining consistency can be used, which is based on indentation of the soil with the thumb and is presented in Appendix E. If the ASTM procedure is used, it should be noted on the logs.

3.7.1.3 Color

Color may be useful in identifying materials of similar geologic origin. Color is an important property in identifying organic soils.

Moist soil samples should be used to describe soil color. Color description is generally confined to a few basic terms such as brown, black, gray and yellow. These terms are often combined in pairs. Examples of combined color descriptors are gray green, yellow brown or yellow gray. In listing two colors, the second color listed is the predominant of the two colors. The ending "ish" is never added to a color description. If dictated by specific project requirements, more accurate color descriptions based on hue and chroma may be obtained by use of the "Munsell Soil Color Charts."

If the soil color is not homogeneous due to layering, describe the color of all layers. If the soil is not layered, use the term mottled, if appropriate, to describe the colors. (Example: mottled brown and gray.)

3.7.1.4 Group Name and Group Symbol

The primary constituent is typed in all uppercase in the Group Name and the Group Symbol is uppercase and set in parentheses.

3.7.1.5 Percent Oversized

When the sample contains cobbles or boulders or both, estimate the percent relative to the total volume observed to the nearest 5 percent.

3.7.1.6 Maximum Particle Size

Describe the maximum particle size found in the sample. The maximum particle size is used to determine the sample size required for field identification and various laboratory tests.

3.7.1.7 Structure

Several terms have been found useful in simplifying the description of some special characteristic of a soil or to add additional information. A list of a few of the more common terms is given in Appendix F, Descriptive Terminology for Soil Structure.

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3.7.1.8 Odor

Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. Unusual odors may indicate soil contamination and should be avoided. This should be called to the attention of the project manager unless contamination was expected in the soil.

3.7.1.9 Moisture Condition

The moisture condition of a soil should be described as dry, moist or wet according to the criteria listed below.

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

3.7.1.10 Geologic Interpretation

A geologic interpretation of the soil is very helpful and should be added; e.g., Glaciofluvial Deposits. Note however that if you are uncertain about an interpretation, it is your responsibility to review it with a senior H&A geologist.

3.7.2 Additional Descriptive Information

The following additional information should be included as a part of a soil description. Methods for describing these soil properties are listed in Appendix G.

a. Hardness of the Plus No. 10 Fraction
b. Angularity of the Plus No. 10 Fraction
c. Particle Shape of the Plus No. 4 Fraction
d. Reaction with Hydrochloric Acid
e. Cementation of Intact Samples
f. Torvane and Pocket Penetrometer Readings
g. Additional Comments

3.8 Contaminated Soils

Contamination of soil can occur from an extremely wide range of hazardous and non-hazardous anthropogenic pollutants being released into the environment from a variety of disposal methods. Naturally deposited undisturbed soils may be stained from liquids passing through them. “Clean” undisturbed soils can absorb and retain strong odors from adjacent vapor sources. The actual soil constituents may be partially or completely comprised of anthropogenic materials: ash, cinders, clinker, slag, glass, brick, concrete, etc. If so, the sample should be described with respect to these constituents.

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Contaminated soil may be any color, may have some odor level, and may retain the actual product. Indicators of potential contamination include, but are not limited to, soil with an unusual color or distinct odor such as gasoline, diesel fuel, solvents, moth balls, etc. However, the soil may not show any of the above indicators and still be contaminated. If unexpected soil contamination is encountered and there is no site-specific Health & Safety plan, or appropriate Health & Safety equipment is not available, immediately cease exploration operations, clear personnel from work area, and contact the H&A Project Manager and Health and Safety Representative for instructions.

3.8.1 Description of Fills

For methods used to describe fills, see Appendix H.

3.9 Presentation of Soil Identification and Descriptive Information

The soil identification should consist of the Group Name, the Group Symbol, and all required descriptive information. **If using this procedure to identify soil, it must be distinctly and clearly stated in all logs, summary tables, and reports that the Group Names and Group Symbols are based on visual-manual procedures.**

As a rule, descriptive information should be listed in the following order:

1. **Percent of Gravel, Sand, and Fines**
2. **Dilatancy**
3. **Toughness**
4. **Plasticity**
5. **Dry Strength**
6. **Density/Consistency***
7. **Color**
8. **Group Name and Group Symbol**
9. **Percent Oversized (boulders and cobbles)**
10. **Maximum Particle Size**
11. **Structure***
12. **Odor**
13. **Moisture**
14. Optional Descriptions
15. **Geologic Interpretation**

Descriptors in **BOLD** should always be included with descriptions. Descriptors followed with an asterisk (*) apply only to intact samples such as split-spoon samples.

Examples:

Several examples of soil identifications and descriptions based on this procedure are presented below. Note not only the order of descriptive terms, but also the use of commas, hyphens, slashes, parentheses, and upper case letters. Abbreviations should not be utilized in writing soil identifications and descriptions.

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Example 1

The example below is a standard identification and description of 50 lb. grab sample from a test pit:

10% fine gravel, 30% coarse sand, 30% medium sand, 30% fine sand, no fines

Brown, poorly graded SAND (SP)
10% boulders, 15% cobbles, maximum particle size 18" (450 mm).
Stratified with coarse to medium grained layers 3" to 6" thick (75-150 mm) alternating with fine grained layers 6" to 12" thick (150-300 mm).
No odor, dry.
GLACIOFLUVIAL DEPOSIT

If the soil above was described from an 8 oz. driller's jar, the following statement should be added to the description:

(Note: Sample size smaller than recommended.)

Example 2

The example below is a standard identification and description of a split-spoon sample:

10% fine gravel, 5% coarse sand, 5% medium sand, 10% fine sand,
70% fines: no dilatancy, medium toughness, medium plasticity, medium dry strength

Stiff, gray green, sandy lean CLAY (CL).
Maximum particle size 13 mm. Laminated. Frequent fine sand partings, occasional medium to fine sand seams. Fine gravel and coarse sand present as dropstones.
No odor. Moist.
MARINE DEPOSIT

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Example 3

The example below is a standard identification and description of split-spoon sample:

5% coarse gravel, 10% fine gravel, 5% coarse sand, 10% medium sand, 40% fine sand, 30% fines: rapid dilatancy, low toughness, low plasticity, low dry strength.

Very dense, brown, silty SAND with gravel (SM)
Maximum particle size 1 in. (25 mm).
Foliated and well bonded, no odor, moist, uncemented.
Coarse fraction generally hard and rounded igneous and metamorphic lithologies, imbedded.
Minor soft and angular, flat to elongated sedimentary lithologies (argillite).
Weak reaction with HCl on minor white 0.5-0.1 mm grains (possible seashell particles).
Note: Drill action indicates occasional cobbles. Possible sand lenses indicated by wash water return.
GLACIAL TILL DEPOSIT

Example 3 (abbreviated):

5% c GVL, 10% f GVL, 5% c SA, 10% m SA, 40% f SA
30% fines: D=R, T=L, P=L, DS=L

Very dense, brown, silty SAND with gravel (SM)
mps 25 mm. Foliated and well bonded, no odor, moist.
Cobbles indicated by drill action.
GLACIAL TILL DEPOSIT

In general, final identification of soil samples for typed boring logs and reports requires a careful review, taking into consideration the laboratory identification tests that were not available at time of sampling.

3.10 Precision and Bias

This procedure provides qualitative information only; therefore, a precision and bias statement is not applicable.

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Figure 1:
Flow Chart for Identifying Fine-Grained Soils (50% or more fines)

Group Symbol				Group Name
ML (SILT)	<30% plus No. 200	<15% plus No. 200		SILT
		15-25% plus No. 200	% sand ≥% of gravel	SILT with sand
			% sand <% of gravel	SILT with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy SILT
			≥15% gravel	sandy SILT with gravel
		% sand <% of gravel	<15% sand	gravelly SILT
			≥15% sand	gravelly SILT with sand
MH (ELASTIC SILT)	<30% plus No. 200	<15% plus No. 200		elastic SILT
		15-25% plus No. 200	% sand ≥% of gravel	elastic SILT with sand
			% sand <% of gravel	elastic SILT with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy elastic SILT
			≥15% gravel	sandy elastic SILT with gravel
		% sand <% of gravel	<15% sand	gravelly elastic SILT
			≥15% sand	gravelly elastic SILT with sand
CL (LEAN CLAY)	<30% plus No. 200	<15% plus No. 200		lean CLAY
		15-25% plus No. 200	% sand ≥% of gravel	lean CLAY with sand
			% sand <% of gravel	lean CLAY with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy lean CLAY
			≥15% gravel	sandy lean CLAY with gravel
		% sand <% of gravel	<15% sand	gravelly lean CLAY
			≥15% sand	gravelly lean CLAY with sand
CH (FAT CLAY)	<30% plus No. 200	<15% plus No. 200		fat CLAY
		15-25% plus No. 200	% sand ≥% of gravel	fat CLAY with sand
			% sand <% of gravel	fat CLAY with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy fat CLAY
			≥15% gravel	sandy fat CLAY with gravel
		% sand <% of gravel	<15% sand	gravelly fat CLAY
			≥15% sand	gravelly fat CLAY with sand
OL/OH (ORGANIC SOILS)	<30% plus No. 200	<15% plus No. 200		ORGANIC SOIL
		15-25% plus No. 200	% sand ≥% of gravel	ORGANIC SOIL with sand
			% sand <% of gravel	ORGANIC SOIL with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy ORGANIC SOIL
			≥15% gravel	sandy ORGANIC SOIL with gravel
		% sand <% of gravel	<15% sand	gravelly ORGANIC SOIL
			≥15% sand	gravelly ORGANIC SOIL with sand

Note: Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%

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Figure 2:
Flow Chart for Identifying Coarse-Grained Soils (less than 50% fines)

				Group Symbol		Group Name
GRAVEL % gravel > % sand	≤5% fines	Well-graded		**GW**	<15% sand	well-graded GRAVEL
					≥15% sand	well-graded GRAVEL with sand
		Poorly-graded		**GP**	<15% sand	poorly-graded GRAVEL
					≥15% sand	poorly-graded GRAVEL with sand
	10% fines	Well-graded	fines = ML or MH	**GW-GM**	<15% sand	well-graded GRAVEL with silt
					≥15% sand	well-graded GRAVEL with silt and sand
			fines = CL or CH	**GW-GC**	<15% sand	well-graded GRAVEL with clay
					≥15% sand	well-graded GRAVEL with clay and sand
		Poorly-graded	fines = ML or MH	**GP-GM**	<15% sand	poorly-graded GRAVEL with silt
					≥15% sand	poorly-graded GRAVEL with silt and sand
			fines = CL or CH	**GP-GC**	<15% sand	poorly-graded GRAVEL with clay
					≥15% sand	poorly-graded GRAVEL with clay and sand
	≥15% fines		fines = ML or MH	**GM**	<15% sand	silty GRAVEL
					≥15% sand	silty GRAVEL with sand
			fines = CL or CH	**GC**	<15% sand	clayey GRAVEL
					≥15% sand	clayey GRAVEL with sand
SAND % sand ≥ % gravel	≤5% fines	Well-graded		**SW**	<15% gravel	well-graded SAND
					≥15% gravel	well-graded SAND with gravel
		Poorly-graded		**SP**	<15% gravel	poorly-graded SAND
					≥15% gravel	poorly-graded SAND with gravel
	10% fines	Well-graded	fines = ML or MH	**SW-SM**	<15% gravel	well-graded SAND with silt
					≥15% gravel	well-graded SAND with silt and gravel
			fines = CL or CH	**SW-SC**	<15% gravel	well-graded SAND with clay
					≥15% gravel	well-graded SAND with clay and gravel
		Poorly-graded	fines = ML or MH	**SP-SM**	<15% gravel	poorly-graded SAND with silt
					≥15% gravel	poorly-graded SAND with silt and gravel
			fines = CL or CH	**SP-SC**	<15% gravel	poorly-graded SAND with clay
					≥15% gravel	poorly-graded SAND with clay and gravel
	≥15% fines		fines = ML or MH	**SM**	<15% gravel	silty SAND
					≥15% gravel	silty SAND with gravel
			fines = CL or CH	**SC**	<15% gravel	clayey SAND
					≥15% gravel	clayey SAND with gravel

Note: Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%

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FIGURE 3a. SAMPLE IDENTIFICATION PROCEDURE CHART

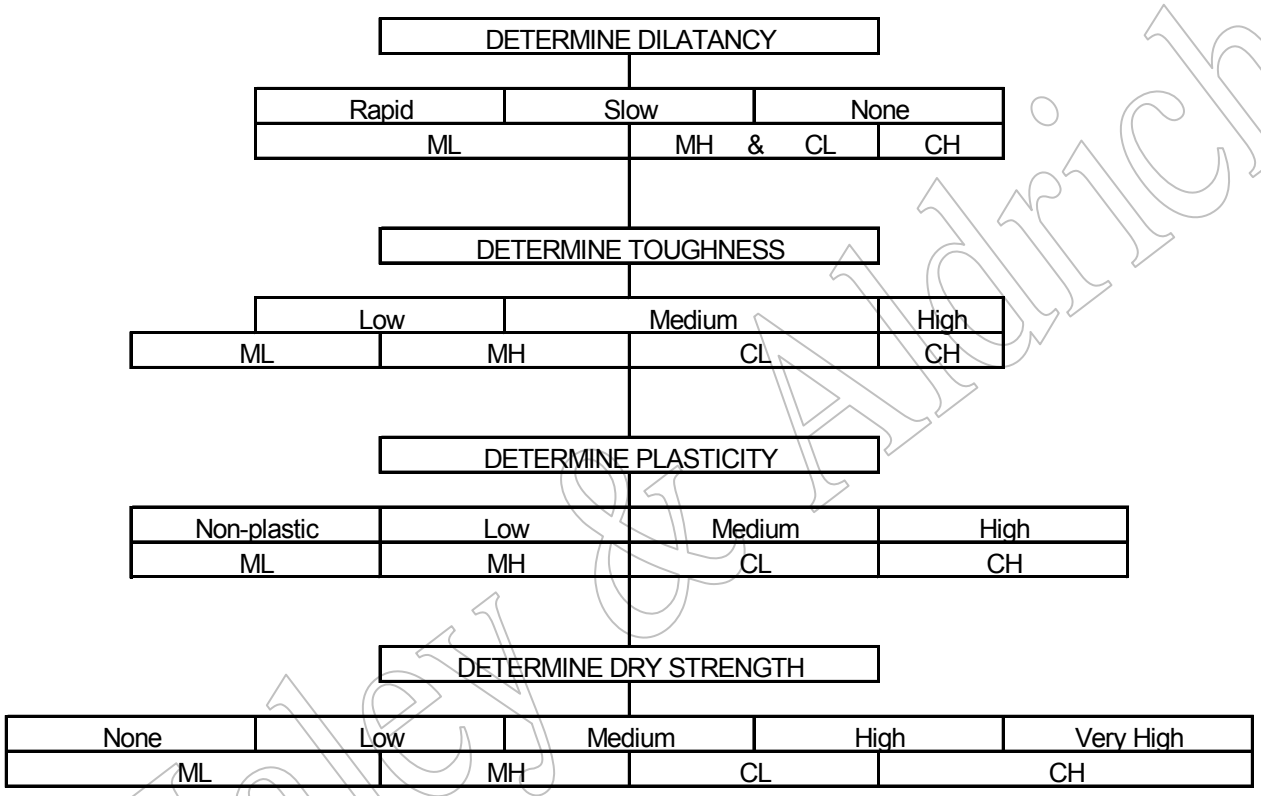

FIGURE 3b. SUMMARY OF TEST CHARACTERISTICS

	Dilatancy	Toughness	Plasticity	Dry Strength
ML	slow - rapid	low	none - low	none - low
MH	none - slow	low - medium	low - medium	low - medium
CL	none - slow	medium	medium	medium - high
CH	none	high	high	high - very high

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APPENDIX A
REFERENCES

A.1 Reference Procedure

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D2488-93, "Description and Identification of Soils (Visual-Manual Procedure)."

A.2 Other References

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D2487-98, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)."

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D1586-99, "Penetration Test and Split-Barrel Sampling of Soils."

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5434-97, "Field Logging of Subsurface Explorations of Soil and Rock."

A.3 COMMENTS ON REFERENCE PROCEDURE

The procedures and equipment listed in OP2001 and used by H&A are generally as specified in the Reference Procedure. Deviations of OP2001 from the Reference Procedure are listed below. The procedure described in Section 3 has been developed to assist H&A personnel in identifying and describing soil, and in some cases simplifies the Reference Procedure.

OP2001 deviates from the ASTM Reference Procedure in the following:

- ASTM D2488-93 defines the minimum amount of soil required for identification and description. The minimum amount required is based on the maximum particle size observed in the soil. However, in many cases it is not possible to obtain the required amount of soil due to the limitations of the sampling techniques used. As a general rule it should be assumed that all split-spoon samples of soils containing coarse gravel do not meet the required sample size. In addition, all jar samples of soil containing particles larger than coarse sand may not meet the required sample size.

- ASTM D2488-93 requires the percentage of cobbles and boulders to be estimated on the basis of volume percentage. The gravel, sand, and fines percentages are to be determined based on an estimate of dry weight. However, in almost all cases this method overly complicates estimating the percentage of different soil components. Haley & Aldrich considers that estimates of percentage based on particle volume and particle weight (either wet or dry) are equivalent for practical purposes. Average specific gravities of soil range between 2.65 and 2.75. Percentages of particle fractions based on volume should, in general, vary by no more than 5 percent from percentages based on weight—well within the error limits of the procedure.

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- To identify the fine grained fraction of a soil, ASTM D2488 requires that particles larger than No. 40 be removed from the sample. With some soils it may be impractical to remove medium and coarse sand from a sample in the field.

- Consistency of cohesive soil is based upon undrained strength as determined by a Torvane or Field Vane shear test. The Standard Penetration Test (SPT) is used in cases where no other data are available.

- The density of granular soils is determined by the Standard Penetration Test, ASTM Designation D1586, performed in test borings.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP2000 Monitoring Field Explorations
- OP2005 Test Borings, Sampling, Standard Penetration Testing and Borehole Abandonment
- OP2026 Exploratory Test Pits

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APPENDIX C
FORMS AND EXAMPLES

C.1 Forms

All Haley & Aldrich field forms are maintained on the server at K:\techproc\op\Forms. The following is a list of forms currently available specifically for the logging of soils using the USCS as practiced by H&A.

C.1.1 Test Boring Logging

- Form 2001 Test Boring Report
- Form 2002 Core Boring Report

C.1.2 Test Pit Logging

- Form 2006 Test Pit Log

C.2 Examples

The following examples of completed forms are intended to provide guidance in field logging. These examples are not intended to show all of the variations of USCS use, rather they are presented as a general reference of the standard logging conventions practiced by H&A.

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TEST BORING REPORT

BORING NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft.	Datum	Boring Location

Item	Casing	Sampler	Core Barrel
Type			
Inside Diameter (in.)			
Hammer Weight (lb.)			
Hammer Fall (in.)			

Rig Make & Model: ☐ Truck ☐ Tripod ☐ Cat-Head; ☐ ATV ☐ Geoprobe ☐ Winch; ☐ Track ☐ Air Track ☐ Roller Bit; ☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☐ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☐ None

Casing Advance: Type Method Depth

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary

Overburden (Linear ft.) _____
Rock Cored (Linear ft.) _____
Number of Samples _____

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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TEST BORING REPORT

BORING NO.

Page of

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel		Sand			% Fines	Field Test			
								% Coarse	% Fine	% Coarse	% Medium	% Fine		Dilatancy	Toughness	Plasticity	Strength

NOTES:

FILE NO.

BORING NO.

*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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CORE BORING REPORT

BORING NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft	Datum	Boring Location

Item	Casing	Sampler	Core Barrel
Type			
Inside Diameter (in)			
Hammer Weight (lb)			
Hammer Fall (in)			

Rig Make & Model

- ☐ Truck
- ☐ ATV
- ☐ Track
- ☐ Skid
- ☐ Tripod
- ☐ Geoprobe
- ☐ Air Track
- ☐ _____
- ☐ Cat-Head
- ☐ Winch
- ☐ Roller Bit
- ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut

Casing: ☐ Driven ☐ Spun

Drill Mud: ☐ Bentonite ☐ Polymer ☐ None

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Sample ID

- O Open End Rod
- T Thin Wall Tube
- U Undisturbed Sample
- S Split Spoon Sample
- G Geoprobe

Well Diagram

- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (Linear ft.)	
Rock Cored (Linear ft.)	
Number of Samples	

BORING NO.

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CORE BORING REPORT

BORING NO.

Page of

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks

FILE NO. BORING NO.

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SAMPLE

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TEST BORING REPORT

BORING NO. **B 7 (OW)**

PROJECT	Greenspace Development	H&A FILE NO.	27921-000
LOCATION	18 Riverside Road, Boston Massachusetts	PROJECT MGR.	S.R. Kraemer
CLIENT	Ecologic Investments	FIELD REP.	C.S. Osgood
CONTRACTOR	Guild Drilling Co., Inc.	DATE STARTED	13-Feb-01
DRILLER	Charlie O'Donnel	DATE FINISHED	14-Feb-01

Elevation 23.3 ft. | Datum Boston City | Boring Location See sketch on reverse of form.

Item	Casing	Sampler	Core Barrel
Type	NW	S	NV2
Inside Diameter (in.)	3	1.385	2
Hammer Weight (lb.)	300	140	
Hammer Fall (in.)	24	30	

Rig Make & Model: CME 75

☑ Truck ☐ Tripod ☑ Cat-Head
☐ ATV ☐ Geoprobe ☐ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☑ Safety ☐ Doughnut ☐ Automatic

Drilling Mud: ☑ Bentonite ☐ Polymer ☐ None

Casing Advance: Type Method Depth — NW Driven 29.0 ft.

Drilling Notes: Flushed slurry prior to coring.

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0																	
	10		0.0			SP-SM	Medium dense brown poorly graded SAND with silt (SP-SM),				20	70	10				
	12	S1					mps 2 mm, distinctly stratified, fines partially organic, no odor, dry.										
	15	21"															
	20		2.0		2.0		-ALLUVIUM-										
	11		2.0			SP	Dense brown poorly graded SAND (SP), mps 25 mm, no odor, dry.	5	5	20	30	35	5				
	15	S2															
	16	10"															
	17		4.0				-ALLUVIUM-										
					4.5												
5																	
	WOR		5.0				Very soft, dark brown ORGANIC SOILS with sand (OL/OH), trace					25	75	S	M	H	VH
	WOR	S3				OL/OH	seashell fragments and particles, soil mps 0.5 mm, strong										
	WOH	24"					organic odor, moist.										
	WOH		7.0				-ORGANIC DEPOSIT-										
					8.0												
							Note: Drilling fluid returning medium to fine sand from 8.0 ft. to										
							10.0 ft. Drilling fluid color change to yellow red at 8.5 ft.										
							-PROBABLE MARINE DEPOSIT-										
					10.0												
10																	
	3		10.0			CH	Stiff yellow brown fat CLAY (CH), trace fine sand, mps 0.5 mm,						100	N	M	H	
	6	S4					apparently laminated with frequent fine sand partings and										
	6	22"					possible organic fibers, no odor, moist.										
	6		12.0				-MARINE DEPOSIT-										
					13.5												
							Note: Drill action indicates gravel below 13.5 ft.										
15																	
	12		15.0			CL	Very stiff yellow brown to gray sandy lean CLAY with gravel (CL),	5	10	10	10	15	50	S	M	M	
	14	S5					mps 35 mm, distinct disrupted laminae in discrete zones, coarse										
	15	17"					fraction consists of well rounded igneous and igneous and										
	19		17.0				metamorphic lithologies, no odor, moist.										
							-GLACIOMARINE DEPOSIT-										
					18.0												
							Note: Drill action and total loss of drilling fluid indicates gravel										
					19.0		and cobbles from 18.0 ft. to 19.0 ft.										
							Very dense gray silty SAND (SM) , mps 15 mm, very well bonded,										
20																	
	21	S6	20.0			SM	coarse fraction consists partly of platy argillite fragments, no odor, moist.		10	15	20	30	25	R			
	25	10"	21.0		21.0		-GLACIAL TILL-										
	33	S6A	21.0			ML	Very dense gray SILT (ML), mps <0.1 mm, no structure, no odor,						100	R		N	
	34	7"	22.0				dry.										
							-RESIDUAL SOIL-										
							Note: Drilling advanced smoothly from 21.0 ft. to 25.0 ft.										
					25.0		PROBABLE TOP OF DECOMPOSED BEDROCK 25.0 FT.										
25																	
	53		25.0				Very dense gray highly to completely weathered ARGILLITE.										
	28	S7					Possible extremely thin relect bedding subparallel to strong										
	39	5"					low angle foliation. Sample is generally well bonded and consists										
	35		27.0				of very soft angular fragments and particles which are easily										
							crushed with finger pressure.										
							-DECOMPOSED BEDROCK-										
							Note: Drill action indicates stratum change at 28.5 ft.										
					28.5		TOP OF "SOUND" BEDROCK 28.5 FT.										
							SEE SHEET 2 FOR CORE BORING REPORT										
30																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
13-Feb-01	15:30	0	29.0	29.0	2.0
14-Feb-01	7:00	15.5	29.0	29.0	6.2
14-Feb-01	15:00	1.0	39.5	39.5	10.4

Sample ID

O Open End Rod
T Thin Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Well Diagram

Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary

Overburden (Linear ft.)	29.5
Rock Cored (Linear ft.)	10.0
Number of Samples	S7 C2

BORING NO. **B 7 (OW)**

Field Tests Dilatancy: R - Rapid S - Slow N - None Plasticity: N - Nonplastic L - Low M - Medium H - High
Toughness: L - Low M - Medium H - High Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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CORE BORING REPORT

BORING NO. B 7 (OW)

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery (in)	RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks
								SEE SHEET 1 TEST BORING REPORT FOR OVERBURDEN DETAILS.
							21.0	TOP OF RESIDUAL SOIL 21.0 FT.
								Note: Advanced borehole with rollerbit and splitspoon and drove NW casing through residual soil from 21.0 ft. to 25.0 ft.
					Residual Soil			-RESIDUAL SOIL-
25							25.0	TOP OF DECOMPOSED BEDROCK 25.0 FT.
					High to Complete			Note: Advanced borehole with rollerbit and splitspoon and drove NW casing through decomposed bedrock from 25.0 ft. to 28.5 ft.
								-DECOMPOSED BEDROCK-
							28.5	TOP OF "SOUND" BEDROCK 28.5 FT.
								Note: Seated NW casing at 29.0 ft. Advanced borehole with rollerbit to 29.5 ft. without sampling prior to coring.
30		29.5	56"		Slight			C1: Moderately hard, slightly weathered, gray, aphanitic ARGILLITE. Bedding extremely thin to very thin, generally low angle (30-35 degrees). Foliation low angle, commonly subparallel to bedding. Cleavage well developed along bedding/foliation planes where coincident.
	6							
					Mod.			Cleavage joints very close to close 29.5 -31.0 ft. and close below 32.5 ft. smooth-planar,
	3	C1			High			slightly oxidized, occasionally calcite-infilled, tight. High angle to vertical joints moderately
					Mod.			close, rough-undulatory, pyritized or highly oxidized and decomposed with silt infilling, open.
	5							Soft, moderately to highly weathered zone 31.0-32.5 ft. associated with extremely close,
					Slight			moderately dipping, slickensided-planar shears intersecting bedding plane and high angle features.
	6							Note: Partial water loss below 31.0 ft.
		34.5	24"	40%				Note: Lost core assumed 31.7-32.0 ft.
35	6	34.5	60"	100%				C2: Similar to bottom of run C1 except cleavage joints close to moderately close. High angle to vertical joints absent. Occasional thin zone of extremely close, extremely thin, moderately dipping to high angle (50-60 degrees) calcite stringers. Occasional calcite-healed low angle joint.
	7							
	6	C2			Slight			-CAMBRIDGE FORMATION-
	6						38.0	
	8							Lithology change at 38.0 ft. to hard, slightly weathered, dark gray to black, fine grained to aphanitic DIABASE. Single high angle joint at 38.7 ft. rough-stepped, slightly oxidized, tight.
		39.5	54"	90%				
40	8							BOTTOM OF EXPLORATION 39.5 FT.

FILE NO. 27921-000 BORING NO. B 7 (OW)

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TEST PIT LOG

Test Pit No.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	
EQUIPMENT		WEATHER	

Ground El. _____ ft. Location _____
El. Datum _____

Groundwater depths/entry rates (in./min.):

Depth (ft.)	Sample ID	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (Color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength

Obstructions:

Remarks:

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:
at depth _____ ft.
measured after _____ hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24		=	
over 24		=	

Test Pit Dimensions (ft.):
Pit Depth _____
Pit Length X Width _____

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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ENVIRONMENTAL TEST PIT LOG

Test Pit No.

Page of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	
EQUIPMENT		WEATHER	

Ground El. ft.
El. Datum

Location

Groundwater depths/entry rates (in./min.):

Depth (ft.)	Sample ID	PID Reading (ppm.)	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (Color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength

Obstructions:

Remarks:

Bucket Decontamination Method:

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth ft.
measured after hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24		=	
over 24		=	

Test Pit Dimensions (ft.):

Pit Depth
Pit Length X Width

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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HALEY & ALDRICH, INC.
SAMPLE

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ENVIRONMENTAL TEST PIT LOG

Test Pit No. **TP 214**

PROJECT	Mirror Lake Watershed Study	**H&A FILE NO.**	28675-309
LOCATION	Essex, Massachusetts	**PROJECT MGR.**	D.H. Gevalt
CLIENT	Citizens Advisory Partnership	**FIELD REP**	C.S. Osgood
CONTRACTOR	Stanley Lynde Const. Co., Inc.	**DATE**	19-Jul-02
EQUIPMENT	Case 580 rubber tire backhoe - 1/4 cu. yd. bucket	**WEATHER**	Thunderstorms 90's

Ground El.	74.5 ft.	**Location**	N 2,089,041.101	**Groundwater depths/entry rates (in./min.):**
El. Datum	NGVD		E 801,444.238	None

Depth (ft.)	Sample ID	PID Reading (ppm.)	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (density/consistency, color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions,	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
					Note: Ground surface strewn with boulders. Numerous depressions indicating										
					subsurface voids noted.										
	1.5				15% coarse to fine sand, 15% cinder fragments and particles, 10% unidentifiable, white										
					ash-like material, 10% fines (largely organic), 10% coarse to fine gravel, 10% wood										
2					(manufactured and treated), 5% glass fragments, 5% metal strips and wire, 5% charcoal										
	S2	15.9			5% plastic sheeting (possibly polyethelene bags), 5% brick particles, 5% clay pipe										
					fragments. Matrix generally dark brown to gray in color with pockets of white and red.										
					15% boulders, 15 % cobbles. Maximum particle size 36 inches.										
	2.5				Distinct decomposed gasoline odor, possible faint napthalene odor. Visible irridescent										
					sheen on moist solids 4.6 to 5.2 ft.										
4					-FILL-										
	4.6														
	S1	140			Note: Bedrock surface smooth and flat, consisting of very hard to hard, slightly										
	5.2		5.2		weathered, light gray to pink, coarse to fine grained granite. Single high angle joint noted.										
					REFUSAL ON BEDROCK 5.2 FT.										
6															
8															

Obstructions:

Remarks:

Note: Sample S1 submitted for laboratory chemical analysis.

Note: Field monitoring of breathing zone and headspace screening conducted using an hNU 11.7 ev. PID.

Bucket Decontamination Method: Steam cleaned

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth	NE	ft.
measured after	0.75	hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24	6.0	=	18.0
over 24	1.0	=	33.0

Test Pit Dimensions (ft.):

Pit Depth	5.2
Pit Length X Width	10.5 x 4.3

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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SAMPLE

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TEST PIT LOG

Test Pit No. **TP-1**

Page 1 of 1

PROJECT	New England Hospital	**H&A FILE NO.**	10715-205
LOCATION	Boston, Massachusetts	**PROJECT MGR.**	M.X. Haley
CLIENT	PFT Associates	**FIELD REP**	C. S. Osgood
CONTRACTOR	J. Marchese & Sons Const.	**DATE**	07-Jan-02
EQUIPMENT	CAT 416 Rubber Tire Extendahoe	**WEATHER**	Mostly Clear 20s

Ground El.	36.3 ft.	**Location**	West of Pedestrian Tunnel	**Groundwater depths/entry rates (in./min.):**
El. Datum	NGVD			7.8 ft. Steadily

Depth (ft.)	Sample ID	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (density/consistency, color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
				Dark brown silty SAND (SM), mps 5 mm, organic odor, moist.		5	5	10	45	40	R			
	0.5		SM	Fines largely organic.										
				-LOAM FILL-										
		1.3												
2	S3			Yellow brown to olive brown sandy fat CLAY (CH), trace roots, clinker fragments,	5	5	5	10	15	60	N	M	H	
			CH	cinder particles and fragments, clay pipe fragments, metal wire, asphalt fragments										
				mps 24 in., no odor, moist.										
				-FILL-										
4	4.0			Note: Poured concrete foundation wall on east side of test pit from 0.0 -4.4 ft.										
	4.0													
6	S2													
8	8.0	8.0												
	8.0			Yellow brown fat CLAY (CH), trace fine sand. mps 0.5 mm, no odor, dry.					5	95	N	M	H	
	S1		CH	Appartantly laminated with frequent fine sand partings and possible organic fibers.										
	9.0			-MARINE DEPOSIT-										
10														
		11.0												
				Yellow brown to gray sandy lean CLAY (CL) with gravel. mps 35 mm.	5	10	10	10	15	50	S	M	L	
			CL	Distinct disrupted laminae in discrete zones. Coarse fraction consists of well-rounded										
				igneous and metemorphic lithologies.										
12	12.0	12.0		-GLACIOMARINE DEPOSIT-										
				Note: Possible stratum change to gray lean CLAY with sand (CL) below 12.0 ft.										
				Coarse fraction apparantly less abundent.										
				-MARINE DEPOSIT-										
				BOTTOM OF EXPLORATION 13.5 FT.										
14														

Obstructions:

Remarks:

Note: Bag samples S1-S3 obtained for potential mechanical analysis from depths indicated.

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth	13.2	ft.
measured after	0.1	hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24	1	=	1.8
over 24	1	=	8.2

Test Pit Dimensions (ft.):

Pit Depth	13.5
Pit Length X Width	9.0 x 6.0

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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APPENDIX D
CRIBSHEETS

D.1 Cribsheets

The following cribsheets are provided as a quick reference to the major soil properties defined by the USCS as practiced by H&A. These abbreviated summary tables are not a comprehensive reference, rather they are intended to be used as a field aid during identification and description of soils by staff thoroughly familiar with OP2001.

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COLOR EXAMPLES

- GRAY
- GRAY-BROWN
- OLIVE-BROWN
- OLIVE
- OLIVE-GRAY
- DARK BROWN
- RED-GRAY
- RED-BROWN
- BROWN
- RED
- LIGHT BROWN
- TAN
- YELLOW-BROWN
- RED-YELLOW
- YELLOW

GRAIN SIZE

Clear Square Sieve Openings: 12" 3" 3/4"

U.S. Standard Series Sieve: 4 10 40 200

SOILS	Boulders	Cobbles	Gravel		Sand			Silts and Clays
			Coarse	Fine	Coarse	Medium	Fine	
FILLS	Blocks	Pieces	Fragments		Particles			Specks

300mm 75mm 19mm 4.75mm 2.0mm 0.42mm 0.075mm

APPARENT/RELATIVE DENSITY NON-COHESIVE SOIL

APPARENT DENSITY	SPT (# blows/ft)	MODIFIED CA. SAMPLER (# blows/ft)	CALIFORNIA SAMPLER (# blows/ft)	RELATIVE DENSITY (%)
Very loose	0-4	0-4	0-5	0 -15
Loose	5-10	5-12	6-15	15-35
Medium dense	11-30	13-35	16-40	35-65
Dense	31-50	36-60	41-70	65-85
Very dense	> 50	>60	>70	85-100

CONSISTENCY COHESIVE SOIL

		TORVANE	POCKET PENETROMETER
CONSISTENCY	SPT (# blows/ft)	UNDRAINED SHEAR STRENGTH (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)
Very soft	0 - 2	<0.13	<0.25
Soft	3 - 4	0.13 - 0.25	0.25 - 0.5
Medium Stiff	5 - 8	0.25 - 0.5	0.5 - 1.0
Stiff	9 - 15	0.5 - 1.0	1.0 - 2.0
Very Stiff	16 - 30	1.0 - 2.0	2.0 - 4.0
Hard	>30	>2.0	>4.0

MOISTURE CONTENT

DESCRIPTION	FIELD TEST
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

SOIL IDENTIFICATION SHOULD INCLUDE:

1. Percent of gravel, sand & fines
2. Dilatancy, toughness, plasticity, dry strength
3. Density/Consistency
4. Color
5. Group name/Group symbol
6. Percent oversized
7. Maximum particle size
8. Structure
9. Odor
10. Moisture
11. Optional descriptions
12. Geologic interpretation

Criteria for Describing Soil Structure

Description	Criteria
Bed	A sedimentary layer bounded by depositional surfaces.
Blocky	A characteristic in which cohesive soil can be broken down into small angular lumps which resist further breakdown.
Bonded	Attached or adhering.
Fissured	Broken along definite planes of fracture.
Foliated	Planar arrangement of textural or structural features.
Frequent	More than one per foot of thickness.
Homogeneous	Same color and appearance throughout.
Interbedded	Alternating soil layers of different composition.
Laminae	A very thin cohesive layer.
Layer	A general term for material lying essentially parallel to the surfaces against which it was formed.
Lens	A lenticular deposit, larger than a pocket.
Occasional	One or less per foot of thickness.
Parting	A very thin granular layer.
Pocket	Small erratic deposits less than 12 in. in thickness.
Seam	A thin layer separating two distinctive layers of different composition or greater magnitude.
Stratified	Alternating layers of varying material or color.
Stratum	A stratigraphic unit.
Varve	A cyclic sedimentary couplet consisting of a coarser and a finer layer representing the variation in depositional energy resulting from the annual freeze-thaw cycle typically found in glaciolacustrine environments.

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USCSFORM.FH10 01-09-03

Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll a 1/8 in. (3 mm) thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8 in. (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger
High	pressure. The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

SUMMARY OF TEST RESULTS

	Dilatancy	Toughness	Plasticity	Dry Strength
ML	slow - rapid	low	none - low	none - low
MH	none - slow	low - medium	low - medium	low - medium
CL	none - slow	medium	medium	medium - high
CH	none	high	high	high - very high

Laminate 1B

K:\techproc\sop\Level 2 (Draft SOPs)\SOP2001\[Manual Tests for Fines Criteria.xls]Summary

APPENDIX E
ESTIMATING SOIL COMPONENT PERCENTAGES

E.1 Estimating Percentages by Weight or Volume

ASTM D2488 goes to great lengths to differentiate between soil component percentages determined by estimates of particle volume, particle weight, and particle dry weight. The dry weight of soil is calculated by dividing the weight of the moist soil by (1+ soil water content percentage expressed as a decimal). ASTM D2488 requires the percentage of cobbles and boulders to be estimated on the basis of volume percentage. Of the fraction of the soil smaller than 3 in., the gravel, sand, and fines percentages are to be determined based on an estimate of dry weight.

However, in almost all cases, this method overly complicates estimating the percentage of different soil components. Haley & Aldrich considers that estimates of percentage based on particle volume and particle weight (either wet or dry) are equivalent. Averages of specific gravity of soil range between 2.65 and 2.75. Percentages of particle fractions based on volume should, in general, vary by no more than 5 percent from percentages based on weight, well within the error limits of the procedure.

There are two cases where weight and volume measurements will not agree.

The first case is for organic soils. The organic portions of the soil will have a low specific gravity ($\leq$ 1.0) and even large quantities will weigh little, while the mineral portions will have a much higher specific gravity and higher weights for smaller volumes. Care and experience are needed to estimate percentages in an organic soil.

The other case where weight and volume measurements will not agree is in areas were soils contain an unusual amount of particles made up of minerals with a very low or very high specific gravity, such as mica and vermiculite, or pyrite and magnetite. Again, care and experience are required to accurately estimate soil fraction percentages.

Listed below are methods for estimating particle size fractions suggested by ASTM D2488. A review of these ASTM methods will show that the recommended methods are based not on dry weight of soil but on volume estimates.

E.2 Preparation for Identification

- The soil identification portion of this procedure is based on the portion of the soil sample that will pass a 3 in. (75 mm) sieve. The larger than 3 in. (75 mm) particles must be removed—manually for a loose sample, or mentally for an intact sample—before classifying the soil.

- Estimate and note the percentage of cobbles and the percentage of boulders.

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E.3 Estimating Soil Component Percentages

Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage of the gravel, sand, and fines. Considerable experience is required to estimate the percentages of particle-size components. Frequent comparisons with laboratory particle-size analyses should be made. The percentages shall be estimated to the closest 5 percent. The percentages of gravel, sand, and fines must add up to 100 percent. If one of the components is present but not in sufficient quantity to be considered 5 percent of the smaller than 3 in. (75 mm) portion, indicate its presence by the term *trac*e, for example, trace of fines. A trace is not to be considered in the total of 100 percent for the components.

E.4 Suggested Procedures for Estimating the Percentages of Gravel, Sand, and Fines in a Soil Sample (ASTM D2488-93)

E.4.1 Jar Method

The relative percentage of coarse and fine grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 seconds. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

E.4.2 Visual Method

Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then do the same with the sand size particles and the fines. Then mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (A.4.3).

E.4.3 Wash Test (for relative percentages of sand and fines)

Select and moisten enough minus No. 4 sieve size material to form a 1 in. (25 mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

E.4.4 Other

While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

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APPENDIX F
ASTM D2488 CONSISTENCY TEST

ASTM D2488 determines consistency using a scale based on a thumb penetration test. This scale is presented here in the event that a client on a project requires it, but it is not used in H&A's general practice. If this scale is used, it should be noted on the exploration log.

For intact fine grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria listed below. This observation is inappropriate for soils with significant amounts of gravel.

ASTM Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

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APPENDIX G
DESCRIPTIVE TERMINOLOGY FOR SOIL STRUCTURE

Describe the structure of intact soils in accordance with the criteria in listed below.

Criteria for Describing Soil Structure

Description	Criteria
Bed	A sedimentary layer bounded by depositional surfaces.
Blocky	A characteristic in which cohesive soil can be broken down into small angular lumps which resist further breakdown.
Bonded	Attached or adhering.
Fissured	Broken along definite planes of fracture.
Foliated	Planar arrangement of textural or structural features.
Frequent	More than one per foot of thickness.
Homogeneous	Same color and appearance throughout.
Interbedded	Alternating soil layers of different composition.
Laminae	A very thin cohesive layer.
Layer	A general term for material lying essentially parallel to the surfaces against which it was formed.
Lens	A lenticular deposit, larger than a pocket.
Occasional	One or less per foot of thickness.
Parting	A very thin granular layer.
Pocket	Small erratic deposits less than 12 in. in thickness.
Seam	A thin layer separating two distinctive layers of different composition or greater magnitude.
Stratified	Alternating layers of varying material or color.
Stratum	A stratigraphic unit.
Varve	A cyclic sedimentary couplet consisting of a coarser and a finer layer representing the variation in depositional energy resulting from the annual freeze-thaw cycle typically found in glaciolacustrine environments.

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APPENDIX H
ADDITIONAL DESCRIPTIVE INFORMATION

The following additional descriptive information should be included as a part of a soil description.

H.1. Angularity of the Plus No. 10 Fraction

If requested by the Project Manager, the angularity of the plus No. 10 fraction (gravel and coarse sand) can be described as angular, subangular, subrounded, or rounded in accordance with the criteria in listed below and Fig. H-1. A range of angularity may be stated, such as: subrounded to rounded.

Criteria for Describing Angularity of Coarse Grained Particles (see Fig. H-1)

Description	Criteria
Angular	Particles have sharp edges and relatively planar sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly planar sides but have well rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

H.2. Particle Shape of the Plus No. 4 Fraction

Describe the shape of the Plus No. 4 fraction (gravel, cobbles and boulders) as flat, elongated, or flat and elongated if they meet the criteria listed below using the dimensions shown in Figure G-2. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

Criteria for Describing Particle Shape (see Fig. G-2)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness ratio > 3
Elongated	Particles with length/width ratio > 3
Flat and elongated	Particles meet criteria for both flat and elongated

H.3. Hardness of the Plus No. 10 Fraction

Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer; for example, gravel size particles fracture with considerable hammer blow, some gravel size particles crumble with hammer blow. “Hard” means particles do not crack, fracture, or crumble under a hammer blow.

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H.4 Reaction with Hydrochloric Acid

Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria listed below. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

Criteria for Describing the Reaction with HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

H.5. Additional Comments

Additional comments shall be noted. These may include:

In-situ bonding, particularly of glacial till soils: poor, moderate, well bonded.
Presence of obstructions: specifically for man-made features (not boulders).
"Running" or "Flowing" sands: typically below the water table, these are a good liquefaction indicator.
Validity of apparent density: Blow counts increased by gravel content.
Water loss: Very important in coring bedrock, but appropriate for soils.
Presence of roots or root holes.
Caving of trench or hole.

H.6. Additional Descriptive Information for Intact Samples - Cementation

Describe the cementation of intact coarse grained soils as weak, moderate, or strong as follows:

Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

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FIGURE H-1 Typical Angularity of Grains

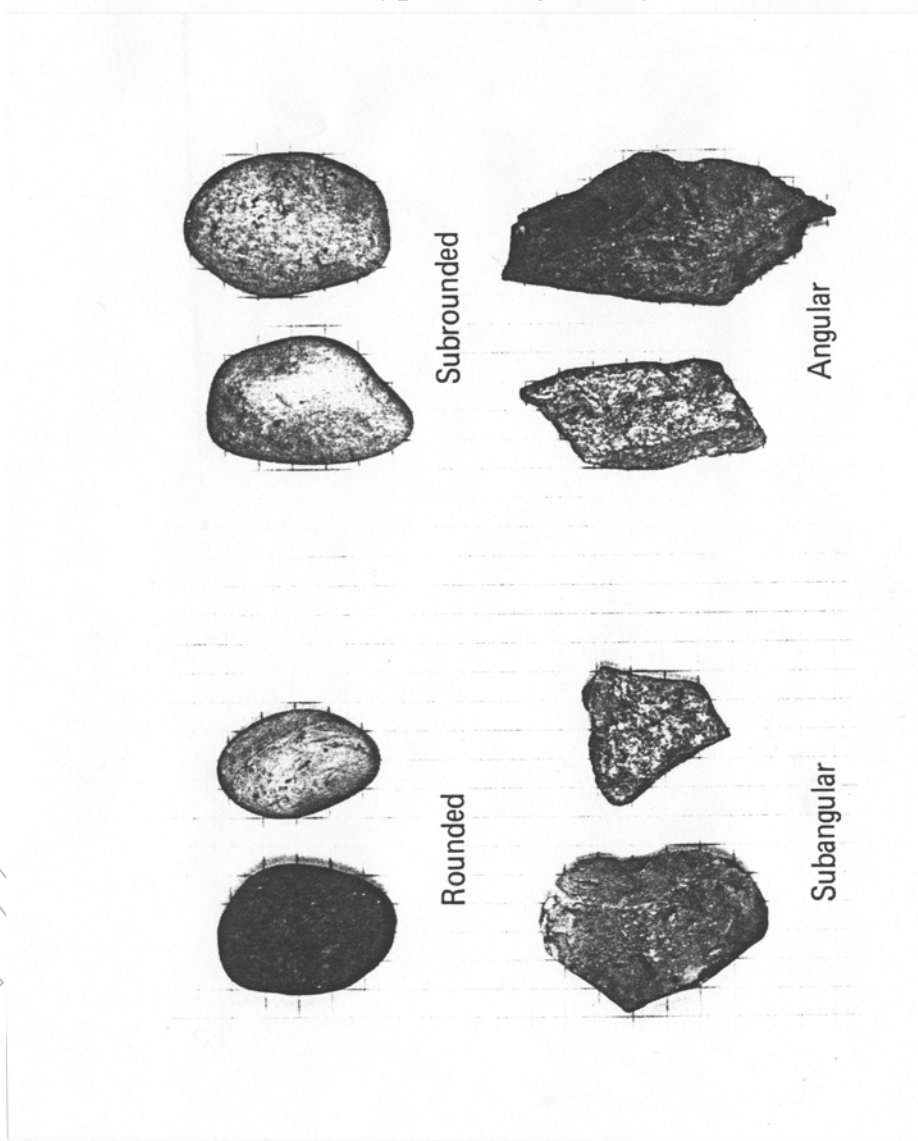
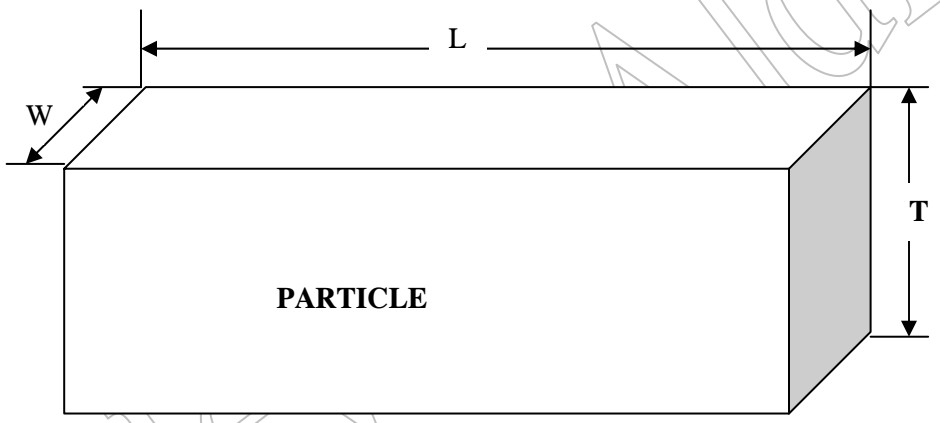


FIGURE H-2 Criteria for Particle Shape

Particle Shape

W = Width
T = Thickness
L = Length



FLAT: W/T > 3

ELONGATED: L/W > 3

FLAT and ELONGATED:
meets both criteria

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APPENDIX I
FILLS

I.1 Fill Description

Fills can be separated into two distinct categories:

Fills consisting largely of natural components can usually be described in a similar manner to natural soils including a particle breakdown and designation of a USCS Group Symbol and Group Name.

Fills containing man-made or deleterious materials that constitute a significant percentage of the total volume cannot be described in the typical fashion, nor can a USCS Group Symbol and Group Name be designated. In fills with substantial quantities of man-made or deleterious materials the typical particle breakdown is not conducted and constituent estimates are simply listed in order of abundance.

The distinction between the two categories of fills defined above will in some cases be unclear. Determination of which method to use to describe fills is a field decision based on the character of the fills observed and the method which best conveys an accurate representation of the materials present.

Many artificial and deleterious materials have very low densities but may constitute a significant percentage of the total fill volume. In such cases constituent estimates may be based upon volume, not weight, and noted in the description.

Since artificial materials will commonly occur across a wide range of sizes it may be impractical to distinguish them separately from the total as oversize components. To do so may necessitate including them twice within a single description. In such cases the descriptive terms for size ranges may be included with the constituent estimates or noted in the description.

The presence of certain materials in extremely small quantities can be of critical importance in fills. Constituents comprising less than 5% of the total are qualified and preceded by the term “trace” and included in the particle breakdown, constituent estimates, or noted in the description.

I.2 Fill Types

Characterizing fill types based upon similarities can aid in estimating quantities for reuse, treatment or disposal. Caution must be exercised that any characterization of fill type is an accurate reflection of site conditions and that field assumptions do not conflict with the site history or project objectives. Consultation with the Project Manager to develop criteria upon which to base fill types is required. The following terminology is used by Haley & Aldrich to denote size ranges of artificial materials within fills:

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Descriptive Fill Term	Size Range	Size Range Metric	Comparative Soil Term
Specks	< No. 200 Sieve	< 0.075 mm	Silt
Particles	No. 200 to 3/16 in.	0.075 mm to 5 mm	Sand
Fragment	3/16 in. to 3 in.	5 mm to 75 mm	Gravel
Pieces	3 in. to 12 in.	75 mm to 305 mm	Cobbles
Blocks	> 12 in.	> 305 mm	Boulders

Definitions of Common Fill Constituents and Terminology

Term	Definition
Anthropogenic	Impacted by man.
Artificial	Man-made.
Ash	Inorganic residue of combusted matter.
Ceramic	Nonmetallic mineral products manufactured by firing.
Charcoal	Carbonaceous residue of incompletely combusted organic material.
Cinder	General term for ash, charcoal, clinkers or slag.
Clinker	Solid waste formed in furnaces consisting of fused stony matter.
Concrete	Solid mass of cemented aggregate.
Deleterious	Having a harmful or obscure affect.
Loam	Soil containing roughly equal proportions of sand, silt and clay. Usually organic matter is present in varying amounts.
Slag	Clinker or solid waste from iron blast furnaces.
Tar	Viscous, dark, bituminous liquid.

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Examples of Fills consisting largely of natural materials:

Example1 (Test Boring Description)

10% medium sand, 25% fine sand, 15% roots
50% fines: slow dilatancy, low toughness, nonplastic, low dry strength

Very loose, dark brown sandy ORGANIC SOIL (OL/OH)
15% roots estimated by volume, trace brick particles.
mps 2.0 mm.
No structure, musty odor, dry.
LOAM FILL

Example 2 (Stockpile Description)

100% coarse gravel

Purple, poorly graded GRAVEL (GP)
No oversize, mps 2.5 in.
Consists entirely of very hard angular processed rhyolite.
No odor, dry.
CRUSHED STONE

Example 3 (Test Pit Description)

15% coarse gravel, 10% fine gravel, 15% coarse sand, 15% medium sand, 25% fine sand
5% brick fragments to particles, 5% concrete or mortar, 10% fines: rapid dilatancy

Brown to dark brown, well graded SAND with silt and gravel (SW-SM)
10% cobbles, 5% boulders, mps 18 in.

Concrete present generally as moderately hard fragments with several elongated blocks observed measuring less than 30 in. maximum dimension. Minor decomposed concrete or mortar observed on brick fragments. Possible asbestos observed in trace quantities as friable white fibers in occasional extremely small pockets. Slight decomposed gasoline odor associated with observed water. Wet at 8.5 ft.
FILL

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Examples of Fills consisting of significant percentages of artificial or deleterious matter:

Example 1 (Test Pit Description)

55% concrete, 20% brick, 10% medium to fine sand, 5% coarse to fine gravel
5% fines, 5% cobbles, mps 6 in., trace metal strips and wire, wood fragments, plastic pieces, glass shards, cinder particles to specks, unidentified apparent precipitate present as blue specks.

Soil components light brown. Consists entirely of apparent demolition debris. Concrete present primarily as hard flat or irregular blocks measuring 18 in. to 36 in. maximum dimension with most containing #6 to #8 rebar. Brick present generally as fragments. No odor, moist.
RUBBLE FILL

Example 2 (Test Pit Description)

20% ash, 20% charcoal particles, 15% clinker fragments to particles, 15% fines, 10% sand
5% paper, 5% glass pieces to fragments, 5% ceramic fragments, 5% wood blocks to fragments, trace metal pieces to fragments, asphalt pieces to fragments.

Color variable changing to dark gray below 4.0 ft. Fines not identified. Consists primarily of partially burned and decomposed household refuse by identifiable remains of newspaper, bottles and cans. Distinct fuel odor and oil saturation below observed water at 4.5 ft. Free product noted 5 mm thick on water surface after a 15 minute stabilization period.
REFUSE FILL

Example 3 (Test Pit Description)

50% cinder fragments to particles, 20% fines, 15% fly ash, 10% gravel, 5% sand, trace possible ceramic particles, glass shards.

Dark gray to black discoloration. Fines not identified. Heavily contaminated with coal tar in discrete zones or pockets of apparently higher permeability ranging in thickness from 6 in. to 24 in. at depths of 2.0 ft. to 7.5 ft. Strong naphthalene odor. Moist below 9.0 ft.
MGP WASTE

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Example 4 (Test Boring Description)

15% coarse sand, 15% clinker fragments to particles, 15% fine gravel, 15% ash, 10% ceramic particles, 10% unidentified fines, 10% wood, 5% fine sand, 5% glass particles, trace brick particles.

Medium dense. Soil components brown to dark brown with dark gray discoloration. Coarse sand and gravel generally hard and angular. Possible organics present partly as fines. Wood present as lumber fragments and possible roots. Strong septic odor and faint possible solvent odor detected. Sample moisture probably due to drilling fluid.
FILL

Suggested Nomenclature

Suggested nomenclature for possible fill types are included below.

Primarily Natural Components	Significant Percentage Artificial or Deleterious
Loam Fill	Bark Mulch
Cohesive Fill	Stump Fill
Hydraulic Fill	Rubble Fill
Granular Fill	Refuse Fill
Structural Fill	Urban Fill
Till Fill	Medical Waste
Crushed Stone	Tannery Waste
Ballast	MGP Waste
Mine Tailings	Cinder Fill
Rock Fill	Miscellaneous Fill
Rip Rap	Grits and Screenings

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OPERATING PROCEDURE: OP2005

TEST BORINGS, SAMPLING, STANDARD PENETRATION TESTING (SPT) AND BOREHOLE ABANDONMENT

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP2005

TEST BORINGS, SAMPLING, STANDARD PENETRATION TESTING (SPT) AND BOREHOLE ABANDONMENT

1. PURPOSE

Exploratory test borings are important sources of subsurface information relating to geologic conditions and site suitability fundamental to environmental site assessment and geotechnical design. The following procedure is an introduction to test boring equipment and techniques and an outline of field staff responsibilities while monitoring test boring methods utilized by Haley & Aldrich Inc.

2. EQUIPMENT & SUPPLIES

2.1 Standard Required Equipment

Required		Additional as Required	
1.	Proposal (signed by Client)	20.	First Aid Kit
2.	Site Plan	21.	Cellular Phone
3.	Contract with Subcontractor (pay items)	22.	Health & Safety Plan
4.	Exploration Criteria/Specifications	23.	Respirator & Tyvek Suit
5.	Field Book	24.	Laptop Computer
6.	Clipboard	25.	Camera & Film
7.	Logs & Forms	26.	Field Procedures
8.	Office Supplies (pencils & markers)	27.	Maps and References
9.	Engineer's Scale	28.	Sample Bags & Jars with Labels
10.	6 ft. Ruler	29.	Survey Stakes/Paint/Flagging
11.	100 ft. Measuring Tape	30.	Shovel
12.	Hand Lens, magnifying	31.	Geologist's Pick
13.	Pocket Knife	32.	Flashlight
14.	Hard Hat	33.	Roadway Box Key/Socket Wrench
15.	Safety Glasses	34.	Water Level Indicator
16.	Sound Dampeners	35.	Hand Level
17.	Steel Toe Boots	36.	Brunton Compass
18.	Protective Gloves	37.	Pocket Penetrometer
19.	Rain Gear	38.	Torvane

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2.2 Required Environmental Equipment

Test borings programs conducted for environmental purposes will require specific equipment for personal protection, air quality monitoring, headspace screening, sampling, testing and decontamination. A comprehensive list of equipment and materials must be developed for each project in coordination with the Project Manager (PM) and the Health & Safety (H&S) Coordinator prior to the start of the field program.

2.3 Additional Equipment, Specialized Instrumentation, Materials & Company Vehicles

Company-wide, Haley & Aldrich maintains an array of equipment, vehicles and specialized instrumentation for a broad variety of uses in addition to the selected equipment listed above. Additional equipment, vehicles and materials may be rented or purchased as needed with the approval of the project manager. Project equipment needs should be addressed proactively so that interoffice allocation can take place. It is recommended that the field staff familiarize themselves with the use, function and availability of all types of equipment standard to the industry.

2.4 Billing Equipment & Materials

Equipment and materials are billed to the project as used on a daily or per item basis. Completion of equipment usage and billing forms and submission of original receipts for items purchased or rented is required in order to charge the project for reimbursement.

3. PROCEDURE

3.1 Preliminary Preparations

Prior to the beginning of a test boring program attendance at a project briefing is required for the purpose of reviewing the proposal, site and utility plans, contract documents and drawings, applicable regulations, test boring sampling, testing and termination criteria, site contacts, phone numbers of team members, and other related documents and references. In addition, certain projects will require the field staff to attend a Health & Safety briefing due to specific occupational safety concerns.

A file folder for the field activities should be created and maintained such that all relevant documents and log forms likely to be useful for the completion of field activities by others are readily available in the event of personnel changes.

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3.2 Duties and Responsibilities

3.2.1 General

The principal reason for providing Haley & Aldrich field representation during test boring drilling is to assure that the field data being collected is accurate and of the type necessary to properly evaluate the site geologic conditions for the subsequent engineering analyses and environmental assessment.

3.2.2 Supervision of Test Boring Programs

Test boring activities regularly include routine soil sampling and testing, rock coring and groundwater observation well installations in addition to more specialized instrumentation or testing. Modifications to the test boring criteria are often made during the execution of the drilling program as the accumulated geologic data and test results are interpreted. For this reason it is essential that all records are maintained current and complete and that uncertainties are identified for resolution as they occur. Supervising field staff are responsible for maintaining communication with the project manager and logistical coordination of the field effort within the workscope and budgetary limits.

3.2.3 Verification of Test Boring Methods and Services

It is the responsibility of H&A field staff to verify that test borings and related instrumentation installation, subsurface sampling and testing methods are in conformance with applicable approved standards and specifications and to document conditions and results. It is the responsibility of the H&A field staff to verify that proper equipment and techniques are employed and to obtain measurements and make observations independently. H&A field staff are responsible for complete field logging of groundwater, soil and bedrock conditions, the maintenance of accurate test records and field exploration location sketches, and ensuring proper instrumentation installation, sample preservation and handling. In addition, payment for services rendered on behalf of the client is commonly handled with H&A providing a daily field report (DFR) including an accurate breakdown of the work activities and itemized costs on a daily basis.

Test boring subcontractor pay items and method of payment are defined in their contract. Typically test borings are paid for in one of the following ways:

- Footage and item basis with stand-by time charged for testing or delays incurred due to no fault of the subcontractor.

- Day rate basis with overtime premium, materials and footage charged for selected items.

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3.2.4 Right of Access

Prior to site entry, Haley & Aldrich staff members must ensure that permission has been gained from the property owner to access the property.

3.2.5 Layout and Utility Clearance

Prior to the start of drilling all proposed locations must be laid out and have utility clearance from all appropriate agencies and utility owners. H&A requires the test boring subcontractor to obtain the utility clearance within the terms of the contract or services agreement. H&A field staff should verify with the contractor that the utilities have been cleared and obtain the clearance number prior to the start of drilling.

3.2.6 Site Safety and Subcontractor Briefing

At the start of fieldwork H&A field staff should coordinate a site briefing and review the schedule and workscope with all subcontractors involved with the project. This briefing should include a review of the following:

- Drilling, sampling and testing equipment and materials,
- Observation well materials
- Test boring lay out, criteria and priority,
- Testing and sampling specifics
- Pay items
- Site conditions
- Environmental concerns, known or suspected contamination
- H&S information
- Decontamination requirements
- Site restoration and waste disposal issues
- A site walkover and utility check

While it is the subcontractor's responsibility to obtain the utility clearance, it is important to verify with the driller that the utilities have been cleared at each proposed test boring location. The field representative should pay attention to the available utility plans, manholes or catch basin grates, and gate or roadway boxes. Distance to overhead utilities must be verified by the driller as well.

3.2.7 Test Boring Monitoring

3.2.7.1 General

Haley & Aldrich field staff must become familiar with the technical details and suitability of all exploration equipment and methods. Test borings are the most common method employed by H&A to obtain high quality data on subsurface conditions. In addition, a variety of special testing techniques and instrumentation installations may supplement the test boring program.

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Specific H&A procedures must be consulted for additional details relating to special testing, sampling and instrumentation installation. See Appendix B: Related Haley & Aldrich Procedures.

3.2.7.2 Test Boring Equipment and Use

Test boring equipment selection is based upon a detailed understanding of the capabilities of the equipment with regard to the anticipated site geological conditions. In addition, the particular project needs may necessitate or preclude certain methods and equipment.

The following table presents several of the common drill rig platform (mounting frame) types and general uses.

Type	Use
Tripod	Shallow soil displacement borings, chop and wash methods remote or difficult access
Skid	General purpose soil and rock drilling difficult access, steep terrain
ATV	General purpose soil and rock drilling off road upland areas, remote access
Track	General purpose soil and rock drilling off road lowland and upland areas, remote or difficult access
Truck	General purpose soil and rock drilling street access

In addition, drill rigs of all types are frequently barge-mounted for drilling over water. Conventional drill rig engines are primarily diesel or gasoline fueled however propane and electric models are available for use in enclosed spaces. There are many drill rig manufacturers and a great deal of variation in drill rig size and capability. Engine horsepower, rig reaction weight, pump capacity and tooling are some of the factors relating to rotary drill rig performance. The suitability of a particular drill rig to a given function is as much a measure of rig design as of the drilling method employed.

Conventional drill rigs vary in size and design but there are several components that are common to most drilling equipment. All rotary drill rigs have engines and transmissions that deliver torque to a drill head. The drill head rotates the drill spindle and controls vertical advance through a feed and bit weight control mechanism. A water or mud pump may be mounted to the drill rig chassis or included separately for wash borings. Drill rigs all have derricks (masts) and hoists for lifting drilling tools. An introduction to the most common drilling tools and equipment is given in the following topic discussions.

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3.2.7.3 Test Boring Methods

Test borings methods generally fall into one of the following categories:

- Displacement Borings
- Pneumatic Borings
- Sonic Borings
- Wash Borings
- Auger Borings

Displacement borings are a simple form of uncased boring conducted by directly advancing sampling tools into unstabilized soils. These probe-type borings may be suitable for reconnaissance mapping or preliminary environmental site investigations. Several methods of displacement borings are discussed in OP2030 Direct Push Borings (Percussion-Vibratory Driven Probes).

Pneumatic or air-rotary borings are typically larger diameter borings conducted for the installation of groundwater production or test wells. Techniques similar to wash and mud-rotary methods are used in combination with air-rotary tooling and pneumatic evacuation.

Sonic borings utilize high frequency resonant sound to advance specialized core barrel and casing equipment for continuous soil and soft rock recovery. This technology is particularly applicable for environmental site investigations and especially where dense, non-aqueous phase liquids (DNAPL) are present or if vertical groundwater profiling is desired.

Wash borings (by cased or mud rotary methods) and auger borings are the principle means of conducting test borings for most geotechnical and many environmental investigations. The details of these test boring methods and preference of use are discussed below.

A. *Cased Borings* - Cased borings are the primary means of borehole stabilization for obtaining high quality overburden samples, conducting in-situ testing, installing instrumentation devices and penetrating to bedrock prior to rock coring. Casing (pipe) is typically advanced to depth and washed out prior to sampling or coring. Cased borings are preferred in geotechnical analysis because the chance of soil disturbance is minimized when the various techniques are properly executed. Telescoping casing allows the test boring to be continued through boulders or other obstructions and facilitates drilling through cohesionless soils encountered at depth. Cased borings also provide a degree of flexibility over the other test boring methods. Permeability testing and most in-situ soil tests may be conducted at depth in cased borings and mud-forming products may be added or flushed out of the drill slurry as needed. Cased borings are preferred for instrumentation installation because the risk of borehole collapse is minimal and for rock coring due to the effective seating obtained by casing at the bedrock surface.

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Casing - Typical drill casing consists of heavy steel pipe in standard 1, 2, 5 and 10 ft. lengths that may be threaded together with flush joints. The following table presents the common flush joint casings with diameter and volume.

Designation	O.D. (in.)	I.D. (in.)	Volume (gal./ft.)
RW	1.44	1.19	0.058
EW	1.81	1.50	0.092
AW	2.25	1.91	0.148
BW	2.88	2.38	0.230
NW	3.50	3.00	0.367
HW	4.50	4.00	0.652
PW	5.50	5.00	1.022
SW	6.63	6.00	1.472
UW	7.63	7.00	2.000
ZW	8.63	8.00	2.610

Driven Casing and Casing Hammers - Casing (drop) hammers usually weigh approximately 300 lbs. and are commonly classified as either a doughnut hammer or as a safety hammer. Safety hammers consist of an external weight with an internal anvil and stem (guide rod) assembly that attaches to the flush coupling (plug) threaded into the top of the uppermost section of casing (pipe). An internal stop on the stem prevents the external weight from coming off the stem during lifting and driving. Doughnut hammers are simply heavy steel weights that have a central hole. These are used in conjunction with a separate drive head anvil and stem assembly that threads to the flush coupling at the top of the casing. Casing hammers are lifted by means of a winch or cathead hoist approximately 24 to 30 inches and allowed to free fall. The energy delivered though the drive head forces the casing into the underlying soils. Driven casing is fitted with a hard-shoe (drive-shoe) on the lead (bottom) section. It is not uncommon to record the number of blows delivered per foot of casing advance as a rough measure of relative penetrative resistance.

Spun Casing - Spun casing is advanced into underlying materials by means of the drill head. Connection is made through a drill rod threaded into the flush plug at the top of the casing. Drill fluid or water is pumped down the casing to cool the bit and flush away the drill solids. Spun casing is fitted with a spin-shoe (econoshoe) in the lead section.

Casing Clean Out and Drill Bits - Whether the casing is driven or spun, the accumulated material within the casing must be completely removed prior to sampling. This is accomplished by means of simultaneously drilling and flushing with fluid

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pressure forced through a drill bit connected by the drill rods to the water swivel at the drill head. The use of a positive displacement pump is essential for providing sufficient lift to remove heavier solids from the annulus. Properly sized drill bits are typically 1/8 to 1/4 inch smaller than the casing being drilled through. Several common drill bit types are used to clean out casing and into the underlying soils depending upon soil conditions as indicated below.

Type	Description and Use
Tricone Rollerbits	Also referred to as tricone roller rock bits or simply rollerbits, these are general purpose, axially discharging drill bits used for casing clean out and borehole advance through overburden and bedrock. Button bits are similar except with carbide tips on the individual teeth of the rollers for drilling through obstructions and hard bedrock.
Drag Bits	Also referred to as wing bits, fish tail bits and mud bugs, these are axially discharging drill bits used for the same purposes as the rollerbits and particularly in cohesive soils where rollerbits may become clogged. Commonly adapted with defectors at the fluid ports that direct the discharge upward to minimize disturbance of underlying sensitive soils.
Chopping Bits	Also referred to chisel bits, these are axially discharging drill bits used for casing clean out, chop and wash techniques and fragmenting lost core in boreholes.

Drilling Fluid, Recirculation and Pumps - Drilling fluid (slurry or mud) may consist primarily of water and soil particles suspended during drilling or may include a number of natural and artificial products developed to coat and stabilize the borehole and aid in lifting coarser materials. Slurry is discussed in more detail in the section dealing with mud-rotary drilling below.

Drilling fluid must be continuously pumped down the borehole during drilling in order to cool the drill bit and flush away the drill solids. For practical reasons it is necessary to collect the returning fluid at the borehole collar into a settling tank (wash or mud tub) by means of a wash “T” or gasket if a through-hull tub is used. Baffles or dams are used to prevent solids from reaching the suction hose strainer at the return sump.

Positive displacement pumps are the standard used in the test boring drilling industry. The progressive cavity (Moyno) pump is widely used in test borings which may involve heavier drill fluids (greater than 75 pcf), higher volumes (up to 35 gpm) and lower pressures (under 650 psi).

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Verification of Clean Out Prior to Sampling - In is necessary to verify that the casing is completely cleaned out prior to sampling. Small amounts of collapsed or settled material at the bottom of the borehole can interfere with sample recovery, confuse or obscure the true nature of the in-situ soils and greatly affect the determination of penetrative resistance as outlined in the section on the Standard Penetration Test (SPT) below.

It is customary to drill slightly below the bottom (ahead) of the casing in order to reduce the possibility of sampling soils densified or disturbed by the casing advance. In collapsing conditions or non-cohesive soils this usually means less than 6 inches below the casing shoe. Careful observation of the drill action and wash return during drilling is an important step toward understanding the conditions within the borehole.

After flushing is complete, the pump is stopped and a reference mark is placed on the drill rods while the drill bit is at the bottom of the borehole. The rods and bit are then lifted into the casing for a short period and any suspended materials are allowed to settle to the bottom of the borehole. The rods and bit are then lowered without restarting the pump or head rotation. The reference mark placed on the drill rods should be in exactly the same position as when the flushing was first completed. If the reference mark is higher, flushing is repeated until clean out is verified. If the reference mark is lower an attempt should be made to determine whether jetting, sinking or some other effect has occurred.

Standard and Continuous Sampling in Overburden - Typically in overburden (soil) borings, once casing clean out has been verified the rods are lifted (pulled), the drill bit is removed and a soil sampler is fixed to the drill string (rods). The soil sampler is then lowered to the bottom of the borehole and advanced into the undisturbed soils.

Several different types of soil samplers are routinely used including thick-walled drive samplers that offer a measure of penetrative resistance as well as a remolded (disturbed) sample and thin-walled fixed-piston tube samplers for undisturbed samples in softer cohesive soils. The 1.385 inch I.D. split barrel (splitspoon) sampler is the most common general purpose sampler for overburden sampling of all types of soils and the standard upon which the Standard Penetration Test (SPT) is based. The SPT is discussed in detail in the section relating to Splitspoon Sampling and the Standard Penetration Test below.

Soil samplers are advanced in test borings by driving, direct-push or drilling into overburden soils at the bottom of the borehole a distance equal to or less than the length of the sample chamber. Care is exercised to prevent undue disturbance, consolidation, compaction or densification of soils due to “stroking”, “bobbing” or excessive penetration (over-drive).

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Standard Sampling refers to the common practice of taking soil samples at 5 foot intervals. The sample is taken and the casing is advanced and washed or the boring is drilled to the next interval with the drill bit prior to the next sample attempt. Since the typical penetration for many soil samplers is two feet and that sample recovery commonly is somewhat lower in coarser and denser materials, approximately 20% to 40% of the soil stratigraphy is directly observed in a standard test boring.

Continuous Sampling refers to the practice of taking repeated soil samples beginning at the bottom of the previous sample. Following each sample attempt the casing may be advanced and washed or the boring drilled to the bottom of sampler penetration. Depending upon the project requirements and soil conditions it may be acceptable to "double up" the soil sampling by skipping the clean-out step between every other sample attempt. In such cases an extension rod with an O.D. equal to or less than that of the sampler itself must be used and care must be exercised to observe and record collapsed or resampled material and to note any increase in penetrative resistance due to the additional skin friction.

Careful observation of the drill action, wash return and the penetrative resistance encountered by the drill bit and sampler is necessary to infer strata changes whether standard or continuous sampling is conducted. Stratigraphic contacts encountered in soil samples are treated with particular care. Split samples are discussed in detail in the section relating to Sample Handling and Preservation below.

Casing Advance, Telescoping and Borehole Stabilization - Typical test borings are conducted with the smallest diameter casing that is anticipated will be needed to advance the boring and all required sampling and testing tools to a particular stratum or depth. Test borings are usually begun with the largest diameter practical in order to provide for the possible successive telescoping of smaller diameter casings should it become necessary. Drill slurry may stabilize the borehole to allow for uncased (open-hole) drilling in cohesive soils or in non-collapsing conditions.

Routinely test borings are begun with the largest casing fitted with a hard-shoe or drive-shoe in the lead (bottom) section. Initially the process of driving casing, washing and standard sampling is repeated until an obstruction is encountered or the casing is seated into material such as clay that will maintain itself uncased.

If an obstruction is encountered a roller bit or button bit may be used to advance through the obstruction. In some cases the drill bit may break the obstruction or a wedge (boulder-buster) may be successfully employed and the casing is advanced. In other cases the next smaller diameter casing will be telescoped down the borehole and advanced through the hole in the obstruction created by the drill bit.

In the event that cohesive soils or non-collapsing conditions are encountered standard sampling may be continued while the casing is not advanced further. Below the casing

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the drill bit is used to advance the boring and the open hole is extended until the test boring termination criteria is reached or subsurface conditions require stabilization techniques be used. Borehole stabilization may be maintained by the suspended fine grained particles naturally developed in the drill wash water or through the use of a bentonite or polymer slurry. Drilling slurry is discussed in detail in the section relating to mud rotary drilling below.

Casing fitted with a spin-shoe (econoshoe) may be telescoped down a borehole cased to a shallower depth and advanced by drilling in a similar manner to drill bit advancement. Slurry or water is pumped down the casing to cool the bit and flush away the drill solids. Prior to sampling the drill bit must be lowered down the borehole and the spun casing must be drilled out in the same fashion as with driven casing.

Spun or driven casing must be seated into the top of the bedrock in order to achieve an effective seal prior to rock coring. Techniques and methods relating to the set up and execution of rock coring are described in detail in OP2017 Rock Coring.

B. *Mud Rotary Drilling* - Mud rotary drilling employs many of the tools and techniques used in cased wash borings with the addition of various commercially prepared products into the native drilling fluid. The method typically is conducted in deeper overburden borings and on projects where there are special concerns for in-situ testing and soil sample integrity such as with sensitive or soft soils. Borehole stabilization is enhanced by the use of a bentonite or polymer based drilling slurry under positive hydrostatic conditions.

*Set Up and Maintenance of Positive Hydrostatic Condition*s - Initially a surface casing is installed to provide a stable borehole collar and an outlet to the recirculation tank (mud tub). Mud rotary drilling requires a higher capacity pump to handle the heavier fluids used to remove cuttings from the borehole and a substantial mud tub complete with baffles (dividers or dams) to allow for effective settling of drill solids and separation from the suction screen at the return sump. Special emphasis is placed upon mixing, de-sanding and maintaining the viscosity and specific gravity of the drilling slurry in order to allow for open-hole drilling below the initial casing. A bypass line should be included in the recirculation circuit to allow the pump to remain operational while the rods are disconnected at the drill head.

Mud drilling requires that positive hydrostatic conditions (head) be maintained in the casing at all times to stabilize the borehole. The practice is to direct the drilling fluid from the bypass line to the top of casing to displace any tooling being withdrawn from the borehole. Use of a mud balance is necessary under certain circumstances to ensure that the required specific gravity is being maintained in the drilling fluid.

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Drill Mud - Drill mud is a properly proportioned slurry prepared from products carefully selected based upon their properties and suitability for the intended purpose under the anticipated conditions. Standard mud forming products consist of highly colloidal, gel-forming, thixotropic clays (primarily bentonite), with various chemicals added to control dispersion, thixotropy, viscosity and gel-strength. Additives and special products are used to prevent flocculation under saline conditions or when anhydrite is encountered. Weighting materials such as ground barite, hematite, galena or other heavy minerals are available in products for use in order increase the specific gravity of the drilling fluid. Biodegradable polymers may be used in boreholes intended for groundwater monitoring well installation.

C. *Auger Borings* - Hollow stem augers (HSA) are an effective and fast method for drilling shallow overburden borings in softer soils above the water table without the introduction of water or drill slurry. Hollow stem augers are routinely used on preliminary geotechnical investigations and are preferred for environmental studies where continuous soil sampling and minimization of potential cross contamination due to the use of drilling fluids is desired. Hollow stem augers and solid stem augers are also used for shallow probes.

Hollow stem augers are a form of casing manufactured with external spiral flighting designed for boring advancement by drilling. Typical hollow stem augers used for test borings range from 2.5 in. to 8 in. I.D. in 5 ft. length sections. The lead section is fitted with a cutter head upon which are fixed several hardened, replaceable teeth. Using a center plug fixed to the bottom of the rods, hollow stem augers are typically advanced by drilling to the desired depth whereupon the center plug is withdrawn to allow for soil sampling. Disturbance below the bottom of the augers due to the cutter head may be substantial and heave is common at the bottom of the borehole due to the piston-like effect of the center plug during removal. As such, augers are not favored for test borings on many geotechnical projects where high quality samples and penetration resistance data are required.

D. *Splitspoon Sampling and the Standard Penetration Test (SPT)* - The typical method for obtaining representative samples and a measure of the penetrative resistance of soils in test borings is by means of the Standard Penetration Test (SPT). This is accomplished utilizing a thick wall, ring-lined, split barrel, split barrel, drive sampler (splitspoon) assembly attached to the drill rods and driven into the soils at the bottom of the borehole at regular intervals. Splitspoon samplers are manufactured in various sizes with the most commonly used being 1 3/8 in. I.D. (2 in. O.D.) and having an interior sample chamber length of 24 in. (approximately 36 in. overall length). Once lowered to the sampling depth, the sampler is typically driven 24 in. into the soils with a 140 lb. hammer freely-falling over a 30 in. drop and the number of blows (SPT blowcount) required for each 6 in. of penetration is recorded. The penetrative resistance in blows per foot obtained from the summation of the blowcounts from 6 in. to 18 in. is referred to as the “N-value”. Terminology for density of granular soils and

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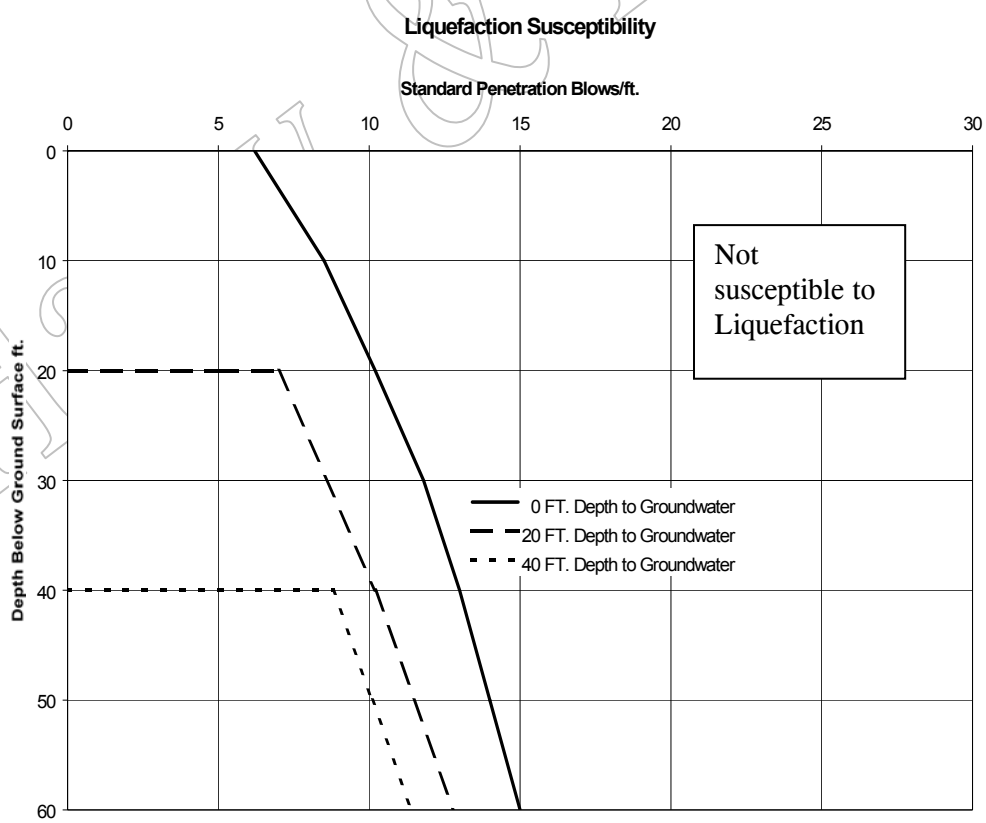
consistency of cohesive soils has been correlated to N-values. When performed properly the SPT provides useful data for determination of the geotechnical behavior of soils and engineering design in addition to representative remolded soil samples for geological interpretation.

E. *Liquefaction* - Loose, saturated, naturally deposited sands will fail when subjected to a sudden shearing stress under certain conditions. Liquefaction susceptible soils have a void ratio greater than the critical void ratio for which a change in volume remains constant during shearing. As such, a sudden decrease in volume may occur during a seismic or blasting event or due to vibrations resulting from railroad traffic or other dynamic activity. Liquefaction potential may be identified during a test boring at a given depth by the relationship between the standard penetrative resistance and the groundwater depth.



Geotechnical protocols for liquefaction susceptible soils supercede all other testing and termination criteria and require that the entire stratum thickness of liquefaction susceptible soils be identified. Practically this means that test borings must be cased

and that positive hydrostatic conditions must be strictly maintained and continuous sampling conducted until it is determined that the zone of liquefaction susceptible soils has been penetrated. The Project Manager should be notified in the event of the unexpected encounter of liquefaction susceptible soils.

F. *Bedrock Coring* - Bedrock coring is conducted in cased borings to obtain accurate detail of the bedrock properties and high quality samples for laboratory testing. A wide variety of rock core equipment is available and rock coring techniques vary greatly depending upon the driller, rock type, equipment and many other factors. Observations related to drilling activities are a primary focus during rock coring including bit weight, feed restriction, head speed, engine speed and gear, pump volume, water loss and fluid return, core rate, drilling halts, jamming, rapid advances, equipment defects, bit type, bit wear, core barrel type, core barrel adjustment. For all projects it is essential that accurate measurements be made when determining the depth of the bedrock surface from drill action or SPT and that detailed observations are recorded concerning the effects noted and the procedures executed upon encountering bedrock. Coring should begin at the minimum depth below the bedrock surface required to seat the casing in order to document the bedrock condition in the uppermost zone where typically fracturing and weathering transitions are greatest. Core hole depth must be verified following each run to account for lost core. When necessary, logging should be broken down into a two step process beginning with sample preservation, labeling and recording of a simple description including recovery and RQD measurements followed by detailed logging of individual features and properties as time and conditions permit. Techniques and methods relating to the set up and execution of rock coring are described in detail in OP2017 Rock Coring. Rock core description and logging is covered in OP2002 Identification and Description of Rock in the Field Using Visual-Manual Methods.

G. *Groundwater Monitoring (Observation) Well Installation* - Groundwater observation or monitoring wells are commonly installed in completed test borings as a means obtaining accurate stabilized groundwater readings essential to engineering design, and hydrogeologic modeling. In addition, permanent observation or monitoring well installations provide for continual long-term sampling for environmental analyses. A wide variety of material types and sizes are employed depending upon the intended use. Typical observation or monitoring wells installations consist of 2 in. I.D. PVC pipe with a machine slotted screen section backfilled with filter sand and sealed with bentonite within the desired stratum or zone. Solid riser sections above the sealed zone may be grouted or backfilled with a variety of materials depending upon the project needs and finished at the ground surface with either a flush-mount roadway box or with a protective casing such as a guard pipe and padlock for undeveloped sites. Careful attention to the placement of screens, backfill and seals is required and accurate depth measurements must be recorded during installation. Initial well development may occur immediately upon completion in order set the sand pack and remove the effects of drill fluids from the formation waters. Rationale and details of

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groundwater observation or monitoring well installation are given in OP2020 Groundwater Monitoring (Observation) Well Installation, Development and Abandonment.

H. *Special Testing, Sampling and Instrumentation* - H&A utilizes a wide variety of well established and state-of-the-art soil, rock and groundwater testing procedures and instrumentation to supplement many subsurface exploration programs. Among the methods and techniques routinely used are fixed-piston tube sampling, vane shear testing, pressuremeter testing, permeability testing, water pressure (packer) testing in rock, inclinometer installation, multiposition borehole extensometers (MPBX) installation and aquifer (pump) testing. Prior to attempting an unfamiliar technique H&A field staff must review all related procedures and consult experienced personnel. Outside support or training that may be necessary to perform new procedures shall be sought with project manager approval. Notes and references obtained should be retained for potential development into procedure format.

I. *Borehole Abandonment* - For many subsurface exploration programs it may be acceptable to simply backfill the borehole upon completion with the accumulated borehole cuttings. Ground surface restoration may be accomplished by removing any drilling residue or debris and installing a concrete surface plug or asphalt cold patch. Often times borehole abandonment procedures may be outlined in the project guidelines in order to accommodate a particular purpose.

Tremie grouting of completed boreholes is commonly specified in order to prevent aquifer cross contamination or the inflow of groundwater into proposed construction excavations. A typical grout mix ratio consists of 7.5 gallons of water to one bag of Portland cement and approximately 5 lbs. of bentonite powder. The grout batch is mixed in a drum and pumped to the bottom of the borehole prior to casing withdrawal until all drill fluid has been purged. The borehole is topped off with grout periodically as the casing is withdrawn to ensure that the grout column is continuous. Grout take is accurately measured and recorded for comparison with the calculated borehole volume in order to verify complete grouting and to identify zones of high transmissivity.

3.2.7.4 Sample Preservation and Shipment

A. *Jar Samples* - Soil samples obtained in test borings are retained in clean, unused, 8 oz. glass jars that have been clearly labeled with the following boring and sample information.

- File Number
- Boring Number
- Sample Number
- Depth
- SPT Blow Counts
- Recovery

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Soil samples should be carefully selected and placed in sample jars as nearly intact and undisturbed as possible. Original soil structure, including bonding, foliation and stratification, are critical to the geological interpretation and understanding the engineering properties of soils. Careless handling of samples may destroy soil structure making any geologic interpretation of soils during the review process impossible. If more than one soil type is obtained in a single sample interval each distinct unit should be preserved in separate jars and identified with the sample drive number distinguished with the sequential letters A, B, C, etc. in addition to the estimated depth range of each material.

Jar samples must be placed in new, unused cardboard boxes identified with the following:

- File Number
- Boring Number
- Sample Number
- Depth

Transportation from the site should be addressed by the project specifications and coordinated with the driller. In some cases the drillers will be required to produce boring bogs and may require the samples for a period of time in order to conduct an independent soil review for their boring report. More commonly samples will be taken at the site by H&A field staff and entered into the sample receiving storage and tracking database.

B. *Tube Samples* - Complete details concerning Thin-Walled Open Drive samples and Undisturbed Fixed-Piston Tube sampling are covered in OP2007 including specifics related to the special care necessary in handling, transportation and storage.

All tube samples must be kept in a vertical position and protected from shock, freezing and desiccation prior to storage in a moisture and temperature controlled environment. The following information must be written on both the top and side of the tube sample:

- File Number
- Boring Number
- Sample Number
- Depth
- Top Indicator
- Recovery

To ensure proper handling during transportation all tube samples must be taken at the site by H&A field staff and entered into the sample receiving storage and tracking database.

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C. *Rock Core* - Complete details concerning rock coring are covered in OP2017 Rock Coring. Rock core description and logging is covered in OP2002 Identification and Description of Rock in the Field Using Visual-Manual Methods.

Rock core is carefully placed in new unused wooden core boxes upon completion of each core run. The core boxes must have been constructed expressly for the purpose of containing rock core with a hinged wooden lid and a hook and eyelet for securing the lid closed. For NX size core the core boxes must be no longer than is necessary to provide a minimum inside length of 5.0 ft. The interior of the core box must be partitioned with wooden dividers such that four 5.0 ft. length runs may accommodated. Interior width of the core boxes must be sized to accept the four cores, the dividers and the use of cardboard liners if split inner core barrels have been specified in the rock core specifications. Blocking must be provided to separate between the top and bottom of consecutive runs.

Placement of the rock core into the core box is conducted with the assistance of the driller to ensure that the structure and orientation is preserved and that undue breakage does not occur. The first core run is placed toward the hinge side of the core box with the top of the run oriented toward the left when viewed such that the hinges and cover are toward the top. (See Figure 1.) Subsequent runs are placed progressively away from the hinged side with the top oriented left. Due to varying length recovery runs may straddle more than one partitioned section. Wooden blocks must be placed between runs identifying top or bottom and run number on either side of the block.

A grid should be drawn on the interior lid of the core box and clearly labeled with the following information:

- File Number
- Project Name
- Boring Number
- Run Number
- Depth
- Recovery
- RQD
- H&A Office Address

It is very important that the exterior top and both ends of the core boxes are be labeled with the following information in order to identify the contents of the box should it be at the bottom of a pallet or stack of core boxes:

- File Number
- Boring Number
- Run Number
- Depth

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3.2.7.5 Environmental Sampling and Monitoring

Environmental sampling combined with discrete field screening of soil and groundwater for contaminants is routinely conducted during the performance of subsurface explorations. In addition, continuous monitoring of air quality within the work zone or at the project site may be required to address H&S concerns. Potential contaminants and sources may be identified in the initial stage of project planning and prior arrangements made for PPE, monitoring, sampling and laboratory analysis.

To minimize the risk of cross-contamination typical environmental sampling programs work from known or suspected clean areas toward areas of known or suspected contamination. Contamination encountered unexpectedly may present serious exposure risks to field personnel without proper PPE and monitoring instrumentation, particularly if the contamination is gross or unidentified. In the event unexpected contamination is encountered, all fieldwork should be suspended and the area evacuated immediately until the Project Manager and the Health & Safety Coordinator can be contacted so that H&S and sampling guidelines can be developed.

A. *Decontamination Procedures and Waste Management* - Standard equipment decontamination practices may include the establishment of a decontamination area such that decontamination fluids are collected and properly stored for disposal. Typically a location within the site is chosen away from sensitive or occupied zones and a decontamination pad is created within a bermed area using polyethylene sheeting. A high-pressure steam cleaner is used to wash all equipment prior to each exploration and wastewater is pumped into adjacent drums. Splitspoons and hand sampling tools are scrubbed between samples at the exploration location using a detergent (water and alconox) solution rinsed with control (tap) water followed by a solvent (methanol) rinse, wiped with a paper towel and rinsed with deionized water before being allowed to air dry. Hexane may be needed for removal of heavy petroleum, grease and coal tar. Decontamination waste, sample residue and drill cuttings are typically drummed, labeled and staged onsite for proper disposal.

B. *Environmental Soil Sampling* - Environmental soil samples obtained for chemical analyses are collected in surface samples and by using many of the techniques employed in typical subsurface explorations with special attention given to decontamination procedures. Preservation, handling and glassware for environmental soil samples varies considerably depending upon several factors including the type and degree of contamination, the analytical method to be conducted, the analytical laboratory being used and the governing regulations. In addition, the depth and location of samples may be strictly controlled under agency guidelines. Documentation of volatile organic compounds (VOC) in the soil through headspace screening is required in order to provide real-time guidance in the field to direct the sampling. Clean 8 oz. jars are partially filled with newly obtained soils and covered with aluminum foil and allowed to stabilized prior to screening with a photoionization detector (PID). The presence of metals in soils is not associated with odors, while coal

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tar, fuels and solvents are often easily distinguished. Particular attention is given to discoloration or odors noted, however it is company policy to avoid fumes and odors at all times. Soils collected from a discrete zone should be homogenized and a representative portion placed into laboratory glassware and labeled. Analytical samples are kept in a cooler with ice blocks and a Chain of Custody form is maintained until transfer to the analytical laboratory. Applicable environmental sampling protocols must be followed as given in OP3000 General Environmental Field Procedures and Protocol, OP3001 Preservation and Shipment of Environmental Samples, OP3002 Headspace Screening Procedure, and OP3006 Procedures for Subsurface Soil Sampling for Chemical Analysis.

C. *Environmental Water Sampling* - Groundwater monitoring (observation) wells must undergo an initial well development following installation and prior to sampling. This is intended optimize well function and to produce formation-derived groundwater samples and valid analytical testing results. Groundwater sampling from existing monitoring wells for chemical analyses involves initially gauging the static groundwater level and the well depth in order to determine the well volume. Waterra® footvalves and tubing, bailers, submersible pumps or peristaltic pumps may be used to purge a minimum of three well volumes in order to minimize well effects. Turbidity, conductivity, resistivity, salinity, dissolved oxygen, temperature and pH are recorded periodically after purging and groundwater parameters must be stable prior to sampling. Low-flow groundwater sampling is required for certain analyses to be valid. In such cases, variable speed submersible pumps are used at extremely slow rates to minimize drawdown and turbidity. Preservation, handling and glassware for environmental water samples varies considerably depending upon several factors including the type and degree of contamination, the analytical method to be conducted, the analytical laboratory being used and the governing regulations. Applicable environmental sampling protocols must be followed as given in OP3000 General Environmental Field Procedures and Protocol, OP3001 Preservation and Shipment of Environmental Samples, OP3002 Headspace Screening Procedure, OP3008 Manual Water Level Measurement Procedure, OP3009 Monitoring Well Development Procedure, OP3010 Groundwater Quality Sampling Procedure, OP3011 Groundwater Sampling Procedure Using Geoprobe System, OP3012 Low Stress/Low Flow Groundwater Sample Collection Procedure, OP3013, and OP3014 NAPL Monitoring and Sampling Procedure.

3.2.7.6 Documentation

Thorough field documentation is the primary responsibility of H&A field staff throughout the execution of any test boring program. Site conditions, soil and rock logging, sample identification and tracking, test and data collection, sketches, photographs, pay item quantities, events, personnel onsite, incidents, discussions and issues must be recorded in the appropriate manner in order to comply with contractual agreements, regulatory requirements and recommended loss prevention practices.

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All field documentation must be duplicated, photocopied or reproduced as soon as is practical in order to guard against loss. In no case should originals be mailed, transferred or removed from the author's custody until a back up copy is made. Copies of field documentation should be delivered to the project manager in a timely fashion as the project warrants. Originals may be issued to word processing or data entry personnel directly upon completion of a short-term test boring program or periodically throughout longer term projects.

Documentation related to environmental sampling, testing and chemical analysis is covered in detail in specific procedures developed for the particular sampling practice, medium, compound and applicable regulations.

A. *Field Book* - The field book is a first line repository of anything observed or discussed onsite without regard to potential use or merit. While the type of information in the field book may in some cases be informal or general in nature, the field book is a legal document and is the property of H&A. Long after a project is completed and the file is closed the field notes may provide an invaluable record of details that may not have been recorded elsewhere. The standard format of the daily field book entry typically includes the following:

- File Number
- Project & Location
- Date
- Weather
- Personnel Onsite
- Equipment Onsite
- Activities
- Observations
- Conversations
- Data
- Issues
- Incidents
- Other items not recorded elsewhere

B. *Photographs* - Photographic documentation of site conditions, activities and incidents are very useful for conveying a visual perspective to what may be difficult to describe otherwise. The fundamentals of good photography must be applied for the images to be of use including:

- Lighting (adequate but not excessive)
- Composition (frame the subject properly)
- Perspective (include a scale)

In addition, subject identification within the photograph by means of a white board and use of the camera date/time feature (if so equipped) renders ease to later captioning as

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does indicating on a site plan during shooting the approximate location and direction of the shot by frame number.

C. *Test Boring Logging* - Test boring logs must be completed entirely and without omission to stand alone as documentation of the subsurface conditions at a given point. See Test Boring Report Form 2700 and Core Boring Report Form 2703. To guard against loss, test boring logs should be proofed in the field and photocopied or faxed as soon as is practical. Protocols for electronic logging using a PDA or laptop computer require periodic file back-up and memory card replacement as well as daily transmission to the H&A server.

Each first page test boring log contains a header to identify the project and boring and to document the boring location and elevation, the contractor equipment and personnel, the H&A representative and the date. Within the body of the overburden log each sampling event is recorded including SPT blow counts (if applicable), sample type and designation, recovery, depth and sample material description. Core boring reports contain fields for core rate and RQD. A column for sketching groundwater monitoring well installation appears in the body of the overburden and rock core logs. In the first page boring log footer the groundwater observations noted during the execution of boring are carefully recorded in relation to the drilling activity in order to assist in the interpretation of the reading. A summary of the drilling and sampling totals also appears in the first page footer. Guidelines for soil and rock logging are detailed in OP2001 Identification & Description of Soils in the Field Using Visual-Manual Methods and OP2002 Identification & Description of Rock in the Field Using Visual-Manual Methods.

In addition to project, boring, groundwater and sample details, numerous field observations should be noted during the conduct of the boring such as casing blow counts, drilling action, the sequence of drilling events, comments on the drilling practices utilized and clues to the subsurface conditions encountered. Notes are typically included within the description field on the boring log, however, the boring log margins may also be used in cases where side bar comments or an additional column for data tied to depth is needed. Commonly the space above the header is used for special callouts relating to boring draft status or disclaimers while the space below the footer is used to record a simple boring location sketch.

D. *Special Testing and Instrumentation* - Forms for documenting specific field sampling procedures, special testing and instrumentation installations are available for use as appropriate. A complete index of forms may be accessed at K:\techproc\sop\Forms\Form Number Index.xls. In addition, new forms may be created as the need arises from a template located within the same directory. Specific guidelines for documenting special testing and instrumentation installations may be given within established procedures. In the absence of documentation standards for a particular procedure the general standards of scope, precision, accuracy and

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completeness from related procedures should be referred to until specific guidelines are developed.

E. *Groundwater Monitoring (Observation) Well Installation* - Geologic conditions within a borehole will generally influence well design, function and purpose. For this reason the relationship between the stratigraphy and the placement of well materials must be recorded during the installation process on Form 2010 Groundwater Observation Well Installation Report. As previously indicated, a separate well sketch is also included on the Test Boring and Rock Coring Reports for quick reference relative to the stratigraphy. These sketches are not intended to replace or be submitted in lieu of the more detailed installation report. In order to ensure that wells perform properly and that subsequent samples or readings are valid and interpretable all borehole depths and well materials must be carefully measured during placement. Improper placement of seals, screens or filter materials may result in false or confusing chemical analyses or misinterpretation of phreatic surfaces and hydraulic gradients.

A separate Form 2170 Groundwater Monitoring Report is used to maintain a record of successive groundwater readings in monitoring (observation) wells.

F. *Borehole Sealing* - A Borehole Sealing Report is used to detail the grout mixture, volumes, equipment and placement techniques employed when a record is required to document the sealing of terminated or abandoned boreholes upon completion and to verify the effectiveness of the effort.

A separate Form 2016 Well Decommissioning Report is used to document groundwater monitoring (observation) well abandonment.

G. *Daily Field Report* - Test boring activities, production and pay items are recorded on a daily basis on Form 2500 Test Borings Daily Report. This record must be continually updated as events unfold in order to maintain a current status of the exploration program production and budget. Blank fields on the form are intended for additional project-specific pay items. An accurate break down of pay items and drilling activities must be maintained for each boring with a detailed record of the daily progress included on the reverse side of the form.

A separate Form 2005 Subcontractor Quantities for Test Borings is used to summarize the pay item totals as defined in the contract or agreement with the subcontractor. This form must be reviewed and signed by the subcontractor's representative upon completion of the subsurface exploration program. Carbon copies are distributed to the subcontractor's representative, the project file and the Field Services Manager.

H. *As-Drilled Test Boring Locations and Elevations* - An accurate sketch showing the actual (as-drilled) location of completed test borings must accompany the test boring logs. In addition, the estimated elevation of the ground surface or boring reference

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elevation must also be included. Locations and elevations should be measured with 0.1 ft. precision from known or permanent features whenever possible, however establishment of a temporary baseline and/or series of benchmarks may be necessary in open or virgin sites. An existing site plan with location and elevation data may have been provided for use during the test boring program. In such cases the scale and elevation datum should be verified and the accuracy of the horizontal and vertical data should be checked. All borings and field references should be painted or staked in the field as appropriate for future field survey.

I. *Geologic Profiles* - Simple geologic columns of individual borings (stick diagrams) may be quickly sketched in the field and combined as needed in order to produce a two-dimensional stratigraphic cross-section or geologic profile. This exercise may be useful in the development and support of the geologic interpretation of the stratigraphy and in the identification of data gaps during the test boring program.

3.2.7.7 Final Review and Summary

The final complete package of field data must include copies of all first draft field logs, test reports, raw data, field book entries, photographs, plans and sketches, daily field reports, subcontractor quantities and any additional notes. All field data must be reviewed for discrepancies, errors and omissions as well as for the identification of factors of critical importance and any areas of uncertainty.

In addition to the field generated data, all relevant research, correspondence, contracts, drawings, test boring rationale and criteria, sample receiving forms, environmental regulations and health and safety protocols assembled for the test boring program should be included in the final package to the file.

A summary of the test boring program should be prepared including the subcontractor and equipment, dates of execution, the total number of borings, sampling types and quantities, drilling depths and total footages of overburden and bedrock.

The site features and geologic conditions should be described incorporating the synthesized data from the test boring program and all available published literature or research. The geologic summary should present the reasoning behind the interpretation and any supporting documentation including geologic profiles developed for the site and related references.

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FIGURES

Figure 1 Core Box Labeling.pdf

Figure 2 Suburface Exploration Key.pdf

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OUTSIDE END

FILE NO. 18675-309

HA 317 C7-C8 152.5-162.0 BOE
HA 318 C1-C3 77.0-90.3

OUTSIDE TOP

FILE NO. 18675-309

BORING	RUN	DEPTH
HA 317	C7-C8	152.5-162.0 BOE
HA 318	C1-C3	77.0-90.3

OUTSIDE END

FILE NO. 18675-309

HA 317 C7-C8 152.5-162.0 BOE
HA 318 C1-C3 77.0-90.3

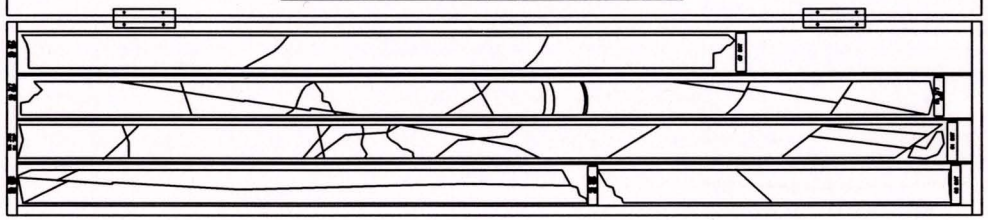
INSIDE COVER

X = drill breaks
/ = joints
* = RQD qualifier

BORING	RUN	DEPTH	REC in.	REC %	RQD in.	RQD %
HA 317	C7	152.5-157.5	48	80	48	80
	C8	157.5-162.0	54	100	31	57
HA 318	C1	77.0-72.0	58	97	19	32
	C2	82.0-87.0	33	55	30	50
	C3	87.0-90.3	24	71	24	71

FILE NO. 18675-309
BATTERYMARCH TOWERS
BOSTON MA

Haley & Aldrich, Inc.
465 Medford St.
Suite 2200
Boston, MA 02129-1400



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UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

CORE BOX LABELING

FIGURE 1

DESCRIPTION AND CLASSIFICATION OF SUBSURFACE MATERIALS

SOIL

Soil description on logs of subsurface explorations are based on Standard Penetration Test results, visual-manual examination of exposed soil and soil samples, and the results of laboratory tests on selected samples. The criteria, descriptive terms and definitions are as follows:

DENSITY OR CONSISTENCY

Density of Cohesionless Soils	Penetration Resistance (Blows per ft.)	Consistency of Cohesive Soils	Penetration Resistance (Blows per ft.)
Very Loose	0–4	Very Soft	0–2
Loose	5–10	Soft	3–4
Medium	11–30	Medium	5–8
Dense	31–50	Stiff	9–15
Very Dense	over 50	Very Stiff	16–30
		Hard	over 30

PENETRATION RESISTANCE

Standard Penetration Test (ASTM D-1586) – Number of blows required to drive a standard 2 in. O.D. split spoon sampler 1 ft. with a 140 lb. weight falling freely through 30 in.

COLOR: Basic colors and combinations: black, brown, gray, yellow-brown, etc.

SUPPLEMENTAL SOIL TERMINOLOGY:

Lamina	– 0 to 1/16 in. thick (cohesive)
Parting	– 0 to 1/16 in. thick (granular)
Seam	– 1/16 to 1/2 in. thick
Layer	– 1/2 to 12 in. thick
Stratum	– > 12 in. thick
Pocket	– Small, erratic deposit less than 12 in. size
Lens	– Lenticular deposit larger than a pocket
Occasional	– One or less per 12 in. of thickness
Frequent	– More than one per 12 in. of thickness
Interbedded	– Alternating soil layers of differing composition
Varved	– Alternating thin seams of silt and clay
Mottled	– Variation of color

GEOLOGIC INTERPRETATION

Deposit type – GLACIAL TILL, ALLUVIUM, FILL.....

The natural soils are identified by criteria of Unified Soil Classification System (USCS), with appropriate group symbol in parenthesis for each soil description. Fill materials may not be classified by USCS criteria.

U.S. Standard Series Seive — Clear Square Sieve Openings

12"	3"	3/4"	4	10	40	200
305 mm	76 mm	19 mm	4.75 mm	2.00 mm	0.43 mm	0.074 mm

Boulders	Cobbles	Gravel		Sand			Silts and Clays
		Coarse	Fine	Coarse	Medium	Fine	

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			Group Symbol	Graphic Symbol	TYPICAL NAMES
Coarse grained soils: more than half is larger than number 200 sieve	Gravels More than half of coarse fraction is larger than number 4 sieve	Gravels with little or no fines	GW		Well graded gravels, gravel-sand mixtures
			GP		Poorly graded gravels, gravel-sand mixtures
		Gravels with over 12% fines	GM		Silty gravels, poorly graded gravel-sand-silt mixtures
			GC		Clayey gravels, poorly graded gravel-sand-clay mixtures
	Sands More than half of coarse fraction is smaller than number 4 sieve	Sands with little or no fines	SW		Well graded sands, gravelly sands
			SP		Poorly graded sands, gravelly sands
		Sands with over 12% fines	SM		Silty sands, poorly graded sand-silt mixtures
			SC		Clayey sands, poorly graded sand-clay mixtures
Fined-grained soils: more than half smaller than number 200 sieve	Silts and Clays Liquid limit 50% or less		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL		Organic clays and organic silty clays of low plasticity
	Silts and Clays Liquid limit greater than 50%		MH		Inorganic silty, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			CH		Inorganic clays of high plasticity, fat clays
			OH		Organic clays of medium to high plasticity, organic silts
Highly organic soils			PT		Peat and other highly organic soils

ROCK

Rock descriptions noted on logs of subsurface explorations are based on visual-manual examination of exposed rock outcrops and core samples. The criteria, descriptive terms and definitions used are as follows:

FIELD HARDNESS: A measure of resistance to scratching.

Very Hard	Cannot be scratched with a knife point or sharp pick.
Hard	Can be scratched with a knife point or sharp pick, only with difficulty.
Moderately Hard	Can be readily scratched with a knife point or pick.
Medium Hard	Can be grooved or gouged 1/16 in. deep with firm pressure on a knife point or sharp pick.
Soft	Can be grooved or gouged easily with a knife point or pick.
Very Soft	Can be carved with a knife and excavated with a pick point.

WEATHERING: The action of organic and inorganic and chemical and physical processes resulting in alteration of color, texture and composition.

Weathering:

Fresh-FR	No visible sign of alteration, except perhaps slight discoloration on major discontinuity surfaces.
Slight-SL	Discoloration of rock material and discontinuity surfaces.
Moderate-MOD	Less than half the rock material decomposed to soil. Some fresh rock; continuous "framework".
High-HIGH	More than half the rock material decomposed and/or disintegrated to soil. Fresh rock corestones or discontinuous "framework".
Complete-COMP	All rock material disintegrated to soil, but mass still intact.
Residual Soil	All rock material converted to soil. Volume of mass changed, but material has not been significantly transported.

COLOR: Basic colors and combinations: gray, light gray, brown, red-brown.

TEXTURE: Size, shape and arrangements of constituents.

Aphanitic	Individual grains invisible.
Fine-grained	Grains barely visible to the unaided eye, up to 1/16 in. diameter.
Medium-grained	Grains between 1/16 and 3/16 in. diameter
Coarse-grained	Grains between 3/16 and 1/4 in. diameter
Very Coarse-grained	Grains larger than 1/4 in.

LITHOLOGY: Rock classification and modifiers; accepted formation names.

DISCONTINUITIES:

Type	Definition
Joint	A natural fracture along which no displacement has occurred. May occur in parallel groups called sets.
Shear	A natural fracture along which displacement has occurred. Surface may be slickensided or striated.
Fault	A natural fracture along which displacement has occurred. Usually lined with gouge and slickensides.
Shear or Fault Zone	Zone of fractured rock and gouge bordering the displacement plane.

ORIENTATION/ATTITUDE:

Term	Angle (degrees)
Horizontal	0–5
Low Angle	6–35
Moderately Dipping	36–55
High Angle	56–85
Vertical	86–100

SPACING:

Term	Inches
Extremely Close	< 3/4
Very Close	3/4 – 2-1/2
Close	2-1/2 – 8
Moderate	8 – 24
Wide	24 – 80
Very Wide	80 – 20 ft.
Extremely Wide	> 20 ft.

PERSISTENCE/CONTINUITY:

Term	Feet
Very Low	0–3
Low	3–10
Medium	10–40
High	40–80
Very High	> 80

SOLUTION CAVITIES:

Term	Size
Pit	Barely visible – 1/4 in.
Vug	1/4 – 2 in.
Cavity	2 in. – 2 ft.
Cave	> 2 ft.

APERTURE/GAP:

Term	Inches
Very Tight	< 0.004
Tight	0.004 – 0.01
Partly Open	0.01 – 0.02
Open	0.02 – 0.1
Moderately Wide	0.1–0.4
Wide	> 0.4
Very Wide	0.4 – 4.0
Extremely Wide	4.0 – 40
Cavernous	> 40

BEDDING:

Term	Inches	Term
Very thin	< 2.5	Thick
Thin	2.5–8	Very thick
Medium	9–24	Massive

GENERAL NOTES

1. Logs of subsurface explorations depict soil, rock and groundwater conditions only at the locations specified on the dates indicated. Subsurface conditions may vary at other locations and at other times.
2. Water levels noted on the logs were measured at the times and under the conditions indicated. During test borings, these water levels could have been affected by the introduction of water into the borehole, extraction of tools on other procedures and thus may not reflect actual groundwater level at the test boring location. Groundwater level fluctuations may also occur as a result of variations in precipitation, temperature, season, tides, adjacent construction activities and pumping of water supply wells and construction dewatering systems.

UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

SUBSURFACE EXPLORATION KEY

NOT TO SCALE

FILENAME: EXPLKEY.DWG

APPENDIX A
REFERENCES

A.1 References

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D420-98, “Standard Guide to Site Characterization for Engineering Design and Construction Purposes.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D653-01, “ Standard Terminology Relating to Soil, Rock and Contained Fluids.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D1452-80, “Standard Practice for Soil Investigation and Sampling by Auger Borings.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6151-97, “Standard Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D1586-99, “Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6066-96, “Standard Practice for Determining the Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D3550-01, “Standard Test Method for Thick Wall, Ring-Lined, Split Barrel Drive Sampling of Soils.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D1587-00, “Standard Practice for Thin-Walled Tube Sampling of Soils.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D2113-99, “Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation.”
- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D2488-93, “Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).”

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- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D5092-90, “Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D5434-97, “Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock.”

- American Society of Civil Engineers, 1976," Subsurface Investigations for Design and Construction of Foundations of Buildings", Manual and Report on Engineering Practice, No. 56, 61 p.

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D5088-90, “Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6286-98, “Standard Guide for Selection of Drilling Methods for Environmental Site Characterization.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D6169-98, “Standard Guide for Selection of Soil and Rock Sampling Devices for Environmental Investigations.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5781-95, “Standard Guide for the Use of Dual-Wall Reverse Circulation Drilling for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5782-95, “Standard Guide for the Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5783-95, “Standard Guide for the Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices.”

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5784-95, “Standard Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices.”

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- Acker II, W.L., 1974, "Basic Procedures for Soil Sampling and Core Drilling", Acker Drill Co., Inc., Scranton, PA, 246 p.
- Hvorslev, M.J., 1949, "Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes", U.S. Army Engineer Waterways Experiment Station, Vicksburg, MI, 251 p.
- Mohr, H.A., 1948, "Exploration of Soil Conditions and Sampling Operations", Bulletin No. 376, Soil Mechanics Series No. 21, Graduate School of Engineering, Harvard University, Cambridge, MA, 79 p.
- U.S. Department of the Army, 1972, "Soil Sampling", Engineer Manual EM1110-2-1907, U.S. Government Printing Office, Washington, D.C., various pages.
- U.S. Department of the Navy, 1986, "Design Manual, Soil Mechanics, Foundations and Earth Structures", NAVFAC DM7.1, U.S. Government Printing Office, Washington, D.C., pp. 7.1-49 through 7.1-110

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APPENDIX B
RELATED HALEY AND ALDRICH PROCEDURES

- OP1002 Drilling Safety
- OP1003 Utility Clearance
- OP2000 Monitoring Field Explorations
- OP2001 Identification & Description of Soils in the Field Using Visual-Manual Methods
- OP2002 Identification & Description of Rock in the Field Using Visual-Manual Methods
- OP2007 Undisturbed, Fixed-Piston Tube Sampling
- OP2010 Borehole Field Permeability Testing
- OP2011 Field Vane Shear Testing
- OP2017 Rock Coring
- OP2020 Groundwater Monitoring (Observation) Well Installation, Development and Abandonment
- OP3000 General Environmental Field Procedures and Protocol
- OP3001 Preservation and Shipment of Environmental Samples
- OP3002 Headspace Screening Procedure
- OP3006 Procedures for Subsurface Soil Sampling for Chemical Analysis

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APPENDIX C
FORMS AND EXAMPLES

C.1 Forms

All Haley & Aldrich field forms are maintained on the server at K:\techproc\sop\Forms. The following is a list of current forms available specifically for use in test boring exploration programs.

- Form 2004 Subcontractor Quantities for Test Borings
- Form 2007 Observation Well Installation Form
- Form 2003 Test Boring Daily Report
- Form 2001 Test Boring Report– USCS
- Form 2002 Core Boring Report

C.2 Examples

The following example of a completed test boring log is intended to provide guidance in soil and bedrock logging. This example is presented as a general reference of the standard test boring logging conventions practiced by H&A.

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SUBCONTRACTOR QUANTITIES FOR TEST BORINGS

Form #2005

Project	**File No.**
Location	**Date**
Contractor	**Project Manager**

No.	Description	Unit	Quantity
I	**MOBILIZATION/DEMOBILIZATION**		
1	Mob/Demob of Truck rig w/ OSHA-trained crew within 100 miles of contractor yard*	ea	
2	Mob/Demob of Skid rig with OSHA-trained crew within 100 miles of contractor yard*	ea	
3	Mob/Demob of Bomb/ATV rig with OSHA-trained crew within 100 miles of contractor yard*	ea	
4	Mob/Demob of Geoprobe rig w/ OSHA-trained crew within 100 miles of contractor yard*	ea	
II	**DRILLING - FOOTAGE RATE**		
5	3-in. dia. cased overburden drilling (0-100 ft.) with no sampling	lf	
6	cased overburden drilling (0-100 ft.) with standard 5-ft. interval sampling	lf	
7	cased overburden drilling (0-100 ft.) continuous sampling	lf	
8	4-in. dia. cased overburden drilling (0-100 ft.) with no sampling	lf	
9	cased overburden drilling (0-100 ft.) with standard 5-ft. interval sampling	lf	
10	cased overburden drilling (0-100 ft.) continuous sampling	lf	
11	4-¼ in. dia. hollow stem auger overburden drilling (0-100 ft.) with no sampling	lf	
12	hollow stem auger overburden drilling (0-100 ft.) w/ standard 5-ft. interval sampling	lf	
13	hollow stem auger overburden drilling (0-100 ft.) continuous sampling	lf	
14	NX rock core via double-tube core barrel (includes bit wear)	lf	
15	HX rock core via double-tube core barrel (includes bit wear)	lf	
16	Extra split spoon samples (for footage rates only)	ea	
17	3-in. undisturbed tube samples	ea	
18	Standby Time for rig and crew/Decon of equipment	hr	
III	**DRILLING - DAY RATE**		
19	Truck mounted drill rig with OSHA-trained crew	day	
20	Truck mounted drill rig with OSHA-trained crew (overtime rate)	hr	
21	Skid rig with OSHA-trained crew	day	
22	Skid rig with OSHA-trained crew (overtime rate)	hr	
23	Bomb/ATV drill rig with OSHA-trained crew	day	
24	Bomb/ATV drill rig with OSHA-trained crew (overtime rate)	hr	
25	Geoprobe rig with OSHA-trained crew	day	
26	Geoprobe rig with OSHA-trained crew (overtime rate)	hr	
27	NX rock core via double-tube core barrel (includes bit wear for day rates)	lf	
28	HX rock core via double-tube core barrel (includes bit wear for day rates)	lf	
29	Geoprobe push samples liners (4' section)	ea	
IV	**OBSERVATION WELL INSTALLATION**		
30	1-in. dia. piezometer (Sch 40 PVC) installed	lf	
31	2-in. dia. well (Sch 40 PVC) installed (slotted and screened)	lf	
32	4-in. dia. well (Sch 40 PVC) installed (slotted and screened)	lf	
33	Standard 4-in. dia. roadway box	ea	
34	Standard 8-in. dia. roadway box	ea	
35	5 ft. protective guard pipe with padlock (4-in. diameter)	ea	
V	**ADDITIONAL ITEMS**		
36	Utility Clearance	ea	
37	Permits - Determined on a job to job basis	ls	
38	State Police Detail	hr	
39	Laborer	hr	
40	Chain Saw	day	
41	Steam Cleaner with Generator	day	
42	Upgrade Crew Personnel Protection to Level "C"	hr	
43	55 gal. soil/water drum	ea	
44	Borehole Grouting (4-in. diameter)	lf	
45	Sand	bag	
46	Concrete	bag	
47	Cold Patch	bag	
48			
49			
VI	**COMMENTS**		

Driller Signature _____ **Date** _____

Geologist Signature _____ **Date** _____

WHITE - FIELD SERVICE MANAGER **CANARY** - CONTRACTOR **PINK** - PROJECT MANAGER

Form 2004

HALEY & ALDRICH

OBSERVATION WELL INSTALLATION REPORT

Well No.

Boring No.

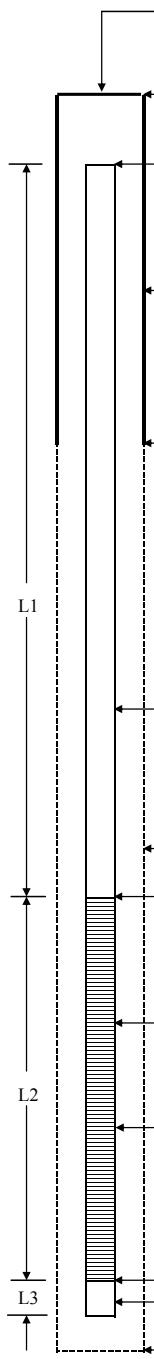
PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE INSTALLED	
DRILLER		WATER LEVEL	

Ground El. _____ ft
El. Datum _____

Location _____

☐ Guard Pipe
☐ Roadway Box

SOIL/ROCK CONDITIONS	BOREHOLE BACKFILL



Type of protective cover/lock _____

Height/Depth of top of guard pipe/roadway box above/below ground surface _____ ft

Height/Depth of top of riser pipe above/below ground surface _____ ft

Type of protective casing: _____
- Length _____ ft
- Inside Diameter _____ in

Depth of bottom of guard pipe/roadway box _____ ft

Type of Seals	Top of Seal (ft)	Thickness (ft)
Concrete		
Bentonite Seal		

Type of riser pipe: _____
- Inside diameter of riser pipe _____ in
- Type of backfill around riser _____

Diameter of borehole _____ in

Depth to top of well screen _____ ft

Type of screen _____
- Screen gauge or size of openings _____ in
- Diameter of screen _____ in

Type of backfill around screen _____

Depth of bottom of well screen _____ ft

Bottom of Silt trap _____ ft

Depth of bottom of borehole _____ ft

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

_____ ft + _____ ft + _____ ft = _____ ft
Riser Pay Length (L1) + Length of screen (L2) + Length of silt trap (L3) = Pay length

COMMENTS: _____

Form 2007

HALEY & ALDRICH

TEST BORING DAILY REPORT

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MANAGER	
CLIENT		FIELD REPRESENTATIVE	
CONTRACTOR		DATE	
DRILLER		DFR NUMBER	
TYPE OF RIG(S)		NUMBER OF RIGS	

SUBCONTRACTOR'S TIME ON SITE

Rig Type	Arrived	Left Site	Lunch/Other	Downtime	Standby Time	Total Billable Hours

HALEY & ALDRICH'S TIME ON SITE

Field Representive(s)	Arrived	Left Site	Lunch/Other	Paperwork	Travel Time	Total Billable Hours

WORK PRODUCTION TO DATE

Boring No.	Type of Drilling	Over Burden (lf)	Rock Core (lf)	Obstr. Drilling	Total Footage (lf)	Tubes Samples	Extra Split Spoons*	Misc. (Wells etc.)	Materials Encountered (Type and Depth Range)

STATUS OF TOTAL PRODUCTION

Unsampled	Continuos	Standard	Inside Dia.	Boring Footages: Item	Today	Total to Date	Estimate	% Complete	Additional pay Items	Today	Total to Date
									Observation Wells I.D. (ft)		
									Roadway Boxes (ea)		
				H.S.A.					Guard Pipes (ea)		
				Casing					Steamer and Generator (day)		
				Casing					Grout (lf)		
				Casing					Undisturbed Tube Samples (ea)		
				Uncased					Extra Split Spoons (ea)*		
				Rock Core					55 Gallon Drums (ea)		
				Geoprobe					Police Details (hr)		
									Stand by Time (hr)		

No. of Borings Completed	Remaining	Rig-Days to Date	Remaining

SYMBOLS

B 2-1/2 inch Standard	**A** 4 inch Hollow Stem Auger	**Z** Probes of Soundings	**T** 2 inch Shelby Tube	**Y** Pressure Test
N 3 inch Standard	**W** Water Borings	**C** Rock Core	**V** Vane Shear Test	**S** Observation Well
H 4 inch Standard	**X** Continuous Sampling	**U** 3 inch Piston Tube	**P** Permeability Test	

* Extra split spoon samples are for footage contracts only.

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TEST BORING DAILY REPORT

REMARKS

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TEST BORING REPORT

BORING NO.

Page of

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel		Sand			% Fines	Field Test			
								% Coarse	% Fine	% Coarse	% Medium	% Fine		Dilatancy	Toughness	Plasticity	Strength

NOTES:

FILE NO.

BORING NO.

*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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TEST BORING REPORT

BORING NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft.	Datum	Boring Location

Item	Casing	Sampler	Core Barrel
Type			
Inside Diameter (in.)			
Hammer Weight (lb.)			
Hammer Fall (in.)			

Rig Make & Model: ☐ Truck ☐ Tripod ☐ Cat-Head; ☐ ATV ☐ Geoprobe ☐ Winch; ☐ Track ☐ Air Track ☐ Roller Bit; ☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☐ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☐ None

Casing Advance: Type Method Depth

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary

Overburden (Linear ft.) _____
Rock Cored (Linear ft.) _____
Number of Samples _____

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

*NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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CORE BORING REPORT

BORING NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft	Datum	Boring Location

Item	Casing	Sampler	Core Barrel
Type			
Inside Diameter (in)			
Hammer Weight (lb)			
Hammer Fall (in)			

Rig Make & Model

- ☐ Truck
- ☐ ATV
- ☐ Track
- ☐ Skid
- ☐ Tripod
- ☐ Geoprobe
- ☐ Air Track
- ☐ _____
- ☐ Cat-Head
- ☐ Winch
- ☐ Roller Bit
- ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut

Casing: ☐ Driven ☐ Spun

Drill Mud: ☐ Bentonite ☐ Polymer ☐ None

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Sample ID

- O Open End Rod
- T Thin Wall Tube
- U Undisturbed Sample
- S Split Spoon Sample
- G Geoprobe

Well Diagram

- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (Linear ft.)	
Rock Cored (Linear ft.)	
Number of Samples	

BORING NO.

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CORE BORING REPORT

BORING NO.

Page of

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks

FILE NO. BORING NO.

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TEST BORING REPORT

BORING NO. **B 7 (OW)**

Page 1 of 2

PROJECT	Greenspace Development	H&A FILE NO.	27921-000
LOCATION	18 Riverside Road, Boston Massachusetts	PROJECT MGR.	S.R. Kraemer
CLIENT	Ecologic Investments	FIELD REP.	C.S. Osgood
CONTRACTOR	Guild Drilling Co., Inc.	DATE STARTED	13-Feb-01
DRILLER	Charlie O'Donnel	DATE FINISHED	14-Feb-01

Elevation 23.3 ft. | Datum Boston City | Boring Location See sketch on reverse of form.

Item	Casing	Sampler	Core Barrel
Type	NW	S	NV2
Inside Diameter (in.)	3	1.385	2
Hammer Weight (lb.)	300	140	
Hammer Fall (in.)	24	30	

Rig Make & Model: CME 75

☑ Truck ☐ Tripod ☑ Cat-Head
☐ ATV ☐ Geoprobe ☐ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☑ Safety ☐ Doughnut ☐ Automatic

Drilling Mud: ☑ Bentonite ☐ Polymer ☐ None

Casing Advance: Type Method Depth — NW Driven 29.0 ft.

Drilling Notes: Flushed slurry prior to coring.

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (density/consistency, color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Toughness	Plasticity	Strength
0																
	10		0.0		SP-SM	Medium dense brown poorly graded SAND with silt (SP-SM),				20	70	10				
	12	S1				mps 2 mm, distinctly stratified, fines partially organic, no odor, dry.										
	15	21"														
	20		2.0	2.0		-ALLUVIUM-										
	11		2.0		SP	Dense brown poorly graded SAND (SP), mps 25 mm, no odor, dry.	5	5	20	30	35	5				
	15	S2														
	16	10"														
	17		4.0			-ALLUVIUM-										
				4.5												
5																
	WOR		5.0			Very soft, dark brown ORGANIC SOILS with sand (OL/OH), trace					25	75	S	M	H	VH
	WOR	S3			OL/OH	seashell fragments and particles, soil mps 0.5 mm, strong										
	WOH	24"				organic odor, moist.										
	WOH		7.0			-ORGANIC DEPOSIT-										
				8.0												
						Note: Drilling fluid returning medium to fine sand from 8.0 ft. to										
						10.0 ft. Drilling fluid color change to yellow red at 8.5 ft.										
						-PROBABLE MARINE DEPOSIT-										
				10.0												
10																
	3		10.0		CH	Stiff yellow brown fat CLAY (CH), trace fine sand, mps 0.5 mm,						100	N	M	H	
	6	S4				apparently laminated with frequent fine sand partings and										
	6	22"				possible organic fibers, no odor, moist.										
	6		12.0			-MARINE DEPOSIT-										
				13.5												
						Note: Drill action indicates gravel below 13.5 ft.										
15																
	12		15.0		CL	Very stiff yellow brown to gray sandy lean CLAY with gravel (CL),	5	10	10	10	15	50	S	M	M	
	14	S5				mps 35 mm, distinct disrupted laminae in discrete zones, coarse										
	15	17"				fraction consists of well rounded igneous and igneous and										
	19		17.0			metamorphic lithologies, no odor, moist.										
						-GLACIOMARINE DEPOSIT-										
				18.0												
						Note: Drill action and total loss of drilling fluid indicates gravel										
				19.0		and cobbles from 18.0 ft. to 19.0 ft.										
						Very dense gray silty SAND (SM) , mps 15 mm, very well bonded,										
20																
	21	S6	20.0		SM	coarse fraction consists partly of platy argillite fragments, no odor, moist.		10	15	20	30	25	R			
	25	10"	21.0	21.0		-GLACIAL TILL-										
	33	S6A	21.0		ML	Very dense gray SILT (ML), mps <0.1 mm, no structure, no odor,						100	R		N	
	34	7"	22.0			dry.										
						-RESIDUAL SOIL-										
						Note: Drilling advanced smoothly from 21.0 ft. to 25.0 ft.										
				25.0		PROBABLE TOP OF DECOMPOSED BEDROCK 25.0 FT.										
25																
	53		25.0			Very dense gray highly to completely weathered ARGILLITE.										
	28	S7				Possible extremely thin relect bedding subparallel to strong										
	39	5"				low angle foliation. Sample is generally well bonded and consists										
	35		27.0			of very soft angular fragments and particles which are easily										
						crushed with finger pressure.										
						-DECOMPOSED BEDROCK-										
						Note: Drill action indicates stratum change at 28.5 ft.										
				28.5		TOP OF "SOUND" BEDROCK 28.5 FT.										
						SEE SHEET 2 FOR CORE BORING REPORT										
30																

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
13-Feb-01	15:30	0	29.0	29.0	2.0
14-Feb-01	7:00	15.5	29.0	29.0	6.2
14-Feb-01	15:00	1.0	39.5	39.5	10.4

Sample ID

O Open End Rod
T Thin Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Well Diagram

Riser Pipe, Screen, Filter Sand, Cuttings, Grout, Concrete, Bentonite Seal

Summary

Overburden (Linear ft.)	29.5
Rock Cored (Linear ft.)	10.0
Number of Samples	S7 C2

BORING NO. **B 7 (OW)**

Field Tests Dilatancy: R - Rapid S - Slow N - None Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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Version Date: January 2003

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CORE BORING REPORT

BORING NO. **B 7 (OW)**

Depth (ft)	Drilling Rate (min/ft)	Core No. Depth (ft)	Recovery RQD (in)	Recovery RQD (%)	Weath-ering	Well Diagram	Stratum Change (ft)	Visual Classification and Remarks
								SEE SHEET 1 TEST BORING REPORT FOR OVERBURDEN DETAILS.
							21.0	TOP OF RESIDUAL SOIL 21.0 FT.
								Note: Advanced borehole with rollerbit and splitspoon and drove NW casing through residual soil from 21.0 ft. to 25.0 ft.
					Residual Soil			-RESIDUAL SOIL-
							25.0	TOP OF DECOMPOSED BEDROCK 25.0 FT.
25					High to Complete			Note: Advanced borehole with rollerbit and splitspoon and drove NW casing through decomposed bedrock from 25.0 ft. to 28.5 ft.
								-DECOMPOSED BEDROCK-
							28.5	TOP OF "SOUND" BEDROCK 28.5 FT.
								Note: Seated NW casing at 29.0 ft. Advanced borehole with rollerbit to 29.5 ft. without sampling prior to coring.
		29.5	56"		Slight			C1: Moderately hard, slightly weathered, gray, aphanitic ARGILLITE. Bedding extremely thin to
30								very thin, generally low angle (30-35 degrees). Foliation low angle, commonly subparallel to
	6							bedding. Cleavage well developed along bedding/foliation planes where coincident.
					Mod.			Cleavage joints very close to close 29.5 -31.0 ft. and close below 32.5 ft. smooth-planar,
	3	C1			High			slightly oxidized, occasionally calcite-infilled, tight. High angle to vertical joints moderately
					Mod.			close, rough-undulatory, pyritized or highly oxidized and decomposed with silt infilling, open.
	5							Soft, moderately to highly weathered zone 31.0-32.5 ft. associated with extremely close,
					Slight			moderately dipping, slickensided-planar shears intersecting bedding plane and high angle features.
	6							Note: Partial water loss below 31.0 ft.
		34.5	24"	40%				Note: Lost core assumed 31.7-32.0 ft.
35	6	34.5	60"	100%				C2: Similar to bottom of run C1 except cleavage joints close to moderately close. High angle to
								vertical joints absent. Occasional thin zone of extremely close, extremely thin, moderately
	7							dipping to high angle (50-60 degrees) calcite stringers. Occasional calcite-healed low angle
								joint.
	6	C2			Slight			-CAMBRIDGE FORMATION-
	6						38.0	
								Lithology change at 38.0 ft. to hard, slightly weathered, dark gray to black, fine grained to
	8							aphanitic DIABASE. Single high angle joint at 38.7 ft. rough-stepped, slightly oxidized, tight.
		39.5	54"	90%				
40	8							BOTTOM OF EXPLORATION 39.5 FT.

FILE NO.	27921-000	BORING NO.	B 7 (OW)

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APPENDIX D
CHECKLISTS

D.1 Test Boring Checklist

D.1.1 Preliminary Preparation

A. Project Briefing
B. Field Project File and Document Assembly
- Proposal
- Contract Documents
- Locus, Site & Utility Plans
- Exploration Criteria
- Subcontractor Agreement
- Site and Project Contacts
- Forms
  - DFR
  - Subcontractor Quantities
  - Test Boring Report
  - Core Boring Report
  - Observation Well Installation Form
  - Special Testing / Instrumentation Forms
  - COC
  - Equipment Usage and Billing Form
  - Sample Receiving Form

C. H&S Briefing
- H&S Plan

D. Equipment Request and Assembly

D.1.2 Onsite Duties

- Site Walkover and Subcontractor Utility and Safety Briefing
- Exploration Program Review
  - Exploration Layout
  - Site Conditions Sketch
  - Preliminary Surficial Geologic Map
- Exploration Monitoring
  - Equipment Inventory
  - Exploration Layout & Utility Check
  - Field Logging Soil & Rock
  - Water Level Measurements
  - Production and Budget Quantities
  - Sample Handling & Transport
  - Instrumentation & Testing Records
  - As-Built Sketches & Exploration Locations

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D.1.3 Follow Up & Summary

- Proof Logs and Test Reports
- Finalize DFR and Subcontractor Quantities
- Sample Receiving and Disposition
- Equipment Return and Billing
- Exploration Program Summary
- Final Site & Geological Conditions Summary
- Geologic Profiles

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OPERATING PROCEDURE: OP2021

PIEZOMETERS

LEVEL II (Interim)

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE 2021

PIEZOMETERS

1. PURPOSE

Piezometers are small-diameter observation wells, installed for the purpose of obtaining water level measurements in a discrete subsurface formation. The hydraulic information obtained from multiple piezometers allows evaluation of horizontal and vertical components of groundwater flow (flow direction and gradients). Piezometers can be installed as individual, stand-alone wells, arranged in a lateral array to monitor one hydrogeologic unit, zone, or formation. They can also be installed as clusters or nests in one location.

2. EQUIPMENT & SUPPLIES

The following materials are required for piezometer installation:

- Personal protective equipment (as required by the Health and Safety Plan)
- Cleaning equipment (as required in the Equipment Cleaning Procedures)
- Weighted Tape
- Water Level Indicator
- Sturdy nylon cable
- Pocket knife
- Digital Camera
- Field notebook
- Haley & Aldrich Form 2008- Piezometer Installation Report
- 1 inch or 1.25 inch inside diameter (ID) schedule 40 PVC with 0.010 inch factory-slotted screen. Screen segments should be a maximum 5 feet long. Screen and riser should be O-ring-sealed, flush-threaded, PVC. No glues or solvents should be used to assemble the well casing.
- Well sand pack and seal materials.
  - U.S. Silica #1, #0, or #00N, or equivalent
  - Bentonite powder, chips, or pellets
  - Protective cover (roadway box, secured guard pipe)

3. PROCEDURE

Decontaminate equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

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Disposed of drill cuttings as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

3.1 Pre-sampling Observations, and Required Data Entries

A number of field measurements and observations should be made in the field when sampling groundwater. This information is listed below and will be recorded on a Piezometer Installation Report. The following list of measurements and observations represents a minimum requirement for groundwater samples.

- Well Number/ID
- Date Installed
- Contractor
- Driller(s)
- Depth profile of Soil/Rock Conditions
- Piezometer construction details
- Elevation (if known)
- Photograph details (i.e. Picture number, orientation, subject matter, etc.)
- Latitude/Longitude (using GPS, collect Waypoint as well).
- Observable Physical Characteristics - Odor, Color, Cloudiness.
- Evidence of Stressed Vegetation, Wildlife, or Dumping.
- Ambient Weather Conditions during Sampling - Air Temperature, Atmospheric Conditions, Recent Precipitation or Drought.
- Samples Collected (enter all sample numbers collected at this location)
- Sample Depths

All entries will be made as described in Haley & Aldrich Operating Procedure OP3029- Field Data Recording.

3.2 Single Piezometer Installation Procedure

Please refer to Haley & Aldrich Operating Procedures OP2005- Test Borings, Sampling, Standard Penetration Testing (SPT) and Borehole Abandonment and OP2030- Direct Push Borings.

1. Don health and safety equipment (as required by the Health and Safety Plan).
2. Sample locations and analyses will be selected with respect to specific site conditions.
3. Identify sampling location in field notebook along with other appropriate information.
4. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'
5. Install the direct-push borehole, per subcontractor's standard practices and OP2005 & OP2030.
6. Install screen and riser sections to the target depth.
7. Place sand pack material to 1 to 2 feet above the top of the screen section.
8. Place bentonite to form a 1- to 2-foot thick seal above the sand.

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9. Hydrate the bentonite if sufficient groundwater is not present in the borehole.
10. Place clean backfill soil, additional bentonite, or grout to create final seal around the riser to ground surface.
11. Install protective cover and secure.
12. Install a surface seal of concrete around protective cover.
13. Notch top of PVC riser, all water level measurements to be taken relative to this point.
14. Fill out Piezometer Installation Report.

Concrete surface seals and protective casing installations (i.e. road box or protective stick up casing) may be required in accordance with site-specific conditions.

3.3 Piezometer Nest Installation Procedure

1. Don health and safety equipment (as required by the Health and Safety Plan).

2. Sample locations and analyses will be selected with respect to specific site conditions.

3. Identify sampling location in field notebook along with other appropriate information.

4. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'

5. Install a 6-inch to 10-inch (4 1/4-inch to 6 1/4-inch ID hollow-stem augers or casing) borehole per subcontractor's standard practices. Drill to depth of deepest piezometer.

6. Install the deepest piezometer to the base of the borehole, or to the target depth. (Note: if the bottom depth of the exploration is greater than 1 foot below the bottom depth of the deepest piezometer fill with sand to desired depth)

7. Place sand pack around the deepest piezometer screen to 1 to 2 feet above the top of the screen.

8. Install a minimum 2-foot thick bentonite seal on top of the sand pack (hydrate if necessary based on water level measurements obtained).

9. Install a minimum 6 inches of sand on top of the bentonite seal before placing the next screen. If gap exists between Piezometers depths, fill space with bentonite or grout dependent on length of gap.

10. Install the next-deepest piezometer to the desired depth.

11. Fill and seal around second piezometer as above.

12. Continue the above procedures for each multi-level piezometer installed.

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13. Piezometer installation and seal placement should be performed as the augers or casing is withdrawn from the borehole. Do not install piezometers in an uncased hole, as this presents the possibility of caving and mixture of formation material with sandpack and seal materials, which will compromise the quality of the installation and therefore the data obtained.

14. Label each individual piezometer casings appropriately to prevent confusion regarding depth intervals measured.

15. Fill out a Piezometer Installation Report for each piezometer.

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APPENDIX A
RELATED HALEY & ALDRICH PROCEDURES

- OP2005 Test Borings, Sampling, Standard Penetration Testing (SPT) and Borehole Abandonment
- OP2030 Direct Push Borings
- OP3001 Preservation and Shipment of Environmental Samples
- OP3027 Decontamination Procedure
- OP3028 Investigation Derived Wastes
- OP3029 Field Data Recording

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APPENDIX B
FORMS

Haley & Aldrich Form 2008- Piezometer Installation Report

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PIEZOMETER INSTALLATION REPORT

Piezometer No.

Boring No.

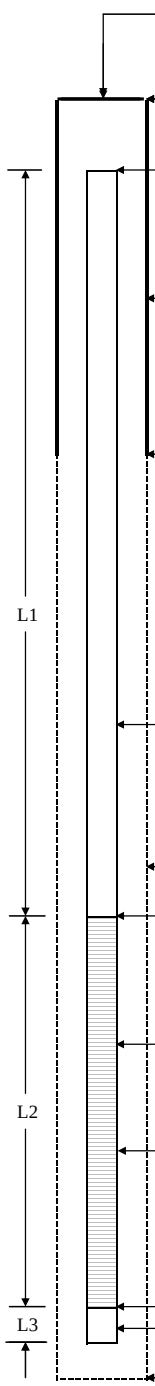
PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP.**	
CONTRACTOR		**DATE INSTALLED**	
DRILLER			

Ground El. _____ ft
El. Datum _____

Location _____

☐ **Guard Pipe**
☐ **Roadway Box**

SOIL/ROCK CONDITIONS	**BOREHOLE BACKFILL**



Type of protective cover/lock _____

Height/Depth of top of guard pipe/roadway box above/below ground surface _____ ft

Height/Depth of top of riser pipe above/below ground surface _____ ft

Type of protective casing: _____
- Length _____ ft
- Inside Diameter _____ in

Depth of bottom of guard pipe/roadway box _____ ft

Type of Seals	**Top of Seal (ft)**	**Thickness (ft)**
Concrete		
Bentonite Seal		

Type of riser pipe:
- Inside diameter of riser pipe _____ in
- Type of backfill around riser _____

Diameter of borehole _____ in

Depth to top of well screen _____ ft

Type of screen _____
- Screen gauge or size of openings _____ in
- Diameter of screen _____ in

Type of backfill around screen _____

Depth of bottom of well screen _____ ft

Bottom of Silt trap _____ ft

Depth of bottom of borehole _____ **ft**

(Bottom of Exlporation)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

ft	+	ft	+	ft	=	ft
Riser Pay Length (L1)		Length of screen (L2)		Length of silt trap (L3)		Pay length

COMMENTS: _____

Form 2008

APPENDIX C
GLOSSARY

ID - Inside Diameter of well
PVC- Polyvinyl Chloride (i.e. composition of well pipe)

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OPERATING PROCEDURE: OP2030

DIRECT PUSH BORINGS

LEVEL II (Interim)

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE 2030

DIRECT PUSH BORINGS

1. PURPOSE

Please refer to Haley & Aldrich Operating Procedure OP2005- Test Borings, Sampling Standard Penetration Testing (SPT) and Borehole Abandonment for a thorough explanation of methods and procedures for soil data collection and monitoring of field activities.

The following operating procedure describes soil sampling by direct push technology. Soil sampling completed by direct push technology and by the advancement of deep soil borings with a drill rig will be completed by a subcontractor. Haley & Aldrich field staff are responsible for ensuring that the recovered samples are acceptable and that they are properly sub-sampled, sealed, labeled and handled during subsequent site storage and transport.

Exploratory test borings are important sources of subsurface information relating to geologic conditions and site suitability fundamental to environmental site assessment and geotechnical design. The following procedure is an introduction to test boring equipment and techniques and an outline of field staff responsibilities while monitoring test boring methods utilized by Haley & Aldrich Inc.

2. EQUIPMENT & SUPPLIES

Required		Additional as Required	
1.	Proposal (signed by Client)	20.	First Aid Kit
2.	Site Plan	21.	Cellular Phone
3.	Contract with Subcontractor (pay items)	22.	Health & Safety Plan
4.	Exploration Criteria/Specifications	23.	Respirator & Tyvek Suit
5.	Field Book	24.	Laptop Computer
6.	Clipboard	25.	Camera & Film
7.	Logs & Forms	26.	Field Procedures
8.	Office Supplies (pencils & markers)	27.	Maps and References
9.	Engineer's Scale	28.	Sample Bags & Jars w/ labels
10.	6 ft. Ruler	29.	Survey Stakes/Paint/Flagging
11.	100 ft. Measuring Tape	30.	Shovel
12.	Hand Lens, magnifying	31.	Geologist's Pick
13.	Pocket Knife	32.	Flashlight
14.	Hard Hat	33.	Roadway Box Key/Socket Wrench
15.	Safety Glasses	34.	Water Level Indicator
16.	Sound Dampeners	35.	Hand Level
17.	Steel Toe Boots	36.	Brunton Compass
18.	Protective Gloves	37.	Pocket Penetrometer
19.	Rain Gear	38.	Torvane

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3. PROCEDURE

Decontaminate equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Disposed of drill cuttings as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

3.1 Pre-Sampling Observations, Notes and Required Entries

The information listed below will be recorded in a project Field Log book and a Sampling Record Form. Haley & Aldrich Form 2032- Direct Push Probe Report is referenced in Appendix B. The following list of measurements and observations represent a minimum requirement for soil samples:

- Sampling Location Number
- Time
- Date Collected
- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory) to receive samples
- Description of Sample Location with Sketch or Map
- Latitude/Longitude
- Sample Depth (i.e., distance in feet from ground surface)
- Photograph Number and Roll Used (if applicable).
- Observable Physical Characteristics
  - Odor
  - Color
  - Density, Consistency, etc.
  - Layering
  - Other
- Evidence of Stressed Vegetation or Wild Life in Area where Sample was taken

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- Ambient Weather Conditions during Sampling
  - Air Temperature
  - Sky Condition
  - Recent Precipitation or Drought

- Samples Collected (enter all sample numbers collected at this location)

3.2 Direct Push Drilling Monitoring

The procedure of retrieving a soil sample by method of direct push (i.e. GeoProbe® or equivalent) will be completed by a subcontractor. The following procedure outlines the responsibility of the Haley and Aldrich field staff in overseeing the subcontractor's work and performing the characterization and subsequent sub-sampling of the material recovered for chemical and geotechnical analyses. The Direct Push Probe Report attached to this operating procedure should be filled out accordingly.

Please refer to Haley & Aldrich Operating Procedure OP2005- Test Borings, Sampling, Standard Penetration Testing (SPT) and Borehole Abandonment.

1. Don health and safety equipment (as required by the Health and Safety Plan).
2. Sample locations and analyses will be selected with respect to specific site conditions.
3. Identify sampling location in field notebook along with other appropriate information.
4. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'
5. Drive boring the full length of sampler
6. Retrieve boring
7. Keep track of original orientation (i.e. "Up")
8. Place boring on ground
9. Repeat process until the desired depth is achieved
10. Cut open Lexan® sleeves
11. Describe soil in accordance with Haley & Aldrich Operating Procedure OP2001- Identification and Description of Soils In the Field Using Visual-Manual Methods.
12. Sample desired depth in accordance with Haley & Aldrich, Inc. Operating Procedure OP3006- Procedures for Subsurface Soil Sampling for Chemical Analysis.
13. Fill out GeoProbe® Report.
14. If required, install piezometer as described in Haley & Aldrich Operating Procedure OP2021- Piezometers.

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APPENDIX A
RELATED HALEY & ALDRICH PROCEDURES

- OP2001 Identification and Description of Soils In the Field Using Visual-Manual Methods
- OP2005 Test Borings, Sampling Standard Penetration Testing (SPT) and Borehole Abandonment
- OP2021 Piezometers
- OP3001 Preservation and Shipment of Environmental Samples
- OP3027 Decontamination Procedure
- OP3028 Investigation Derived Wastes

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APPENDIX B
FORMS

Haley & Aldrich Form 2032- Direct Push Probe Report

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DIRECT PUSH PROBE REPORT

PROBE NO.

Page 1 of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE STARTED	
DRILLER		DATE FINISHED	

Elevation ft.	Datum	Probe Location	
Sampler Diameter in.	Rig Make & Model	PID Make & Model	eV

Depth (ft.)	Push Number & Depth Range	Sample Number & Depth Range	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (Recovery, color, natural grain size and artificial component percentage estimates, manual test properties, structure, odors, moisture, other descriptions and observations, geologic interpretation)	PID Readings Sample/ Background
0							

Water Level Data					
Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water

Component Percentage Estimates	
Term	Range
adjective modifier	20%-50%
and	20%-50%
some	20%-33%
little	10%-20%
trace	5%-10%
with	0%-5%

Well Diagram
Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary	
Overburden (Linear ft.)	
Number of Samples	
PROBE NO.	

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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DIRECT PUSH PROBE REPORT

PROBE NO.

Page of

Depth (ft.)	Push Number & Depth Range	Sample Number & Depth Range	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (Recovery, color, natural grain size and artificial component percentage estimates, manual test properties, structure, odors, moisture, other descriptions and observations, geologic interpretation)	PID Readings Sample/ Background

DRILLING NOTES:

FILE NO.

PROBE NO.

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

OPERATING PROCEDURE: OP3001

PRESERVATION AND SHIPMENT OF ENVIRONMENTAL SAMPLES

PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP3001

PRESERVATION AND SHIPMENT OF ENVIRONMENTAL SAMPLES

1. PURPOSE

This operating procedure (OP) has been established to maintain consistency in preservation and shipment of environmental samples to protect the integrity of the samples prior to analysis. This OP may be modified to suit the needs of an individual site and to comply with specific regulatory programs (i.e. state, CERCLA, RCRA).

The objectives of this OP are to maintain the physical form and chemical composition of the sample and to prevent changes in contaminant concentration. To meet these objectives, there must be a measure of control over all sample handling procedures beginning with sample container cleaning procedures and ending with laboratory analysis. This OP deals with the first half of the control process: the procedures leading up to and ending with sample packaging and transport to the laboratory. The information provided herein will make it possible to choose the minimum number of sample handling and preservation practices necessary to ensure the integrity of a sample designated for analysis.

Refer to OP3026 for Operating Procedures on completing a Chain of Custody.

2. EQUIPMENT & SUPPLIES

- Prepackaged or decontaminated sampling device
- Laboratory supplied sample containers
- Preservatives, as applicable
- Disposable gloves
- Litmus/pH paper, as applicable
- Labels
- Permanent/indelible marker
- Cooler
- Ice
- Bubble wrap
- Packing tape
- Chain of Custody

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3. PROCEDURE

There are four basic steps necessary to obtain meaningful analytical data: preparation of the sample container, sampling, sample preservation, and analysis. The amount of sample to be collected, and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. In order to obtain meaningful analytical data, sample preservation techniques must be effective from the time of sample collection to the time of analysis.

3.1 Selection of Sampling Parameters

The selection of sampling parameters is dependent on the specific work objectives for a Site. When choosing preservatives for your sampling and analysis program, verify that the preservatives or lab techniques used do not contain chemicals that are also constituents of concern at the Site.

In addition, it is important to recognize acetone, as a high purity solvent rinse in sampling equipment decontamination procedures, is included as an analyte on the Target Compound List (TCL) and SW-846, but not on the Priority Pollutant List (PPL).

3.2 Sampling Equipment and Container Selection

Proper selection of sampling equipment and containers for sample collection is an important means of protecting the integrity of the sample. When selecting sampling equipment and containers, verify that the materials that come into direct contact with the sample are compatible with the chemical or physical properties of the contaminant(s) of concern. The type of sample containers to be used in a sampling event should be determined during sampling event planning and documented in the sampling and analysis plan.

As a general rule when obtaining soil samples using core barrel samplers, samples obtained for semivolatile organic compound (SVOC) analysis can be obtained within a core barrel or core barrel liner that is composed of stainless steel, steel, or brass. When only inorganic constituents are of concern, a plastic core barrel liner would be more appropriate. All of these materials are suitable for volatile organic compounds (VOCs) as long as the contact time is minimized. Often all of the above samples (SVOCs, inorganic, and VOCs) are obtained from a single soil core. In this situation, soils should be taken from the interior of the soil core to avoid potential interferences between the contaminants of concern and the surface of the core barrel that is in direct contact with the sample.

For sediment sampling, the analytical sediment sample is arbitrarily defined as that which passes a 10-mesh (approximately 2-mm openings) sieve. The purpose of this is to provide a basis for discrimination of sediment and foreign objects or materials. Stainless steel or nylon sieves may be used when inorganic constituents are to be determined. (For inorganic analyses, stainless steel sieves are acceptable provided the mesh is not soldered or welded to the frame.) Stainless steel or brass sieves are suitable for use when organic substances are to be determined. (For organic analyses, organic materials such as rubber or plastics should not be used in the storage or handling of samples.)

For water sampling, specifications on container design, including shape, volume, gas tightness, materials of construction, and use of cap liners, are defined for specific parameters or suites of parameters (for example, amber glass containers protect photosensitive analytes, such as polychlorinated biphenyls (PCBs) from chemical alteration). Specifications for sample container selection are documented in parameter-specific analytical methods (for example, ASTM, U.S. EPA SW846, AWWA Standard Methods) as well as in Federal (40 CFR

Part 136), state, and local regulatory guidelines on groundwater sample collection and preservation. Table 1 provides examples of common container materials, colors and volumes.

3.2.1 Reactivity of Container Material with Sample

Choosing the proper composition of sample containers will help to ensure that the chemical and physical integrity of the sample is maintained. For potentially hazardous material, glass is the recommended container type because it is chemically inert to most substances. Plastic containers are not recommended for most hazardous wastes because the potential exists for contaminants to adsorb to the surface of the plastic or for the plasticizers to leach into the sample.

In some instances, the sample characteristics or analytes of interest may dictate that plastic containers be used instead of glass. Because some metals species will adhere to the sides of glass containers in an aqueous matrix, plastic bottles must be used for samples collected for metals analysis. In the case of a strong alkali waste or hydrofluoric solution, plastic containers may be more suitable because glass containers may be etched by these compound creating adsorptive sites on the container surface.

3.2.2 Volume of the Container

The volume of sample to be collected will be dictated by the analytical method and the sample matrix. The laboratory must supply bottles of sufficient volume to perform the required analysis. Table 1 indicates the container volumes required for the various parameters. In most cases, the methodology dictates the volume of sample material required to complete the analysis. However, individual labs may provide larger volume containers for various analytes to ensure sufficient quantities for replicates or other quality control checks.

3.2.3 Color of Container

Whenever possible, amber glass containers should be used to prevent photodegeneration of the sample, except when samples are being collected for metals analysis. If amber containers are not available, containers holding samples should be protected from light. However, 40-milliliter (ml) clear glass vials are often provided by laboratories for aqueous VOC analysis and are acceptable for use.

3.2.4 Container Closures

Container closures should form a leak-proof seal (i.e., screw caps or ground glass stoppers). Closures must be constructed of a material which is inert with respect to the sampled material, such as Polytetrafluoroethylene (PTFE) (e.g., Teflon®). Alternately, the closure may be separated from the sample by a closure liner that is inert to the sample material such as PTFE liner or septum.

3.2.5 Decontamination of Sample Containers

Sample containers must be laboratory cleaned, preferably by the laboratory performing the analysis. The cleaning procedure is dictated by the specific analysis to be performed on the sample.

When sampling for organic compounds, if your sample containers are not provided by the analytical laboratory, care should be taken to ensure that the containers are properly cleaned and prepared. Refer to ASTM Standard D3694-96 *Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents* for guidance.

After the sample containers are cleaned, they can be pre-preserved or preserved in the field. Information on sample preservation is given in Section 3.4. Sample containers provided by a commercial analytical laboratory are cleaned and in many cases pre-preserved by the laboratory. The sample bottles should be prepared for shipment accompanied by a chain-of-custody and the cooler containing them should be sealed. The chain-of-custody must also accompany the bottles during transportation to the field, sample collection, transportation back to the lab, during analysis and final disposal of the sample container.

3.3 Sample Labels

Sample labels may be in the form of adhesive labels or tags, or both. Tags have the advantage of being removable to become part of the record keeping process, although their inadvertent loss or inappropriate removal may leave the sample without documentation. Labels should be made of waterproof paper and indelible ink should be used to make entries. Alternatively, sample information may be written directly on the sample container, as long as the writing can be done indelibly. Containers should be free from other labels and other writing to prevent any confusion. If both tags and labels are used, care should be taken to ensure that the information on both is identical.

Labels or tags should be filled out just before or immediately after sample collection. Labels should contain spaces for the following information:

- Project identification code.
- Sample identifying name
- Sampling location ID, sampling point ID.
- Sampling date and time.
- Analyses desired.
- Company name.

3.4 Sample Presevation

The need for sample preservation for specific analytes should be defined prior to the sampling event and documented in the site-specific sampling and analysis plan. Certain analytical methodologies for specific analytes require chemical additives in order to stabilize and maintain sample integrity. Unless the analysis is accomplished within 2 hours after sampling, preservation is preferred and usually required.

Preservatives are generally added to the sampling bottles by the laboratory prior to shipment into the field. If the sample bottles are not pre-preserved by the laboratory, preservatives may be added in the field immediately after the samples are collected. Many laboratories provide pre-preserved bottles as a matter of convenience and to help ensure that samples will be preserved immediately upon collection. A problem associated with this method arises if not enough sample is collected, resulting in too much preservative in the sample. More commonly encountered problems with this method include the possibility of insufficient preservative provided to achieve the desired pH level or the need for additional preservation due to chemical reactions caused by the addition of sample liquids to pre-preserved bottles.

3.4.1 Soil

3.4.1.1 Composite Samples

When composite samples are collected, the appropriate preservation reagents must be added to the compositing vessel prior to collection. If the preservation requirements call for refrigeration, the sample must be refrigerated during the collection. The collection time for a single composite sample should not exceed 24 hours. If longer sampling periods are necessary, a series of composite sample should be collected.

3.4.1.2 Grab Samples

In the absence of specific instructions, storage at a temperature of 4°C or lower for a period of time not to exceed 1 week is recommended.

3.4.1.3 Sediment Samples

Sediment samples intended for both organic and inorganic compound analysis may undergo changes in composition during storage. The analytical method should specify the conditions necessary to assure requisite stability. In the absence of specific instructions, storage at a temperature of 4°C or lower for a period of time not to exceed 1 week is recommended, although it is known that microbiological activity does not cease under these conditions.

3.4.2 Water

3.4.2.1 Groundwater Samples

Groundwater samples are subject to chemical, physical, and biological change at the ground surface relative to in-situ conditions as a result of exposure to ambient conditions during sample collection.

Groundwater sample preservation procedures are grouped into two general categories: (1) physical preservation and (2) chemical preservation. Groundwater samples should be preserved in the field at the time of sample collection using physical means to prevent sample container breakage or temperature increases, and chemical means to minimize changes in groundwater sample chemistry prior to laboratory analysis.

Physical groundwater sample preservation methods include: (*1*) use of appropriate sample collection containers for each parameter being analyzed, *(2)* use of appropriate sample collection procedures (i.e. making sure there are no air bubbles in VOA vials) (*3*) use of appropriate packing of sample containers for shipment to prevent sample container breakage and potential cross-contamination of samples during shipment, and (*4*) temperature control. Samples are cooled to reduce biological activity on the organic chemicals. Cool the sample to 4°C immediately after sampling using a wet ice water bath. During storage or shipment, or both, maintain the sample at 4°C. A temperature blank should be used with each shipping container of samples to determine actual sample temperatures at the time the sample shipment is received by the laboratory.

Chemical preservation of groundwater samples involves the addition of one or more chemicals (reagent-grade or better) on a parameter-specific basis to protect sample integrity. Table 1 provides examples of common analyte-specific chemical preservation methods. Chemical preservation is specified in numerous analytical methods as well as in various regulatory guidance documents such as 40 CFR Part 136.3. Chemicals can be used to adjust sample pH or

inhibit microbial activity to prevent chemical alteration of samples. In most cases the samples containers will be pre-preserved by the analytical laboratory. In the case that the sample containers are not pre-preserved, refer to *ASTM D 6517-00 Standard Guide for Field Preservation of Ground-Water Samples* for guidance.

After the sample container is filled and preserved, it should be securely capped and gently inverted to ensure uniform distribution of the preservative throughout the sample.

Preservation must take place immediately upon sample collection except when samples are to be filtered. Samples requiring filtration must be processed immediately after collection. Filtered samples are then preserved immediately following the filtration process.

Samples must be placed into a cooler and maintained at 4°C immediately upon collection and preservation.

When collecting samples in pre-preserved containers, care must be taken not to pre-rinse the container with the sample and to avoid overfilling the container to prevent loss of chemical preservative. It may be necessary to establish site-specific protocol to address acceptable periods for storage and storage conditions for pre-preserved sample containers due to the potential for chemical reactions to occur between the chemical preservative and the empty sample container

Records should be kept for all forms of sample preservation used for groundwater samples. The following should be reported:

- Type of sample container(s) used for each parameter being analyzed (volume, materials of construction, type of cap, etc.);
- Packaging method(s) used to prevent sample bottle breakage during sample storage and shipment;
- How groundwater samples were cooled to 4°C, if required for physical preservation;
- Chemical preservative(s) used on a parameter-specific basis;
- Description of appearance of unpreserved and preserved samples, specifically noting any chemical reactions which may occur upon addition of chemical preservative (for example, effervescence, formation of precipitates, change in color).

3.4.3 Air/Vapor Samples

Air/Vapor samples are subject to chemical, physical, and biological change as a result of exposure to ambient conditions following sample collection.

Air /vapor samples should be placed in within a container in the field at the time of sample collection to prevent exposure of the sample to sunlight or temperature extremes (<10 C or > 30C, to minimize changes in the sample chemistry prior to laboratory analysis.

3.5 Chain-Of-Custody

The purpose of a chain-of-custody is to provide accountability for and documentation of sample integrity from the time the samples are collected until sample disposal. A chain-of-custody is intended to be a legal form documenting sample possession during collection, shipment, storage and the process of analysis. Chain-of-custody procedures are necessary in a program to assure the ability to support data and conclusions adequately in a legal or regulatory situation. Refer to OP3026 for Operating Procedures on completing a Chain of Custody.

A single field sampling person should be assigned responsibility for custody of samples. An alternate custodian should also be assigned to cover the prime custodian's absence. As few people as possible should handle samples. The assigned field sampler should be personally responsible for the care and custody of the samples collected until they are properly transferred. While samples are in their custody, field personnel should be able to testify that no one was able to tamper with the samples without their knowledge.

A standard chain-of-custody form included in Appendix A has been designed for recording custody information related to field sample handling. The following information should be on the form:

- Sample identifying name.
- Sampling location ID, sampling point ID.
- Sampling date and time.
- Sampling interval.
- Signatures of sampling personnel and signatures of all personnel handling and receiving the samples.
- Project identification code.
- Preservation (to alert lab personnel): amount and type.
- Number of containers. Indicate number of replicates if there are multiple containers of the same type.
- Field notes.
- Analyses desired.
- Sample type: grab, composite, etc.

When transferring the possession of samples, the individuals relinquishing and the individuals receiving the samples should sign, date, and note the time on the custody record. Provisions should be made for receipt of samples at nonstandard hours, such as nights and weekends by non-laboratory personnel. Shipping documents, with noted time of receipt and receipt by whom, should be made part of the custody record.

3.6 Sample Sealing

Sample custody seals of waterproof adhesive paper may be used to detect unauthorized tampering with samples prior to receipt by the lab. When seals are used, they should be applied so that it is necessary to break them in order to open the sample cooler. It is helpful to cover the custody seal with clear packing tape to ensure the security of the cooler.

3.7 Holding Times

Table 1 lists maximum holding times cited in the U.S. EPA "Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act". Sample containers should be shipped and received by the laboratory and as soon as possible to allow sufficient time for the laboratory to perform the requested analyses within the holding time defined by the applicable laboratory analytical method for each parameter.

3.8 Sample Storage and Transport

Field personnel should package and ship samples in compliance with all applicable regulations including the Department of Transportation (for example, Title 49 Code of Federal Regulations, Part 172) and the International Air Transportation Association (IATA). Samples should be placed in a cooler to be maintained at 4°C. Special care should be taken when packaging glass (i.e., using bubble wrap). Sample containers should be shipped in a manner that will ensure the samples are received intact by the laboratory, at the appropriate temperature, and as soon as possible to allow sufficient time for the laboratory to perform the requested analyses within the holding time. Samples should be shipped well before the holding time is up and ideally should be shipped within 24 hours of sample collection.

TABLE 1 - Required Containers, Preservation Techniques, and Holding Times

Using USEPA-Contract Lab Program Methodologies for Aqueous and Nonaqueous Samples

Parameter	Sample Container (1)	Container Volume	Preservation	Maximum Holding Time
Volatile Organics	Aqueous-G, black phenolic plastic screw cap, teflon-lined septum	Aqueous 40 ml	Cool, 4 deg C, dark, 0.08% $Na_2S_2O_3$ if residual Cl_2	10 days
	Nonaqueous-G, polypropylene cap, white teflon liner	Nonaqueous 120 ml		10 days
Total Organic Carbon	G - Preferred, P - If determined that there is no contributing organic contamination	100 ml	Cool, 4 deg C, dark, HCl or H_2SO_4 to pH<2 if analysis can't be done within 2 hrs	2 Hrs - unpreserved 28 days - preserved
Base Neutral/Acid Extractable (Semivolatile) Organics	Amber Glass, Teflon lined cap	1 liter	Cool, 4 deg C, dark	Extraction Aqueous continuous liquid-liquid extraction must be started within 5 days Non-aqueous - 10 days Analysis 40 days from validated time of sample receipt at the lab.
Total Petroleum Hydrocarbons	G	1 liter	Cool, 4 deg C	Aqueous 7 days
		4 oz		Non-Aqueous 28 days Gasoline in soil 7 days
Pesticide/PCBs	Amber G, Teflon lined cap	1 liter	Cool, 4 deg C, dark	Extraction Aqueous continuous liquid-liquid extraction must be started within 5 days Non-aqueous - 10 days Analysis 40 days from validated time of sample receipt at the lab.
Metals except Mercury	Aqueous-P bottle, P cap, P liner	Aqueous - 1000 ml	Aqueous - HNO_3 to pH<2	180 days
	Nonaqueous-Flint G bottle, black phenolic cap, polyethylene liner	Nonaqueous 4, 8, 16, or 32 oz	Nonaqueous - 4 deg C until analysis	
Hexavalent Chromium	P, G	400 ml	Cool, 4 deg C	24 hrs
Mercury	Aqueous-P bottle, P cap, P liner	Aqueous - 1000 ml	Aqueous - HNO_3 to pH<2	26 days
	Nonaqueous-Flint G bottle, black phenolic cap, polyethylene liner	Nonaqueous 4, 8, 16, or 32 oz	Nonaqueous - 4 deg C until analysis	
Phenols	G Only	1 liter	Cool, 4 deg C, H_2SO_4 to pH<2	28 days

TABLE 1 - Required Containers, Preservation Techniques, and Holding Times (CONTINUED)

Parameter	Sample Container (1)	Container Volume	Preservation	Maximum Holding Time
Cyanide	Aqueous-P bottle, P cap, P liner	Aqueous - 1000 ml	Aqueous - 0.6g ascorbic acid if residual Cl_2, NaOH to pH>12, cool, 4 deg C until analyzed $CaCO_3$ in presence of sulfide	12 days
	Nonaqueous-Flint Glass bottle, black phenolic cap, polyethylene liner	Nonaqueous 4, 8, 16, or 32 oz	Nonaqueous Cool, 4 deg C until analyzed	
Sulfates	P, G	100 ml	Cool, 4 deg C	28 days
Sulfides	P, G	1 liter	Cool, 4 deg C, add 4 drops zinc acetate per 100 ml sample, NaOH to pH>9	7 days
Chloride	P, G	1 liter	Cool, 4 deg C	28 days
Total Nitrogen	Aqeous - P bottle, P cap, P liner	Aqueous - 1000 ml	H_2SO_4 to pH<2	12 days
Nitrate	P, G	1 liter	Cool, 4 deg C,	24 hrs - Unpreserved
			H_2SO_4 to pH<2, (2 ml/L)	28 days - preserved
Fluoride	Aqeous - P bottle, P cap, P liner	Aqueous - 1000 ml	4 deg C until analysis	26 days

Excerpt from Appendix 2-1 (NJDEP Field Sampling Procedures Manual, May 1992) which is based on 40 CFR part 136.3

P - Plastic, hard or soft

G - Glass

$Na_2S_2O_3$ - Sodium thiosulfate

HCl - Hydrochloric acid

Cl_2 - Chlorine

H_2SO_4 - Sulfuric acid

HNO_3 - Nitric Acid

NaOH - Sodium hydroxide

$CaCO_3$ - Calcium carbonates

APPENDIX A
REFERENCES

A.1 Reference Procedure

- American Society for Testing and Materials International, Standard Guide for Field Preservation of Groundwater Samples, ASTM D 6517-00, April 2000.
- American Society for Testing and Materials International, Standard Guide for Sample Chain-of-Custody Procedures, ASTM D 4840-99, January 2000.
- American Society for Testing and Materials International, Standard Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations, ASTM D 6640-01, April 2001.
- American Society for Testing and Materials International, Standard Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents, ASTM D 4841-88, October 1985.
- American Society for Testing and Materials International, Standard Practice for Preparation of Sediment Samples for Chemical Analysis, ASTM D 3 976-92, December 1992.
- American Society for Testing and Materials International, Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents, ASTM D 3694-96, March 1997.

A.2 Other References

- New Jersey Department of Environmental Protection, Field Sampling Procedures Manual, May 1992.
- United States Environmental Protection Agency Environmental Response Team, Groundwater Well Sampling SOP #: 2007, 26 January 1995.

APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1004 Operation/Calibration of PID Photoionization Detector
- OP1007 Field Monitoring for Volatile Organics (breathing space-work zone)
- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP3006 Procedures for Subsurface Soil Sampling and Chemical Analysis
- OP3008 Manual Water Level Measurement Procedure
- OP3009 Monitoring Well Development Procedure
- OP3010 Groundwater Quality Sampling Procedure
- OP3012 Low Stress/Low Flow Groundwater Sample Collection Procedure
- OP3026 Chain of Custody

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APPENDIX C
FORMS

Form 3001	Sampling Labels (Environmental)
Form 3003	Chain of Custody Record (Field)
Form 3005	Groundwater Sampling Record
Form 3006	Monitoring Well Devel Rpt
Form 3010	Low Flow Field Sampling Form

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APPENDIX D
GLOSSARY

Chemical preservation - the addition of acidic, alkaline or biologically toxic compounds, or combination thereof, to a groundwater sample to prevent changes in chemical properties of the sample that may occur after collection.

Custody - physical possession or control. A sample is under custody if it is in possession or under control so as to prevent tampering or alteration of its characteristics.

Holding time - the maximum amount of time that may transpire from the moment a sample container is filled to the time the sample is extracted or analyzed. Holding times are parameter-specific, variable in length, and defined by laboratory analytical methods.

Physical preservation - methods that are implemented to protect the physical integrity of a groundwater sample from the time the sample is collected until the sample is analyzed.

Temperature blank - a laboratory quality control sample that is transported with samples and is used by the laboratory performing sample analyses to verify that temperature-sensitive samples have been adequately cooled to 4°C for shipment to and arrival at the laboratory.

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APPENDIX E
CHAIN OF CUSTODY RECORD

See three-piece form in Forms cabinet.

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OPERATING PROCEDURE: OP3003

SURFICIAL SOIL SAMPLING

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP3003

SURFICIAL SOIL SAMPLING

1. PURPOSE

The purpose of this Operating Procedure (OP) is to describe the procedures for the collection of representative samples of surficial soil. The procedures are intended specifically to minimize alteration of samples during collection. Surficial soil samples as referenced herein mean soils or soil-like material located less than 6 feet below ground surface which may contain quantities of contaminants.

Refer to OP3000 for General Environmental Field Procedures and Protocol, including procedures for decontamination of sampling equipment and/or containers. Refer to OP3001 for Operating Procedures on Preservation and Shipment of Environmental Samples.

Haley & Aldrich (H&A) personnel are to use the techniques in OP3003 to collect surficial soil samples. These operating procedures may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

2. EQUIPMENT & SUPPLIES

Required:
1. Site map(s)/plan(s)
2. Safety equipment, as specified in the site-specific Health and Safety Plan
3. Field Log book
4. Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
5. Plastic or stainless steel spoons and/or wooden tongue depressors
6. Appropriate size sample containers
7. Plastic zip lock bags
8. Sample Labels
9. Chain of Custody records and custody seals
10. Sampling Record Form (H&A Form 3004)
11. Cooler(s)
12. Ice
13. Decontamination supplies/equipment

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Sampling equipment may include one or more of the following:

1. Stainless steel trowel(s) or scoop(s)
2. Stainless steel spade or shovel
3. Bucket auger
4. Bit auger
5. Continuous flight (screw) auger
6. Post-hole auger
7. Extension/drill rods
8. T-handle
9. Core sampler
10. Sampling trier
11. Thin wall tube sampler
12. Split spoons
13. Vehimeyer soil sampler outfit
14. Tubes
15. Points
16. Drive head
17. Drop hammer
18. Puller jack and grip
19. Backhoe
20. Telescopic mechanical sampling arm (aluminum poles)
21. Stainless steel sampling beaker

Optional:

1. Tape measure
2. Survey equipment or global positioning system (GPS) to locate sampling points
3. Survey stakes or flags
4. Camera and film
5. Plastic sheeting or cover

3. PROCEDURE

3.1 Preparation

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.

- Obtain necessary sampling and monitoring equipment.

- Decontaminate or pre-clean equipment, and ensure that it is in working order.

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- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.

- Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.

- Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator prior to soil sampling, and utility clearance should always be confirmed before beginning work.

3.2 Presampling Observations, Notes and Required Entries

The information listed below will be recorded in a project Field Log book and a Sampling Record Form. The Sampling Record Form is referenced in Appendix C. The following list of measurements and observations represent a minimum requirement for soil samples:

- Sampling Location Number

- Time

- Date Collected

- Samplers (names of individuals who actually collected samples)

- Sample Destination (Analytical Laboratory) to receive samples

- Description of Sample Location with Sketch or Map

- Sample Depth (i.e., distance in feet from ground surface)

- Photograph Number and Roll Used (if applicable).

- Observable Physical Characteristics
  - Odor
  - Color
  - Density, Consistency, etc.
  - Layering
  - Other

- Evidence of Stressed Vegetation or Wild Life in Area where Sample was taken

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- Ambient Weather Conditions during Sampling
  - Air Temperature
  - Sky Condition
  - Recent Precipitation or Drought

- Samples Collected (enter all sample numbers collected at this location)

3.3 Sampling Procedures

- After entries are completed, label and number required sample bottles. Fill out the label in indelible ink and carefully and clearly address all categories and parameters.

- Sample analyses will be specified by the Project Coordinator and Site Manager. A list of these analyses and required containers and handling procedures is presented in a Site work plan or related document.

- Sampling instructions have been provided for seven sampling devices most often used to collect surficial soil samples. Select the appropriate sampling device.

- Refer to Operation Procedure OP2001 - Identification and Description of Soils in the Field Using Visual-Manual Methods, if observations of surficial soils are to be recorded.

- Decontaminate sampling device and/or container prior to use according to Operation Procedure OP3000 - General Environmental Field Procedures and Protocol.

- Sample containers (glass jars and vials) should be filled to the top. Refer to a Site work plan or related document for sample volume size and appropriate containers for given analyses. Sample containers should contain laboratory-provided preservatives, if necessary. Care should be taken to prevent the presence of air bubbles in VOA vials. All container caps will include an inner teflon septa or lining and must be tightly secured to contain the sample. All samples will be stored and shipped at 4ºC. Refer to OP3001 for operating procedures on sample handling and preservatives.

- Check for appropriate liner in cap and secure cap tightly. Store the samples with ice in a cooler, following these sealing and packing procedures:

  - Ice will be placed in plastic zip-lock bags to contain ice water. Sample containers will be adequately layered in bubble wrap to prevent breakage. Samples will be positioned upright in the cooler to prevent breakage, and samples will be stored and shipped at 4ºC.

  - All 40-milliliter VOA vials will be sealed in thick or heavy duty plastic zip lock bags.

  - Check to make sure all appropriate information is in Field Log Book or Sampling Record form and Chain-of-Custody form using indelible ink.

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- If samples are to be shipped to a laboratory for analysis, a Chain-of-Custody record, custody seals, fragile markers, and reinforced nylon tape will all be properly affixed to or on the sample cooler. If samples are to be delivered to the laboratory directly by Haley & Aldrich, then only the Chain-of-Custody record is required.
    - Chain-of-Custody Form - enclose in large plastic zip lock bag and tape to inside top of cooler lid.
    - Custody Seals - place custody seal over cooler gasket separating the cooler lid from the cooler bottom at all sides except hinged location.
    - Nylon Tape - tape completely around cooler at two locations. Tape reinforcing will prevent cooler from opening if the lid locking mechanism fails.
    - Fragile Markers - fragile markers and upright stickers will be affixed to each side of the cooler.

3.4 Sampling Device Instructions

The specific procedures and equipment for surficial soil sampling will be defined in a Site work plan or related document. The following presents a description of seven sampling devices commonly used to collect surficial soil samples within 6 feet of ground surface. The split spoon sampler, when used with drilling equipment, can also collect subsurface soil samples to much greater depths. The most appropriate device for a specific sampling program as described in a Site work plan or related document has been selected based on site conditions (accessibility, type of soil, desired depth of samples, etc.) and on climate conditions (e.g. frozen ground in winter).

The selected devices for each sampling task are described in detail in a Site work plan or related document. Any changes to procedures outlined in a Site work plan or related document will be specified by the Site Manager.

3.4.1 Hand Scoops, Trowels, Spades and Shovels

This method is probably the simplest, most expeditious, direct method for making soil samples accessible. Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. These devices are easy to operate, decontaminate and work well for sampling most surficial soils. Surface material is removed to the required depth and a stainless steel or plastic scoop is then used to collect the sample. This method can be used in most soil types but is limited to sampling at or near the ground surface. Accurate, representative samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member.

Hand scoops and trowels consist of the usual garden type trowel or scoop usually constructed of stainless steel. A stainless steel laboratory scoop is a preferred scoop device due to its non-corrosive nature. Scoops or trowels work well in collecting grab samples of surficial soils or sludges. A flat,

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pointed mason trowel to cut a block of the desired soil is helpful when undisturbed profiles are required. A typical shovel or spade constructed of stainless steel can be used to collect representative soil samples near the surface. Devices plated with chrome or other exterior coatings that may chemically alter the sample should not be used. Plating is particularly common with garden implements such as potting trowels.

Procedures for Use

1. Carefully remove the top layer of soil to the desired sample depth with a cleaned, stainless steel spade, shovel, trowel, or scoop. In the case of sludges exposed to air, it may be desirable to remove the first 1-2 centimeters of material prior to collecting sample.

2. Using a cleaned, stainless steel scoop or trowel, collect the desired quantity of soil.

3. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a stainless steel lab spoon, new wooden tongue depressor or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

3.4.2 Bucket and Bit Augers with Thin-Wall Tube Attachment

This system consists of a bucket or bit auger, or a thin-wall tube sampler, a series of extensions/drill rods, and a "T" handle (Figure 1). A cleaned bucket or bit auger is used to bore a hole to the desired sampling depth and then is withdrawn. When using the bucket auger, the soil sample must be removed from the bucket with a cleaned, stainless steel spoon or trowel. The bucket auger can collect a large soil sample (up to 24 ounces) but is limited in penetrating depth to approximately 2 feet under ideal conditions. Bucket augers are useful for direct sample recovery, because they provide a large volume of sample in a short time. The bit auger has greater penetrating depth (up to 6 feet) but collects a small soil sample. The bit auger tip is removed from the auger when the desired sampling depth is reached and replaced with the thin wall tube attachment. The system is then lowered down the cored hole, and driven into the soil to the completion depth. The system is withdrawn and the core is collected from the thin wall tube sampler.

Other types of augers include continuous flight (screw) and post-hole augers. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

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This equipment can be used in a wide variety of soil conditions. The presence of rock layers and collapsing of the borehole usually prohibit sampling at depths greater than 3 to 6 feet. The equipment is inexpensive, easy to operate, and generally works well to sample most soils.

Procedures for Use

1. Attach the cleaned auger bucket or bit to a drill rod extension and further attach the "T" handle to the drill rod.

2. Clear the area to be sampled of any surface debris (twigs, rocks, litter). It may be advisable to remove the first 3 to 6 inches of surface soil for an area approximately 6 inches in radius around the drilling location.

3. Begin augering by rotation of the "T" handle, periodically removing accumulated soils onto a plastic sheet spread near the hole. This prevents accidentally brushing loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.

4. After reaching the desired depth, slowly and carefully remove the auger from the hole.

5. If a bucket auger is used, remove the soil sample with a cleaned, stainless steel spoon or trowel.

6. If a bit auger is used, remove the auger tip from the extension rods and replace with a cleaned, thin-wall tube sampler. Install the proper cutting tip.

7. Carefully lower the tube sampler down the borehole. Gradually press the tube sampler into the soil. Take care to avoid scraping the borehole sides. Avoid hammering the drill rods to facilitate coring, as the vibrations may cause the boring walls to collapse.

8. Remove the tube sampler and unscrew the drill rods.

9. Remove the cutting tip, and remove the core from the device.

10. Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.

11. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, wooden tongue depressor or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval

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into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

12. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and repeat previous steps, making sure to decontaminate the auger and tube sampler between samples.

13. Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

3.4.3 Hand Held Corer

The device consists of a "T" handle and cylindrical core tube (Figure 2). The device is equipped with a check valve at the top to prevent washout during retrieval through an overlying water layer, if applicable, and a nosepiece at the bottom to help contain the sample. This device can be used in a wide variety of soil conditions. Hand corers can also be fitted with brass or polycarbonate plastic liners.

Procedures for Use

1. Inspect the corer for proper pre-cleaning.

2. Press the corer in with a smooth continuous motion.

3. Twist the corer, and then withdraw the corer in a single smooth motion.

4. Remove the nosepiece and withdraw the sample into a stainless steel, plastic or other appropriate homogenization container.

5. Transfer the sample into an appropriate sample container with a stainless steel spoon, wooden tongue depressor or equivalent.

3.4.4 Thin Tube Hand Held Sampling Trier

The system consists of a trier, a long hollow cylindrical tube with a slot trending almost its entire vertical length, and a "T" handle (Figure 3). The trier is driven into the soil to be sampled and used to extract a core sample from the appropriate depth. The tip and edges of the tube are sharp to allow the trier to cut a core by rotation of the "T" handle once it is completely pushed-down or manually driven to the depth of collection. Triers range from approximately 20 to 60 inches in length and from approximately 0.5 to 1 inch in diameter.

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Procedures for Use

1. Insert the cleaned trier into the soil or sludge material at a 0 to 45° angle from horizontal. This orientation minimizes the spillage of sample from the sampler. Extraction of samples might require tilting of the containers.

2. Rotate the trier once or twice to cut a core of material.

3. Slowly withdraw the trier, making sure the slot is facing upward.

4. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, wooden tongue depressor or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

3.4.5 Split Spoon Sampler

Split spoon sampling is generally used to collect undisturbed soil cores of 18 or 24 inches in length. A split spoon sampler consists of a cylindrical hollow steel or stainless steel sampler usually 24 inches long and 2 or 3 inches in outside diameter. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted. Split spoon samplers collect in-situ soil samples that permit stratigraphic logging. To remove the split spoon sampler and collect a soil sample, remove the sampler from the driving rods and unscrew the tapered nosepiece and top piece from the sampler. The spoon will then split into two longitudinal sections. It may be necessary to use a pipe wrench to unlock the threaded nosepieces. This sampling device is almost always used in conjunction with a drilling rig and as such is an equipment intensive effort. However, the split spoon may be used with a hand-held drop hammer for collection of shallow soil samples (less than 6 feet below ground surface).

Refer to Operation Procedures OP2005 - Test Borings, Sampling, Standard Penetration Testing and Borehole Abandonment, and OP3006 - Procedures for Subsurface Soil Sampling for Chemical Analysis, which describe the use of this sampler in greater detail.

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Procedures for Use

1. Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.

2. Place the sampler in a position perpendicular to the sample material.

3. Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.

4. Record in the Field Log book or test boring log the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.

5. Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler is typically available in 2 and 3 1/2 inch diameters. A larger barrel may be necessary to obtain the required sample volume.

6. Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

3.4.6 Test Pit/Trench Excavation

A backhoe can be used to remove sections of soil, when detailed examination of soil characteristics are required. This is a relatively expensive sampling method because of the cost of backhoe operation. Refer to Operation Procedure OP2026 - Exploratory Test Pits for more information on test pit excavations.

Procedures for Use

1. Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities.

2. Review the site specific Health & Safety plan and ensure that all safety precautions including appropriate monitoring equipment are installed as required.

3. Using the backhoe, excavate a trench approximately three feet wide and approximately one foot deep below the cleared sampling location, or as specified in a Site work plan or related document. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.

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4. A shovel may be used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.

5. Record in the Field Log book or test pit log the depth intervals from which the samples are being collected.

6. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket. A telescopic mechanical arm (see next sampling device) and stainless steel sampling beaker may be used to collect samples.

7. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, wooden tongue depressor or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

8. Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material. The test pit/excavation should be backfilled in accordance with a Site work plan or related document.

3.4.7 Telescopic Mechanical Sampling Arm

The device consists of an aluminum pole approximately 1 to 2 inches in diameter divided into three, 4-foot sections. Attached to the end of the pole is a stainless steel sampling beaker (usually with an 18-ounce capacity). The pole is capable of telescoping from 4 to 12 feet. This mechanical sampling arm is used to collect soil samples from test pits or other excavations. It allows a sample to be collected from a location that would otherwise be difficult to access.

<u>Procedures for Use</u>

1. Attach the cleaned, stainless steel beaker to the end of the pole either by tightening a clamp or wing nuts.

2. Make sure your feet are safely and securely positioned.

3. Telescope the pole to the required length.

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4. Lower the pole end into the test pit or other excavation.

5. Collect the sample.

6. Remove the sample from the beaker with a cleaned, stainless steel scoop, trowel or new wooden tongue depressor.

3.5 Sample Containers

The samples for each analysis will be collected in the appropriate containers and handled in accordance with the procedures described in a Site work plan or related document.

3.6 Chain-of-Custody Forms

All samples submitted to the contract analytical laboratory for analyses, will be accompanied by a Chain-of-Custody form. Appropriate Chain-of-Custody procedures will be followed at all times during a sampling event and subsequent transport to the contract analytical laboratory. Refer to OP3026 for operation procedures on completing a Chain-of-Custody form and Chain-of-Custody procedures.

3.7 Decontamination

Soil sampling equipment will be cleaned prior to and between each use according to Operation Procedure OP3000 – General Environmental Field Procedures and Protocol. After decontamination, the equipment will be wrapped in aluminum foil and placed on clean racks off the ground until it is used.

3.8 Quality Assurance/Quality Control

There are no specific quality assurance (QA) activities that apply to the implementation of these operating procedures. However, the following QA procedures apply:

- All data must be documented on field data sheets or within site logbooks.

- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in a Site work plan or related document. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

3.9 Health and Safety

When working with potentially hazardous materials, follow H&A health and safety procedures, in addition to the procedures specified in the site specific Health & Safety Plan.

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FIGURES

Figure 1. Sampling Augers

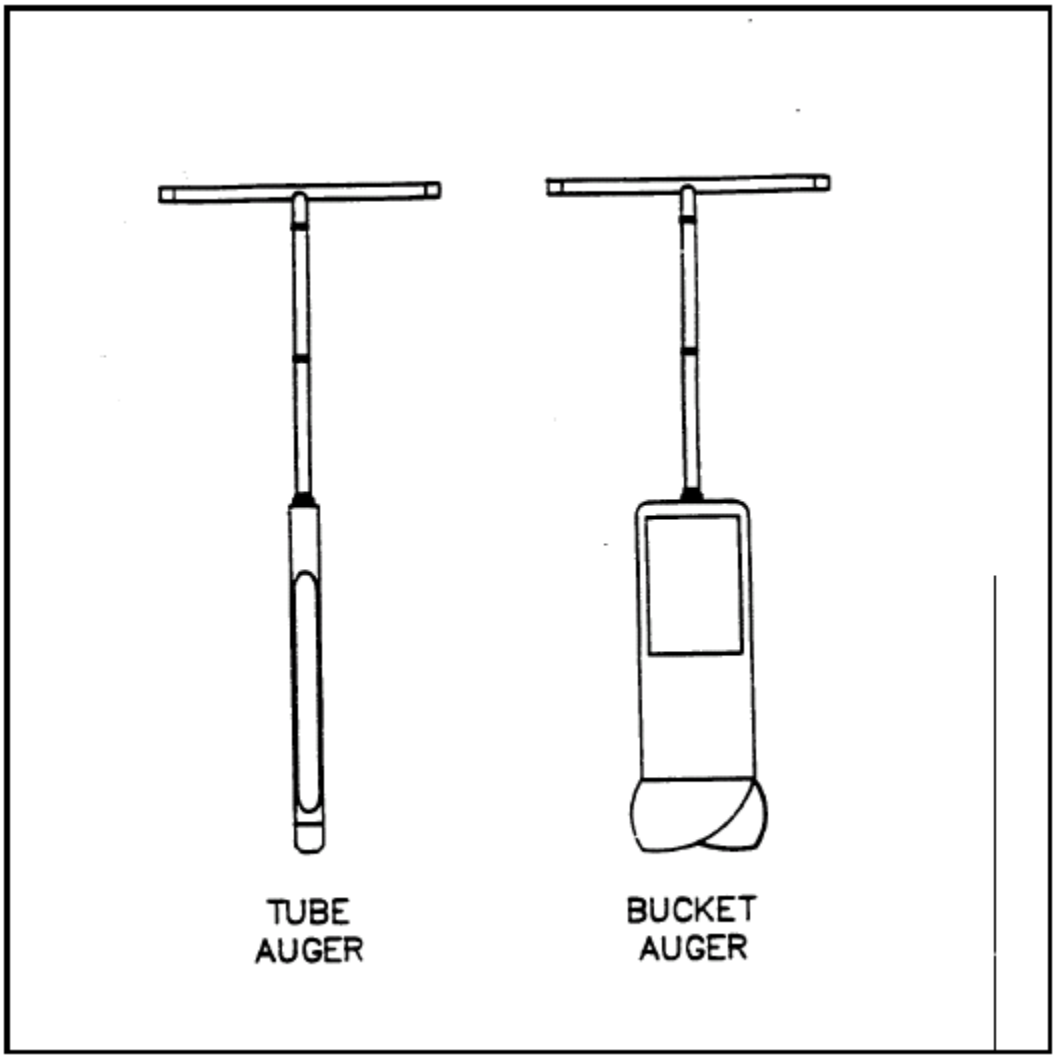


Figure 2. Sample Coring Device

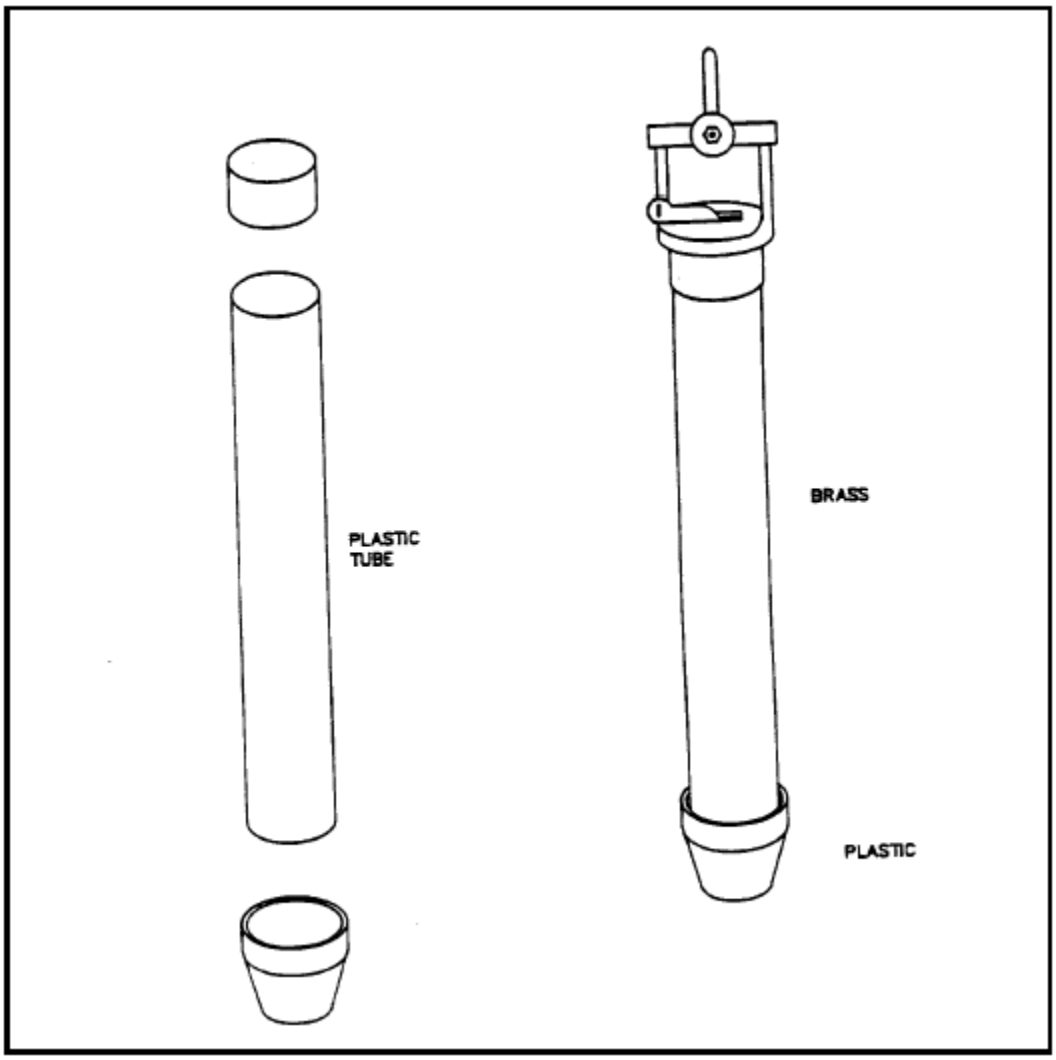
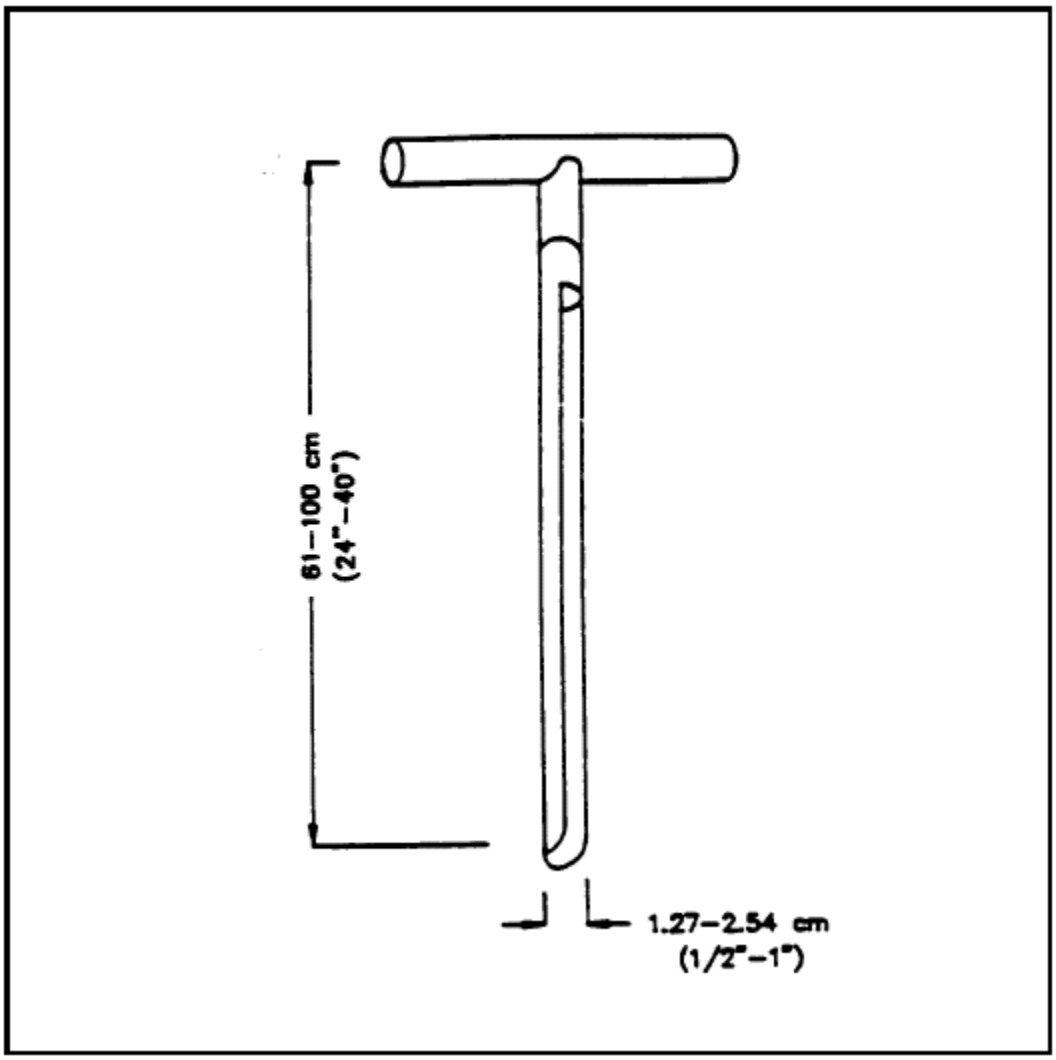


Figure 3. Sampling Trier



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- United States Environmental Protection Agency Environmental Response Team (2000), Standard Operating Procedures: Soil Sampling, SOP 2012, Rev. 0.0, pp. 1-13, dated 02/18/00.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP2001 Identification and Description of Soils in the Field Using Visual-Manual Methods
- OP2005 Test Borings, Sampling, Standard Penetration Testing and Borehole Abandonment
- OP2026 Exploratory Test Pits
- OP3001 Preservation and Shipment of Environmental Samples
- OP3004 Stream Sediment and Wetlands Soil Sampling
- OP3026 Chain of Custody

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APPENDIX C
FORMS

- Form 3001 Sampling Labels (Environmental)
- Form 3002 Chain of Custody (Electronic)
- Form 3003 Chain of Custody (Field)
- Form 3004 Sampling Record

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APPENDIX D
GLOSSARY

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OPERATING PROCEDURE: OP3003A

SOIL INVESTIGATION AND SAMPLING PROCEDURES

LEVEL II (Interim)

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.1	RWS 04/05/08	MDK 06/04/08	HJC 06/06/08		

Total Pages: 15

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OPERATING PROCEDURE: 3003A

SOIL INVESTIGATION AND SAMPLING PROCEDURES

1. PURPOSE

The following procedures are an addendum to Haley & Aldrich Operating Procedure 3003 – Surficial Soil Sampling.

The purpose of this Operating Procedure (OP) is to describe the procedures for the collection of representative samples of surficial soil. The procedures are intended specifically to minimize alteration of samples during collection. Surficial soil samples as referenced herein mean soils or soil-like material located less than 6 feet below ground surface which may contain quantities of contaminants.

Refer to Haley & Aldrich Operating Procedure OP3000 for General Environmental Field Procedures and Protocol, including procedures for decontamination of sampling equipment and/or containers.

Refer to OP3001 for Operating Procedures on Preservation and Shipment of Environmental Samples.

Refer to OP3004 for Operating Procedures on Stream Sediment and Wetlands Soil Sampling.

Refer to OP3006 for Operating Procedures on Subsurface Soil Sampling for Chemical Analysis.

Haley & Aldrich (H&A) personnel are to use the techniques in OP3003 to collect surficial soil samples. These operating procedures may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

2. EQUIPMENT AND SUPPLIES

The following is a general list of equipment necessary for soil sample collection:

Required:

1. Site map(s)/plan(s)
2. Safety equipment, as specified in the site-specific Health and Safety Plan
3. Field Log book
4. Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
5. Plastic or stainless steel spoons and/or wooden tongue depressors
6. Appropriate size sample containers

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7. Plastic zip lock bags
8. Sample Labels
9. Chain of Custody records and custody seals
10. Sampling Record Form (H&A Form 3004)
11. Cooler(s)
12. Ice
13. Decontamination supplies/equipment

Sampling equipment may include one or more of the following:

1. Stainless steel trowel(s) or scoop(s)
2. Stainless steel spade or shovel
3. Bucket auger
4. Bit auger
5. Continuous flight (screw) auger
6. Post-hole auger
7. Extension/drill rods
8. T-handle
9. Core sampler
10. Sampling trier
11. Thin wall tube sampler
12. Split spoons
13. Vehimeyer soil sampler outfit
14. Tubes
15. Points
16. Drive head
17. Drop hammer
18. Puller jack and grip
19. Backhoe
20. Telescopic mechanical sampling arm (aluminum poles)
21. Stainless steel sampling beaker

Optional:

1. Tape measure
2. Survey equipment or global positioning system (GPS) to locate sampling points
3. Survey stakes or flags
4. Camera and film
5. Plastic sheeting or cover

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3. PROCEDURE

Decontaminate equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Disposed of drill cuttings as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

3.1 Preparation

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
- Obtain necessary sampling and monitoring equipment.
- Decontaminate or pre-clean equipment, and ensure that it is in working order.
- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
- Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.
- Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator prior to soil sampling, and utility clearance should always be confirmed before beginning work.

3.2 Presampling Observations, Notes and Required Entries

The information listed below will be recorded in a project Field Log book and a Sampling Record Form. Haley & Aldrich Form 3004- Sampling Record is referenced in Appendix C. The following list of measurements and observations represent a minimum requirement for soil samples:

- Sampling Location Number
- Time
- Date Collected

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- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory) to receive samples
- Description of Sample Location with Sketch or Map
- Latitude/Longitude
- Sample Depth (i.e., distance in feet from ground surface)
- Photograph Number and Roll Used (if applicable).
- Observable Physical Characteristics
  - Odor
  - Color
  - Density, Consistency, etc.
  - Layering
  - Other
- Evidence of Stressed Vegetation or Wild Life in Area where Sample was taken
- Ambient Weather Conditions during Sampling
  - Air Temperature
  - Sky Condition
  - Recent Precipitation or Drought
- Samples Collected (enter all sample numbers collected at this location)

3.3 Surficial Soil Sampling by Manual Methods

The field procedures presented in this section will be used to obtain representative samples of surficial soil. The procedures are intended specifically to minimize alteration of samples during collection. Surficial soil samples as referenced in this section mean soils or soil-like material located less than six feet below ground surface which may contain concentrated quantities of contaminants.

3.3.1 Soil/Peat Sampling in Wetlands by Russian Peat Corer

The Russian peat corer is an open chambered instrument used to collect undisturbed soil samples. The side-filling corer is inserted into the sediment in the closed position to the desired depth. Once at the desired depth, the corer is rotated and the sample stored within the core. The following steps outline the procedure for using the Russian peat corer.

1. Don health and safety equipment (as required by the Health and Safety Plan).

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2. Sample locations and analyses will be selected with respect to specific site conditions.

3. Identify sampling location in field notebook along with other appropriate information.

4. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'

5. Manually insert the bottom point of the Russian peat corer with the blunt edge of the core tube turned against the cover plate to prevent sediment from entering the tube during advancement. If the soil is highly consolidated or otherwise hard to penetrate, a slide hammer can be used to aid in driving the sampler.

6. When the Russian peat corer is driven to the required depth, turn the core tube clockwise 180 degrees allowing to tube to rotate and allowing the sharp edge to cut through the sediment longitudinally.

7. Pull up the corer and retrieve the sample by turning the core tube counterclockwise. The sample will be exposed on the core cover plate.

8. Describe physical characteristics of the soil in accordance with Haley & Aldrich Operating Procedure OP2001 – Identification and Description of Soils in the Field and Using Visual-Manual Methods.

9. Collect soil sub-samples from extracted cores and process as described in Haley & Aldrich Operating Procedure 3006- Procedures For Subsurface Soil Sampling for Chemical Analysis.

3.3.2 Soil Penetration Test (SPT) by Peat Probe/Rod

The Standard Penetration Test (SPT) is a measure of the penetrative resistance of soils. This test (ASTM D4544) investigates the resistance of a peat layer to penetration by a driven rod. The thickness of the peat layer will be determined by abrupt increase in the resistance which marks the rod hitting the underlying soil layer. The standard graduated steel rod has a diameter of 9.5 +/- 1.0-mm diameter and 1.0 or 1.2-m in length with the option of adding on additional lengths of rod to extend the testing depth. The standard procedure for SPT by peat probe is as follows:

1. Don health and safety equipment (as required by the Health and Safety Plan).

2. Sample locations and analyses will be selected with respect to specific site conditions.

3. Identify sampling location in field notebook along with other appropriate information.

4. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'

5. Align the rod vertically

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6. Penetrate the peat with the rod by pushing or diving. Add sections to the rod with increasing depth

7. Measure the thickness of the peat when the resistant to penetration of the rod increases sharply owing to the resistance of the material underlying the peat. It may be possible to hear the scraping of the rod in the underlying soil

8. Pull up the rod and inspect the rod for evidence that mineral material was encountered

9. Record the lateral position of the sounding

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APPENDIX A
REFERENCES

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APPENDIX B
FORMS

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SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

Weather _____ **Temperature** _____

Ground surface Conditions ☐ Dry ☐ Wet ☐ Damp ☐ Standing Water ☐ Snow (_____in) ☐ Other_____

Comments _____

SOIL SAMPLING AND SURFACE WATER SAMPLING INFORMATION

Sample No.	Location	Depth (ft)	Time	Sample Description	Sampling Device	Cleaning Prodedure	Container Type

General Comments: (ie: field filtrations, persons communicated with at site, etc.)

Form 3004

OPERATING PROCEDURE: OP3004

SEDIMENT AND WETLAND SEDIMENT/SOIL SAMPLING

LEVEL II (Interim)

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PREPARATION AND APPROVALS

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Ver. 0.1	ABD: 3/04/04	RVE: 8/09/04			
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Ver. 0.3	HJC: 2/03/2011	RAS 03/09/2011			RAS/March 2011

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Haley & Aldrich categorizes Operating Procedures by Levels, to facilitate their preparation and use. The Levels are defined as follows:

Level III - miscellaneous procedure from a variety of sources; not sanctioned as appropriate for any particular use by the company but provided on the Intranet as a potential resource when current company operating procedure is not available; (e.g., project-specific procedure submitted by staff member, old procedures, ASTM procedures, etc.)

Level II - in-progress or draft procedure, typically written in the standard format; in various stages of review; has not yet been sanctioned an official operating procedure but could be suitable for project-specific application upon verification by project staff

Level I - company sanctioned operating procedure suitable for use on projects

The company encourages and welcomes feedback regarding its Operating Procedures. If staff members have recommendations related to the use or improvement of any procedures, or suggestions for developing new procedures, please contact the Boston Office Field Services Manager or a Service Delivery Leader.

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OPERATING PROCEDURE OP3004

SEDIMENT AND WETLAND SEDIMENT/SOIL SAMPLING

1. PURPOSE

The purpose of this Operating Procedure (OP) is to describe the procedures for the collection of representative stream sediment and wetland soils samples. Sediment and wetland sediment/soil as referenced herein mean deposited sediment or soil-like material below both flowing and standing surface water. Wetlands are lands transitional between terrestrial and aquatic systems where the water table is typically at or near the surface, or the land is covered by shallow water. Wetland sediment/soils exhibit features characteristic of the wetland conditions of saturation, flooding, or ponding, which must occur long enough during the growing season to develop anaerobic and reducing conditions in the upper horizons of the soils. Hydric soil indicators are currently termed "redoximorphic" features of the soils, a term used to replace descriptions of "soil mottling" due to wetness. Wetland sediment/soils include organic and mineral soils ranging from poorly drained to well drained.

Stream sediment and wetland sediment/soil samples may contain contaminants that are insoluble in water, persistent in the environment, relatively immobile in the soil, and/or exhibit low volatility. Accordingly, the procedures are intended specifically to minimize the alteration of samples.

Refer to OP3000 for General Environmental Field Procedures and Protocol, including procedures for decontamination of sampling equipment and containers. Refer to OP3001 for Operating Procedures on Preservation and Shipment of Environmental Samples.

Refer to OP3003 for Operating Procedures on Surficial Soil Sampling, and OP3007 for Operating Procedures on Surface Water Sampling.

Haley & Aldrich (H&A) personnel are to use the techniques in OP3004 to collect stream sediment and wetland sediment/soil samples. These operating procedures may be varied or changed as required, depending upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

2. EQUIPMENT & SUPPLIES

Required:

1. Site map(s)/plan(s), including Work Plan (WP), Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), or other applicable project planning document
2. Safety equipment, as specified in the site-specific Health & Safety Plan (HASP)
3. Field book and/or field data sheets (H&A Sampling Record Form #3004)
4. Tape measure (100 ft)
5. Global Positioning System (GPS) unit to document station locations

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6. Stainless steel, plastic, or other appropriate composition bucket, bowl or pan
7. Appropriate environmental sample containers (4 oz., 8 oz., or wide mouth glass jars, with Teflon lined lids)
8. Plastic zip-lock bags
9. Sample labels
10. Chain-of custody records and custody seals
11. Cooler(s)
12. Ice
13. Decontamination supplies/equipment

Sampling equipment may include one or more of the following:

1. Stainless steel spade or shovel
2. Stainless steel trowel(s) or scoop(s)
3. Bucket auger with thin-wall tube attachment (stainless steel)
4. Bit auger with thin-wall tube attachment (stainless steel)
5. Thin-wall tube sampler
6. Split-spoon sampler
7. Gravity corer
8. Ponar grab sampler
9. Ekman dredge
10. Lexan® tubes
11. Peristaltic pump
12. Russian peat corer
13. Piston corer

Optional:

1. Camera and film
2. Survey equipment or global positioning system (GPS) to locate sampling points
3. Survey stakes, flags or buoys and anchors
4. Nylon rope
5. Plastic sheeting or cover

3. PROCEDURE

Decontaminate equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Disposed of drill cuttings as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

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3.1 Preparation

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
- Obtain the necessary sampling and monitoring equipment.
- Obtain the necessary personal protection equipment (PPE) in accordance with the site-specific HASP.
- Decontaminate or pre-clean equipment, and ensure that it is in working order.
- Prepare schedules and coordinate staff, client and regulatory agencies, if appropriate.
- Perform a general site survey prior to site entry in accordance with the site-specific HASP.
- Use stakes, flagging, or buoys to identify and mark all sampling locations within wetlands. Verify and/or document locations using calibrated GPS unit. Use GPS to locate sediment stations and deploy anchor(s) alongside or downstream of intended sampling locations. Occupy river stations in an upstream sequence whenever possible. All wetland staked locations and in-water sampling areas should be utility-cleared by the property owner or the On-Scene-Coordinator prior to sampling. Utility clearance should always be confirmed prior to beginning work.

3.2 Pre-sampling Observations, Notes and Required Entries

Field measurements and observations should be recorded in the field at the time of sampling. A Sampling Record Form is included as Appendix C. Typically required information is listed below and will be recorded in a project Field Log Book or Sampling Record Form, whichever is more appropriate:

- Sample location number
- Date collected
- Time collected
- Samplers (names of individuals who actually collected the sample)
- Sample destination (Analytical laboratory) to receive samples
- Description of sample location with sketch or map (i.e. sludge lagoon, stream, wetland, etc.)
- GPS coordinates of sampled locations
- Sample depth (i.e. distance in feet from ground surface)
- Depth of water above sample (distance in feet from top of water surface to top of sediment)
- Indicate photograph number and roll used (if applicable)

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- Observable physical characteristics
  - Odor
  - Color
  - Texture
  - Layering
  - Other

- Samples collected (enter all sample numbers colleted at this location)

3.3 Sampling Procedures

- After all entries are completed, label and number required sample bottles. Fill our label in indelible ink and carefully and clearly address all categories and parameters.

- Sampling instructions have been provided for various optional sampling devices which may be used to collect sediment and wetland sediment/soil samples. Select the prescribed sampling device, or an appropriate alternative to meet project objectives. Any change in sampling device should be cleared first with an authorized project team member.

- Decontaminate sampling device and/or container immediately prior to and following its use according to Operation Procedure OP#3000 – General Environmental Field Procedures and Protocol.

- When collecting sediment samples that may consist of very soft, high water content or flocculent-like sediment (e.g. lacustrine setting, low energy environments), efforts should be made to minimize disturbance during sampling. Appropriate measures should also be taken during sub-sampling (e.g., keeping sampler upright, carefully draining overlying water by drilling small holes in the coring tubes at the top of the cohesive sediment layer) to minimize loss and/or disturbance of "flocculent" fine-grained particles.)

- Sub-sampled sediment samples must be homogenized or when called for, composited and homogenized, before placing in containers. Homogenization is appropriate for most chemical analytical parameters, including but not limited to: metals, pesticides/PCBs, herbicides, semi-volatile organic compounds (SVOCs). However, samples for volatile organic compounds (VOCs) should not be homogenized prior to adding to VOC sample containers.

- Because sediment samples may be stored frozen to extend holding time, sample containers should be filled approximately two-thirds to three-quarters of their capacity, depending on their water content. For high-moisture sediments, jars should be filled no more than two-thirds full. Specific instructions will be should be provided by the analytical laboratory for VOC samples. Refer to a project WP, FSP, or QAPP for required sample volumes and appropriate containers for given analyses. Only VOC sample containers should contain any laboratory-provided preservatives. An additional, unpreserved VOC sample is required for moisture content of the unhomogenized sediment. All container caps will include an inner Teflon septa or lining and must be tightly secured. Refer to OP#3001 for operating procedures on sample handling and preservation.

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- Check for appropriate liner in cap and secure cap tightly. Store the samples with ice in a cooler, following these sealing and packing instructions:
  - Ice will be placed in plastic zip-lock bags to contain ice and water. Sample containers will be adequately layered in bubble wrap to prevent breakage. Samples will be positioned upright in the cooler to prevent breakage, and samples will be stored and shipped at 4°C.
  - All VOC vials will be sealed in a thick or heavy duty plastic zip-lock bag, bubble wrap, or foam VOC vial holders provided by the laboratory.
  - Check to make sure all appropriate information is in the Field Log Book or the Sampling Record Form and Chain-of-Custody document using indelible ink.
  - If samples are to be shipped to a laboratory for analysis, a Chain-of-Custody record, custody seals, "Fragile" markers, and reinforced nylon tape will all be properly affixed to or on the sample cooler. If samples are to be delivered to the lab by courier, only the Chain-of-Custody record is required.

    - Chain-of-Custody Record – enclose in a large zip-lock bag and tape to inside of top of cooler lid.

    - Custody Seals – place custody seal over cooler gasket separating cooler lid from the cooler bottom at all sides except the hinged location.

    - Nylon Tape – tape completely around cooler at two locations. Tape reinforcement will prevent cooler from opening if the lid locking mechanism fails.

    - Fragile Markers – fragile markers and upright stickers will be affixed to each side of the cooler.

3.4 Sampling Device Instructions

The sampling devices presented below may be used to collect sediment and wetland sediment/soil samples within several feet of the ground surface. The specific procedures and equipment for sediment and wetland sediment/soil sampling may be specified in the project WP, FSP, QAPP or related document. The most appropriate device for a specific sampling program may be based on the depth of water at a sampling location, the physical characteristics of the sediment to be sampled, and/or site conditions (accessibility, type of soil or sediment, desired depth of samples, etc.).

3.4.1 Trowels, Hand Scoops, Spades & Shovels

This method is probably the simplest, most expeditious, direct method for sampling accessible sediment. These devices are easy to operate, decontaminate, and work well for sampling low-mositure, exposed (e.g., intertidal or wetland surface) locations. Stainless steel or rigid non-contaminating plastic are the preferred material for these tools.

Surface material is sampled to the specified depth using a stainless steel or plastic scoop, trowel, spade or shovel. In wetlands, vegetation may or may not be considered part of the sediment/soil sample; any such distinction must be discussed and cleared with an authorized project team leader, unless addressed in the project WP, FSP, or QAPP. For the purpose of this method, surface sediment or wetland sediment/soil is considered to range from 0 to 6 inches in depth and a shallow aqueous layer is

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considered to range from 0 to 12 inches in depth. Scoops or trowels can be disruptive to the liquid/sediment interface and may cause substantial alteration of the sample. Thus, these methods are limited in application to bulk surface "grab" sampling.

Procedures for Use

1. Carefully remove the top layer of sediment or wetland sediment/soil to the desired sample depth with a cleaned, stainless steel spade, shovel, trowel or scoop. In the case of sludges exposed to air, it may be desirable to remove the first 1-2 centimeters of material prior to collecting the sample.

2. Using a cleaned, stainless steel scoop or trowel, collect the desired quantity of sediment.

3. If compositing a series of grab samples, use a stainless steel mixing bowl or Teflon tray for mixing.

4. Surface water should be decanted from the sample or the composition mixing bowl prior to sealing or transfer to the sample container. Care should be taken to retain the fine sediment fraction during this procedure.

5. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a laboratory-supplied cut-off syringe or Encore® sampler. Place the remainder of the sample into a stainless steel, plastic, or other appropriate compositing container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, place the sample into the appropriate labeled containers.

6. Check that a Teflon liner is present in cap if required. Secure cap tightly.

7. The chemical preservation of solids is generally not recommended, except in the case of VOC samples. Refrigeration is usually the best approach for solid samples supplemented by minimal holding time. Sediment samples may be stored frozen to extend holding times up to one year for most analyses.

3.4.2 Bucket and Bit Augers with Thin-Wall Tube Attachment

This method should only be attempted on very consolidated sediment absent overlying surface water, such as within an intertidal zone during low tide, or for wetland sediment/soil. Collection of a sub-surface sediment or wetland sediment/soil sample can be accomplished with a system consisting of a bucket or bit auger, a series of extensions, a "T" handle, and a thin wall tube attachment (Figure 1). The use of additional extensions in conjunction with a bucket auger can increase the sampling depth from which sediment can be collected.

A cleaned bucket or bit auger is used to bore a hole to the desired sample depth and then is withdrawn. When using a bucket auger, the soil sample must be removed from the bucket with a cleaned, stainless steel spoon or trowel. The bucket auger can collect a large sediment sample (up to 24 ounces) but is limited in penetrating depth to approximately two feet under ideal conditions. The bit auger has a greater penetrating depth (up to six feet) but collects a lesser volume of sediment. The bit auger tip is removed

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from the auger when the desired sampling depth is reached and replaced with the thin wall tube attachment. The system is then lowered back into the cored hole and driven into the sediment at the completion depth. The corer is then withdrawn and the sample collected from the thin wall tube sampler. The various depths represented by the core are homogenized for the appropriate depth. This equipment can be used in a wide variety of sediment and wetland sediment/soil conditions. This equipment is inexpensive, easy to operate, and generally works well to sample most sediments.

Procedures for Use

1. Attach the cleaned auger head to the required length of extensions, then attach the "T" handle to the upper extension.

2. Clear the area to be sampled of any surface debris (twigs, rocks, litter). It may be advisable or necessary to remove the first 8 to 15 cm of surface sediment for an area approximately 15 cm in radius around the sampling location.

3. Insert the bucket auger or bit auger into the sediment at a 0° to 20° angle from vertical. This orientation minimizes spillage of the sampler upon extraction from the sediment.

4. Begin drilling by rotation of the "T" handle, to cut a core of sediment. If desired sample location is at a depth, periodically remove accumulated sediment in the auger and place on a plastic sheet spread near the hole. This prevents accidentally brushing loose material back down the borehole when removing the auger or adding extensions. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.

5. After reaching the desired depth, slowly and carefully remove auger from boring.

6. If a bucket auger is being used, remove soil sample with cleaned, stainless steel spoon or trowel.

7. If a bit auger is being used, remove auger tip from the extension rods and replace with cleaned thin wall tube sampler. Install proper cutting tip.

8. Carefully lower the tube sampler down the borehole. Gradually press the tube sampler into the sediment. Take care to avoid scraping the borehole side. Avoid hammering the drill rods to facilitate coring, as the vibrations may cause the boring walls to collapse.

9. Remove the tube sampler and the unscrew drill rods.

10. Remove the cutting tip and remove the core from the device.

11. Discard the tope of the core (approximately 1 inch), as this represents material collected before penetration of the layer of concern. Transfer the remaining sample or a specified aliquot of sample into an appropriate sample container.

12. If VOC analysis is to be performed, transfer the sample into an appropriate methanol preserved, labeled container with a stainless steel spoon, wooden tongue depressor or equivalent, and secure the cap tightly.

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13. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and repeat previous steps, making sure to decontaminate the auger and tube sampler between samples.

14. Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed sediment or wetland soil material.

3.4.3 Hand Held Corer

This device consists of a "T" handle and cylindrical core tube (Figure 2). The device is equipped with a check valve at the top to prevent washout during retrieval through overlying water, if applicable, and a nosepiece at the bottom to help contain the sample. This device can be used in a wide variety of sediment conditions. Hand corers can also be fitted with brass or polycarbonate plastic liners.

Procedures of Use

1. Inspect the corer for proper pre-cleaning.

2. Press the corer in with a smooth, continuous motion.

3. Twist the corer, and then withdraw the corer in a single smooth motion.

4. Remove the nosepiece and withdraw the sample into a stainless steel, plastic or other appropriate homogenization container.

5. Transfer the sample into an appropriate sample container with a stainless steel spoon, wooden tongue depressor or equivalent.

6. Check that a Teflon liner is present in the cap, if required. Secure the cap tightly.

3.4.4 Gravity Corer (with Stabilizing Fins)

This method consists of a cylindrical metal tube with a detachable tapered nosepiece on the bottom and a ball or check valve located on the top. The device may have stabilizing fins to maintain vertical positioning as the device is moving through a liquid. The tapered nosepiece facilitates cutting and reduces core disturbances during penetration. Gravity corers are capable of collecting benthic sediment samples ranging from 15 to 30 inches depending upon the density of the sampled material and weight of the device. This device works well to collect sediment samples in a marine environment or from a low velocity stream, pond or river. Some gravity corers have attachable weights and may accept plastic or brass liners.

Procedures for Use

1. Attach a pre-cleaned corer to the required length of a sample line. Solid braided 5-millimeter (3/16 inch) nylon line is sufficient; 20-millimeter (3/4 inch) nylon, however, is easier to grasp during hand hoisting.

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2. Secure the free end of the line to a fixed support to prevent accidental loss of the corer.

3. Lower the corer through the water column to the top of sediment; push the corer manually through the sediment to the desired depth, or refusal.

4. Retrieve the corer slowly using a smooth, continuous lifting motion. Do not bump the corer as this may result in some sample loss.

5. Remove the nosepiece from the corer and slide the sample out of the corer into a stainless steel, plastic or other appropriate homogenization container. For vertical sub-sampling, the core tube may be cut along its entire length and opened to facilitate observation of lithology.

6. When subsampling for homogenization and chemical analysis, scrape the outer layer of sediment in contact with the core tube prior to homogenizing. This outer layer may be used for grain size analysis, which is not compromised by cross-contamination.

7. Transfer the homogenized sample into an appropriate sample jar with a stainless steel spoon, wooden tongue depressor or equivalent.

8. Check that a Teflon liner is present in the cap, if required. Secure the cap tightly.

3.4.5 Ponar Grab Sampler

Collection of surface sediment can be accomplished with a system consisting of a remotely activated device (Ponar Grab or Ponar Dredge) and a deployment system. The Ponar Grab is a weighted, clamshell-type grab sampling device with jaws that are lever- or spring-activated. This technique consists of manually opening the sampler and latching it in place, then slowly lowering the Ponar Grab sampler to the surface of the sediment by use of nylon rope, cable, or extended handle. When the tension in the drop line is released and a lifting action is applied to the lowering line, the level system snaps the clamshell device closed. The mechanism is activated, and the device entraps sediment in spring loaded or lever operated jaws.

This device is used to collect consolidated fine- to coarse-textured sediment The sampler is only capable of collecting a shallow surface sediment sample (from 1 to 4 inches), depending on the dimensions of the sampler.

<u>Procedures for Use</u>

1. Attach a sturdy nylon rope or steel cable to the ring provided on top of the pre-cleaned Ponar Grab sampler. Solid braided 5-millimeter (3/16 inch) nylon line is sufficient; 20-millimeter (3/4 inch) nylon, however, is easier to grasp during hand hoisting.

2. Measure and mark the distance to the sediment surface on the sample line. A secondary mark, slightly shallower will indicate proximity, so that the lowering rate can be reduced, this preventing unnecessary bottom disturbance.

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3. Tie the free end of the sample line to a fixed point to prevent accidental loss of sampler.

4. Arrange the Ponar sampler with the jaws latched in the open position, setting the trip bar so the sampler remains open when lifted from the top. If the sampler is so equipped, place the spring loaded pin into the aligned holes in the trip bar. From this point on, support sampler by its lift line or the sampler will be tripped and the jaws will close.

5. Begin lowering the sampler until the proximity mark is reached, or to a point approximately 2 inches above the sediment.

6. Drop the sampler to the sediment. Slack on the line (several centimeters) will release the trip bar or spring loaded pin. In strong currents more slack may be necessary to release mechanism. Pull up sharply on the line closing the sampler.

7. Slowly raise the sampler to the surface and slowly decant any free liquid through the screens on the top of the sampler. Care should be taken to retain the fine sediment fraction during this operation.

8. Open the sampler and transfer the sediment to a stainless steel, plastic or other appropriate composition container. Ensure that non-dedicated containers have been adequately decontaminated. If necessary, continue to collect additional sediment samples until sufficient material has been secured to fulfill laboratory requirements. Thoroughly homogenize and then transfer the sediment to sample containers appropriate for the analysis requested. Samples for VOCs must be collected directly from the bucket before homogenization to minimize volatilization of contaminants.

Check for a Teflon liner in the cap, if required, and secure cap tightly

3.4.6 Thin-Tube Hand-Held Sampling Trier

The system consists of a trier, a long hollow cylindrical tube with a slot extending almost its entire vertical length, and a “T” handle (Figure 3). The trier is driven into the sediment or wetland sediment/soil to be sampled and used to extract a core sample from the appropriate depth. The tip and edges of the tube are sharp to allow the trier to cut a core by rotation of the “T” handle once it is completely pushed-down or manually driven to the depth of collection. Triers range from approximately 20 to 60 inches in length and from approximately 0.5 to 1 inch in diameter.

Procedures for Use

1. Insert the cleaned trier into the sediment or wetland soil at a 0 to 45° angle from horizontal. This orientation minimizes spillage of sample from the sampler. Extraction of sample might require tilting of the containers.

2. Rotate the trier once or twice to cut a core of material.

3. Slowly withdraw the trier, making sure the slot is facing upward.

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4. Transfer the sample into an appropriate labeled container with a stainless steel scoop, wooden tongue depressor or equivalent and secure caps tightly.

3.4.7 Telescopic Mechanical Sampling Arm

The device consists of an aluminum pole approximately 1 to 2 inches in diameter divided into three 4-foot sections. Attached to the end of the pole is a stainless steel sampling beaker (usually with an 18-ounce capacity). The pole is capable of telescoping from 4 to 12 feet. This mechanical sampling arm is used to collect sediment or wetland sediment/soil samples from excavations, or water bodies with high banks. It allows a sample to be collected from a location that would otherwise be difficult to access.

Procedures of Use

1. Attach the cleaned, stainless steel beaker to the end of the pole either by tightening a clamp or wing nuts.
2. Make sure your feet are safely and securely positioned.
3. Telescope the pole to the required length.
4. Lower the pole end into the excavation or otherwise difficult to reach sediment or wetland soils.
5. Collect the sample.

Remove the sample from the beaker with a cleaned, stainless steel scoop, trowel or new wooden tongue depressor.

3.4.8 Sediment Sampling with Lexan® Coring Tube

This method consists of a coring tube that samples soft sediments to depths of approximately 1-2 meters. Sampling with a Lexan® coring tube extracts an undisturbed sediment sample which allows the study of the sediment-water interface. Using a vacuum pump allows the tube to be capped without disturbing the sample. The process described below can be facilitated if necessary by creating a sharp edge on the coring tube prior to advancing the tube into the sediment. The sharp edge will help advance the coring tube.

Procedures for Use

1. If using a boat to access the sampling location, anchor the boat if necessary to remain within a radius of approximately 1-5 meters from the originally identified sample location.
2. Identify the proposed sample location in the field notebook along with other appropriate information collected during sediment sampling activities.
3. Measure the total depth of water with a weighted tape.
4. At each sample location, lower a section of Lexan® tube until it reaches the top of the sediment.

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5. Push the Lexan®. tube into the sediment by hand, or using a core driver block, to the desired depth, or until refusal. If the procedure is being performed to determine sediment depth (probing), a calibrated rod may be used in place of the Lexan® tube. If the procedure is being performed to collect samples for laboratory analysis, continue with Step 5.

6. Drive the tube several more inches using a core driver block and measure the distance. This procedure is performed to obtain a "plug" at the bottom of the core and prevent the loose sediment from escaping.

7. Place a vacuum pump on top of the Lexan®. tube, or even a plastic core tube cap to create suction, which should prevent the sediments/plug from escaping.

8. Slowly pull the tube from the sediment, twisting it slightly as it is removed (if necessary).

9. Before the tube is fully removed from the water, place a cap on the bottom end of the tube while it is still submerged.

10. Keeping the tube upright, wipe the bottom end dry and seal the cap with duct tape and label. Measure the length of sediment recovered and evaluate the integrity of the core. If the core is not suitably intact, repeat coring procedure within 5 to 10 feet of the first location attempted.

11. While still keeping the core upright, use a hacksaw to make a horizontal cut in the tube approximately one inch above the sediment.

12. Re-cap the cut end of the tube, seal the cap with duct tape, and mark this end as "top".

13. Wipe the tube dry.

14. Slice tube open or push sediment from tube onto pre-cleaned aluminum foil; scrape the outer surface of the sediment core that was in contact with the coreing tube wall to prevent vertical smearing.

15. Sediment samples to be analyzed for volatile organic compounds (VOCs) will be transferred directly from the sample collection device to the sample containers.

16. All other surface sediment samples will be transferred to a stainless-steel mixing bowl for homogenization. Additional samples may be required to collect the volume of sediment specified in the study design. The mixing bowl should be covered with aluminum foil while additional samples are being collected to prevent sample contamination (e.g., from precipitation, splashing water). After a sufficient volume of sediment is transferred to the mixing bowl, homogenize the contents of the bowl using stainless-steel spoons until the texture and color of the sediment appears to be uniform.

17. After the sample is homogenized, distribute sub-samples to the various containers and preserve the samples.

18. Place filled sample containers on ice in a cooler.

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3.4.9 Piston Corer

The method of using a piston corer utilizes the general procedure as described above for using a Lexan® tube. The piston inserted into the core tube aids in maintaining suction to minimize loss of unconsolidated material from the bottom of the tube. Piston corers are typically used when undisturbed sediment samples at significant penetration depths are required.

Procedures for Use

1. If using a boat to access the sampling location, anchor the boat if necessary to remain within a radius of approximately 1-5 meters from the originally identified sample location.

2. As provided in the WP, FSP, or QAPP, determine how deep of a penetration is needed at the specific sampling location. Prepare the appropriate length of tubing to be able to achieve the desired penetration depth plus an additional couple of feet.

3. Run the line through the tubing and connect to the piston stopper. Insert the piston stopper approximately 0.5 inches from the end of the tube.

4. Attach the tubing to the piston core with provided clamps and/or other mechanism.

5. Slowly lower the tube/piston unit through the water column until it reaches the top of sediment. When the tube has reached the sediment, try to minimize movement of the tube therefore minimizing sediment disturbance. Tie off the line attached to the stopper to a permanent anchor on the vessel.

6. Drive the tubing into the sediment to the penetration depth required.

7. Remove the line and attach to the piston corer. Bring up tube and core and position horizontally on the boat or ground.

8. Immediately cap the open end of the tube. Remove piston corer from the tube and cap the other end.

9. After both ends are capped and properly secured, the core should be stored vertically to allow for the sediment to settle. Once settled, cut Lexan® tube where necessary to accommodate the size of the extracted core.

10. If the required depth was not reached and or there was not the acceptable retrieval. Redeploy the piston corer prior to capping the ends. There may be debris in the way of the tube and/or other hard objects that impede penetration. In the event that the desired penetration depth is not achieved, slightly change the sample location (within the 1-5 m radius of the original sample location). If the area continues to be problematic, contact an authorized project team leader.

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11. Once an acceptable core is extracted, capped and left to settle. Cut tube open and describe and sample from the core as described in Section 3.3.

3.4.10 Sediment Sampling in Wetlands with Russian Peat Corer

The Russian peat corer is a chamber-type instrument that collects an unconsolidated sediment/soil sample in wetlands. The side-filling corer is inserted into the sediment in the closed position to the desired depth. Once at the desired depth, the corer is rotated and the sample stored within the core. The following steps outline the procedure for using the Russian peat corer:

Procedures for Use

1. Manually insert the bottom point of the Russian Peat Corer with the blunt edge of the core tube turned against the cover plate to prevent sediment/soil from entering the tube during advancement. If the sediment is highly consolidated or otherwise hard to penetrate, a slide hammer can be used to aid in driving the sampler.

2. When the Russian Peat Corer is driven to the required depth, turn the core tube clockwise 180 degrees allowing to tube to rotate and allowing the sharp edge to cut through the sediment longitudinally.

3. Pull up the corer and retrieve the sample by turning the core tube counterclockwise. The sample will be exposed on the core cover plate.

4. Describe physical characteristics of the sediment/soil in accordance with H&A OP2001 – Identification and Description of Soils in the Field and Using Visual-Manual Methods.

5. Sub-sample and/or homogenize the sample for chemical analyses as described previously.

3.4.11 Sediment Sampling with Peristaltic Pump

The method of sediment sampling with a peristaltic pump consists of lowering tubing to a desired sampling location and using the peristaltic pump to extract the sediment from the bottom of the water body. This method of sediment sampling may be efficient for the collection of flocculent, unconsolidated sediments with very high water content.

Procedures for Use

1. If using a boat to access the sampling location, anchor the boat if necessary to remain within a radius of approximately 1-5 meters from the originally identified sample location.

2. Identify the proposed sample location ID in the field notebook along with other appropriate information collected during sediment sampling activities.

3. Measure the total depth of water using a weighted tape.

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4. Lower a new piece of Waterra tubing of sufficient length (potentially with weight added) to a depth 1-2 feet above measurement from step 3.

5. Initiate pump and purge 3 tube volumes. Deactivate pump, but do not allow backflow.

6. Lower tubing to a depth 6 inches above measurement from step 3.

7. Initiate pump, wait until flocculate 'floc' comes to end of line, then collect floc in a beaker. When sufficient volume is available, fill sample container.

8. Label each sample container with the following: date, time, sample location, and depth of sample.

9. Place samples in a cooler on ice.

10. After the sampling at a sample location is completed and the appropriate sample jars filled, decontaminate re-useable sampling equipment in accordance with the section entitled Decontamination. Discard Waterra tubing.

3.4.12 Sediment Sampling with Ekman Dredge

The method of sediment sampling with the Ekman dredge consists of slowly lowering the grab sampler, in the open position, through the water column to the sediment surface with a cable or nylon rope. Once the sampler has reached the top of sediment, the dredge buckets are released, collecting a surface grab sample (depth depending on the dimensions of the dredge bucket). The Ekman dredge can be used in water of various depths and can be released from a boat, or off-water from a pier or bridge. This type of sediment sampler is most efficient in waters with little to no current. reached the sediment dredge method is best employed on consolidated, fine textured sediments as well as soft sediments, such as silt, muck and sludge in water.

Procedures for Use

1. Once at the predetermined sample location, anchor the boat if necessary to remain within a radius of approximately 1-5 meters from the originally identified sample location.

2. Identify the proposed sample location ID in the field notebook along with other appropriate information collected during sediment sampling activities.

3. Measure the total depth of water using a weighted tape.

4. Thread a study nylon cable through the top bracket of the sampler.

5. Arrange the Ekman dredge sampler so that the jaws are in the open position and trip cables are positioned over the release studs. Take extra precaution to ensure that there is nothing in the way of the jaws during this step in the event of accidental deployment of the spring loaded jaw.

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6. Slowly lower the sampler over the side of the boat to a point just above the sediment surface. When the sampler hits the surface of the sediment, the field person should be able to feel the impact.

7. Raise the dredge 6 inches above sediment surface.

8. Trigger the jaw release mechanism by lowering a messenger down the line.

9. Raise the sampler back up through the water column keeping the sampler upright.

10. Open the flaps of the sampler to get access to the collected sediment. Estimate the sample volume and percent water by volume. Record on sampling sheet.

11. Label each sample container with the following: date, time, sample location, and depth of sample.

12. Place samples in a cooler on ice.

3.5 Chain-of-Custody Forms

All samples submitted to the contract analytical laboratory for analyses, will be accompanied by a Chain-of-Custody form. Appropriate Chain-of-Custody procedures will be followed at all times during a sampling event and subsequent transport to the contract analytical laboratory. Refer to OP3026 for operation procedures on completing a Chain-of-Custody form and Chain-of-Custody procedures.

3.6 Decontamination

Sediment and wetlands soil sampling equipment brought into actual contact with a laboratory sample, other than sample containers, will be cleaned prior to and between each use according to Operating Procedure OP3000 – General Environmental Field Procedures and Protocol. After decontamination, the equipment will be wrapped in aluminum foil and placed on clean racks off the ground until it is used.

3.7 Quality Assurance/Quality Control

To assure quality of field sampling procedures, the following procedures must be followed:

- All data must be documented on field data sheets or within site logbooks.

- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in a Site work plan or related document. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

Additional, project-specific collection of field quality control samples (e.g., field duplicates, equipment blanks, trip blanks, etc.) should be specified in the project WP, FSP, or QAPP. Project-specific QA/QC requirements supersede procedures described herein for that particular project.

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Figure 1:
Sampling Augers

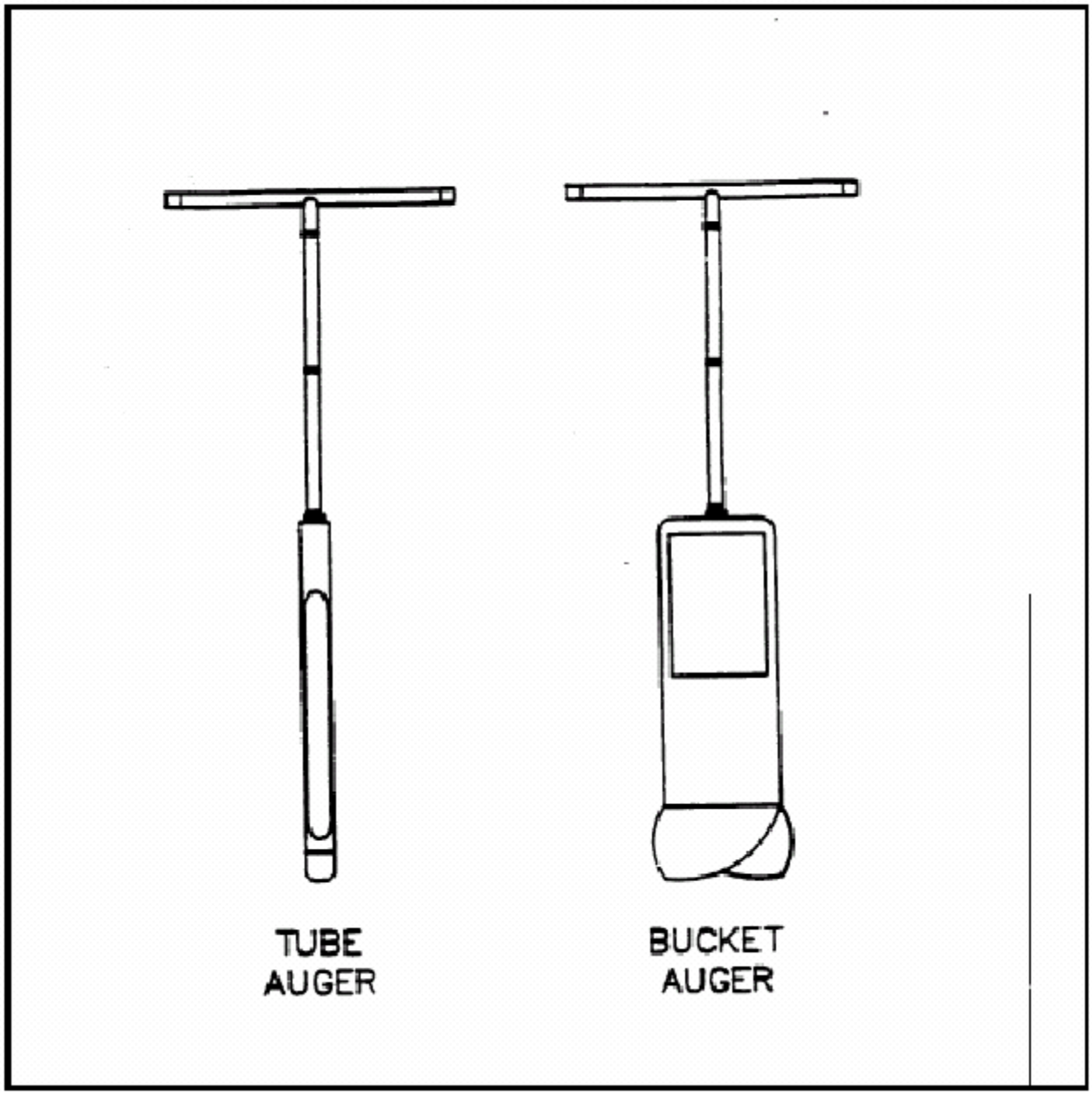


Figure 2:
Sample Coring Device

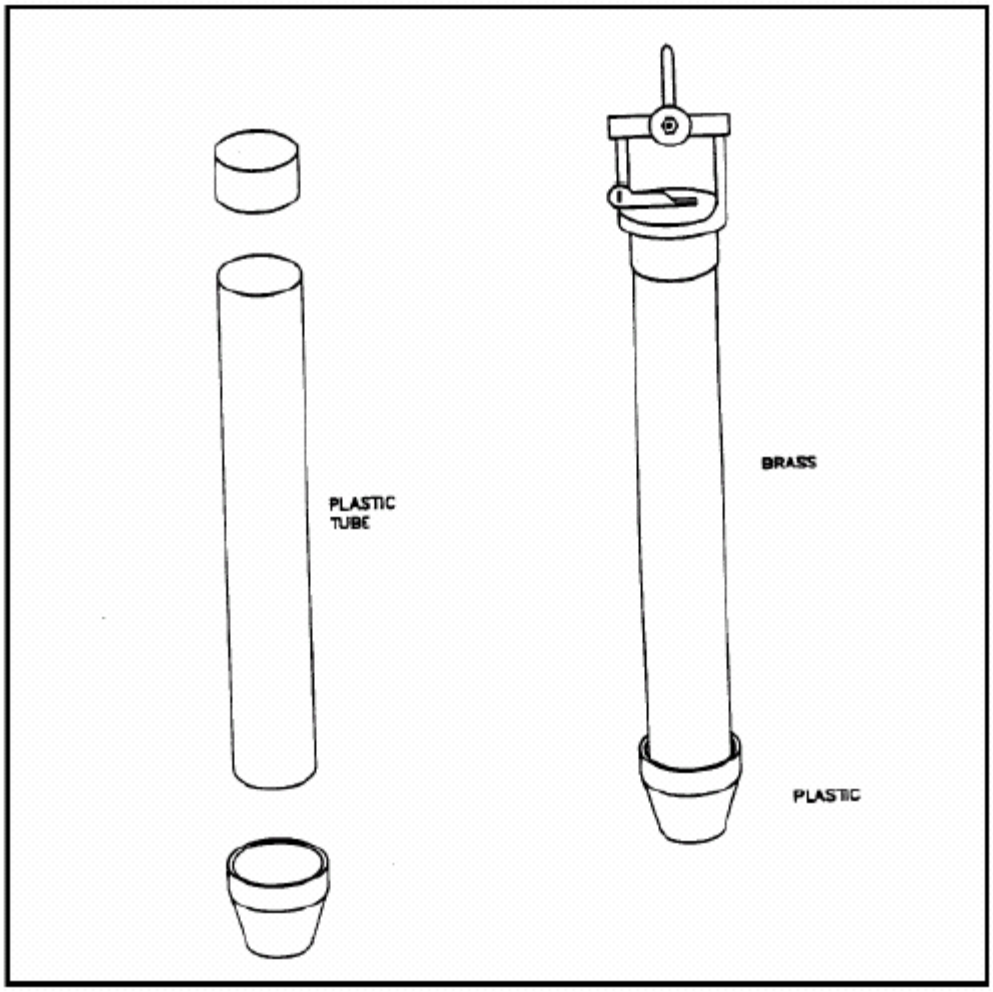
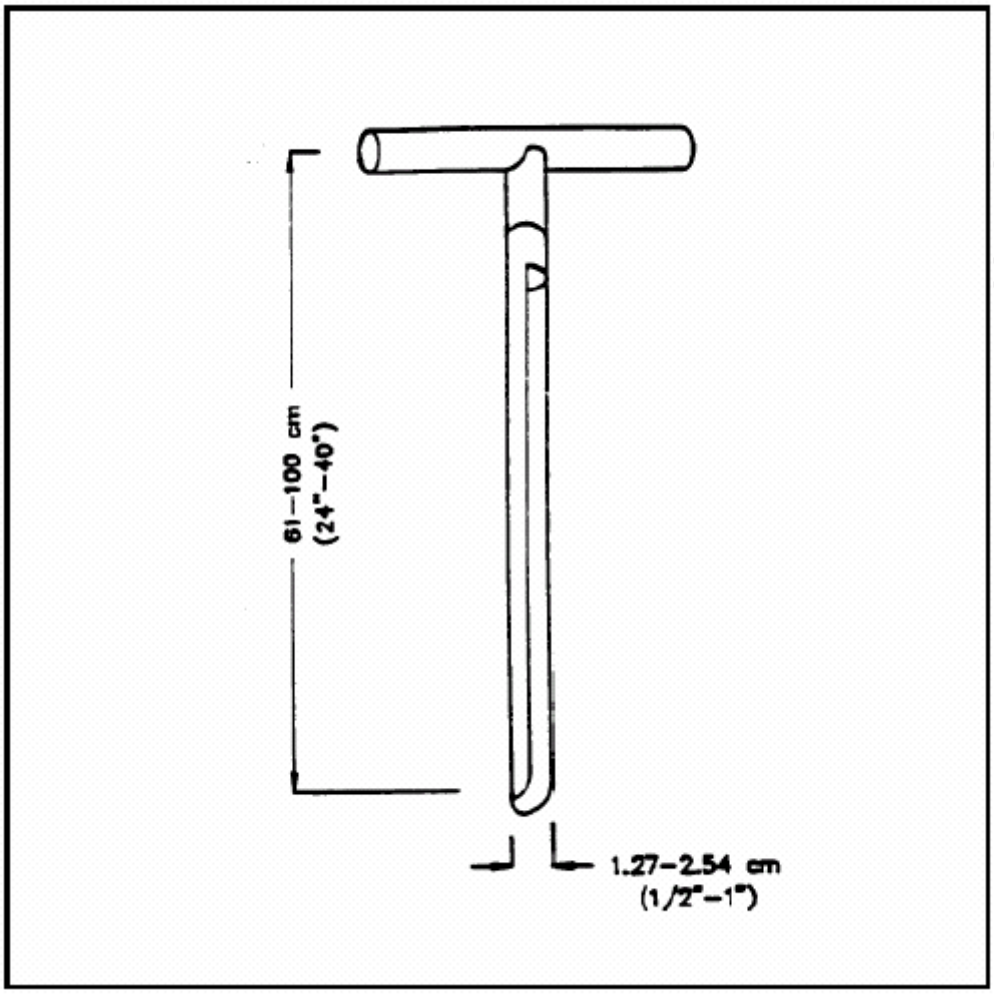


Figure 3:
Sampling Trier



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1. Scalf, M.R., McNabb, J.F., Robert F. Kerr, Manual of Groundwater Quality Sampling Procedures, Environmental Research Laboratory, pp. 72-80.

2. United States Environmental Protection Agency (1982), Test Methods For Evaluating Solid Waste, Physical/Chemical Methods, U.S. EPA SW-846, 3rd Edition.

3. United States Environmental Protection Agency, (1983) A Methods Manual-Volume II Available Sampling Methods, U.S. EPA-600/X-83-018, March 1983.

4. United States Environmental Protection Agency, (1983) Standard Operating Procedures Toxics and Waste Management Division.

5. Barth, D.S., Mason, B.J. (1984) Soil Sampling Quality Assurance Guide, Environmental Research Center, University of Nevada, U.S. EPA-600/4-84-043, May 1984.

6. United States Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, pp. 10-40 to 10-48.

7. New York State Department of Environmental Conservation (1991), RCRA Quality Assurance Project Plan Guidance, Division of Hazardous Substance Regulation.

8. United States Environmental Protection Agency Environmental Response Team (1994), Standard Operating Procedures: Sediment Sampling, SOP 2016, Rev. 0.0, p. 11, dated 11/17/94.

9. United States Environmental Protection Agency Environmental Response Team (2000), Standard Operating Procedures: Soil Sampling, SOP 2012, Rev. 0.0, pp. 1-13, dated 02/18/00.

10. United States Environmental Protection Agency (2003), A Compendium of Chemical, Physical and Biological Methods for Assessing and Monitoring the Remediation of Contaminated Sediment Sites. P. 113.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP2001 Identification and Description of Soils in the Field Using Visual-Manual Methods
- OP2005 Test Borings, Sampling, Standard Penetration Testing and Borehole Abandonment
- OP2026 Exploratory Test Pits
- OP3000 General Environmental Field Procedures and Protocol
- OP3001 Preservation and Shipment of Environmental Samples
- OP3003 Surficial Soil Sampling
- OP3006 Procedures for Subsurface Soil Sampling for Chemical Analysis
- OP3026 Chain of Custody

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APPENDIX C
FORMS

All Haley & Aldrich field forms are maintained on the server at K:\techproc\sop\Forms. The following forms are attached:

- Form 3001 Sampling Labels (Environmental)
- Form 3002 Chain of Custody (Electronic)
- Form 3003 Chain of Custody (Field)
- Form 3004 Sampling Record

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OPERATING PROCEDURE: OP3006

PROCEDURES FOR SUBSURFACE SOIL SAMPLING FOR CHEMICAL ANALYSIS

LEVEL II (Interim)

Haley & Aldrich

PREPARATION AND APPROVALS

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OPERATING PROCEDURE: 3006

PROCEDURES FOR SUBSURFACE SOIL SAMPLING FOR CHEMICAL ANALYSIS
Haley & Aldrich employees are responsible for describing soil samples, screening, and sub-sampling for laboratory analyses.

1. PURPOSE

The purpose of this Operating Procedure (OP) is to describe the procedures for the collection of representative samples of subsurface soil. The procedures are intended specifically to minimize alteration of samples during collection. Surficial soil samples as referenced herein mean soils or soil-like material located less than 6 feet below ground surface which may contain quantities of contaminants.

Refer to OP3001 for Operating Procedures on Preservation and Shipment of Environmental Samples.

Refer to OP3004 for Operating Procedures on Stream Sediment and Wetlands Soil Sampling.

Refer to OP3003 for Operating Procedures on Surficial Soil Sampling.

Haley & Aldrich (H&A) personnel are to use the techniques in OP3006 to collect subsurface soil samples. These operating procedures may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

2. EQUIPMENT AND SUPPLIES

The following is a general list of equipment necessary for soil sample collection:

Required:

1. Site map(s)/plan(s)
2. Safety equipment, as specified in the site-specific Health and Safety Plan
3. Field Log book
4. Aluminum Foil
5. Wide mouth glass jars (driller's jars)
6. Photoionization detector (PID)
7. Stainless steel trowel
8. Stainless steel, homogenization bucket, bowl or pan
9. Stainless steel spoons and/or wooden tongue depressors
10. Appropriate size sample containers

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11. Sample Labels
12. Chain of Custody records and custody seals
13. Sampling Record Form (H&A Form 3004)
14. Cooler(s)
15. Ice
16. Decontamination supplies/equipment

Optional:

1. Tape measure
2. Survey equipment or global positioning system (GPS) to locate sampling points
3. Survey stakes or flags
4. Camera and film
5. Plastic sheeting or cover

3. PROCEDURE

Decontaminate equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Disposed of drill cuttings as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

3.1 Visual Manual Description

1. Collect soil sample either manually or from the subcontractor. Visually inspect sample to verify that it will be adequate for sub-sampling. If it is not, collect a new sample.

2. Characterize and describe each sample or each interval sampled in accordance with Haley & Aldrich, Inc. Operating Procedure 2001 – Identification and Description of Soils in the Field Using Visual Manual Methods.

3.2 Field Screening for Volatile Organics

Each soil sample will be screened with a photoionization detector (PID). The daily operation and calibration of the instrument shall be performed in accordance with the manufacturer's instructions.

1. Place the sample as quickly as possible into the sample jar upon opening the sampler or exposing the sampled soil.

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2. Place the soil being used for the headspace analysis into an eight ounce, wide-mouth glass jar using decontaminated stainless steel sampling instruments. The jar will be filled to half its volume.

3. Immediately cover the jar with aluminum foil, cap the jar with a screw-on lid, and shake for 15 seconds, then let stand for 10 min and shake again for 15 seconds. If the temperature is below freezing headspaces should follow same procedures inside a heated vehicle or building.

4. Remove the lid, exposing the inner aluminum foil cap.

5. Pierce the aluminum foil with a clean PID probe equipped with a 10.2 eV (or greater) lamp or a FID to one half the headspace depth in order to measure the organic vapor concentration in the head space above the sample.

6. Record the observed organic vapor concentration in a field log book or Soil Sampling Sheet for future reference.

7. Seal jar with lid.

3.3 Soil Samples for Laboratory Analysis

Soils sampled either manually or by the subcontractor to be sub-sampled for laboratory analysis will be described and screened as described above. Following these steps, samples will be collected in laboratory provided containers with decontaminated stainless steel sampling tools. Review the project Work Plan (WP), Field Sampling Plan (FSP), or Quality Assurance/Project Plan (QAPP) for instruction on what analyses are needed during specific sampling events.

3.3.1 Samples for Chemical Analyses

1. Pre-label all laboratory provided sample containers using indelible ink.

2. Samples for Volatile Organic Compounds (VOCs) will be taken first, using a decontaminated stainless steel trowel, sample syringe, or tongue depressor from the previously undisturbed soil sample to minimize the time that the soil is in contact with the atmosphere.

3. A sufficient amount of the remaining soil should be homogenized in a decontaminated stainless steel tray or bowl with a decontaminated stainless steel trowel. Sample specific bowls and trowels can also be used if appropriate. Fill the laboratory provided containers with the homogenized soil for the remaining analytes to be tested.

3.3.2 Samples for Microbial Analyses

1. Pre-label all laboratory provided sample containers using indelible ink.

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2. Soil samples collected for DNA analysis by DGEE and /or CENSUS should be collected in an 8oz laboratory provided container. Minimize the exposure of the soil sample to ambient air.

3. Wear nitrile gloves when sampling and make sure not to contaminate the inside of the sample jar with skin, dirt or any form of debris.

4. Preserve samples in cooler with ice and ship overnight to laboratory facility. Double bag individual samples to protect samples from getting wet.

4 DECONTAMINATION

4.1 Decontamination of Sampling Equipment

All equipment that comes in contact with the sampling media (i.e. Surface Water, Sediment, etc.) must be decontaminated as specified below. An alternative approach is to have multiple pieces of equipment, and a centralized decontamination location where the procedures below can be reproduced in a grouped setting. Stainless steel samplers used for the collection of samples for chemical analysis will be cleaned prior to use and between each sampling point in accordance with the following procedure:

1. Brush with soapy (phosphate-free soap) water; and rinse with de-ionized water provided by the laboratory.
2. Decontaminate prior to use and between each location according OP 3027.

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APPENDIX A
REFERENCES

1. Barth, D.S., Mason, B.J. (1984) Soil Sampling Quality Assurance Guide, Environmental Research Center, University of Nevada, U.S. EPA-600/4-84-043.

2. New York State Department of Environmental Conservation (1991), RCRA Quality Assurance Project Plan Guidance, Division of Hazardous Substance Regulation.

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8. United States Environmental Protection Agency Environmental Response Team (2000), Standard Operating Procedures: Soil Sampling, SOP 2012, Rev. 0.0, pp. 1-13, dated 02/18/00.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

OP3001	**Preservation and Shipment of Environmental Samples**
OP3004	**Stream Sediment and Wetlands Soil Sampling**
OP3026	**Chain of Custody**
OP3027	**Decontamination Procedure**
OP3028	**Investigation Derived Wastes**

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OPERATING PROCEDURE: OP3007

SURFACE WATER SAMPLE AND DATA COLLECTION

LEVEL II (Interim)

Haley & Aldrich

PREPARATION AND APPROVALS

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OPERATING PROCEDURE 3007

SURFACE WATER SAMPLE AND DATA COLLECTION

1. PURPOSE

This procedure provides a uniform, standardized approach to collect representative surface water samples and perform real-time surface water quality data collection. Surface water refers to standing or flowing water above ground surface.

The method of sample collection and handling can affect the quality and interpretation of the sampling and analytical results. This procedure and attached reference documents are intended to minimize variability in sample collection to ensure uniformity between sampling events. This procedure has been developed with guidance from the U.S. EPA guidance document A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, OSWER Directive 9355.0-14.

The general procedures for collecting surface water samples are outlined below. All work will be performed in accordance with the Site-Specific Health and Safety Plan (HASP).

2. EQUIPMENT

The following materials will be available, as required, during surface water sampling:

- Health and safety equipment (as required by the Health and Safety Plan [HASP]);
- Cleaning equipment;
- Weighted Tape;
- Duct tape;
- Graduated beaker;
- Flagging;
- Multi-parameter sonde for water quality monitoring (YSI 6820 with YSI 650 MDS data display, or equivalent) with 6883 ammonium (NH_4^+) probe and calibration kit;
- Appropriate transport containers and packing, labeling, and shipping materials (coolers) with ice;
- Appropriate filters and filtering apparatus (if necessary);
- Appropriate sample containers and forms;
- Field notebook and sampling sheets; and
- High resolution (1 meter) Global Positioning System (GPS).
- Velocimeter

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3. PROCEDURE

Decontaminate equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information

3.1 Pre-sampling Observations, and Required Data Entries

A number of field measurements and observations should be made in the field at the time of sampling. This information is listed below and will be recorded in a project Field Log Book or Surface Water Sampling Record Form (Appendix C). For large sampling programs both documentation reports may be completed.

3.2 Field Log Book Entry for Surface Water Samples

- Surface water Sample Location ID
- Date collected
- Time Collected
- Sample Depth
- Sample characteristics (measured in separate transfer container not in sample glassware or if possible, water quality monitoring sonde may be submerged in water body to sample depth), if requested by the project manager – pH, Conductivity, Dissolved Oxygen, Oxidation Reduction Potential, Turbidity, Temperature, NH_4^+ Ion Concentration and sample preservative(s)
- Samplers (names of individuals who actually collected samples)
- Sample destination (Analytical Laboratory)
- Description of the sample location
- Photograph details
- Latitude/Longitude (using GPS, collect Waypoint as well).
- Velocity of water (estimated from floating object)
- Flow rate if moving water (i.e., streams and drainways) (in cubic feet/second; using the following formula)

$$Q = Au = wdu$$

where:
Q = discharge in cubic feet/second (cfs)
A = area in square feet
u = velocity in feet/second (ft/sec; measured by Velocimeter)
w = width in feet
d = depth in feet

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- Observable physical characteristics - odor, color, cloudiness, proximity to erosional/depositional features
- Evidence of stressed vegetation, wildlife, or waste disposal
- Ambient weather conditions during sampling - air temperature, sky condition, recent precipitation or drought
- Samples collected (enter all sample numbers collected at this location)

All entries will be made as described in Haley & Aldrich Operating Procedure OP3029- Field Data Recording.

3.3 General Surface Water Sampling and Real-Time Data Collection Procedures

1. If needed, sample bottles will be labeled in the lab prior to sampling using indelible ink.

2. Calibrate multi-parameter sonde per manufacturer's specification. Verify that calibration is within the acceptable range as described in the manufacturer's guidance manual.

3. Don health and safety equipment (as required by the HASP).

4. Sample locations and analyses will be selected with respect to specific site conditions.

5. Identify sampling location in field notebook along with other appropriate information.

6. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'

7. Collect real-time water quality NH_4^+ ion concentration, temperature, pH, DO, conductivity, ORP and turbidity.

8. Collect surface water sample or real-time data in accordance with the appropriate equipment specific section presented under this standard operating procedure (presented below).

If collecting samples, continue with the following general steps:

1. All samples should be collected before any physical features of the water body are measured and prior to sediment sampling. Downstream locations should be sampled first and then proceeding upstream.

2. Fill glassware by directed method. Leave headspace in sample collection bottles with the exception of the volatile organics analysis (VOA) vials.

3. If no water is present in the stream at the particular sample location, then a sample and/or data will not be collected during the sampling event.

4. If collecting samples, field duplicates and matrix spike/matrix spike duplicate samples will be prepared by filling two sets of containers with water collected at the same time and depth.

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5. Secure all sample jar caps tightly.

6. Place filled sample containers on ice in a cooler.

3.4 Surface Water Sampling by Grab Sample Method

The following steps describe the procedure of collecting near-surface water samples. This grab sample method is to be employed when the water is shallow enough to wade through and shallow enough that a sample can be taken comfortably from at mid-depth.

1. Wade into the center of the stream. Generally, samples are to be collected at the stream center-line, at 6/10 stream depth (per average flow convention) if possible. In the event that it is impossible to safely reach the center of the stream, the sample will be collected as close as possible to the center. No sampling will occur if the stream cannot be accessed safely.

2. Use a YSI multi-parameter sonde (or equivalent) with a data display system to measure conventional water quality parameters. Calibrate sonde per manufacturer's specifications prior to use and verify that calibration is within the acceptable range suggested by the manufacturer. Use sonde to measure the following at each sample location: NH_4^+, pH, dissolved oxygen, conductivity, temperature, and turbidity, as described in Field Sampling Plan (FSP). Record results on sample sheet.

3. If there is no preservative in the sample container, submerge the laboratory sample container in the stream and allow water to flow gently down the side of the bottle with minimal entry turbulence Collect the sample from mid-depth.

4. If there is preservative in the sample container, collect the water sample by submerging the graduated beaker into the stream as above. Fill sample containers. Collect the sample from mid-depth.

5. If the water depth is less than one foot, collect the sample from 1/3 depth, as to avoid disturbing the bottom of the stream.

6. If the stream is too shallow to fill the bottle directly, block stream flow with sand bags, allow stream to pond behind bags, then use a graduated beaker to sample stream water and fill the bottle.

7. Water samples that will be tested for dissolved metals will be filtered in the field with a 0.45 micron filter or cartridge or according to procedures described in the U.S. EPA SW-846 Manual, Method 3005. The filtrate will be preserved to pH <2 with nitric acid.

8. Measure depth at centerline and width of stream using weighted tape. Make note of features that would affect the cross-sectional area (i.e. localized channelization or depositional banks). Record data on sampling sheet.

9. Using velocimeter, measure velocity of stream at 0.60 stream depth at centerline of stream, record data on sampling sheet.

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3.5 Surface Water Sampling with Peristaltic Pump

This section describes the method for surface water sampling with a peristaltic pump. This type of sampling is required for mid-depth sampling in ponds and in other water bodies where a near surface sample may not sufficiently characterize the body as a whole. An on-water vessel will be needed to complete this sampling. This procedure shall be performed in accordance with the on-water section of the site-specific HASP.

3.5.1 Additional Materials for Sampling with Peristaltic Pump

In addition to the general surface water sample/data collection materials listed above, the following materials are also required to perform surface water sampling with a peristaltic pump

- Peristaltic Pump with Waterra/Masterflex tubing
- Pocket Calculator (to calculate tubing volumes for purging between sample at different depths but at the same location.)

3.5.2 Sampling Methods with Peristaltic Pump

1. Identify sampling location in field notebook along with other appropriate information.

2. Purge three tube volumes prior to sampling at a particular depth at each location. *NOTE: If the tubing is dedicated to each monitoring location and disposed of after sampling, decontamination is not required.*

3. Lower YSI sonde to desired depth; measure NH_4^+, pH, dissolved oxygen, conductivity, temperature, and turbidity, as described in FSP. Record results on sample sheet.

4. Lower Waterra tubing to desired depth, activate pump once YSI metrics have stabilized to within +/- 10% of the time-averaged trend. *NOTE: The Waterra tubing may be attached to the Sonde prior to lowering.*

5. Water samples that will be tested for microbiology will be filtered in the field with a 0.20 micron filter or cartridge or according to procedures specified by the laboratory performing the analyses.

3.6 Surface Water Screening with Ion-Specific Ammonia Probe

This section describes the process of field screening of surface water quality by method of collecting real-time water quality data across a transect.

1. Calibrate the multi-parameter sonde for water quality monitoring (YSI 6820 with YSI 650 MDS data display, or equivalent) with 6883 ammonium (NH_4^+) probe (or equivalent) per manufacturer's

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instrument specific calibration instructions. Verify calibration before continuing with screening activity.

2. Use the multi-parameter sonde to measure NH_4^+, pH, dissolved oxygen, conductivity, temperature, and turbidity, as described in the FSP.

   a. Record results on sample sheet. Note: If dramatic change (e.g. presence/absence) in NH_4^+ is observed between locations, try to isolate source, call field coordinator, and arrange to collect sample, per approval. No sampling is required for locations that conform to readings from surrounding areas.
   b. Collect confirmatory NH_4^+ concentration samples to be sent to the laboratory for analysis.

3. Proceed upstream to the next sampling location (distance between sampling locations as determined in the FSP).

3.7 Sampling with ISCO Automated Sampler

1. Set up ISCO 6712 Automated sampler (or an equivalent) as directed by the manufacturer.

2. Visually inspect sampler for any damage or external deficiencies. If sampler has been damaged in any way, contact the project manager.

3. Program the ISCO 6712 Automated sampler to take samples as required (i.e., time interval, and volume of sample) in the FSP.

4. Water quality parameters will be recorded and stored by the automatic sampler during the storm event as programmed by personnel.

5. Each sampler will fill un-preserved sample bottles within the samplers at the programmed time and volume.

6. Upon completion of the storm event and the sample collection program, personnel will remove the samples from the sampler, composite the samples, transfer the sample to new sample bottle, and preserve the samples.

7. Perform routine maintenance/cleaning and decontamination procedures as specified by the manufacturer.

3.8 Sonde Deployment and Manual Sampling Methods During Aeration Tests

The following section describes the procedure for using and deploying a sonde for long term data collection.

1. Calibrate the multi-parameter sonde for water quality monitoring (YSI 6820 with YSI 650 MDS data display, or equivalent) with 6883 ammonium (NH_4^+) probe (or equivalent) per manufacturer's

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instrument specific calibration instructions. Verify calibration before continuing with screening activity.

2. While the sonde is connected to the data display system, program the sampling frequency and duration of sampling per manufacturer's instructions. After the sonde has been programmed to start logging data, disconnect the sonde from the data display system.

3. Secure sonde to a weight and buoy system that will keep the sonde in one location in the water body. The system consists of a weight attached to a buoy by a chain (the length of the chain is approximately equal to the depth of water where the sonde will be deployed). Attach the sonde to the chain at the desired monitoring depth described in the FSP with a sea clamp or other galvanized connector.

4. After the predetermined time, as described in the FSP, retrieve the sonde and deployment system.

5. Safely secure the sonde. Reconnect the sonde to the data display system, stop logging, and review data.

6. Decontaminate sonde by cleaning with Alconox and distilled water. Take care not to get wire connection ports wet.

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3.9 Collection and Processing Methods for Surface Water Samples

Descriptions for collecting and processing surface water samples for specialized analyses are presented below. The general procedure and methods described for each surface water sampling method described above should be followed with the addition of the details below.

3.9.1 Samples for Chemical Analyses

1. Sample glassware should be filled to the top of the VOA vials. Air bubbles are not acceptable in the sample. When collecting a sample for VOA, allow sample to spill over before attempting to cap vial. After collecting the sample, cap the 40 ml VOA vial and turn up-side down to verify bubble-free conditions. If there are bubbles present in the sample, remove the cap and continue to fill the sample to remove the air.

2. Water samples that will be tested for dissolved metals will be filtered in the field with a 0.45 micron filter or cartridge or according to procedures described in the U.S. EPA SW-846 Manual, Method 3005. The filtrate will be preserved to pH <2 with nitric acid.

3.9.2 Samples for Microbial Analysis

Surface water samples taken for microbial analysis must be filtered and handled as described in this section. Samples for Q-potential (DNA)/Denaturing Gradient Gel Electrophoresis (DGGE) (DNA) Analysis and Samples for Pospholipid Fatty Acid (PLFA) Analysis are as follows:

1. Prepare surface water sampling equipment as normal.

2. Remove the sample dedicated Bio-Flo analysis-specific filter provided from the Falcon tube.

3. Attach the inlet of the filter with a ¼”- 5/16” inner diameter tubing using a clamp to secure the tubing to the filter.

4. Place the filter within a receiving container so that the volume of water filtered can be measured accurately.

5. Filter between 1-2 L of water. Volume filtered can be determined by first calculating the flow rate of the pump and then allowing water to pass through the filter for a determined amount of time. The volume of water filtered will vary depending on the turbidity of the water.

6. Record the volume of water that passed through the filter, and place the filter back into the Falcon tube that it cam in and submit the filter for analysis.

7. If the filter clogs before 1L has been filtered, record how much water has passed through the first filter, and then collect and additional filter, also recording the volume of water that went

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through the second filter. In this case, both filters are then submitted for testing. For each location, there should be no more than 2 filters used and there is no need to filter more than 2L of water.

8. Record volume of water that passed through the filter as well as the requested analysis. Samples should be shipped in a cooler with ice to the laboratory for next day delivery. Individual samples should be double bagged inside the cooler to protect the samples from getting wet.

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APPENDIX A
FORMS

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Stream Surface Water Sampling Data Sheet

Project		**Report No.**	
Location		**Date**	
Client		**File No.**	
Contractor		**Field Rep.**	
Weather		**Outdoor Temp**	

Sample Location _____ **Sample ID** _____ **Time** _____

Total Depth _____ **Total Width** _____ **Flow Velocity** _____

Sampling Device _____ **Decon** _____

Conductivity (umhos/cm) _____

Turbidity (NTU) _____

Dissolved Oxygen (mg/L) _____

pH _____

ORP _____

Temp, C _____

Ammonium (mg/L) _____

Channel Diagram:

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

LOCATION ID:

Sample Location _____ **Sample ID** _____ **Time** _____

Total Depth _____ **Total Width** _____ **Flow Velocity** _____

Sampling Device _____ **Decon** _____

Conductivity (umhos/cm) _____

Turbidity (NTU) _____

Dissolved Oxygen (mg/L) _____

pH _____

ORP _____

Temp, C _____

Ammonium (mg/L) _____

Channel Diagram:

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

LOCATION ID:

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Pond Surface Water Sampling Data Sheet

Project		**Report No.**	
Location		**Date**	
Client		**File No.**	
Contractor		**Field Rep.**	
Weather		**Outdoor Temp**	

Sample Location _____ **Sample ID** _____ **Time** _____

Pond Depth _____

Sampling Device _____ **Decon** _____

Easting _____ **Northing** _____

Conductivity (umhos/cm) _____

Turbidity (NTU) _____

Dissolved Oxygen (mg/L) _____

pH _____

ORP _____

Temp, C _____

Ammonium (mg/L) _____

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

_____

_____

_____

_____

_____

LOCATION ID:

Sample Location _____ **Sample ID** _____ **Time** _____

Pond Depth _____

Sampling Device _____ **Decon** _____

Easting _____ **Northing** _____

Conductivity (umhos/cm) _____

Turbidity (NTU) _____

Dissolved Oxygen (mg/L) _____

pH _____

ORP _____

Temp, C _____

Ammonium (mg/L) _____

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

_____

_____

_____

_____

_____

LOCATION ID:

OPERATING PROCEDURE: OP3008

MANUAL WATER LEVEL MEASUREMENT PROCEDURE

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP3008

MANUAL WATER LEVEL MEASUREMENT

1. INTRODUCTION

This procedure describes the measurement of water levels in groundwater monitoring and extraction wells, piezometers and boreholes. This procedure does not cover automated measurement of water levels with a transducer/datalogger and does not cover measurement of phase-separated liquids.

This procedure discusses collection of water levels using either an electric water level indicator or a chalked, graduated steel tape. Water levels will be acquired in a manner that provides accurate and precise data. These data may then be used to calculate groundwater elevations, determine hydraulic gradients and construct groundwater elevation contour maps. Accuracy and precision in obtaining the measurements are critical to insure the usability of the data.

1.1 Background

Water level measurements should be made from a fixed reference point marked on the well. The fixed reference mark will usually be located on the top of the well casing or on the top of the water level access point into the well, depending on the completion of the well at the surface. Following well installation, a survey mark is placed on the top of the well casing (typically PVC) as a reference point for groundwater level measurements. If such a survey mark is not present, the reference point is typically established and marked on the north side of the well casing.

If possible, avoid using steel protective casings or flush-mounted road boxes as a measurement reference point due to the greater potential for damage. All field personnel must be made aware of the measurement reference point being used in order to ensure the collection of comparable data. The well reference point elevation is surveyed to the nearest 0.01 ft. for later use in calculating groundwater elevation.

Before measurements are made, water levels in monitoring wells and piezometers should be allowed to stabilize for a minimum of 24 hours after well construction and development. In low-yield situations, recovery of water levels to equilibrium may take longer. All measurements should be made to an accuracy of 0.01 feet. All water level measuring equipment must be decontaminated prior to entering the Site. Water level measurements should, if possible, proceed progressively from the least-contaminated to the most-contaminated well, if applicable to the project.

In order to provide reliable data, water levels at a given site should be collected within a 24-hour period or the shortest time practical. However, certain situations may produce rapidly changing groundwater levels that require taking measurements as close in time as possible. Large changes in water levels within wells may be indicative of such conditions. Rapid groundwater level changes may occur due to:

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- Barometric pressure changes
- Tidal fluctuations
- Navigation controls on rivers
- Rainfall events
- Groundwater pumping

Due to possible changes during the groundwater level collection period, it is imperative that the time of data collection at each station be accurately recorded. In addition, personnel collecting water level data must record if any of the above conditions are known or suspected to be occurring during the groundwater level collection period.

In conjunction with groundwater level measurements, surface water (e.g. ponds, lakes, rivers, and lagoons) may be monitored as well. This information is useful (and can be critical) in understanding the hydrogeologic setting of the site and how contaminants may move beneath the site.

2. EQUIPMENT & SUPPLIES

Main field equipment includes:

- Battery-operated, non-stretch, electric water level probe with permanent markings at 0.01 ft. increments.
- Surveyor's steel tape with permanent markings at 0.01 ft. increments.
- Well key, screw driver and socket set.
- Decon Kit.

The electric water level indicator and the chalked steel tape are two devices commonly used to measure water levels. Both have an accuracy of 0.01 feet. The calibrated cable on the depth indicator will be checked against a surveyor's steel tape periodically. The time period between calibrations will be established based on the site-specific project conditions and the equipment usage. Calibration on a minimum quarter year basis is recommended. A new cable will be installed if the cable has changed by more than 0.1% (0.1 feet for a 100 foot cable) or becomes faded or difficult to read.

Other field equipment may include:

- Air monitoring instrumentation (Photo ionization detector (PID) or Flame ionization detector (FID))
- Survey tape or other well depth measurement device
- Chalk
- Ruler
- Site field book or project-/site-specific forms

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- Paper towels and trash bags
- Decontamination supplies, if applicable to the project
- Site-specific water level data forms

3. PROCEDURE

3.1 Preparation

1. Review the site-specific Sampling and Analysis Plan and Health and Safety Plan to determine project requirements. Determine and obtain the equipment and supplies needed. Obtain previous water level monitoring data, if available.

2. Obtain site access, and any necessary well keys or well wrenches.

3. Decontaminate or pre-clean equipment, and ensure that it is in working order.

4. Identify water level monitoring locations on site plan prior to going into the field.

3.2 Procedure

Procedures for determining water levels are as follows:

1. If possible, and when applicable, start at wells that are the least contaminated and progressively proceed to wells that are the most contaminated.

2. Clean/decontaminate all the equipment prior to entering the Site and between well locations, if required by Site protocol.

3. Remove any exterior lock and steel protective cover. Bail or remove any precipitation or surface water that may have accumulated in the well vault or the annulus between any steel protective cover and the casing, to prevent the water from draining into the well.

4. Remove any interior lock and cap or plug. Record the well ID, time of day (military format) and any other pertinent information.

5. If required by site-specific protocol, monitor the headspace of the well with a photoionization detector (PID) or flame ionization detector (FID) to determine the presence of volatile organic compounds. Record the results in the field book or on the site-specific forms. If necessary, initiate personal protective measures indicated by the site-specific health and safety plan.

6. Turn on the electric water level indicator and adjust the sensitivity. Chalk a 1- to 5-foot section of the steel tape. Lower the water level measuring device into the well. Electrical devices are lowered until

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the audible or visual signals indicate that the probe has contacted the water surface. Chalked steel tapes are lowered a foot or more below the water surface as determined by review of previous measurements at the well. Several repeat measurement attempts may be required with a chalked steel tape to determine this depth.

7. Measure and record the depth to water from the marked reference point and also record a description of the reference point used for the measurement (e.g. Top of four-inch PVC casing).

   For electrical indicators record the distance from the water surface (as determined by the audio signal, visual signal or meter) to the reference measuring point.

   For chalked tapes, an even-foot mark is held at the reference point, once the chalked section of the tape is below the water level. Both the water level indicated by wet chalk on the tape and the foot mark held at the reference point are recorded. The depth to the water is the difference between the two readings.

   Two water levels should be collected from each well and the results compared. If results do not agree to within 0.02 feet, a third measurement should be taken and the readings averaged. Consistent failure of consecutive readings to agree suggest that water levels are changing; that there is water cascading in the well; that the electric indicator is giving a false signal (such as the probe contacting moisture in the casing or an obstruction); or that some other anomalous condition with the well or equipment is precluding a correct measurement.

8. Remove all downhole equipment; replace well caps, plugs, locks and protective steel cover.

9. Decontaminate all downhole equipment that has contacted groundwater, if required by Site protocol, and store for transport to the next well.

10. Record any physical changes, such as evidence of tampering with the well or cover, vandalism, erosion or cracks in protective concrete pad, or variation in total depth of well. See the example format of water level data collection below.

Example Format of Water Level Data Collection

Date	Well ID	Depth to Water (from Top of PVC)	Time of Day	Comments/Notes
10/10/2001	MW-1	8.72'/8.72'	13:05	Surface water in manhole, cement pad cracked
10/10/2001	MW-2	9.51'/9.51'	13:07	Petroleum odor, sheen noted on probe

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3.3 Calculations

To calculate groundwater elevation above mean sea level, use the following equation:

$$E_W = E - D$$

Where:

E_W	=	Elevation of water above mean sea level (feet) or local datum
E	=	Elevation above sea level or local datum at point of measurement (feet)
D	=	Depth to water (feet)

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APPENDIX A
REFERENCES

- ASTM 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
- ASTM D6000 Guide for Presentation of Water-Level Information from Ground-Water Sites
- Driscoll, F.G. 1986. Groundwater and Wells. Second Edition. Chapter 16. *Collection and Analysis of Pumping Test Data*. pp 534-579. Johnson Filtration Systems Inc. St. Paul, Minnesota.
- U.S. Environmental Protection Agency, 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document, pp. 207.
- U.S. Environmental Protection Agency, 1987. A Compendium of Superfund Field Operations Methods. EPA/540/p-87/001 Office of Emergency and Remedial Response Washington, D.C. 20460.
- U.S. EPA Environmental Response Team, Standard Operating Procedures, Manual Water Level Measurements. Dated 02/11/2000, SOP 2043.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1004 Operation/Calibration of PID Photoionization Detector
- OP1007 Field Monitoring for Volatile Organics (breathing space-work zone)
- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP1022 Health and Safety Manual
- OP3001 Preservation and Shipment of Environmental Samples
- OP3008 Manual Water Level Measurement Procedure
- OP3009 Monitoring Well Development Procedure
- OP3012 Low Stress/Low Flow Groundwater Sample Collection Procedure
- OP3027 Decontamination Procedure

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APPENDIX C
FORMS

- Form 2021 Groundwater Monitoring Report

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APPENDIX D
GLOSSARY (To Be Updated As Appropriate)

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OPERATING PROCEDURE: OP3009

MONITORING WELL DEVELOPMENT PROCEDURE

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OPERATING PROCEDURE: OP3009

MONITORING WELL DEVELOPMENT PROCEDURE

1. PURPOSE

This procedure provides guidance on methods and techniques for groundwater monitoring well development typically performed after well installation, but prior to groundwater quality sampling, specifically for instrumentation installed in overburden or bedrock for environmental monitoring and geotechnical purposes. Groundwater well development increases the yield of the well by removing fine sediments and particles from within the well and the well filter pack, enhances the hydraulic communication between the well and the screened formation, decreases turbidity, increases precision of hydrologic measurements, and increases representativeness of groundwater quality data. Well development is an integral component of a groundwater sampling program, with the objective of obtaining high quality, reproducible groundwater quality data.

The selected method and duration of groundwater well development will be dependent on a number of factors, including: well construction method and materials, depth to groundwater, anticipated groundwater testing parameters and data quality objectives, presence of contamination (i.e., degree of contamination and presence of free-phase non-aqueous phase liquids), method of borehole advancement, and site physical setting/access.

IMPORTANT NOTES:

It is not necessary to follow all of the methods in this procedure for every monitoring well development performed. The procedures may be adapted to conform to specific local practice, site-specific geologic conditions, or to support local, municipal or state regulatory requirements.

The term “groundwater monitoring well” or “well” in the procedure is used to denote groundwater monitoring wells, groundwater observation wells, piezometers, gas monitoring wells, lysimeters or other devices constructed in similar manner to a well. Certain well constructions (i.e., large-diameter pumping test wells, injection/extraction wells, commercial, residential or industrial water supply wells) may be developed using the information contained in the procedure, but are typically installed using specialized drilling equipment and are typically developed using that equipment by specific methods that are beyond the scope and intent of this field procedure.

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2. EQUIPMENT & SUPPLIES

Required

1. Water Level Indicator, Sinco or equivalent
2. Oil/Water Interface Probe
3. Thermometer
4. pH meter and buffering/calibration solutions
5. Conductivity meter and probe
   Dissolved oxygen meter and probe
7. Turbidity meter and probe
8. Oxidation/Reduction Potential meter and probe
9. Salinity meter
10. Pump (Grundfos, peristaltic, whale etc.)
11. Pump accessories (Cables, fittings, tools)
12. ½ in. or 5/8 in. HDPE or Teflon discharge tubing; also silicon tubing for peristaltic pump
13. Power source for pump (generator with fuel; automotive battery, rechargeable battery)
14. Graduated plastic bucket (5-gallon) or flow meter
15. Stopwatch
16. Standard decontamination equipment (water jug, buckets or washtubs, brushes, Alconox, distilled water, tap water, methanol, squeeze bottles)
17. Ruler, engineer's 6 ft. folding
18. Scale, engineer's
19. Graduated tape, 100 ft. length, weighted end
20. Field Logs & Forms/Field Book 6.
21. Site Plan, Maps, Boring and Well Installation Logs
22. Personal protective equipment
23. Calculator
24. Keys to well padlocks/covers
25. Paper towels
26. Trash bags

Optional:

1. Horiba MultiMeter (measures pH, temperature, conductivity, DO, turbidity, and salinity)
2. Horiba U-22 Flow Cell (measures pH, temperature, conductivity, DO, turbidity, ORP and salinity)
3. Inertial Pump Materials: Waterra Foot Valves, HDPE Tubing
4. Bailers; rope, knife

3. PROCEDURE

3.1 Summary of Procedure Purpose and Intent

The primary purpose of developing groundwater quality monitoring wells at sites containing, or potentially containing, solid or hazardous materials or their byproducts, is to create an effective filter pack around the well screen, rectify impact to the formation caused by drilling and the associated drilling fluid, remove fine

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particles from the formation near the borehole and assist in restoring the natural water quality of the aquifer in the vicinity of the well. The properly developed well ensures the reliable collection of representative ground water samples, of acceptably low turbidity.

Well development induces movement of water in two directions across the well screen and filter pack. This movement removes fines or other foreign materials from within the well, the filter pack, and the surrounding natural formation, creating a stable graded filter yielding water of relatively low turbidity.

3.2 Role of Environmental Professional or Engineer

Groundwater monitoring well development requires evaluation and consideration of a variety of site-specific characteristics, which precludes the use of one single development practice or procedure. The procedure is provided as a guide to aid the environmental professional, geologist or engineer in selecting the technical approach and methodology to effectively complete a well development program.

At the initiation of project planning, the Project Manager, Project Engineer or Scientist, and field personnel, determine any project-specific requirements for groundwater well development. Municipal, state or federal regulations, local practice, client requirements or project requirements may dictate the use of a different or modified well development method.

3.3 General Methods of Monitoring Well Development

There are three general types of well development methods typically employed on small diameter monitoring wells (equal to or less than 4 in. I.D.) installed for environmental purposes:

- Pumping and overpumping
- Bailing
- Surging with a Surge Block

Well development methods that potentially alter the chemical composition of the groundwater are not acceptable. Therefore, methods that introduce fluids (including water pumped from the well) or air, to accomplish development are generally considered unsuitable. This eliminates several methods commonly used to develop large-diameter water supply wells. These methods include backwashing, jetting, airlift pumping or air surging.

The majority of well development for environmental purposes is conducted by mechanical pumping and overpumping, use of inertial lift pumps, inertial lift pumps with surge blocks, bailers, or a combination of these methods.

3.4 Preliminary Procedures

In preparation for well development activities (and subsequent groundwater quality sampling event), the Project Manager and groundwater developer/sampler reviews project-specific requirements and considerations of the well development and groundwater sampling program.

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The information reviewed may include site map or plans, drilling methods and records, well construction records, depth to groundwater data, previous groundwater quality data, data trends, earlier sampling records and field procedures used, and preferred well sampling sequence or sampling order. Identify project documentation needs and records of well development execution.

Other information to be reviewed are specific laboratory analyses to be performed on samples to be obtained from each well, sampling glassware, need for field filtration and container preservatives. Related aspects of the procedure include site health & safety plan review, evaluation of the site physical setting, availability of electrical power, property access permission and constraints, and purge water disposal.

Design the well development program to support the data quality objectives of the chemical analyses of the groundwater samples to be obtained. Based on the types of data to be collected in the field, identify the appropriate types of mechanical purging required (by pumps or other specialized equipment), likelihood of the presence of non-aqueous phase liquid (NAPL) and accommodations for measuring NAPL. Generally, a series of wells are developed starting with the least contaminated well working towards the well exhibiting the most significant contamination, if known.

Other considerations are identifying protocol for personnel protective equipment (PPE) use and specialized handling of purged water and decontamination wastewater, as generated. Recently installed monitoring wells should not be developed before well sealant materials (bentonite annular seal, cement/bentonite grout) have set or cured, typically assumed to be approximately one week.

In some cases, groundwater obtained from wells installed and sealed with a column of cement grout has exhibited artificially high pH, due to migration and influence of the calcium carbonate from the cement. The Project Manager and field representative are cautioned of this possibility, manifested during the well development procedure by inconsistent, unstable or high pH readings.

Table I presents common well development equipment, and lists advantages/disadvantages of the equipment.

3.5 Calculate Volume of Standing Water in Well

Calculate the estimated volume of standing water in the well. Some useful formulae for calculating well volumes are provided below:

- $V = L\ r^2 (0.163)$

  Where:

  V = volume of standing water in well, in gallons
  r = internal radius of well, in inches
  L = length of standing water column, in feet
  0.163 = derived constant converting well radius in inches to feet, and cubic feet to gallons

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Other useful formulae:

- Gallons per 100 ft. = 4.08 * (D)2

  Where D = Inside well or borehole diameter, in inches

- Cubic feet of water per 100 ft. = 0.55 * (D)2

  Where D = Inside well or borehole diameter, in inches

- 7.48 gallons = 1 cubic foot

- 0.134 cubic feet = 1 gallon

3.6 Field Procedures

3.6.1 Locate Well

Locate the subject well in the field, using site plans, sketches, fixed references or other available documentation. Metal detectors may be useful in locating buried metal well casings; however, non-ferrous (i.e., aluminum or PVC) or missing well casings will not respond to metal detector signals.

Verify well designation, particularly individual wells located in closely spaced well clusters or well nests. If necessary, verify and document the location of the well to be decommissioned, referenced by taped distance to three fixed features, or acquire coordinates using global positioning system (GPS) methods or by instrument survey.

3.6.2 Evaluate Well Integrity and Construction

Evaluate and document condition of protective well casing and surface seal (padlock missing/broken, well cap missing, staining on well riser observed, concrete surface seal cracked, surface runoff entering well etc.). Record well construction material (stainless steel, PVC, fiberglass, galvanized steel, black carbon steel etc.).

Establish/verify monitoring well reference point (i.e., PVC rim, roadway box rim, protective guard pipe casing rim, ground surface).

3.7 Well Development Procedure – Mechanical Pump Method

Mechanical pumps include electrically powered submersible pumps (Grundfos and Whale brands), or suction lift surficial pumps, such as centrifugal or peristaltic types. Pumps may have variable speed controls to regulate discharge rate. Other types of suction lift surface pumps may be driven by internal combustion gasoline engines (not discussed in this procedure).

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1. Follow Preliminary Procedures above, including evaluation of well integrity and documentation of well construction details.

2. Don appropriate personnel protective equipment (PPE) as identified in project health & safety plan. Pay particular attention to splash hazards.

3. Decontaminate all downhole development equipment prior to placement within wells, between uses in either the same well, or in other wells. Clean and prepare equipment using an Alconox soapy wash, tap water rinse, methanol rinse, and distilled/deionized water rinse. Containerize decontamination rinseate, if required.

4. If warranted, measure for possible presence of non-aqueous phase liquids (NAPL), using oil/water interface probe. Modify well development program based on findings and discussion with Project Manager, including postponing/canceling well development.

5. Measure well diameter, depth to water (static water level), depth to bottom of well using water level indicator or weighted graduated tape. Calculate standing water volume (see above).

6. Verify information on the respective well record, if available, and note any discrepancies. If well logs are not available, determine screen length and depth, if possible, to determine whether the well construction will provide useful data.

7. Evaluate obstructions present within the well or material accumulated in bottom of well. The presence of substantial quantity of accumulated materials (i.e., silt > 0.5 ft.) in bottom of well may warrant modifying the well development method to remove the sediment (i.e., use of peristaltic pump or hand bailer to remove sediment).

8. Remove any unsuitable dedicated groundwater sampling devices, if present (i.e., Waterra-type inertial pumps and discharge tubing, bailers, SoakEase absorbent material). Retain and discard as solid waste.

9. Groundwater purged from the borehole may or may not require containment or may be discharged on the ground in vicinity of well head, depending on groundwater quality, site setting, regulatory considerations and project requirements. Resolve with Project Manager prior to entering field.

10. Cut a clean piece of discharge tubing for selected pump (typically ½ in. or 5/8 in. high density polyethylene (HDPE) or Teflon tubing) of sufficient length to fully penetrate the well to its screened depth and to accommodate measuring purge volumes and inorganic parameters at ground surface. Cut tubing should not fall or drop into the well.

11. For submersible pumps, attached tubing and lower pump intake into well, suspending pump intake at the approximate midpoint of the saturated zone for water table wells, or at the screen midpoint for deeper wells. Connect power cables and controller box, and operate the pump according to manufacturer's instructions.

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12. Initially operate pump at a discharge rate approximately equal to well recharge rate, using graduated bucket or flow meter and stopwatch to estimate flow, and adjust until drawdown of approximately 0.3 ft. is obtained. At the start of purging, obtain inorganic field parameters of the discharge, in the following order: pH, temperature, specific conductance (conductivity), oxidation-reduction potential (ORP), dissolved oxygen (DO) and turbidity, and record on field forms or in logbook.

13. Well development continues until representative groundwater, free from drilling fluids, drill cuttings, accumulated sediment or other materials introduced during the well construction is obtained.

    Unless determined by project specific requirements, remove approximately 3 to 5 well volumes, measuring and recording inorganic field parameters for each well volume removed. If, during removal of 3 to 5 well volumes, field parameters have stabilized within 10% for two successive readings, and turbidity has been reduced to 5 nephelometric turbidity units (NTU) or less, then well development is considered complete. Based on discussion with the Project Manager or environmental professional, consider the applicability of Step 14 below, and complete if warranted.

    In certain circumstances and based on project objectives, well development may consist of removing a fixed volume of water from the well that is predicated on the drilling method used for well installation. For wells installed without the introduction of drilling fluids (i.e., hollow stem augers, driven well points), three (3) well volumes are removed. For wells where drilling fluids were introduced (i.e., cased borings, rock coring, mud rotary methods), ten (10) well volumes are removed. In these cases, inorganic field parameter readings may be obtained for informational purposes.

14. A parallel objective of well development may be to remove drilling fluid lost to the formation(s) that was introduced during the drilling process. This aspect of development is complete when the identified volume of fluid is removed, and stabilized inorganic parameters are achieved.

15. If field parameters have not stabilized after Step 13, increase pumping rate to dislodge fine-grained materials from the filter pack, or remove sediment in suspension. It may be necessary to lower pump intake to accommodate drawdown. Avoid pulling coarse sediment into well intake to prevent pump impeller damage.

16. If slow recharge rate does not allow for continuous operation, shut off pump, allow well to recharge, and resume pumping at slower rate and well evacuation until discharge water clears. Resume measuring field parameters (Step 13) until stabilized.

17. Complete documentation as appropriate.

3.8 Well Development Procedure – Inertial Pump Methods

Inertial pumps use a dedicated pre-cleaned single ball check valve ("foot valve") and HDPE discharge tubing to manually remove water from the well.

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1. Follow Preliminary Procedures above, including evaluation of well integrity and documentation of well construction details, and Section 5.7, Steps 1 through 10.

2. Attach foot valve (i.e. Waterra type) to bottom end of HDPE tubing and lower into well. Allow approximately 2 to 4 ft. extra tubing above well casing for controlling discharge of purge water.

3. To remove groundwater from the well, manually lift and lower the HDPE tubing within the well bore by hand, approximately once every three to five seconds, timing the motion to optimize purge water volume removed with each stroke. Clean foot valve if it becomes clogged or obstructed by sediment by carefully removing tubing from well, unthreading the foot valve, and rinsing with distilled water.

4. Monitor inorganic field parameters as in Steps 12 to 14, above.

5. If slow recharge rate does not allow for continuous purging, allow well to recharge, and resume purging and well evacuation until discharge water clears. Resume measuring field parameters until stabilized. HDPE tubing and foot valves are typically dedicated and left in groundwater well following sampling.

6. Complete documentation as appropriate.

3.9 Well Development Procedure - Surge Blocks

Surge blocks can be used in conjunction with pre-cleaned, dedicated inertial pumps (single ball check valve or "foot valve") and HDPE discharge tubing.

1. Follow Preliminary Procedures above, including evaluation of well integrity and documentation of well construction details, and Section 5.7, Steps 1 through 10.

2. Press fit the surge block device securely onto foot valve (i.e. Waterra type), attach foot valve to bottom end of HDPE tubing and lower into well. Allow approximately 2 to 4 ft. extra tubing above well casing for controlling discharge of purge water.

3. To surge the groundwater, lower the surge block into the water column and use as a "plunger" by manually lifting and lowering the HDPE tubing by hand, forcing water to flow into and out of the screened portion of the aquifer. Surge each well for a minimum of 30 minutes to remove the finer material from the aquifer surrounding the borehole, providing a developed zone of uniformly graded sand of higher porosity and higher permeability surrounding the well screen, allowing the water to flow more freely into the well, and reducing potential turbidity.

4. Following the surging portion of the well development, remove the surge block from the foot valve, and purge a minimum of one well volume from the well by removing the fine particles brought into the well during surging.

5. Monitor inorganic field parameters as in Steps 12 to 14, above.

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6. If slow recharge rate does not allow for continuous purging, allow well to recharge, and resume purging and well evacuation until discharge water clears. Resume measuring field parameters until stabilized. HDPE tubing and foot valves are typically dedicated and left in well following sampling.

7. Complete documentation as appropriate.

3.10 Well Development Procedure - Bailers

Hollow, cylindrical bailers are a type of grab sampling device, and may be constructed of stainless steel, Teflon, or PTFE, typically with a single ball check valve fixed on the bottom. They are manually lowered into the well using a rope tether, allowed to collect well water, then lifted from the well. The collected water is discharged to a graduated bucket, and the process repeated until the well is deemed adequately developed. Stainless steel bailers are generally simple to decontaminate. Teflon or PTFE bailers are considered dedicated or disposable after one-time use.

In general, the use of bailers are not a preferred well development method, due to the time required to remove potentially large volumes of development water, especially in deep wells. Their use, however, creates agitation and mixing within the water column, which suspends sediment and fines, incrementally aiding in clearing the well and filter pack, thereby reducing turbidity.

PTFE ("clear") bailers are often used to collect NAPL for thickness measurements or product analysis. Although not discussed in this procedure, bailers are generally not recommended for groundwater sampling overall, and not acceptable for low-flow groundwater sampling in particular, especially sampling for volatile organic compounds (VOCs), volatile petroleum hydrocarbons (VPH), dissolved metals or other analytes requiring field filtration.

3.11 Restoration and Cleanup

The area around the well head and ground surface shall be completely cleaned up of any development materials (plastic sheeting, tubing, paper towels, litter, etc.), and the well secured.

3.12 Documentation

A complete record of the well development procedure should be documented and incorporated into the project file. Complete portions of the Groundwater Sampling Record form, recording the following information:

- Project information, date and personnel present
- Well location and designation
- Well condition inventory
- Presence of NAPL

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- Diameter, depth of well, screened interval (if known), depth to static groundwater, volume of standing water column in well
- Detailed description of well development equipment and procedure used
- Time(s) development started and ended
- Incremental and total volume of purge water removed
- Inorganic field parameter measurements
- Comments on discharge water quality
- Modifications to procedures
- Decontamination method, and discharge water management method
- Drum count of accumulated discharge water, if applicable

Appendix C contains a blank Sampling Report (Form #3004), Groundwater Sampling Record (Form #3005), Monitoring Well Development Report (Form #3006) and Low Flow Field Sampling Form (Form #3010) for reference.

3.13 Precision and Bias

This procedure provides qualitative information only; therefore, a precision and bias statement is not applicable.

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TABLE 1
Common Well Development Equipment

Material	Type	Power Requirement	Positive Attributes	Negative Attributes
Mechanical Pumps:				
Grundfos Pump	Submersible pump (variable speed)	120V A.C. current	-Lift height only constrained by cable length (+/- 150 ft.) -Controllable, variable flow rate from 0.01 to ≈35 L/minute -Stainless steel disassembles for simple decontamination See note 1	-Requires generator if no power source available -Risk of cross contamination of sample glassware or tubing from generator fuel -Heavy/cumbersome -Sediment may clog pump impellers -2.0 in. minimum well diameter See note 2
GeoDurham	Submersible Pump (variable speed)	12V D.C. current (Automotive battery)	-Portable power supply -Lift height only constrained by cable length (+/- 75 ft) -Controllable, variable flow rate -Stainless steel for simple decontamination See note 1	-Limit on lowest pump speed/discharge -Sediment may clog pump impellers -Power supply limits duration of pump use -2.0 in. minimum well diameter See note 2
Whale Pumps	Submersible pump (variable speed)	12V D.C. current (Automotive battery)	-Portable power supply -Lift height only constrained by cable length (+/- 30 ft.) -Disassembles for simple decontamination -1.5 in. minimum well diameter	-Power supply limits duration of pump use See note 2
Peristaltic Pumps	Suction lift surface pump (single speed)	12V D.C. current (Automotive Battery)	-Good for purging sediment from silt trap during development -Dedicated tubing -Easy to operate -0.5 in. minimum well diameter	-Not appropriate for sampling VOCs (agitation) -Lift limited to ≈25 ft. BGS -Pump rate 0.01 L/min.
Manual Methods:				
Inertial Pump	Submersible foot valve with discharge tubing	Manually operated	-Dedicated tubing -Inexpensive -Simple to operate -0.5 in. minimum well diameter	-Depth limited by manual capability to lift tubing (typically 70 to 80 ft.) -Tiring for large volumes of development water -Sediment may clog foot valve
Stainless Steel Bailer	Grab sample device with single check valve	Manually operated	-Disassembles for simple decontamination -Simple to operate	-Not appropriate for groundwater sampling (agitation) -Tiring for large volumes of development water -Splash hazard
Teflon Bailer	Grab sample device with single check valve	Manually operated	-Dedicated -Simple to operate -Inexpensive	-Not appropriate for groundwater sampling (agitation) -Tiring for large volumes of development water -Splash hazard
Clear Bailer	Grab sample device with single check valve	Manually operated	-Dedicated -Simple to operate -Inexpensive -Can collect NAPL for evaluation	-Not appropriate for groundwater sampling (agitation) -Tiring for large volumes of development water -Splash hazard

Notes and References:
1. Appropriate for low flow/low stress groundwater sampling.
2. Not appropriate if DNAPL/LNAPL present in monitoring well.

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APPENDIX A
REFERENCES

A.1 Reference Procedures

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D5521-94, "Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers."

- Puls, R.W., Barcelona, M.J., 1996. "Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures," US EPA Ground Water Issue, US Environmental Protection Agency. Office of Solid Waste, EPA/540/S-95/504, pp. 1 to 12.

- US Environmental Protection Agency, Region I, (30 July 1996). "Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells," SOP # GW 0001, Revision 2.

A.2 Other References

- US Environmental Protection Agency, 1992. Office of Solid Waste," RCRA Groundwater Monitoring: Draft Technical Guidance," EPA/530/R-93/001, NTIS PB 93-139350, November 1992, pp. 6-46 to 6-50.

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D6634-01, "Standard Guide for the Selection of Purging and Sampling Devices for Groundwater Monitoring Wells."

- American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D5903-96 (Reapproved 2001), "Standard Guide for Planning and Preparing for a Groundwater Sampling Event."

- Massachusetts Department of Environmental Protection, "Standard References For Monitoring Wells," January 1991, document WSC-310-91, Section 4.5 Well Development.

A.3 COMMENTS ON REFERENCE PROCEDURES

The procedures and equipment listed in EFP No. 01a and used by Haley & Aldrich are generally as specified in the ASTM and US EPA Reference Procedures. Deviations of EFP No. 01a from the Reference Procedures are not provided. The procedure described in Section 5 has been developed to assist Haley & Aldrich personnel in performing well development, and in some cases simplifies the Reference Procedures.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP2020 Groundwater Monitoring (Observation) Well Abandonment
-
-
- OP3007 Procedures for Surface Water Sampling
- OP3008 Manual Water Level Measurement Procedure
- OP3010 Groundwater Quality Sampling Procedure
- OP3012 Low Stress/Low Flow Groundwater Sample Collection Procedure
-
- OP3015 Aquifer Parameter Testing Procedure

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APPENDIX C
FORMS

- 3004 Sampling Report
- 3005 Groundwater Sampling Record
- 3006 Monitoring Well Development Report
- 3010 Low Flow Field Sampling Form

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SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

Weather _____ **Temperature** _____

Ground surface Conditions ☐ Dry ☐ Wet ☐ Damp ☐ Standing Water ☐ Snow (_____in) ☐ Other_____

Comments _____

SOIL SAMPLING AND SURFACE WATER SAMPLING INFORMATION

Sample No.	Location	Depth (ft)	Time	Sample Description	Sampling Device	Cleaning Prodedure	Container Type

General Comments: (ie: field filtrations, persons communicated with at site, etc.)

Form 3004

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GROUNDWATER SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

GROUNDWATER SAMPLING INFORMATION

Well No.							
Water Depth (ft)							
Time							
Product							
Depth Of Well (ft)							
Inside Diameter (in)							
Standing Water Depth (ft) (1)							
Volume Of Water In Well (gal)							
Purging Device							
Volume of Bailer/Pump Capacity							
Cleaning Procedure							
Bails Removed/ Volume Removed							
Time Purging Started							
Time Purging Stopped							
Sampling Device							
Cleaning Procedure							
TIME SAMPLES TAKEN	VOA						
	ABN						
	Metals						
PARAMETERS	Color						
	Odor						
	pH						
	Conductivity						
	Turbidity						
	Dissolved Oxygen						
	Temp, ^{0} C						
	Salinity						

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

1. Standing Water Depth = Depth of Well - Water Depth

Form 3005

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MONITORING WELL DEVELOPMENT REPORT

Well No.

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE	
ELEVATION SUBTRAHEND			

Estimated Volume of Water Lost During Drilling: _____ gallons

Comments: _____

Depth to Water Before Development: _____ feet

Comments: _____

Depth to Well Bottom Before Development: _____ feet

Comments: _____

Turubitiy of Water Before Development: _____ NTU

Comments: _____

Volume of Water Removed: _____ gallons

Comments: _____

Method of Removal (bailing, pumping): _____

Comments: _____

Depth to Well Bottom After Development: _____ feet

Comments: _____

Depth to Water After Development: _____ feet

Comments: _____

Turubitiy of Water After Development: _____ NTU

Comments: _____

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LOW FLOW/MNA FIELD SAMPLING FORM

PROJECT _____ **H&A FILE NO.** _____

LOCATION _____ **PROJECT MGR.** _____

CLIENT _____ **FIELD REP** _____

CONTRACTOR _____ **DATE** _____

Sampling Data:

Well ID: _____ Well Depth: _____ ft Initial Depth To Water: _____ ft Purging Device: _____

Start time: _____ Depth To Top Of Screen: _____ ft Depth Of Pump Intake: _____ ft Tubing Present In Well: ☐ Yes ☐ No

Finish Time: _____ Depth To Bottom Of Screen _____ ft Tubing Type: _____

Elapsed Time (24 hour)	Depth To Water From Casing (ft)	Pump Setting (ml/min) or (gal/min)	Purge Rate (ml/min) or (gal/min)	Cumulative Purge Vol. (liters) or (gal)	Temp-erature (°F) or (°C)	pH	Conduct-ivity (us/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	ORP/eH (mv)	Comments

OPERATING PROCEDURE: OP3010

GROUNDWATER SAMPLING

LEVEL II (Interim)

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.1	R. Selover: 04/05/08	JCP06/05/08	MDK 6/6/08		

Total Pages: 52

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OPERATING PROCEDURE: OP3010

GROUNDWATER SAMPLING

1. PURPOSE

Groundwater samples from monitoring wells, piezometers, temporary well points, and other subsurface borings can be used for a variety of applications, including characterization of groundwater chemistry, and delineation/nature & extent of contaminant plumes. The intended use of the data collected frequently dictates the process by which samples are collected; however there are general guidelines for collecting these samples. The following operating procedure was developed to ensure uniform collection standards.

2. EQUIPMENT & SUPPLIES

- Personal protective equipment (as required by the Health and Safety Plan)
- Cleaning equipment (as required in the Equipment Cleaning Procedures)
- Weighted Tape or Water Level Indicator
- Sturdy nylon cable
- Pocket knife
- Digital Camera
- Coolers with ice
- Appropriate sample containers, labels and forms
- Field notebook
- Haley & Aldrich Form 3005- Groundwater Sampling Record
- Appropriate Sampler
  - Reusable Teflon® or disposable polyethylene bailer, equipped with bottom check ball
  - Polyethylene or nylon string.
  - Grundfos®, Whale®, or peristaltic pump
  - Silicone sample tubing (i.e. Masterflex® or equivalent)
  - Polyethylene sample tubing (i.e. Waterra® or equivalent)

3. PROCEDURE

The following procedures describe the use of several devices for the purpose of collecting groundwater samples. In addition, several relevant Haley & Aldrich Operating Procedures (OPs) are listed here:

Decontaminate reusable equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

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Disposal of excess purge water as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

3.1 Pre-sampling Observations, and Required Data Entries

A number of field measurements and observations should be made in the field when sampling groundwater. This information is listed below and will be recorded on a Groundwater Sampling Record. The following list of measurements and observations represents a minimum requirement for groundwater samples.

- Well number/ID
- Static water level (depth to water)
- Time
- Depth to product (if applicable)
- Depth to bottom of the well
- Inside diameter of well
- Calculated well volume
- Purging device
- Volume of bailer/Pump capacity [Note: This is "Continuous" for peristaltic, Grundfos® and Whale® pumps]
- Cleaning procedure
- Bails removed/volume removed
- Time purging started
- Time purging stopped
- Sampling device [Note: For pumps, this is "Waterra Tubing" or equivalent]
- Cleaning procedure [Note: If applicable, this is "Dedicated"]
- Time samples taken
- Sample Characteristics: pH, Conductivity, Dissolved Oxygen, Temperature, Preservative(s)
- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory)
- Description of the Sample Location
- Photograph details (i.e. Picture number, orientation, subject matter, etc.)
- Latitude/Longitude (using GPS, collect Waypoint as well).
- Observable Physical Characteristics - Odor, Color, Clarity.
- Evidence of Stressed Vegetation, Wildlife, or Dumping.
- Ambient Weather Conditions during Sampling - Air Temperature, Atmospheric Conditions, Recent Precipitation or Drought.
- Samples Collected (enter all sample numbers collected at this location)

All entries will be made as described in Haley & Aldrich Level III Operating Procedure OP3029- Field Data Recording.

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3.2 Bailer

A bailer is a simple, but effective method of collecting groundwater samples. It allows for direct sampling, generally does not have limitations on its depth of implementation, and can be deployed easily. However, purging large volumes of water is difficult, and use of this device may physically disturb water within the well more than with other methods. Hence, this method should only be used when determined to be appropriate by the project manager.

1. Develop the well as described in Haley & Aldrich, Inc. Level I Operating Procedure 3009- Monitoring Well Development Procedure.

2. Collect samples in order of increasing volatility
   a. Samples for VOA should be collected within three hours of well evacuation if sufficient volume is present.
   b. Fill sample vial until there is a meniscus above the sample container rim, so as to ensure that no air bubbles are in the container, once sealed.
   c. Cap sample container and turn up-side down to verify a there are no bubbles in the sample.
   d. If the volume of water in the well is insufficient to sample for other parameters after three hours, sample it within 24 hours of initial evacuation.

3. Attach a polypropylene or nylon line to the bailer.

4. Slowly lower bailer to desired depth within well.

5. Gently raise bailer to surface.

6. Slowly fill appropriate sample containers.

7. If sampling for metals, field filter samples using a 0.45 micron filter and a hand operated vacuum pump assembly.

8. Discard disposable bailer after each use.

3.3 Check Ball

A check ball is a simple device that is attached to polyethylene tubing, and manually agitated to withdraw water out of a well. The device allows for simple and direct sampling procedures, however it may be tedious to purge large amounts of water, and the agitation can physically disturb the water within the well. Hence, this method should only be used when determined to be appropriate by the project manager.

1. Attach stainless steel or polyethylene check valve to polyethylene tubing.

2. Lower tubing and check valve through the probe rods.

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3. Agitate tubing up and down until water is flowing out of tubing. [The foot valve opens and closes, drawing water up the tube.]

4. Slowly fill appropriate sample containers.

5. If sampling for metals, field filter samples using a 0.45 micron filter and a hand operated vacuum pump assembly.

6. Tubing and check ball may be dedicated to a single well, otherwise discard tubing and check ball.

7. Complete Groundwater Sampling Record.

3.4 Grundfos® Pump

A Grundfos® pump is a submersible pump that allows for precise control of purge rates by use of a variable frequency drive. This pump works well in a variety of depths and is chemically inert. However, it can be impractical in wells with low recharge rates, and needs to be decontaminated prior to each use.

Please see the Grundfos® company literature in Attachment 1.

1. Develop the well as described in Haley & Aldrich, Inc. Level I Operating Procedure 3009- Monitoring Well Development Procedure.

2. Collect samples in order of increasing volatility
   a. Samples for VOA should be collected within three hours of well evacuation if sufficient volume is present.
   b. Fill sample vial until there is a meniscus above the sample container rim, so as to ensure that no air bubbles are in the container, once sealed.
   c. Cap sample container and turn up-side down to verify a there are no bubbles in the sample.
   d. If the volume of water in the well is insufficient to sample for other parameters after three hours, sample it within 24 hours of initial evacuation.

3. Attach sample polyethylene tubing to pump.

4. Use variable frequency drive to maintain appropriate withdrawal rate.

5. Slowly fill appropriate sample containers.

6. If sampling for metals, field filter samples using a 0.45 micron filter and a hand operated vacuum pump assembly.

7. Leave dedicated sample tubing in well, or dispose if tubing is not permitted in well.

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8. Fill out Groundwater Sampling Record.

3.5 Whale® Pump

A Whale® Pump is a submersible pump that allows for gross control of purge rates by use of an amperage controller. This pump works well in shallow depths and is chemically inert. Furthermore, several pumps can be combined in order to sample deep wells. However, it can be impractical in wells with low recharge rates, and needs to be decontaminated prior to each use.

1. Develop the well as described in Haley & Aldrich, Inc. Level I Operating Procedure 3009- Monitoring Well Development Procedure.

2. Collect samples in order of increasing volatility
   a. Samples for VOA should be collected within three hours of well evacuation if sufficient volume is present.
   b. Fill sample vial until there is a meniscus above the sample container rim, so as to ensure that no air bubbles are in the container, once sealed.
   c. Cap sample container and turn up-side down to verify a there are no bubbles in the sample.
   d. If the volume of water in the well is insufficient to sample for other parameters after three hours, sample it within 24 hours of initial evacuation.

3. Attach sample polyethylene tubing to pump.

4. Use variable frequency drive to maintain appropriate withdrawal rate.

5. Slowly fill appropriate sample containers.

6. If sampling for metals, field filter samples using a 0.45 micron filter and a hand operated vacuum pump assembly.

7. Leave dedicated sample tubing in well, or dispose if tubing is not permitted in well.

8. Fill out Groundwater Sampling Record.

3.6 Drive Point

Please refer to Haley & Aldrich Operating Procedure OP3011- Groundwater Sampling Using Direct Push Technology.

3.7 Peristaltic Pump

Peristaltic pumps are devices that agitate the sample tubing outside of the well, thereby withdrawing water from the well without physically disturbing the water within the well. They can maintain very low withdrawal rates, and are therefore ideal for wells with low recharge rates.

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Please refer to Haley & Aldrich, Inc. Operating Procedure 3012- Low Stress/Low Flow Groundwater Sample Collection Procedure.

For situations that do not require Low Stress/Low Flow conditions, operate the peristaltic pump as described above, but disregard procedures related to the flow cell, and monitoring of water quality parameters.

3.8 Collection and Processing Methods for Groundwater Samples

Descriptions for collecting and processing groundwater samples for specialized analyses are presented below. The general procedure and methods described for each groundwater sampling method described above should be followed with the addition of the details below.

3.8.1 Samples for Chemical Analyses

1. Sample glassware should be filled to the top of the sample container for analysis VOA. Air bubbles are not permitted in the sample. When collecting a sample for VOA allow sample to spill over before attempting to cap vial. After collecting the sample, cap the 40 ml VOA vial and turn up-side down to verify bubble-free conditions. If there are bubbles present in the sample, remove the cap and continue to fill the sample to remove the air.

2. Water samples that will be tested for dissolved metals will be filtered in the field with a 0.45 micron filter or cartridge or according to procedures described in the U.S. EPA SW-846 Manual, Method 3005. The filtrate will be preserved to pH <2 with nitric acid.

3.8.2 Samples for Microbial Analysis

Groundwater samples taken for microbial analysis must be filtered and handled as described in this section. Samples for Q-potential (DNA)/ Denaturing Gradient Gel Electrophoresis (DGGE) (DNA) Analysis and Samples for Pospholipid Fatty Acid (PLFA) Analysis are as follows:

1. Prepare groundwater sampling equipment as normal.

2. Remove the sample dedicated Bio-Flo analysis-specific filter provided from the Falcon tube.

3. Attach the inlet of the filter with a ¼”- 5/16” inner diameter tubing using a clamp to secure the tubing to the filter.

4. Place the filter within a receiving container so that the volume of water filtered can be measured accurately.

5. Filter between 1-2 L of water. Volume filtered can be determined by first calculating the flow rate of the pump and then allowing water to pass through the filter for a determined amount of time. The volume of water filtered will vary depending on the turbidity of the water.

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6. Record the volume of water that passed through the filter, and place the filter back into the Falcon tube that it cam in and submit the filter for analysis.

7. If the filter clogs before 1L has been filtered, record how much water has passed through the first filter, and then collect and additional filter, also recording the volume of water that went through the second filter. In this case, both filters are then submitted for testing. For each location, there should be no more than 2 filters used and there is no need to filter more than 2L of water.

8. Record volume of water that passed through the filter as well as the requested analysis. Samples should be shipped in a cooler with ice to the laboratory for next day delivery. Individual samples should be double bagged inside the cooler to protect the samples from getting wet.

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APPENDIX A
REFERENCES

Grundfos® Redi-Flo 2 Installation and Operating Instructions.
Grundfos® Redi-Flo Variable Frequency Drive Installation and Operating Instructions.

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Redi-Flo 2

Stainless Steel Submersible Pumps for Environmental Purge & Sampling Applications

USA Installation and operating instructions

Please leave these instructions with the pump for future reference.

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Grundfos Stainless Steel Submersible Pumps

Your Grundfos Redi-Flo2 Environmental Pump is of the utmost quality. Combined with proper installation, your Grundfos pump will give you many years of reliable service.

To ensure the proper installation of the pump, carefully read the complete manual before attempting to install the pump.

⚠ SAFETY WARNING

Electrical Work

Before beginning installation procedures, these installation and operating instructions should be studied carefully. All electrical work should be carried out by a qualified electrician in accordance with the latest edition of the National Electrical Code (NEC), local codes and regulations.

Adherence To Environmental Regulations

When handling and operating the Redi-Flo Variable Performance Pump system, all environmental regulations concerning the handling of hazardous materials must be observed. When the pump is taken out of operation, great care should be taken to ensure that the pump contains no hazardous materials that might cause injury to human health or to the environment.

Returning a Pump for Service

Only pumps that are certified as uncontaminated will be accepted by GRUNDFOS for servicing. GRUNDFOS must receive this certification prior to receiving the pump. If not, GRUNDFOS will refuse to accept delivery of the pump. In these cases, all costs incurred in returning the product to the customer will be paid by the customer. Contact your distributor for details on returning Redi-Flo products for servicing.

Electrical Hazards

The Redi-Flo Variable Performance Pump system is not approved for Class 1, Division 1, Group D locations as specified by the National Electrical Code (NEC). Consult local authorities and regulations if you have any doubt about its suitability for a specific application.

Shipment Inspection

Examine the components carefully to make sure no damage has occurred to the pump-end, motor, cable or control box during shipment.

This Grundfos Redi-Flo2 Environmental Pump should remain in its shipping carton until it is ready to be installed. The carton is specially designed to protect it from damage. During unpacking and prior to installation, **make sure that the pump is not contaminated, dropped or mishandled.**

The motor is equipped with an electrical cable. **Under no circumstance should the cable be used to support the weight of the pump.**

Pre-Installation Checklist

Before beginning installation, the following checks should be made. They are all critical for the proper installation of this submersible pump.

A. Condition of the Well

If the pump is to be installed in a new well, the well should be fully developed and bailed or blown free of cuttings and sand. Dispose of discharged materials in accordance with the specific job site requirements. The stainless steel construction of the Redi-Flo2 Environmental Pump makes it resistant to abrasion; however, no pump, made of any material, can forever withstand the destructive wear that occurs when constantly pumping sandy groundwater.

The inside diameter of the well casing should be checked to ensure that it is not smaller than the size of the pump and motor.

B. Condition of the Water

Redi-Flo2 pumps are designed for pumping cold groundwater that is free of air or gases. Decreased pump performance and life expectancy can occur if the groundwater is not cold or contains air or gases.

C. Installation Depth

Pumping sand or well sediment can occur when the pump motor is installed lower than the top of the well screen or within five feet of the well bottom. This can reduce the performance and life expectancy of the pump and should be avoided.

D. Electrical Supply

The Redi-Flo2 motor is a 3 phase 220 VAC unit designed to be driven by the Redi-Flo2 VFD.

Wire Cable Type

The wire cable used between the pump and control box or panel should be approved for submersible pump applications. The conductor insulation should have a continuous Teflon® jacket with no splices and must be suitable for use with submersible pumps.

Installation

The riser pipe or hose should be properly sized and selected based on estimated flow rates and friction-loss factors.
A back-up wrench should be used when attaching a riser pipe or metallic nipple to the pump. The pump should only be gripped by the flats on the top of the discharge chamber. The body of the pump, or motor should not be gripped under any circumstance.

If Steel Riser Pipe is Used

An approved pipe thread compound should be used on all joints. Make sure the joints are adequately tightened in order to resist the tendency of the motor to loosen the joints when stopping and starting.

After the first section of the riser pipe has been attached to the pump, the lifting cable or elevator should be clamped to the pipe. Do not clamp the pump. When raising the pump and riser section, be careful not to place bending stress on the pump by picking it up by the pump-end only. A check valve may be added to the pump to prevent fluid from flowing back into the pump after it is turned off.

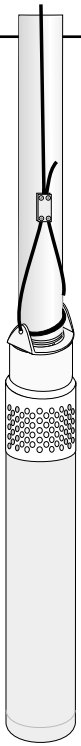
Make sure that the electrical cables are not cut or damaged in any way when the pump is being lowered in the well.

The drop cable should be secured to the riser pipe at frequent intervals to prevent sagging, looping or possible cable damage.

If Plastic or Flexible Riser Pipe is Used:

Use the correct compound recommended by the pipe manufacturer or specific job specifications. Make sure that joints are securely fastened.

Do not connect the first plastic or flexible riser section directly to the pump. Always attach a metallic nipple or adapter into the discharge chamber of the pump. When tightened, the threaded end of the nipple or adapter must not come in contact with the check valve retainer in the discharge chamber of the pump.



IMPORTANT - Plastic and flexible pipe tend to stretch under load. This stretching must be taken into account when securing the cable to the riser pipe.

Leave enough slack between tie points to allow for this stretching. This tendency for plastic and flexible pipe to stretch will also affect the calculation of the pump setting depth. If the depth setting is critical, check with the manufacturer of the pipe to determine how to compensate for pipe stretch.

When these types of pipe are used, it is recommended that a safety cable be attached to the pump to lower and raise it. A safety cable bracket is available from Grundfos (part # 001A0019)

Protect the Well from Contamination

While installing the pump, proper care should be used not to introduce foreign objects or contaminants into the well. To protect against surface water entering the well and contaminating the well, the well should be finished off utilizing a locally approved well seal.

Lowering the Pump Into the Well

Make sure the electrical motor leads are not cut or damaged in any way when the pump is being lowered into the well. Do not use the motor leads to support the weight of the pump.

Operating Conditions

To ensure the Redi-Flo Variable Performance Pumping system operates properly, follow these guidelines:

- The Redi-Flo2® pump must be installed vertically with the discharge end pointed upwards.
- The pump and motor must always be completely submerged in fluid to ensure lubrication and cooling of the motor.
- The temperature of the fluid being pumped should be according to the technical specifications.
- The installation depth of the pump should always be at least three feet below the maximum drawdown level of the well.
- Redi-Flo pumps are not recommended for well development or pumping fluid containing abrasives.
- Redi-Flo2® pumps are not recommended for continuous operation applications.
- The warranty of the Redi-Flo pumps will be void if other than the Redi-Flo VFD is used or if corrosive fluids are pumped.
- The service life of dedicated Redi-Flo pumps may be compromised if the ambient water quality exceeds one or more of the following values:
  pH<5 DO>2 ppm H2S>1 ppm CL->500 ppm TDS>1000 ppm

Electrical

WARNING: To reduce the risk of electrical shock during operation of this pump requires the provision of acceptable grounding. Refer to the Redi-Flo Variable Frequency Drive Instructions Manual (L-RF-IO-009) for proper wiring instructions.

All electrical work should be performed by a qualified electrician in accordance with the latest edition of the National Electrical Code, local codes and regulations.

Dismantling & Reassembling Pump End

The Redi-Flo2® pump can be dismantled and reassembled quickly and easily by referring to the diagram on page 12 and following these steps:

DISMANTLING

1. Shut the pump off by placing the Redi-Flo VFD in the stop position.
2. Disconnect Redi-Flo VFD from power supply or generator.
3. Disconnect the motor lead from the Redi-Flo VFD.
4. Remove the pipe or tubing connected to the pump (OPTIONAL).
5. Remove the Set Screw (position 12 in the diagram on page 12). Grasp the Inlet Screen (position 1) and slowly but forcefully pull it up over the Pump Housing (position 2).

DO NOT ALLOW THE INLET SCREEN TO SCRAPE THE INSULATION FROM THE MOTOR LEAD.

6. Unscrew and remove the Pump Housing (counterclockwise when viewed from the top). This will expose the impeller assembly (guide vanes, wear rings, etc.), which can now be removed by hand for extended cleaning or replacement.

REASSEMBLY

To reassemble the Redi-Flo2® pump, refer to the diagram on page 12 and:

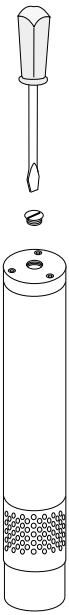
1. Make sure the motor lead is not connected to the Redi-Flo VFD.
2. Return the impeller assembly components (guide vanes, wear rings, etc.) to the shaft in the proper order per impeller assembly diagram.
3. Screw the Pump Housing (position 2) back onto the top of the pump. If all of the impellers and chambers were replaced correctly, the Pump Housing should screw on easily. Hand tighten.
4. Slip the Inlet Screen (position 1) back over the Pump Housing. Screw the Set Screw (position 12) back into the Inlet Screen.

MAKE SURE TO LINE UP THE MOTOR LEAD WIH THE RECESSED AREA IN THE PUMP HOUSING TO AVOID SCRAPING THE INSULATION FROM THE LEAD.

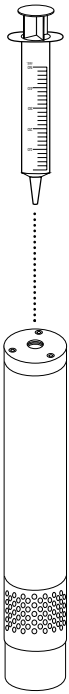
Dismantling & Reassembling Motor

If the pump is moved from well to well, it should be thoroughly decontaminated prior to being installed in the next well. In addition to cleaning the individual components inside and outside, the water in the pump motor should be replaced using the syringe that came with your pump. This can be accomplished through the following steps:

1. Shut the pump off by placing the Redi-Flo VFD in the stop position.
2. Disconnect Redi-Flo VFD from power supply or generator.
3. Disconnect the motor lead from the Redi-Flo VFD.
4. Remove the discharge tubing and the pump end (follow dismantling procedure page 5).
5. Turn the pump and motor upside down.



6. Use a flat blade screwdriver to remove the filling screw on the bottom of the motor.
7. Remove the three Allen head set screws at the bottom of the motor with a 2.5 mm Allen wrench.
8. Push gently on the motor shaft to move bearing housing out of the stator housing.
9. Continue to remove bearing housing and motor shaft from stator housing.
10. Clean motor shaft with a brush.
11. Empty the water from the motor.
12. Clean inside of stator housing with a brush.
13. Replace motor shaft into stator housing.



14. Refill motor using contaminant-free deionized water using the syringe that came with your Redi-Flo2® pump.
15. Replace bearing housing and tighten Allen screws.
16. Continue to add water until the level is even with the bottom edge of the screw hole.
17. Replace and tighten the filling screw.
18. Turn the pump over several times, then remove the filling screw again to let any trapped air escape (if air is left inside the motor, the life of the motor will be shortened). Add more water, as necessary. Fluid should overflow when the fill cap is screwed back on the motor cavity.
19. Replace and tighten the filling screw.
20. Replace pump end and piping (see reassembly page 6)

Replacing the Motor Lead

To replace the motor lead, refer to the diagram on page 12 and follow these steps:

REMOVING THE OLD MOTOR LEAD

1. Make sure the Redi-Flo VFD is turned **OFF**, and the motor lead is not connected to the Redi-Flo VFD.

2. Loosen and remove the Set Screw (position 12) from the Inlet Screen (position 1).

3. Slide the Inlet Screen off the pump. If you plan to use this motor lead again, be careful not to scrape insulation from it as the Inlet Screen is removed.

4. Loosen and remove the Pump Housing (position 2). Remove the impeller assembly (impellers, guide vanes, etc.).

5. Refer to the illustration on page 12. Use a 6mm wrench to loosen and remove the Motor Lead Screw (position 14) for the ground lead (green/yellow wire).

6. Pull up on the ground lead to remove it. Using a small screwdriver and precision electronics pliers, pry up and remove the Teflon® Washer (position 15) and Brass Washers (position 16) from inside the enlarged Ground Motor Screw (position 13). Remove the 8mm Ground Motor Screw.

7. Use an Allen wrench (2.5 mm) to remove the two Motor Screws (position 19) holding the Suction Interconnector (position 10) in place. Remove the Suction Interconnector but be very careful to note which of its slots is lined up with which motor lead -- this will be very helpful during reassembly. You may wish to scratch a mark on both the Suction Interconnector and the motor to aid in matching them up later.

8. Refer to the illustration on the next page. Use a 6mm wrench to loosen and remove the remaining Motor Lead Screws (position 14).

9. Pull up on each of the leads to remove them. Make a note which lead comes out of each hole-- **this is a MUST** when installing the new motor lead. Using a small screwdriver and precision electronics pliers, unscrew and remove the Teflon® Washer (position 15) and the Grommet (position 17).

Installing the New Motor Lead

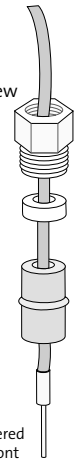
10. Ensure the motor lead holes are clean and free of moisture.

11. String the Inlet Screen (position 1) onto the motor lead.

12. String the motor lead components (shown at right) onto the end of each motor lead wire (except the striped green ground wire). Using a wire crimp tool, properly crimp each pin onto the lead wires.

13. For each wire, place the Crimped Pin (position 18) down into the motor lead hole. Press the Grommet (position 17) and Teflon® Washer (position 15) down around the lead. Be sure to reconnect the lead wires in their previous pattern described below.

Power Conducting Motor Leads



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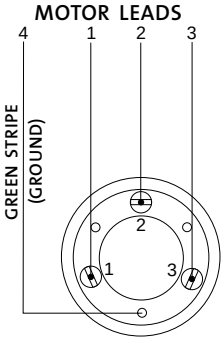


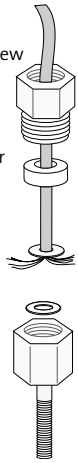
NOTE: For Tefzel motor lead, use the following wiring pattern: 1, 2, 3 clock wise from ground terminal (striped green).

14. While pushing the lead down into the motor lead hole, use a 6mm wrench to tighten the Motor Lead Screw (position 14) into place. Repeat for the other two lead wires.

15. Replace the Suction Interconnector (position 10). Replace the Ground Motor Screw (position 13). Since the ground wire will be attached to this screw, you will want to put it into the hole that will cause the least amount of twisting to the wire.

16. Replace and tighten the two Motor Screws (position 19) with an Allen wrench.

Ground Motor Load



17. String the motor ground lead through the hex lead screw, teflon washer and brass washers. Strip about 1/4 inch of insulation from the lead and fray the copper strands outward as shown. Press the washers down into the ground screw and tighten the motor lead screw in place.

18. Return the impeller assembly to the top of the Suction Interconnector (position 10). Refer to the diagram on page 12 for the proper sequence.

19. Screw the Pump Housing (position 2) back onto the Suction Interconnector.

20. Position the motor lead in the recessed area of the Pump Housing.

21. Carefully push the Inlet Screen (position 1) over the Pump Housing and the Suction Interconnector.

BE VERY CAREFUL TO AVOID SCRAPING THE INSULATION FROM THE MOTOR LEAD AS THE INLET SCREEN IS FITTED.

22. Line up the screw hole in the Inlet Screen with the screw hole in the Pump Housing. Fit and tighten the Set Screw (position 12).

23. Connect the motor lead to the Redi-Flo VFD and test the rotation of the pump. Submerge the pump in water, start it at its slowest speed and make sure the pump shaft is turning counterclockwise (when viewed from the top). If the rotation is incorrect, switching any two power leads (with POWER OFF) will correct the problem.

24. Reconnect the tubing or pipe.

Periodic Motor Inspection

If the pump is operating at a decreased capacity and the impeller assembly components (impellers, guide vanes, etc.) do not appear to be the cause, the motor should be checked. A checklist of things to examine includes:

- Check the fluid level inside the motor (refer to page 7). Replace and refill as necessary.
- Inspect the outside of the motor for cracks, dents, etc.
- Remove the Inlet Screen (position 1), Pump Housing (position 2), and the impeller assembly (guide vanes, wear rings, etc.). Try to spin the motor shaft by hand. It should spin freely. If it does not, the motor must be replaced.
- Check the winding and insulation resistance of the motor and lead as described on page 11.

Winding Resistance

Turn the power off and disconnect the motor lead from the converter. Using an ohmmeter, set the scale to R X 1. Zero-adjust the meter and measure the resistance between any two power conducting leads (prongs on the motor lead plug). If the ohm value is too low, the motor may be shorted. If too high, the motor windings or the leads may be open.

Lead Length	Ohm Value
0 ft	3.0 - 3.5 Ω
50 ft	3.6 - 4.1 Ω
75 ft	3.9 - 4.4 Ω
100 ft	4.2 - 4.7 Ω
125 ft	4.5 - 5.0 Ω
150 ft	4.8 - 5.3 Ω
175 ft	5.1 - 5.6 Ω
200 ft	5.4 - 5.9 Ω
250 ft	6.0 - 6.5 Ω
300 ft	6.6 - 7.1 Ω

Insulation Resistance

Turn the power off and disconnect the motor lead from the converter. Use a 500V megohmmeter or megger (1 Meg = 1 M = 1 million). Zero-adjust the meter and measure the resistance between any power conducting leads (prongs on the motor lead plug) and ground. If the pump has been removed from the well, a good way to test this (as shown above) is to submerge the motor lead and Redi-Flo2® pump in a bucket of water. Touch one lead of the megohmmeter to the pump and one to a motor lead.

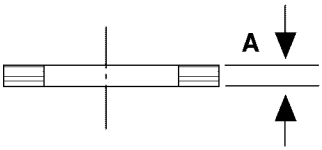
If the ohm value is lower than 1.5M Ω on any lead other than ground, the motor or lead is defective and must be replaced.

Checking Components For Wear

The pump components should be periodically checked to ensure they are still within their minimum operating tolerance (refer to the Assembly Diagram below).

Impeller (position 5) .....The impellers should show no visible wear.
Guide Vane (position 3).....The guide vanes should show no visible wear.
Wear Ring (position 4).....The minimum thickness ("A" in the illustration) should never be less than 0.04" (1.0 mm)

In addition, visually check all components for cracks, corrosion, or wear.



Storage Requirements

The pump should be thoroughly cleaned before storage to ensure no contamination is present. Both the pump and the converter should be stored in a clean and dry area in the following temperature range:

34°F (1°C) to 120°F (50°C)

Assembly Diagram — Redi-Flo2®

Pump Components

Pos. No.	Part Description	No. Used Per Pump	Part Number
1	Inlet Screen	1	1A0004
2	Pump Housing 1/2" NPT	1	1A0044
3	Guide Vane	2	see Service Kits
4	Wear Ring	2	"
5	Impeller	2	"
6	Spacer Ring	2	"
7	Wear Plate	2	"
8	Motor Lead Assembly	4	see Pos. 13 - 18
9	Shaft	1	not available *
10	Suction Interconnector	1	1A5004
11	Stator Housing	1	not available *
12	Set Screw	1	see Service Kits
13	Ground Motor Screw	1	"
14	Motor Lead Screw	4	"
15	Teflon® Washer	4	"
16	Brass Washer	2	"
17	Grommet	3	"
18	Crimped Pin	3	"
19	Motor Screw (long)	2	"
20	Motor Screw (short)	6	"
21	Filling Screw w/ O-Ring	1	"
22	Motor Thrust Washers	2	"
23	Lip Seal	1	ID5566
24	Bearing Housing O-Ring	2	see Service Kits

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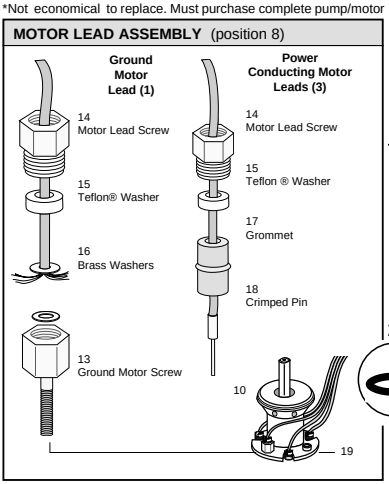
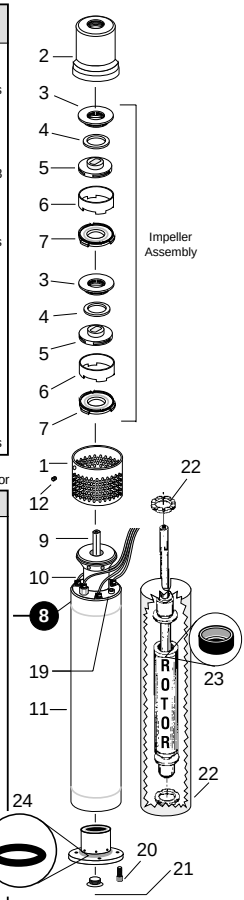
*Not economical to replace. Must purchase complete pump/motor





Redi-Flo2® Pump & Motor

ELECTRIC	
Full Load Rating	.5 HP / 220V / 3 PH / 400 Hz / 5.5A
Maximum Current (SFA)	5.5 amps
Motor Protection	Thermal overload - Thermik Geratebau, Series SY6 - (176°F [80°C]) Current Overload - Incorporated into Redi-Flo VFD
PIPING CONNECTION	
Discharge Port	½" Female NPT
OPERATING CONDITIONS	
Minimum Ambient Fluid Temperature	34°F (1°C)
Maximum Ambient Fluid Temperature	80°F (28°C)
MOTOR FLUID	
Motor Lubricating Fluid	Deionized (DI) Water
STORAGE CONDITIONS	
Minimum Ambient Temperature	34°F (1°C)
Maximum Ambient Temperature	120°F (50°C)
DIMENSIONS AND WEIGHT (PUMP AND MOTOR)	
Dimensions	11.3" length x 1.81" diameter
Net Weight	5.5 lbs., excluding motor lead
LEAD LENGTHS	
Standard Lengths in Feet	30, 50, 75, 100, 125, 150, 175, 200, 250, 300
Custom Lengths	Available in 1 ft. increments from 30 to 300 ft.

Redi-Flo2® Service Kits, Tools and Motor Leads

Replacement parts, service tools and motor leads are available using the following part numbers:

Position in Diagram	Part Description .....No. In Kit	Park Number
	Service Kits	
3	Guide Vane 2	125061
4	Wear Ring 2	
5	Impeller 2	
6	Spacer Ring.....2	
7	Wear Plate 2	
4	Wear Ring 4	1A5050
7	Wear Plate 4	
13	Ground Motor Screw.....1	1A00028
14	Motor Lead Screw 4	
15	Teflon® Washer.....4	
16	Brass Washer 2	
17	Grommet.....3	
18	Crimped Pin 3	
5	Impeller 1	1A00018
12	Set Screws 25	1A00038
14	Motor Lead Screws 12	1A00048
15	Teflon® Washer 25	1A00058
16	Brass Washer 25	1A00068
17	Grommet 25	1A00078
18	Crimped Pin.....50	1A00088
19	Motor Screw (Long) 25	1A00098
20	Motor Screw (Short).....25	1A00108
21	Filling Screw with O-Ring 5	1A00118
22	Motor Thrust Washers 4	1A00128
Teflon® Motor Lead Replacement Kits		
	30 foot Length	1A5100
	50 " "	1A5102
	100 " "	1A5103
	125 " "	1A5104
	150 " "	1A5105
	175 " "	1A5106
	200 " "	1A5107
	250 " "	1A5108
	300 " "	1A5109
Accessory List		
Redi-Flo2® Safety Cable Bracket (Placed between the top of the pump and discharged piping connector)		1A0019
Redi-Flo2® Cooling Shroud		1A004Z

LIMITED WARRANTY

All Redi-Flo products manufactured by GRUNDFOS are warranted to the original user only to be free of defects in material and workmanship for the following periods of time. Redi-Flo2® pumps; 24 months from date of installation, but not more than 30 months from the date of manufacture, whichever comes first.

GRUNDFOS' liability under this warranty shall be limited to repairing or replacing at GRUNDFOS' option, without charge, F.O.B. GRUNDFOS' factory or authorized service station, any product of GRUNDFOS manufacture. GRUNDFOS will not be liable for any costs of removal, installation, transportation, or any other charges which may arise in connection with a warranty claim. Products which are sold but not manufactured by GRUNDFOS are subject to the warranty provided by the manufacturer of said products and not by GRUNDFOS' warranty. GRUNDFOS will not be liable for damage or wear to products caused by abnormal operating conditions, accident, abuse, misuse, unauthorized alteration or repair, or if the product was not installed in accordance with GRUNDFOS' printed installation and operation instructions.

To obtain service under this warranty, contact the Distributor or Dealer from which it was purchased to obtain instructions. **Under no circumstances should defective product be returned to the Distributor, Dealer, or GRUNDFOS without a Return Materials Authorization (RMA).**

GRUNDFOS WILL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES, LOSSES, OR EXPENSES ARISING FROM INSTALLATION, USE, OR ANY OTHER CAUSES. THERE ARE NO EXPRESS OR IMPLIED WARRANTIES, INCLUDING MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, WHICH EXTEND BEYOND THOSE WARRANTIES DESCRIBED OR REFERRED TO ABOVE.

Some jurisdictions do not allow the exclusion or limitation of incidental or consequential damages and some jurisdictions do not allow limitations on how long implied warranties may last. Therefore, the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights and you may also have other rights which vary from jurisdiction to jurisdiction.

BE > THINK > INNOVATE >

Being Responsible is our foundation
Thinking ahead makes it possible
Innovation is the essence

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U.S.A.
Grundfos Pumps Corporation
17100 W. 118th Terrace
Olathe, Kansas 66061
Telephone: (913) 227-3400
Fax: (913) 227-3500

Canada
Grundfos Canada, Inc.
2941 Brighton Rd.
Oakville, Ontario L6H 6C9
Telephone: (905) 829-9533
Fax: (905) 829-9512

Mexico
Bombas Grundfos de Mexico, S.A. de C.V.
Boulevard TLC #15, Parque Industrial Stiva Aeropuerto
C.P. 66600 Apodaca, N.L. Mexico
Telephone: 011-52-81-8144-4000
Fax: 011-52-81-8144-4010

www.grundfos.com

Redi-Flo Variable Frequency Drive

USA Installation and operating instructions

SAFETY NOTICE

This equipment contains voltages that may be as great as 1000 volts! Electrical shock can cause serious or fatal injury. Only qualified personnel should attempt the start–up procedure or troubleshoot this equipment.

PRECAUTIONS:

⚠ **WARNING:** Do not touch any circuit board, power device or electrical connection before you first ensure that power has been disconnected and there is no high voltage present from this equipment or other equipment to which it is connected. Electrical shock can cause serious or fatal injury. Only qualified personnel should attempt the start–up procedure or troubleshoot this equipment.

⚠ **WARNING:** Be sure the system is properly grounded before applying power. Do not apply AC power before you ensure that grounds are connected. Electrical shock can cause serious or fatal injury.

⚠ **WARNING:** Do not remove cover for at least five (5) minutes after AC power is disconnected to allow capacitors to discharge. Electrical shock can cause serious or fatal injury.

⚠ **CAUTION:** Disconnect motor leads (T1, T2 and T3) from control before you perform a “Megger” test on the motor. Failure to disconnect motor from the control will result in extensive damage to the control. The control is tested at the factory for high voltage / leakage resistance as part of Underwriter Laboratory requirements.

⚠ **CAUTION:** Do not connect AC power to the Motor terminals T1, T2 and T3. Connecting AC power to these terminals may result in damage to the control.

QUICK START GUIDE

To operate the Redi-Flo VFD system, simply:

1. Submerge the RF2 or RF4 pump in the water to be pumped.

2. Connect the motor lead to the Redi-Flo VFD. (Note: With RF4 Variable Performance Pumps you must have an adapter cord to connect to Redi-Flo VFD.

   #3 and #4 for operation with generator only.
   WARNING: Do not let the generator run out of gas while powering the VFD.
   If it surges and creates excessive voltage, internal VFD damage could result.

3. If using a generator, start the generator and allow it to warm up.

4. If the generator has a circuit breaker, close the breaker and check the output voltage from the generator. The output voltage must be within the specified ranges (refer to Technical Specifications, at the end of this manual) to ensure proper operation and prevent damage to the system. If the voltage is too high or too low, adjustments to the generator must be performed to allow the system to run.

5. Plug the Redi-Flo VFD into a generator or connect to utility power supply. The unit accepts 115V or 230V sources. Refer to the Input Power Terminals section for wiring instructions.

   WARNING: Incorrect wiring on the 115V or 230V terminals will damage the drive.

6. The VFD will initialize and be ready to drive the motor. After the initialization screen appears, the following will be displayed:

STP	0V	REDIFL2
LOC	0.0A	0.00HZ

- STP means the drive is stopped
- V indicates motor volts
- REDIFL2 indicates Redi-Flo2 pump mode
- LOC means the drive is in Local Keypad Mode
- A indicates motor amps
- HZ indicates motor frequency

   The VFD defaults to Redi-Flo2 operation. To change to Redi-Flo4 press the sequence SHIFT-▼-SHIFT keys. Use sequence SHIFT-▲-SHIFT to return to Redi-Flo2.

7. Press the FWD key to start the motor and use the ▲ and ▼ arrow keys to increase or decrease speed. Continuous holding of the arrow key will increase the rate of speed change. The STOP key is used to stop the motor.

8. Pressing the ENTER key allows the user to quickly set the speed to any given value by using the ▲ and ▼ arrows to change speed and the SHIFT key to cursor between digits.

9. When powering down, unplug the Redi-Flo VFD from the generator BEFORE removing the motor lead from the Redi-Flo VFD or turning off the generator.

Note: To prevent tripping power source circuit breakers please observe the following: When using the Redi-Flo4 pump and a VFD power source of 115VAC, motor speeds of greater than 70Hz may draw over 15 amps. For 230VAC power source motor speeds greater than 90 Hz may draw over 15 amps. In RediFlo4 mode, 100 Hz cannot be exceeded without changing parameters.

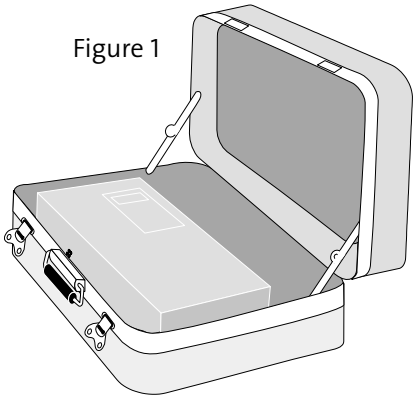
PRE-INSTALLATION CHECKLIST

Components of Your Redi-Flo VFD System

Your Redi-Flo Variable Performance Pump system should contain the following components:

1. Redi-Flo Variable Frequency Drive, (See Figure 1)
2. Either a Redi-Flo2® pump and motor with lead (Figure 2) or a Redi-Flo4™ Variable Performance pump, motor, lead, lead/plug and RF4 x VFD adapter cord (Figure 3).

Figure 1



Redi-Flo2®

Figure 2

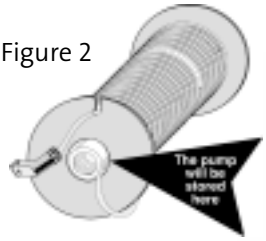


Figure 3

Redi-Flo4®

To operate the system you will also need:

1. A discharge hose or pipe to connect to the pump (See Figure 4).

2. An electrical plug to connect the Redi-Flo VFD power cord to your portable generator may be needed if the supplied plug is not compatible with your generator (See Figure 5).

3. Safety cable and hardware for lowering and lifting the pump (See Figure 6).

Figure 4

Figure 5

The exact type of plug used will depend upon your generator, The Redi-Flo VFD is supplied with a standard NEMA 5-15P, 115V, 3 prong plug.

Figure 6

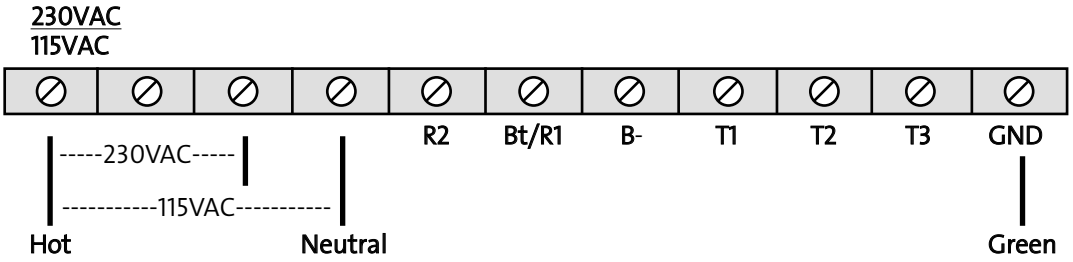
Redi-Flo2®

Redi-Flo4®

INPUT POWER TERMINALS

The input voltage can be changed between 115V and 230V by changing the line input connections as shown below:

Warning - If the Redi-Flo VFD is miswired for the incoming voltage, internal damage may occur to the drive.



Attaching the Pump to the pipe

When connecting the discharge pipe or tubing to the pump, a back-up wrench should be used. It is recommended that a safety cable be attached to the pump (using special brackets and cables, sold separately) anytime plastic pipe or flexible tubing is used (as shown if figure 6). A check valve may also be added to Redi-Flo2® pumps to prevent fluid from flowing back into the pump after it is turned off (backflow prevention). A check valve is standard on Redi-Flo4™ pumps. Always check to ensure joints are fastened securely. The use of a torque arrestor is not required when using the Redi-Flo VFD.

Lowering the Pump Into the Well

Make sure the electrical motor leads are not cut or damaged in any way when the pump is being lowered into the well. Do not use the motor leads to support the weight of the pump. To protect against surface water entering the well and contaminating the well, the well should be finished off utilizing a locally approved well seal.

The motor lead should be secured to the discharge pipe or tubing at frequent intervals to prevent sagging, looping and possible motor lead damage. Teflon® wire ties are recommended for environmental applications.

IMPORTANT

Plastic pipe and tubing tend to stretch under load. This stretching must be taken into account when securing the motor lead to the riser pipe or tubing. Leave three to four inches of slack between clipped points. This tendency to stretch will also affect the calculation of the pump setting depth. When plastic pipe or tubing is used, it is recommended that a safety cable be attached to the pump to raise and lower it. Redi-Flo4™ pumps are designed to accommodate this cable and Redi-Flo2® pumps can be fitted with a safety cable bracket (part number 1A0019).

OPERATING CONDITIONS

To ensure the Redi-Flo Variable Performance Pumping system operates properly, follow these guidelines:

- The Redi-Flo2® or Redi-Flo4™ pump must be installed vertically with the discharge end pointed upwards.
- The electrical voltage supply to the Redi-Flo VFD must always be within + or - 10% of the specified power supply (103.5 - 126.5 VAC at 115V connection or 207 - 253 VAC at 230V).
- For best performance when operating on a generator, 115V generators should be set at 120V without load and 230V generators should be set at 240V without load. Use a separate meter to set voltage; do not rely on built-in meters found on generators. Verify generator voltage stays within tolerance at full load.
- The pump and motor must always be completely submerged in fluid to ensure lubrication and cooling of the motor.
- The temperature of the fluid being pumped should be according to the technical specifications shown in the motor specifications.
- The installation depth of the pump should always be at least three feet below the maximum drawdown level of the well.
- Redi-Flo pumps are not recommended for well development or pumping fluid containing abrasives.
- Redi-Flo2® pumps are not recommended for continuous operation applications.
- The warranty of the Redi-Flo pumps will be void if other than the Redi-Flo VFD is used or if corrosive fluids are pumped.
- The service life of dedicated Redi-Flo pumps may be compromised if the ambient water quality exceeds one or more of the following values:

pH<5 DO>2 ppm H2S>1 ppm CL->500 ppm TDS>1000 ppm

Adherence To Environmental Regulations

When handling and operating the Redi-Flo Variable Performance Pump system, all environmental regulations concerning the handling of hazardous materials must be observed. When the pump is taken out of operation, great care should be taken to ensure that the pump contains no hazardous materials that might cause injury to human health or to the environment.

Purging A Well

If the pump is used to purge a well, start the pump at minimum speed and gradually increase to desired speed. Redi-Flo products are not recommended for well development.

Generator Usage

Minimum generator size	**(Redi-Flo2/Redi-Flo4)**
For generators with voltage regulation	2500/3400 watts at 115/230VAC, single phase
For generators without voltage regulation	5000/6700 watts at 115/230VAC, single phase
Recommended for optimal performance	4000/5400 watts at 115/230 VAC, single phase with voltage regulation

Dual Input Capability

Redi-Flo VFD can accept 115V or 230V single phase input voltage. Refer to the input power terminal section on page 4 for connection instructions.

Enclosure

The Redi-Flo VFD NEMA 4 enclosure is designed for outdoor duty and is resistant to damage as a result of incidental exposure to rain.

UL Approvals

The Redi-Flo VFD is UL Listed to U.S. and Canadian electrical safety standards.

Dual Functionality

The Redi-Flo VFD can change from operating Redi-Flo2® (MP1) to Redi-Flo4™ Variable Performance pumps with a few keystrokes.

Optimized Volts/Frequency (V/HZ) Pattern

The Redi-Flo VFD V/Hz pattern is specially optimized to allow the most efficient operation of Redi-Flo2® and Redi-Flo4™ variable performance pumps.

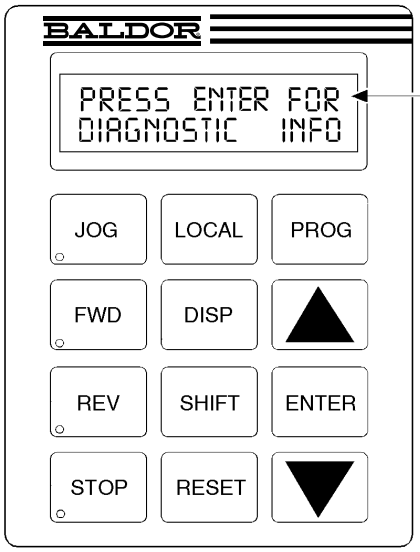
REDI-FLO VFD KEYPAD OVERVIEW

Overview

The keypad is used to program the control parameters, to operate the motor and to monitor the status and outputs of the control by accessing the display options, diagnostic menus and the fault log.

Indicator Lights

JOG - (Green) lights when Jog is active.
FWD - (Green) lights when FWD direction is commanded.
REV - (Green) lights when REV direction is commanded.
STOP - (Red) lights when motor STOP is commanded.



Keypad Display - Displays status information during Local or Remote operation. It also displays information during parameter setup and fault or Diagnostic Information.

Motor Selection - The VFD defaults to Redi-Flo2 operation, to change to Redi-Flo 4, press the key sequence "Shift -▼- Shift." Use the sequence "Shift -▲- Shift" to return to Redi-Flo2.

JOG - Press JOG to select the preprogrammed jog speed. After the jog key has been pressed, use the FWD or REV keys to run the motor in the direction that is needed. The JOG key is only active in the local mode.

FWD - Press FWD to initiate forward rotation of the motor. (Active in Local and Jog modes).

REV - Press REV to initiate reverse rotation of the motor. (Active in Local and Jog modes).

STOP - Press STOP to initiate a stop sequence. Depending on the setup of the control, the motor will either regen or coast to a stop. This key is operational in all modes of operation unless it has been disabled by the Keypad Stop parameter in the Keypad (programming) Setup Block.

LOCAL - Press LOCAL to change between the local (keypad) and remote operation.

DISP - Press DISP to return to display mode from programming mode. Provides operational status and advances to the next display menu item.

SHIFT - Press SHIFT in the program mode to control cursor movement. Pressing the SHIFT key once moves the blinking cursor one character position to the right. While in program mode, a parameter value may be reset to the factory preset value by pressing the SHIFT key until the arrow symbols at the far left of the keypad display are flashing, then press an arrow key. In the display mode the SHIFT key is used to adjust the keypad contrast.

RESET - Press RESET to clear all fault messages (in local mode). Can also be used to return to the top of the block programming menu without saving any parameter value changes.

PROG - Press PROG to enter the program mode. While in the program mode the PROG key is used to edit a parameter setting.

▲ (UP Arrow).
Press ▲ to change the value of the parameter being displayed. Pressing ▲ increments the value to the next greater value. Also, when the fault log or parameter list is displayed, the ▲ key will scroll upward through the list. In the local mode pressing the ▲ key will increase motor speed to the next greater value.

ENTER - Press ENTER to save parameter value changes and move back to the previous level in the programming menu. In the display mode the ENTER key is used to directly set the local speed reference. It is also used to select other operations when prompted by the keypad display.

▼ (Down Arrow)
Press ▼ to change the value of the parameter being displayed. Pressing ▼ decrements the value to the next lesser value. Also, when the fault log or parameter list is displayed, the ▼ key will scroll downward through the list. In the local mode pressing the ▼ key will decrease motor speed to the next lesser value.

The Redi-Flo VFD can operate the motor in three (3) different ways from the keypad.

1. Speed adjustment using the Keypad arrow keys
2. Speed adjustment with Keypad entered values
3. JOG Command

1) Keypad arrow speed control

Press FWD or REV to select desired direction of motor rotation, then press or hold the up arrow key ▲ to increase speed or use the down arrow key ▼ to reduce motor speed. Continuously holding the arrow key will cause the speed to change in larger increments. The minimum speed increment produced by the arrow keys is defined in PROG/Keypad Setup/Keypad Speed INC. Default value of 0.10 Hz can be changed by the user.

2) Keypad speed entered value

Press the ENTER key and use the ▲ and ▼ arrow keys to adjust digits and the SHIFT key to cursor to the desired digit. Press ENTER when finished selecting desired motor speed to return to the display mode. Press the FWD or REV key to run the motor in the desired direction at the programmed speed.

3) JOG Command

The JOG key can be used to ramp the pump up to a predetermined speed in the forward or reverse direction. Press the JOG key then hold the FWD or REV key, and the pump will ramp to the speed set in PROG/Jog Settings/Jog Speed. Acceleration and deceleration times for Jog can also be set in this programming menu.

DISP Key

The DISP key can be used for accessing diagnostic and troubleshooting screens as shown below:

Action	Description	Display	Comments
Apply Power	Display mode showing mode, voltage, current & frequency status.	STP 0V REDIFL2 LOC 0.0 A 0.0 HZ	No faults present. Local keypad mode. If in remote mode, press local for this display.
Press DISP key	Scroll to fault log block.	PRESS ENTER FOR FAULT LOG	Press ENTER to view the fault log if desired.
Press DISP key	Scroll to diagnostic info block.	PRESS ENTER FOR DIAGNOSTIC INFO	Press ENTER to view diagnostic information if desired.
Press DISP key	Scroll to local speed ref. block.	PRESS ENTER FOR LOCAL SPEED REF	Press ENTER to change motor speed.
Press DISP key	Display mode showing output frequency.	STOP FREQUENCY LOCAL 0.00 HZ	
Press DISP key	Display mode showing motor speed (based on output frequency).	STOP MOTOR SPEED LOCAL 0 RPM	
Press DISP key	Display mode showing output current.	STOP CURRENT OUT LOCAL 0.00 A	
Press DISP key	Display mode showing output voltage.	STOP VOLTAGE OUT LOCAL 0 V	

Adjusting Display Contrast

When AC power is applied to the VFD, the keypad should display the status of the unit. If there is no display visible, or if it is difficult to read, use the following procedure to adjust the display. Contrast may be adjusted in the display mode when motor is stopped or running.

Action	Description	Display	Comments
Apply Power	No visible display		
Press DISP Key	Places control in display mode		Display mode.
Press SHIFT key 2 times	Allows display contrast adjustment		
Press ▲ or ▼ Key	Adjusts display intensity	ADJUST CONTRAST ⇕ [ENTER] TO SAVE	
Press ENTER	Saves level of contrast and exits to display mode	STP 0V 0 RPM LOC 0.0 A 0.0 HZ	

Advanced Programming

A password is required for advanced programming features. **Altering some default settings for Redi-Flo2 or Redi-Flo4 could possibly damage the motor or VFD.** For additional programming instructions, please refer to the full programming guide found at the Baldor website: www.Baldor.com The manual can be found under Support — installation and operation manuals. It is Baldor manual number MN715, Series 15H Inverter.

LEVEL 1 BLOCKS		LEVEL 2 BLOCKS	
Preset Speeds	**Input**	**Output Limits**	**Brake Adjust**
Preset Speed #1	Operating Mode	Operating Zone	Resistor Ohms
Preset Speed #2	Command Select	Min Output Frequency	Resistor Watts
Preset Speed #3	ANA CMD Inverse	Max Output Frequency	DC Brake Voltage
Preset Speed #4	ANA CMD Offset	PK Current Limit	DC Brake Frequency
Preset Speed #5	ANA CMD Gain	REGEN Limit	Brake on Stop
Preset Speed #6	CMD SEL Filter	REGEN Limit ADJ	Brake on Reverse
Preset Speed #7	Power Up Mode	PWM Frequency	Stop Brake Time
Preset Speed #8			Brake on Start
Preset Speed #9	**Output**	**Custom Units**	Start Brake Time
Preset Speed #10	Digital Out #1	MAX Decimal Places	
Preset Speed #11	Digital Out #2	Value at Speed	**Process Control**
Preset Speed #12	Digital Out #3	Value DEC Places	Process Feedback
Preset Speed #13	Digital Out #4	Value Speed REF	Process Inverse
Preset Speed #14	Zero SPD Set PT	Units of Measure	Setpoint Source
Preset Speed #15	At Speed Band	Units of MEAS 2	Setpoint Command
	Set Speed Point		Set PT ADJ Limit
Accel / Decel Rate	Analog Out #1	**Protection**	At Setpoint Band
Accel Time #1	Analog Out #2	External Trip	Process PROP Gain
Decel Time #1	Analog Scale #1	Local Enable INP	Process INT Gain
S-Curve #1	Analog Scale #2		Process DIFF Gain
Accel Time #2	Underload Set Point	**Miscellaneous**	Follow I:O Ratio
Decel Time #2		Restart Auto/Man	Follow I:O Out
S-Curve #2	**V/HZ and Boost**	Restart Fault/Hr	Encoder Lines
	Ctrl Base Frequency	Restart Delay	Integrator Clamp
Jog Settings	Torque Boost	Factory Settings	Minimum Speed
Jog Speed	Dynamic Boost	Language Select	
Jog Accel Time	Slip Comp Adj	STABIL ADJ Limit	**Skip Frequency**
Jog Decel Time	V/HZ Profile	Stability Gain	Skip Frequency #1
Jog S-Curve	V/HZ 3-PT Volts		Skip Band #1
	V/HZ 3-PT Frequency	**Security Control**	Skip Frequency #2
Keypad Setup	Max Output Volts	Security State	Skip Band #2
Keypad Stop Key		Access Timeout	Skip Frequency #3
Keypad Stop Mode		Access Code	Skip Band #3
Keypad Run Fwd			
Keypad Run Rev		**Motor Data**	**Synchro Starts**
Keypad Jog Fwd		Motor Voltage	Synchro Starts
Keypad Jog Rev		Motor Rated Amps	Sync Start Frequency
3 Speed Ramp		Motor Rated Speed	Sync Scan V/F
Switch on Fly		Motor Rated Frequency	Sync Setup Time
LOC. Hot Start		Motor Mag Amps	Sync Scan Time
			Sync V/F Recover
			Sync Direction
			Communications
			Protocol
			Baud Rate
			Drive Address

TROUBLESHOOTING GUIDE TO ERROR MESSAGES

INDICATION	POSSIBLE CAUSE	CORRECTIVE ACTION
Command Select	Incorrect operating mode programmed.	Change Operating Mode in the Level 1 Input block to one that does not require the expansion board.
	Need expansion board.	Install the correct expansion board for selected operating mode.
Bus Overvoltage Trip or HW Overvoltage	DECEL Rate set too low a value	Lengthen DECEL time. Add external dynamic braking resistors or module.
	Input voltage too high.	Verify proper AC line voltage. Use step down transformer if needed. Use line reactor to minimize spikes.
Bus Undervoltage	Input voltage too low.	Verify proper AC line voltage. Use step up transformer if needed. Check power line disturbances (sags caused by start up of other equipment). Monitor power line fluctuations with date and time imprint to isolate power problem.
External Trip	Motor draws excessive current.	Check motor for overloading. Verify proper sizing of control and motor.
	External trip parameter incorrect.	Verify connection of external trip circuit at J4-16. Set external trip parameter to “OFF” if no connection made at J4-16.
Hardware Protect	Fault duration too short to be identified.	Reset control. Check for proper grounding of power wiring and shielding of signal wiring. Replace control board.
Heatsink Temp	Motor Overloaded.	Correct motor loading. Verify proper sizing of control and motor.
	Ambient temperature too high.	Relocate control to cooler operating area. Add cooling fans or air conditioner to control cabinet.
	Built-in fans are ineffective or inoperative.	Verify fan operation. Remove debris from fan and heatsink surfaces. Replace fan or check fan wiring.

INDICATION	POSSIBLE CAUSE	CORRECTIVE ACTION
HW Desaturation	Accel/Decel rate set too short. Torque Boost set too high. Electrical noise in logic circuits. Motor overloaded.	Lengthen Accel/Decel rate. Reduce torque boost value. Check for proper grounding of power wiring and shielding of signal wiring. Verify proper sizing of control and motor or reduce motor load.
HW Power Supply	Power supply malfunctioned.	Check internal connections. Replace logic power board.
HW Ground Fault	Output current (motor current) leakage to ground.	Disconnect wiring between control and motor. Retry test. If GND FLT is cleared, reconnect motor leads and retry the test. Repair motor if internally shorted. Replace motor lead wire with low capacitance cable. If GND FLT remains, contact your dealer.
Motor Will Not Start	Motor overloaded.	Check for proper motor loading. Check couplings for binding. Verify proper sizing of control and motor.
	Motor may be commanded to run below minimum frequency setting.	Increase speed command or lower minimum frequency setting.
	Incorrect Command Select parameter.	Change Command Select parameter to match wiring at J4.
	Incorrect frequency command.	Verify control is receiving proper command signal at J4.
Motor Will Not Reach Maximum Speed	Max Frequency Limit set too low.	Adjust Max Frequency Limit parameter value.
	Motor overloaded.	Check for mechanical overload. If unloaded motor shaft does not rotate freely, check motor bearings.
	Improper speed command.	Verify control is receiving proper command signal at input terminals. Verify control is set to proper operating mode to receive your speed command.
Motor Will Not Stop Rotation	MIN Output Speed parameter set too high.	Adjust MIN Output Speed parameter value.
	Improper speed command.	Verify control is receiving proper command signal at input terminals. Verify control is set to receive your speed command.
Motor runs rough at low speed	Torque boost set too high.	Adjust torque boost parameter value.
	Misalignment of coupling.	Check motor/load coupling alignment.
	Faulty motor.	Replace with a new motor.

TROUBLE SHOOTING GUIDE (CONT.)

INDICATION	POSSIBLE CAUSE	CORRECTIVE ACTION
New Base ID	Replaced Control or circuit board.	Restore parameters to factory settings. Reset control.
No Display	Lack of input voltage.	Check input power for proper voltage.
	Loose connections.	Check input power termination. Verify connection of operator keypad.
	Adjust display contrast.	See Adjust Display Contrast.
NV Memory Fail	Memory fault occurred.	Press “RESET” key on keypad. Restore parameter values to factory settings. If fault remains, call dealer.
3 Sec Overload	Peak output current exceeded 3 sec rating.	Check PK Current Limit parameter in the Level 2 Output Limits block. Check motor for overloading. Increase ACCEL time. Reduce motor load. Verify proper sizing of control and motor.
1 Min Overload	Peak output current exceeded 1 minute rating.	Check PK Current Limit parameter in the Level 2 Output Limits block. Check motor for overloading. Increase ACCEL/DECEL times. Reduce motor load. Verify proper sizing of control and motor.
Over Speed	Motor exceeded 110% of MAX Output Freq parameter value.	Check Max Output Freq in the Level 2 Output Limits block.
Param Checksum	Memory fault occurred.	Press “RESET” key on keypad. Restore parameter values to factory settings. If fault remains, call dealer.
Unknown Fault Code	Microprocessor detected a fault that is not defined in the fault code table.	Press “RESET” key on keypad. Restore parameter values to factory settings. If fault remains, call dealer.
Unstable Speed	Oscillating load. Unstable input power. Slip compensation too high.	Correct motor load. Correct input power. Adjust slip compensation.
uP Reset	A software watchdog timer has reset the processor because a process has timed out.	Press “RESET” key on keypad. If fault remains, call dealer.
FLT Log MEM Fail	Corrupt data in fault log (may occur on older systems only).	Press “RESET” key on keypad. If fault remains, call dealer.
Current SENS FLT	Failure to sense phase current.	Press “RESET” key on keypad. If fault remains, call dealer.
Bus Current SENS	Failure to sense bus current.	Press “RESET” key on keypad. If fault remains, call dealer.

Action	Description	Display	Comments
Apply Power			
	Display mode showing Local mode voltage, current & frequency status.	STP 0V REDIFL2 LOC 0.0 A 0.0 HZ	No faults present. Local keypad mode. If in remote/serial mode, press local for this display.
Press DISP key	Scroll to fault log block.	PRESS ENTER FOR FAULT LOG	Press ENTER to view the fault log if desired.
Press DISP key	Scroll to diagnostic info block.	PRESS ENTER FOR DIAGNOSTIC INFO	Press ENTER to view diagnostic information if desired.
Press ENTER key	Access diagnostic information.	STOP FREQ REF LOCAL 2.00 HZ	.
Press DISP key	Display mode showing control temperature.	STOP CONTROL TEMP LOCAL 25.0° C	Displays operating temperature in degrees C.
Press DISP key	Display mode showing bus voltage.	STOP BUS VOLTAGE LOCAL 321V	
Press DISP key	Display mode showing bus Current.	STOP BUS CURRENT LOCAL 0.00A	
Press DISP key	Display mode showing PWM Frequency.	STOP PWM FREQ LOCAL 2497 HZ	
Press DISP key	Display mode showing % overload current remaining.	STOP OVRLD LEFT LOCAL 100.00%	
Press DISP key	Display mode showing real time opto inputs & outputs states. (0=Open, 1=Closed)	DIGITAL I/O 000000000 1110	Opto Inputs states (Left); Opto Outputs states (Right).
Press DISP key	Display mode showing actual drive running time since the Fault log was cleared.	TIME FROM PWR UP 0000000.01.43	HR.MIN.SEC format.
Press DISP key	Display operating zone with rated hp and input voltage (for the operating zone) and control type.	1 HP STD CT 230V INVERTER	
Press DISP key	Display mode showing continuous amps; PK amps rating; amps/volt scale of feedback, power base ID.	X.XA X.XAPK X.XXA/V ID:XXX	
Press DISP key	Display mode showing which Group1 or 2 expansion boards are installed.	I NOT INSTALLED II NOT INSTALLED	
Press DISP key	Display mode showing software version and revision installed in the control.	SOFTWARE VERSION XXX-X.XX	
Press DISP key	Displays exit choice. Press ENTER to exit.	PRESS ENTER FOR DIAGNOSTIC EXIT	Press ENTER to exit diagnostic information.

HOW TO ACCESS THE FAULT LOG

When a fault condition occurs, motor operation stops and a fault code is displayed on the Keypad display. The control keeps a log of the last 31 faults. If more than 31 faults have occurred, the oldest fault will be deleted from the fault log. To access the fault log, perform the following procedure:

Action	Description	Display	Comments
Apply Power			
	Display mode showing Local mode voltage, current & frequency status.	STP 0V REDIFL2 LOC 0.0 A 0.0 HZ	No faults present. Local keypad mode. If in remote/serial mode, press local for this display.
Press DISP key	Press DISP to scroll to the Fault Log entry point.	PRESS ENTER FOR FAULT LOG	
Press ENTER key	Display first fault type and time fault occurred.	EXTERNAL TRIP 1: 0:00:30	Typical display.
Press ▲ key	Scroll through fault messages.	PRESS ENTER FOR FAULT LOG EXIT	If no messages, the fault log exit choice is displayed.
Press RESET key	Return to display mode.	STOP FREQUENCY LOCAL 0.00 HZ	Display mode stop key LED is on.

How to Clear the Fault Log Use the following procedure to clear the fault log.

Action	Description	Display	Comments
Apply Power			
	Display mode showing Local mode voltage, current & frequency status.	STP 0V REDIFL2 LOC 0.0 A 0.0 HZ	Display mode.
Press DISP key	Press DISP to scroll to the Fault Log entry point.	PRESS ENTER FOR FAULT LOG	
Press ENTER key	Displays most recent message.	EXTERNAL TRIP 1: 00000:00:30	
Press SHIFT key		EXTERNAL TRIP 1: 00000:00:30	
Press RESET key		EXTERNAL TRIP 1: 00000:00:30	
Press SHIFT key		EXTERNAL TRIP 1: 00000:00:30	
Press ENTER key	Fault log is cleared.	FAULT LOG NO FAULTS	No faults in fault log.
Press ▲ or ▼ key	Scroll Fault Log Exit.	PRESS ENTER FOR FAULT LOG EXIT	
Press ENTER key	Return to display mode.	PRESS ENTER FOR DIAGNOSTIC INFO	

FAULT MESSAGE	DESCRIPTION
Invalid Base ID	Failure to determine control horsepower and input voltage configuration from the Power Base ID value in software.
NV Memory Fail	Failure to read or write to non-volatile memory.
Param Checksum	Parameter Checksum error detected.
Low INIT Bus V	Low bus voltage detected on startup.
HW Desaturation	High output current condition detected (greater than 400% of rated output current). On B2 size controls, a desat error can indicate any of the following: low line impedance, brake transistor failure or internal output transistor overtemperature.
HW Surge Current	High output current condition detected (greater than 250% of rated output current).
HW Ground Fault	Ground Fault detected (output current leakage to ground).
HW Power Supply	Control Board power supply failure detected.
Hardware Protect	A general hardware fault was detected but cannot be isolated.
1 MIN Overload	Peak output current exceeded the 1 minute rating value.
3 SEC Overload	Peak output current exceeded the 3 second rating value.
Overcurrent	Continuous current limit exceeded.
BUS Overvoltage	High DC Bus voltage.
Bus Undervoltage	Low DC Bus voltage condition detected.
Heat Sink Temp	Control heatsink exceeded upper temperature limit. For size B2 controls, this fault may indicate the main heatsink or the gate drive circuit board is too hot.
External Trip	Connection between J4-16 and J4-17 is open.
New Base ID	Control board detected a change in the Power Base ID value in software.
REGEN RES Power	Excessive power dissipation required by Dynamic Brake Hardware.
Line REGEN	Fault in Line REGEN converter unit - Series 21H Line REGEN Inverter control.
EXB Selection	Expansion board not installed to support the selected Level 1 Input Block, Command Select parameter.
Torque Proving	Unbalanced current in the three phase motor leads.
Unknown FLT Code	Microprocessor detected a fault that is not identified in the fault code table.
µP RESET	A software watchdog timer has reset the processor because a process has timed out.
FLT Log MEM Fail	Corrupt data in fault log (may occur on older systems only).
Current SENS FLT	Failure to sense phase current.
Bus Current SENS	Failure to sense bus current.

TECHNICAL SPECIFICATIONS

DESCRIPTION	RF2	RF4
Part I	Rated Power & Markings	
Input Voltage	1 X 115V +/- 10% or 1 X 230V +/- 10%	
	Single Phase Input	
Output Voltage	3 X 220V	3 X 230V
Continuous Output Current (230V input)	6.05A	8.25A
Continuous Output Current (115V input)	6.05A	6.50A
Part II	Fundamental Parameters	
Control System	PWM	
Output Voltage	Clamp @ 220V	Clamp @ 230V
Carrier Freq.	Selectable: 1-5 KHz	
Freq. Resolution	0.1Hz*	
Input Freq. Range	48 – 62 Hz	
Maximum Output Frequency(230V input)	400 Hz	100 Hz
Maximum Output Frequency(115V input)	400 Hz	80 Hz
Base Frequency	400 Hz	100 Hz
Torque Boost	0 – 15% Nominal Voltage	
V/F Pattern	Selectable Linear/Square Law	
Accel Time	0.5 – 3600 Seconds	
Decel Time	0.5 – 3600 seconds	
Accel/Decel Pattern	Linear	
Part III	Protective Functions	
Ground Fault	Ground Fault detection for Equipment Protection	
Overcurrent	Output Short Circuit Locked Rotor	
Over Voltage	400VDC	
Under Voltage	200VDC	
Motor Overload	I^2 x T Characteristic	
Line Start Lock Out	VFD will not start upon input power application	
Line Transient Rating	860 VAV, 810J MOV Between any power input terminal & Ground 360 VAC, 380 J MOV Between any two power input terminals	
Part IV	Ambient Operating Conditions	
Operating Temp.	-10 to 40 degree C	
Storage Temp.	-30 to 65 degree C	
Vibration	0.5G, Max / 57-150 Hz	
Elevation	3300 ft. without derating	
Max source fault current	5 Kamps	
Enclosure rating	UL Type 4, No Direct Sunlight	

The Redi-Flo VFD is covered by the original equipment manufacturers warranty for a period of 24 months. To obtain warranty services, contact the distributor or dealer from which it was purchased to obtain instructions. **Under no circumstances should defective product be returned to the distributor, dealer, or GRUNDFOS without a return materials authorization (RMA).**

SERVICE PARTS

Only four repair parts are available, the carrying case, the keypad, power cord and Harting motor connection. Contact the dealer from which the unit was purchased for these parts.

BE > THINK > INNOVATE >

Being responsible is our foundation
Thinking ahead makes it possible
Innovation is the essence

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Printed in the U.S.A.	

North American Regional Headquarters
Grundfos Pumps Corporation
17100 W. 118th Terrace
Olathe, KS 66061
Telephone (913) 227-3400
Fax: (913) 227-3500

www.grundfos.com

Grundfos Canada, Inc.
2941 Brighton Road
Oakville, Ontario L6H 6C9, Canada
Telephone: (905) 829-9533
Fax: (905) 829-9512

Bombas Grundfos de Mexico, S.A. de C.V.
Boulevard TLC #15
Parque Stiva Aeropuerto
Apodaca, N.L. Mexico
C.P. 66600
Telephone: 52-81-8144-4000
Fax: 52-81-8144-4010

Installation with a Manual Slide Hammer

1. Ensure that all components are clean prior to use.
2. Cut the piezometer tubing to the depth of the proposed installation plus an additional 5 feet.
3. Connect the piezometer tubing to barbed fitting on the Drive Point Piezometer Tip by pushing firmly until the tubing reaches the base of the fitting.
4. Slide a length of extension drive pipe over the tubing, and thread it firmly onto the Drive Point Piezometer Tip. Tighten with a pipe wrench.

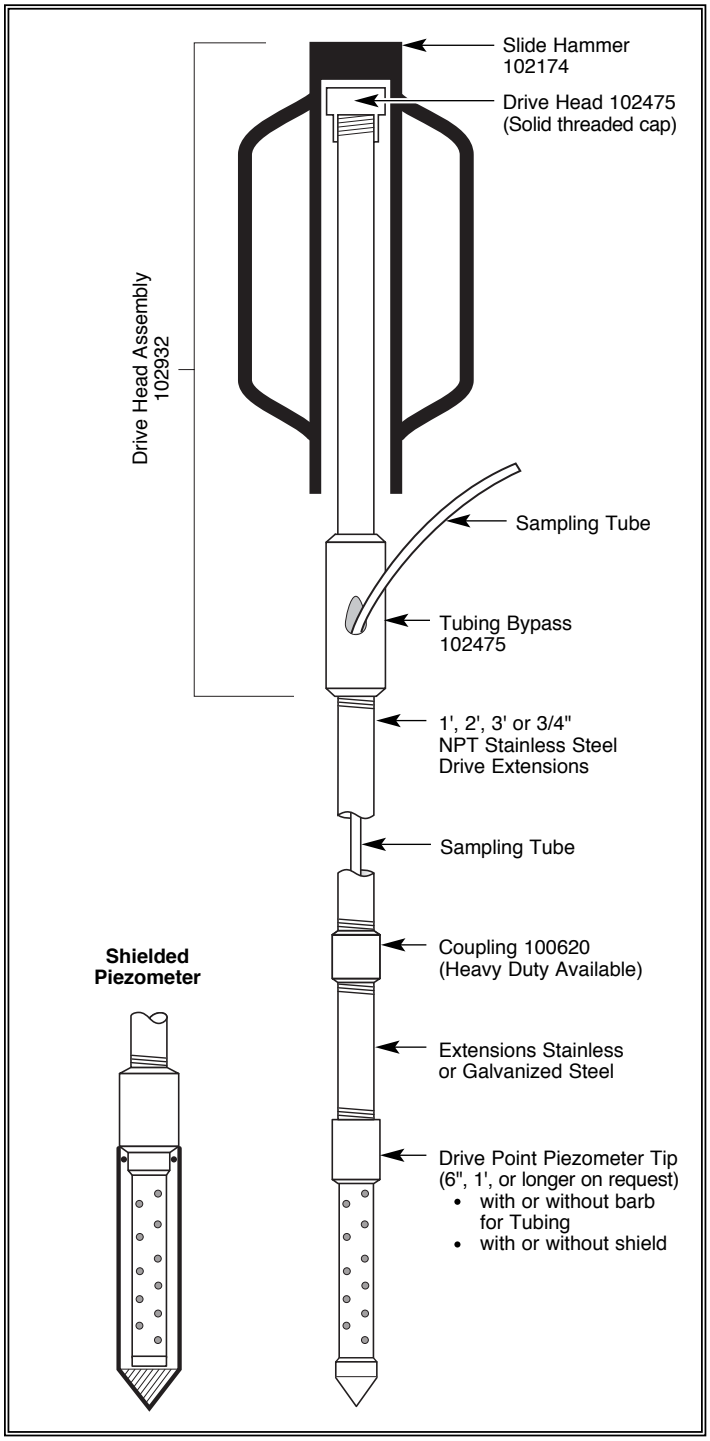
> **WARNING:** When connecting or removing the Tubing Bypass, it is very important to hold the tubing to prevent it from turning. Failure to do so may result in the tube being dislodged from the Drive-Point Tip.

5. Hold the tubing to prevent it from turning, then slide the Tubing Bypass over the tubing and tighten it firmly onto the extension pipe, with the tubing extending through the side hole.
6. Thread a Drive Extension and the Drive Head onto the Tubing Bypass onto the Tubing Bypass and tighten firmly.
7. Thread the Drive Head onto the Drive Extension and tighten firmly.
8. Slide the Slide Hammer over the Drive Head and operate the hammer to drive the device until only about 6 inches of the extension pipe below the Tubing Bypass remains above the ground.
9. Hold the tubing to prevent it from turning, then remove all sections of the Drive Head Assembly.
10. Slide a coupling over the tubing and tighten firmly onto the previous extension pipe. Slide the next extension pipe over the tubing and tighten it securely.
11. Repeat steps 4 through 10 until the desired sampling depth is reached.
12. Cut the piezometer tubing to fit flush to the top of the extension pipe. Attach a cap to the top of the piezometer to complete the installation.

Component List

- Drive Point Piezometer Tip
- Extensions (suitable to reach the required depth)
- Couplings (one required for each extension)
- Manual Slide Hammer
- Piezometer tubing (suitable to reach the required depth)
- Drive Head Assembly (3 parts)

  Includes: Drivehead, Drive Extension & Tubing Bypass
- Cap (101057)



Important Note about Shielded Piezometers

1. Before driving into the ground, ensure that the shield is on firmly and the o-ring seats properly.
2. Once the desired sampling depth is reached, retract the piezometer the length of the shield. At this time, sampling may commence.

For further information contact: Solinst Canada Ltd.
Fax: +1 (905) 873-1992; (800) 516-9081 Tel: +1 (905) 873-2255; (800) 661-2023
35 Todd Road, Georgetown, Ontario Canada L7G 4R8
Web Site: www.solinst.com E-mail: instruments@solinst.com

APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

Haley & Aldrich, Inc. Operating Procedure 3012- Low Stress/Low Flow Groundwater Sample Collection Procedure
Haley & Aldrich Operating Procedure OP3027- Decontamination Procedure
Haley & Aldrich Operating Procedure OP3028- Investigation Derived Wastes
Haley & Aldrich Operating Procedure OP3001- Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information

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APPENDIX C
FORMS

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GROUNDWATER SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

GROUNDWATER SAMPLING INFORMATION

Well No.							
Water Depth (ft)							
Time							
Product							
Depth Of Well (ft)							
Inside Diameter (in)							
Standing Water Depth (ft) (1)							
Volume Of Water In Well (gal)							
Purging Device							
Volume of Bailer/Pump Capacity							
Cleaning Procedure							
Bails Removed/ Volume Removed							
Time Purging Started							
Time Purging Stopped							
Sampling Device							
Cleaning Procedure							
TIME SAMPLES TAKEN	VOA						
	ABN						
	Metals						
PARAMETERS	Color						
	Odor						
	pH						
	Conductivity						
	Turbidity						
	Dissolved Oxygen						
	Temp, ^{0} C						
	Salinity						

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

1. Standing Water Depth = Depth of Well - Water Depth

Form 3005

OPERATING PROCEDURE: OP3011

GROUNDWATER SAMPLING USING DIRECT PUSH TECHNOLOGY

LEVEL II (Interim)

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.1	R. Selover: 04/07/08	JBB 6/4/08	MDK: 6/5/08		

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OPERATING PROCEDURE: OP3011

GROUNDWATER SAMPLING USING DIRECT PUSH TECHNOLOGY

1. PURPOSE

Direct push systems (i.e. GeoProbe® or equivalent) can be mounted on a variety of vehicles, (e.g. trucks, vans, all-terrain vehicles (ATVs), etc.). They use hydraulics to drive hollow steel probes into the subsurface to collect samples of various media (e.g. soil, groundwater, soil-vapor). The individual probe sections (i.e., rods) are approximately 4-5 ft. long; and are threaded together before being driven into the subsurface.

The following operating procedure describes the use of direct push technology to install vertical water quality profilers, and the techniques used to collect groundwater samples from them.

2. EQUIPMENT & SUPPLIES

- Personal protective equipment (as required by the Health and Safety Plan)
- Cleaning equipment (as required in the Equipment Cleaning Procedures)
- Weighted Tape or water level indicator
- Pocket knife
- Digital Camera
- Coolers with ice
- Appropriate sample containers, labels and forms
- Field notebook
- Haley & Aldrich Form 3005- Groundwater Sampling Record
- Haley & Aldrich Form 2008- Piezometer Installation Report
- Drive Point Piezometer (i.e. Solnist® 615 Drive Point Piezometer).
- Flow Through Cell and/or Field Water Quality Meter
- Appropriate Sampler
  - Peristaltic Pump
  - Bladder Pump
  - Silicone sample tubing (i.e. Masterflex® or equivalent)
  - Polyethylene sample tubing (i.e. Waterra® or equivalent)

3. PROCEDURE

Procedures used in conjunction with direct push drill rigs (i.e. GeoProbe® or equivalent) should be implemented in conjunction with those followed by the drilling subcontractor, and are not intended to serve as guidance or instruction for the operation of such a drill rig. Haley & Aldrich employees will not operate drill rigs.

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The following procedures describe the use of several devices for the purpose of collecting groundwater samples. In addition, several relevant Haley & Aldrich Operating Procedures (OPs) are listed here:

Decontaminate reusable equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Disposed of excess purge water as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

Please refer to Haley & Aldrich Operating Procedure OP3001 Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information.

3.1 Pre-sampling Observations, and Required Data Entries

A number of field measurements and observations should be made in the field when sampling groundwater. This information is listed below and will be recorded on a Groundwater Sampling Record. The following list of measurements and observations represents a minimum requirement for groundwater samples.

- Well number/ID
- Static water level (depth to water)
- Time
- Depth to product (if applicable)
- Depth to bottom of the well
- Inside diameter of well
- Calculated well volume
- Purging device
- Volume of bailer/Pump capacity [Note: This is “Continuous” for peristaltic, Grundfos® and Whale® pumps]
- Cleaning procedure
- Bails removed/volume removed
- Time purging started
- Time purging stopped
- Sampling device [Note: For pumps, this is “Waterra Tubing” or equivalent]
- Cleaning procedure [Note: If applicable, this is “Dedicated”]
- Time samples taken
- Sample Characteristics: pH, Specific Conductance, Dissolved Oxygen, Oxidation Reduction Potential (ORP), Temperature, Salinity, and Turbidity
- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory), and Preservatives for collected samples
- Description of the Sample Location
- Photograph details (i.e. Picture number, orientation, subject matter, etc.)
- Latitude/Longitude (using GPS, collect Waypoint as well).

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- Observable Physical Characteristics - Odor, Color, Cloudiness.
- Evidence of Stressed Vegetation, Wildlife, or Dumping.
- Ambient Weather Conditions during Sampling - Air Temperature, Atmospheric Conditions, Recent Precipitation or Drought.
- Samples Collected (enter all sample numbers collected at this location)

All entries will be made as described in Haley & Aldrich Level III Operating Procedure OP3029- Field Data Recording.

3.2 Peristaltic Pump

The following procedure can be used as a simple method for obtaining groundwater samples from a direct push borehole (i.e. GeoProbe® or equivalent), without the use of additional equipment.

1. Drive hollow stainless steel casing to desired depth using direct push drill rig (i.e. GeoProbe).

2. If groundwater is encountered, lower polyethylene tubing (i.e. Waterra® or equivalent) to bottom of casing.

3. Sample as described in Haley & Aldrich Operating Procedure OP3010- Groundwater Sampling.

4. Remove sample tubing and casing.

5. Fill boring hole with cuttings or sand.

3.3 Drive Point

The following procedure utilizes a drive point piezometer (i.e. Solnist® 615 Drive Point Piezometer device specifications in Attachment 1) to sample groundwater using a direct push drilling rig (i.e. GeoProbe® or equivalent) or by hand using a slide hammer.

1. Set up apparatus
   a. Attach drive point piezometer to direct push drill rig (i.e. GeoProbe® or equivalent).
   b. Use slide hammer to drive piezometer

2. Drive piezometer to desired sampling depth, using extender rods as necessary.

3. Feed polyethylene through tubing bypass fixture to bottom of screen.

4. Sample as described in Haley & Aldrich Operating Procedure OP3010- Groundwater Sampling.

5. If permanent installation is desired, use 1 in Sch. 40 PVC, cut piezometer tubing to be flush with ground surface & cap. Otherwise, remove piezometer.

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6. Decontaminate reusable equipment, discard disposable equipment.

3.4 Vertical Profiling

Please refer to Haley & Aldrich Operating Procedure OP3018- Vertical Profiling of Groundwater Using Direct Push Technology.

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APPENDIX A
REFERENCES

Solnist Drivepoint Piezometer Instructions, Model 615 & 615S

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

Haley & Aldrich Operating Procedure OP3012- Low Stress/Low Flow Groundwater Sample Collection Procedure
Haley & Aldrich Operating Procedure OP3018- Vertical Profiling of Groundwater Using Direct Push Technology
Haley & Aldrich Operating Procedure OP3027- Decontamination Procedure
Haley & Aldrich Operating Procedure OP3028- Investigation Derived Wastes
Haley & Aldrich Operating Procedure OP3001- Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information

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APPENDIX C
FORMS

Haley & Aldrich Form 3005- Groundwater Sampling Record
Haley & Aldrich Form 2008- Piezometer Installation Report

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PIEZOMETER INSTALLATION REPORT

Piezometer No.

Boring No.

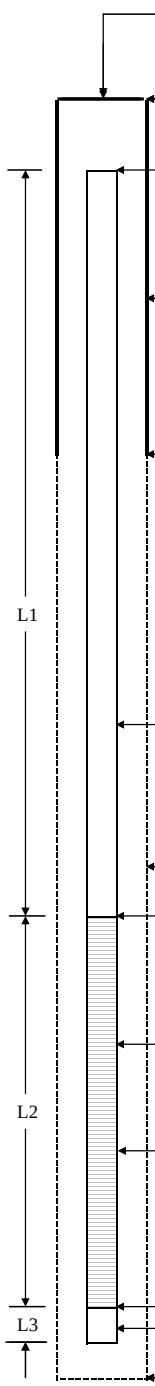
PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP.**	
CONTRACTOR		**DATE INSTALLED**	
DRILLER			

Ground El. _____ ft
El. Datum _____

Location _____

☐ **Guard Pipe**
☐ **Roadway Box**

SOIL/ROCK CONDITIONS	**BOREHOLE BACKFILL**



Type of protective cover/lock _____

Height/Depth of top of guard pipe/roadway box above/below ground surface _____ ft

Height/Depth of top of riser pipe above/below ground surface _____ ft

Type of protective casing: _____
- Length _____ ft
- Inside Diameter _____ in

Depth of bottom of guard pipe/roadway box _____ ft

Type of Seals	**Top of Seal (ft)**	**Thickness (ft)**
Concrete		
Bentonite Seal		

Type of riser pipe:
- Inside diameter of riser pipe _____ in
- Type of backfill around riser _____

Diameter of borehole _____ in

Depth to top of well screen _____ ft

Type of screen _____
- Screen gauge or size of openings _____ in
- Diameter of screen _____ in

Type of backfill around screen _____

Depth of bottom of well screen _____ ft

Bottom of Silt trap _____ ft

Depth of bottom of borehole _____ **ft**

(Bottom of Exlporation)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

ft	+	ft	+	ft	=	ft
Riser Pay Length (L1)		Length of screen (L2)		Length of silt trap (L3)		Pay length

COMMENTS: _____

Form 2008

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GROUNDWATER SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

GROUNDWATER SAMPLING INFORMATION

Well No.							
Water Depth (ft)							
Time							
Product							
Depth Of Well (ft)							
Inside Diameter (in)							
Standing Water Depth (ft) (1)							
Volume Of Water In Well (gal)							
Purging Device							
Volume of Bailer/Pump Capacity							
Cleaning Procedure							
Bails Removed/ Volume Removed							
Time Purging Started							
Time Purging Stopped							
Sampling Device							
Cleaning Procedure							
TIME SAMPLES TAKEN	VOA						
	ABN						
	Metals						
PARAMETERS	Color						
	Odor						
	pH						
	Conductivity						
	Turbidity						
	Dissolved Oxygen						
	Temp, ^{0} C						
	Salinity						

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

1. Standing Water Depth = Depth of Well - Water Depth

Form 3005

OPERATING PROCEDURE: OP3012

LOW STRESS/LOW FLOW GROUNDWATER SAMPLE COLLECTION PROCEDURE

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP3012

LOW STRESS/LOW FLOW GROUNDWATER SAMPLE COLLECTION PROCEDURE

1. PURPOSE

This document describes procedures for collection of groundwater samples for laboratory analysis utilizing the "Low Stress/Low Flow Method". This method should be employed when it is critical to collect groundwater samples not impacted by over-purging, aeration, and sediment/colloid presence. Although the procedures described in this document are generally appropriate for obtaining groundwater samples as part of Monitored Natural Attenuation (MNA) programs, a more complete procedure for MNA programs is described in a separate document (Monitored Natural Attenuation Sample Collection Procedure).

The method described herein is most appropriate for wells that can accept a submersible pump and have a screened interval of ten feet or less. However, the procedure is flexible and can be modified for a variety of well construction and groundwater yield situations. The low-flow purging and sampling method is not appropriate for use in all hydrogeologic regimes, and certain groundwater monitoring well designs may make the method unsuitable (e.g. open hole and long screen monitoring wells in bedrock and stratified sand and clay where the water bearing zones have not been characterized).
This procedure does not address wells that contain Non-Aqueous Phase Liquids (NAPLs).

Note: The methods described in this document are provided for training use and general information. Depending upon regulatory agency and other project specific requirements, appropriate field procedures may differ from those described herein. These procedures should be confirmed with the Haley & Aldrich Project Manager prior to implementation.

1.1 BACKGROUND

Research conducted by Puls et al. (1992), Puls and Powell (1992), and Powell and Puls (1993) has shown that high-volume purging and sampling cause significant turbidity and suspended particulate artifacts that can result in an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Additionally, standard purging procedures can cause pressure changes and bailing can cause aeration that can strip volatile organic compounds from groundwater samples (Pennino, 1988) and provide misrepresentative data on aquifer conditions (such as dissolved oxygen and redox). Overpurging of a well can cause water to cascade down the well screen, causing undesirable aeration and volatilization.

The use of low-flow pumping devices for purging and sampling minimizes both the disturbance of water in well casing and the potential for mobilization of colloidal material (Barcelona et al., 1994). Low-flow purging with maintenance of water level in the well and stabilization of indicator parameters (especially turbidity) allows collection of groundwater samples that are more representative of conditions without filtering (U.S. EPA, 1993; Backhus et al., 1993). In many cases, use of a low-flow pump to purge and sample monitoring

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wells decreases sampling time, reduces the need to handle large volumes of purge water and lowers the cost associated with its disposal, and may allow collection of samples for without filtering.

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface that can be affected by flow regulators or restriction. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practicable taking into account established site sampling objectives (USEPA, Puls and Barcelona, April 1996).

2. EQUIPMENT & SUPPLIES

1. Adjustable rate, positive displacement pumps (e.g. low flow-rate submersible centrifugal or bladder pumps constructed of stainless steel or Teflon). The pump should be easily adjustable and capable of operating reliably at lower flow rates. An example is QED MicroPurge bladder pump (available for purchase or rental at US Environmental 781-899-6969, among others).

   Under most regulatory programs, peristaltic pumps may be used for collection of inorganic samples only – they are NOT appropriate for collection of VOCs. Bailers are inappropriate for use in this procedure. Waterra tubing purging and sampling is also not recommended for low-flow sampling by the USEPA.

2. Tubing: Tubing used in purging and sampling each well must be dedicated to the individual well. Once properly located, moving the pump in the well should be avoided. Consequently, the same tubing should be used for purging and sampling. The tubing wall thickness should be maximized (3/8 to ½ inch) and the tubing length should be minimized (i.e. do not have excess tubing outside of the well)

   - **Organic analysis**: Teflon or Teflon-lined polyethylene tubing must be used to collect samples.
   - **Inorganic analysis**: Teflon or Teflon lined polyethylene, PVC, Tygon or polyethylene tubing may be used to collect samples.

3. Polyethylene sheeting and sampling gloves.

4. Water level measuring device, 0.01 feet accuracy, (electronic preferred for tracking water level drawdown during all pumping operations).

5. Flow measurement supplies (e.g. graduated cylinder and stopwatch).

6. Interface probe, if needed.

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7. Power source (e.g. generator, located downwind; nitrogen tank, etc). The generator should not be oversized for the pump.

8. In-line flow-through cell containing purge criteria parameter monitoring instruments for pH, turbidity, specific conductance, temperature, Eh and dissolved oxygen (DO). The in-line device should be bypassed or disconnected during sample collection. An example is the Horiba U-22 which is a flow-through cell that comes with probes capable of measuring pH, dissolved oxygen, conductivity, salinity, TDS, temperature, turbidity and oxidation-reduction potential. Available from Ashtead Technologies, 800.242.3910, www.ashtead-technology.com or Pine Environmental, 800-301-9663, www.pine-environmental.com, among others.

9. Photoionization detector (PID), or flame ionization detector (FID) or equivalent.

10. Nylon stay-ties

11. Decontamination supplies

12. Field book or well sampling form

13. Sample Bottles. It is recommended that preservatives be added to sample bottles prior to field activities to reduce potential error or introduction of contaminants.

14. Sample preservation supplies (as required by the analytical method; see previous item)

15. Sample tags or labels, and chain of custody.

16. Well construction data, location map, field data from last sampling event.

17. Sampling Plan or Work Plan

18. Health & Safety Plan

19. pH meter

20. Conductivity meter

21. Dissolved Oxygen (DO) meter

22. Oxidation -reduction (REDOX) reaction potential (ORP) meter

23. Nephlometer (turbidity)

24. Temperature gauge

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25. Field test kits (such as Hach kits for measurement of dissolved iron (Fe^{+2}), carbon dioxide, and alkalinity). See the document "Monitored Natural Attenuation Groundwater Sample Collection Procedure" for specifications and ordering information for these types of kits.

26. Field filtration units (if required)

3. PROCEDURE

3.1 Sampling Preparatory Activities

Prior to entering the field there are several activities that should be conducted. The activities are as follows:

- Obtain and review a copy of the Sampling or Work Plan and Health & Safety Plan.
- Obtain and review previous groundwater sampling data (if available), previous water level measurements and well construction details (total depth and length of well screen).
- Locate a site map denoting the wells to be sampled.
- Obtain well wrenches, well keys and any other equipment needed to access the wells.
- Coordinate site access.
- Coordinate with laboratory to obtain sample bottles and necessary quality assurance samples.
- Perform an inventory of necessary purging, sampling, and field measurement equipment. Certain equipment may need to be purchased or rented for the sampling event. Check field measurement probes for proper calibration and ensure that the probes and kits are complete (i.e., contain calibration and analytical solutions) for the entire sampling event.

3.2 Preliminary Site Activities

Once on site the following activities should be conducted prior to beginning sampling.

- Verify well identification and location using borehole log details and location site map. Check the condition of the well and record any evidence of damage or need for repair in the field book or field sampling form. Following field activities inform the Project Manager of any necessary repair work required.
- Lay out sheet of clean polyethylene around the well for monitoring and sampling equipment.

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- Prior to opening the well cap, measure the breathing space above the well casing with a PID or FID to establish baseline levels. Repeat this measurement once the well cap is opened. If either of these measurements exceeds the air quality criteria in the health and safety plan, field personnel should adjust their PPE accordingly.

- If the well does not have a water level reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the field book or sampling form.

- Collect a round of synoptic water level measurements and well depth (in the shortest possible time) before any purging or sampling activities begin. Water levels and well depths should be measured and reported to 0.01 ft. The water levels should be obtained from the denoted reference point on the well.

- Water level and total depth measurements must be obtained to determine the well volume for hydraulic purposes. In some settings it maybe necessary to allow the water level time to equilibrate. This condition exists if a watertight seal exists at the well cap and the water level has fluctuated above the top of screen thereby creating a vacuum or pressurized area in this air space. Three water level checks will verify static water level conditions or changing conditions.

- Check newly constructed wells for the presence of light or dense aqueous phase liquids before sampling.

3.3 Sampling Procedure

It is preferable to sample the wells in order of increasing chemical concentrations (known or anticipated). The following describes the procedure for the low-flow purging and sampling method. Equipment calibration, logbook documentation, sample bottle filling and preservation, and shipping will be conducted in accordance with the site-specific Quality Assurance Project Plan (QAPjP). Personal protective equipment will be donned in accordance with the requirements of the site-specific Health and Safety Plan.

1. Attach and secure the polyethylene tubing to the low-flow pump. See the equipment and materials section for recommended pump types. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties. It is recommended that the pump be placed in the well 12 to (preferably) 48 hours prior to purging/sampling to minimize the effects of turbidity and mixing in the well from introducing the pump.

2. Pump, safety cable, tubing and electrical lines should be lowered slowly into the well to a depth corresponding to the center of the saturated screen section of the well, or at a location determined to either be a preferential flow path or zone where contamination is present. The pump intake should be kept above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

3. Before starting the pump, measure the water level again with the pump in the well. Start pumping water from the well at a rate of **100 to 500 milliliters per minute (mL/min) which correlates to 0.03**

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to 0.13 gallons per minute. Avoid surging. Observe air bubbles displaced from discharge tube to assess progress of steady pumping until water arrives at the surface. The pumping rate should cause little or no water level drawdown in the well (less than 0.2 ft) and the water level should stabilize.

Water level measurements should be made every three to five minutes. Precautions should be taken to avoid pump suction loss or air entrainment. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump to avoid pumping the well dry and ensure stabilization of indicator parameters. If the recharge rate of the well is very low, purging should be interrupted so as not to cause the drawdown within the well to advance below the pump intake but the operator should attempt to maintain a steady flow rate with the pump to the extent practicable. Record adjustments made to the pumping rates and water levels immediately after each adjustment.

In low-yielding wells, where 100 mL/min exceeds the entrance rate of groundwater into the well, it is important to avoid dewatering the well screen interval and purging the well dry should be avoided to the extent possible. In these cases, the pump should remain in place and the water level should be allowed to recover repeatedly until there is sufficient volume in the well to permit collection of samples. Under these low-yield conditions, it may become difficult to maintain an adequate water volume in the flow-through cell described in the next step. An alternative means of sample collection may be necessary under these conditions and should be discussed with the Project Manager.

4. While purging the well, measurements of water quality indicator parameters utilizing an in-line flow-through cell (or similar equipment) should be collected every three to five minutes until all of the parameters have stabilized. See the Equipment and Materials section for recommendations. Stabilization is achieved when three successive readings are within the following tolerances noted in the table below.

Parameter	Stabilization Level (3 successive readings within)
Turbidity	+10% and final value between 5 and 10 NTU
Specific conductance	+3%
pH	±0.1
Dissolved oxygen (DO)	±10%
Redox potential (Eh)	±10mv

In general, the order of stabilization is pH, temperature and specific conductance, followed by redox potential, dissolved oxygen, and turbidity (USEPA, 1996). A minimum subset of these parameters that can be used to determine stabilization during purging in this procedure are pH, specific conductivity and turbidity or DO. Turbidity and DO are typically the last parameters to stabilize. If the parameters have stabilized, but the turbidity is not in the range of 10 NTU, then follow step 6. For informational purposes, the following table provides typical ranges of the various field parameters. Field data collected during purging and sampling should be compared against these values and, if substantial differences exist, the accuracy of the meter should be verified to rule out potential operational problems with the equipment.

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Parameter	Typical Range of Values
Turbidity	10 – 500 NTU
Specific conductance	50 – 500 mS
pH	6 - 9
Dissolved oxygen (DO)	ND – 9 mg/L
Redox potential (Eh)	-250 - +400 mV

5. Once stabilization has been documented, go to step 8.

6. Should stabilization not be achieved for all field parameters (or turbidity only as described in Step 4), purging is continued until a maximum of 20 well screen volumes have been purged from the well. Since low-flow purging (LFP) likely will not draw groundwater from a significant distance above or below the pump intake, the screen volume is based upon a 5-foot (1.4 m) screen length. After purging 20 well screen volumes, purging is continued if the purge water remains visually turbid and appears to be clearing, or if stabilization parameters are varying slightly outside of the stabilization criteria listed above and appear to be approaching stabilization.

   - If low-turbidity samples are critical to the project goals, purging will be extended until turbidity has been reduced to 5 NTU or less.

   - The pump must not be removed from the well between purging and sampling.

7. If the turbidity measurements do not approach the range of that of natural groundwater (10 NTU), both filtered and unfiltered samples should be collected for analysis of compounds such as metals or hydrophobic compounds[1]. Filtered metal samples are to be collected with an in-line filter. A high capacity, in-line 0.45 micron particulate filter must be pre-rinsed according to the manufacturers recommendations, or with approximately 1 liter of groundwater following purging and prior to sampling. After the sample is filtered it must be preserved immediately.

8. Collect groundwater samples. All sample containers should be filled by allowing the pump discharge to gently flow down inside the container with minimal turbulence. The flow-through cell, or similar equipment, should be bypassed during sampling. As each sample bottle is collected, the bottle should be labeled with the following information then place into a cooler with the proper temperature control.

   - Sample number/ID
   - Date and time
   - Parameters to be analyzed
   - Project Reference ID
   - Samplers initials

[1] Filtering of samples for analysis is a project-specific requirement and should be confirmed with the Project Manager prior to filtration.

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After collection of the samples, the tubing from the pump should be properly discarded or dedicated to the well for re-sampling (by hanging the tubing inside the well). Avoid handling the interior of the bottle or bottle cap and don new gloves for each well sampled to avoid contamination of the sample.

VOC and gas sensitive (e.g. Fe^{+2}, CH_4, H_2S/HS) parameter samples should be collected first. Refer the project sampling and analysis plan to determine which analytes will be measured in the field (wellhead) and which will be submitted to a fixed-base laboratory. The order of sample collection is as follows:

1. Volatile organic compounds
2. Gas sensitive parameters (e.g. Fe^{+2}, CH_4, H_2S/HS)
3. Semi-volatile organic compounds
4. Total organic carbon (TOC)
5. Total organic halogens (TOX)
6. Extractable organics
7. Total metals
8. Dissolved metals
9. Phenols
10. Cyanide
11. Sulfate and chloride
12. Nitrate and ammonia
13. Radionuclides

*Note: **The pumping rate used to collect a sample for VOCs should not exceed 100 mL/min.** Samples should be transferred directly to the final container 40 mL glass vials completely full and topped with a Teflon cap. Once capped the vial must be inverted and tapped to check for headspace/air presence (bubbles). If air is present the sample vial will be discarded, and re-collected until free of air. Field filtration will be performed if dictated by the project Work Plan.*

9. Measure and record final water level and well depth.

10. Secure the well (close and lock).

3.4 Decontamination

Decontaminate sampling equipment prior to use in the first well and following sampling of each subsequent well. Pumps will not be removed from well between purging and sampling operations. The pump and tubing (including support cable and electrical wires that are in contact with the well) will be decontaminated by one of the procedures listed below.

3.4.1 Procedure 1

Decontamination solutions can be pumped from buckets through the pump, or the pump can be disassembled and flushed with the decontamination solutions. It is recommended that the detergent

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and isopropyl alcohol be used sparingly in the decontamination process and that water-flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

1. Flush the equipment/pump with potable water.

2. Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

3. Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

4. Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event shows that the level of contamination is low, then this step may be skipped.

5. Flush with distilled/deionized water. The final water rinse must not be recycled.

6. Decontaminate the in-line flow-through cell and other sampling equipment with similar procedures, as appropriate.

3.4.2 Procedure 2

1. Steam clean the outside of the submersible pump.

2. Pump hot potable water from the steam cleaner through the outside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

3. Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

4. Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.
5. Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

6. Decontaminate the in-line flow-through cell and other sampling equipment with appropriate procedures.

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3.5 Field Documentation

Field notes must document all the events, equipment used, and measurements collected during the sampling activities. The logbook or sampling form (see Appendix C Forms) should document the following for each well sampled:

- Identification of well
- Well depth
- Static water level depth and measurement technique
- Sounded well depth
- Presence of immiscible layers and detection/collection method
- Well yield - high or low
- Purge volume and pumping rate
- Time well purged
- Measured field parameters - record measurements obtained every 3-5 minutes to monitor for stabilization, see attached example record log.
- Purge/sampling device used
- Well sampling sequence
- Sampling appearance
- Sample odors
- Sample volume
- Types of sample containers and sample identification
- Preservative(s) used
- Parameters requested for analysis
- Field analysis data and method(s)
- Sample distribution and transporter

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- Laboratory shipped to
- Chain of custody number for shipment to laboratory
- Field observations on sampling event
- Name collector(s)
- Climatic conditions including air temperature
- Problems encountered and any deviations made from the established sampling protocol.

3.6 Groundwater/Decontamination Fluid Disposal

Groundwater disposal methods will vary on a case-by-case basis and field personnel should consult the Project Manager for site-specific requirements. Disposal options may include:

- Off-site treatment at private treatment/disposal facilities or public owned treatment facilities.
- On-site treatment at Facility operated facilities.
- Direct discharge to the surrounding ground surface, allowing groundwater infiltration to the underlying subsurface regime.
- Direct discharge to impervious pavement surfaces, allowing evaporation to occur
- Decontamination fluids should be segregated and collected separately from wash waters/groundwater containers. Often small volumes of solvents used during the day can be allowed to evaporate if left in an open pail. In the event evaporation is not possible or practical, off-site disposal arrangements must be made.

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APPENDIX A
REFERENCES

- USEPA Low-flow (minimal drawdown) groundwater sampling procedures (EPA/540/S-95/504), April 1996.
- USEPA Ground-Water Sampling-A Workshop Summary, Dallas, Texas, November 30 - December 2, 1993. EPA/600/R-94/205.
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- USEPA Region 3. 1997. Recommended Procedure for Low-Flow Purging and Sampling of Groundwater Monitoring Wells. Waste and Chemicals Management Division - Low Flow Sampling. Bulletin No. QAD023.
- USEPA Region 1. 1996. Low Stress (Low Flow) Purging and Sampling for the Collection of Groundwater Samples from Monitoring Wells. SOP #: GW 001. Revision 2. pp.13.
- USEPA Region 2. 1998. Ground Water Sampling Procedure, Low Stress (Low Flow) Purging and Sampling. GW Sampling SOP, Final.

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

-
- OP3001 Preservation and Shipment of Environmental Samples
- OP3008 Manual Water Level Measurement Procedure
- OP3009 Monitoring Well Development Procedure
- OP3010 Groundwater Quality Sampling Procedure
- OP3013 Monitored Natural Attenuation Groundwater Sample Collection Procedure
-

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APPENDIX C
FORMS

- Form 3001 Sampling Labels (Environmental)
- Form 3003 Chain of Custody
- Form 3004 Sampling Record
- Form 3005 Groundwater Sampling Record
- Form 3006 Monitoring Well Development Report

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Haley & Aldrich, Inc.
465 Medford St., Suite 2200
Boston, MA 02129
Tel: 617-886-7400

Sample ID:	File Number:
Depth:	Project:
Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

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Date:	Analysis:
Time:	Preservative:
Collected By:	Laboratory:
Comments:	

Form 3001

HALEY & ALDRICH
Haley & Aldrich, Inc.
465 Medford St.,
Suite 2200,
Boston, MA 02129-1400

CHAIN OF CUSTODY RECORD

Phone (617) 886-7400
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H&A FILE NO.		LABORATORY		DELIVERY DATE	
PROJECT NAME		ADDRESS		TURNAROUND TIME	
H&A CONTACT		CONTACT		PROJECT MANAGER	

Sample No.	Date	Time	Depth	Type	VOA	ABNs PAH only	Metals RCRA (8) PP(13)	Pesticides PCBs	VPH Full Suite C-ranges only	EPH Full Suite C-ranges only	TPH (specify)	TCLP (specify)	Reactivity Ignitability Corrosivity				Number of Containers	Comments (special instructions, precautions, additional method numbers, etc.)

Sampled and Relinquished by	Received by
Sign	Sign
Print	Print
Firm	Firm
Date Time	Date Time
Relinquished by	**Received by**
Sign	Sign
Print	Print
Firm	Firm
Date Time	Date Time
Relinquished by	**Received by**
Sign	Sign
Print	Print
Firm	Firm
Date Time	Date Time

LIQUID												
												VOA Vial
												Amber Glass
												Plastic Bottle
												Preservative
												Volume
SOLID												
												VOA Vial
												Amber Glass
												Clear Glass
												Preservative
												Volume

Sampling Comments

Evidence samples were tampered with? YES NO

If YES, please explain in section below.

PRESERVATION KEY

A Sample chilled	**C** NaOH	**E** H_2SO_4	**G** Methanol
B Sample filtered	**D** HNO_3	**F** HCL	**H** Sodium Bisulfate

WHITE - Laboratory **CANARY** - Project Manager **PINK** - Haley & Aldrich Laboratory **GOLDENROD** - Haley & Aldrich Contact

Form 3003

WATER AND WASTEWATER METHODS

Analysis Description	Method No.	Preservative	Solid Sample Volume/Container	Liquid Sample Volume/Container	Holding Time
Alkalinity	310	Cool 4° C	N/A	250 mL HDPE	14 days
Amenable Cyanide	Std. Mth. 412 F.	pH>12 NaOH, Cool 4° C	N/A	1 L HDPE	14 days
Ammonia	350	pH<2 H2SO4, Cool 4° C	N/A	1 L HDPE	28 days
Base/Neutral & Acid Extractables	625	Cool 4° C	N/A	1 L Amber	7 days Ext/40 days Analyze
Biochemical Oxygen Demand (BOD)	405.1	Cool 4° C	N/A	2 L HDPE	48 hours
Chemical Oxygen Demand (COD)	410	pH<2 H2SO4, Cool 4° C	N/A	125 mL HDPE	28 days
Chloride	300.0, 325	None Required	N/A	125 mL HDPE	28 days
Chromium, Hexavalent	3500D, 218.4/5	None Required	N/A	1 L HDPE	24 hours
Fluoride	300.0, 340	None Required	N/A	500 mL HDPE	28 days
Hardness, Total (as CaCO3)	130	pH<2 H2SO4, Cool 4° C	N/A	250 mL HDPE	6 Months
Nitrate	300.0, 352.1	Cool 4° C	N/A	250 mL HDPE	48 Hours
Nitrite	300.0, 354.1	Cool 4° C	N/A	125 mL HDPE	48 Hours
Orthophosphate	300.0, 365	Filter, Cool 4° C	N/A	125 mL HDPE	48 Hours
PCBs	608	Cool 4° C	N/A	1 L Amber	7 days Ext/40 days Analyze
Pesticides	608	Cool 4° C	N/A	1 L Amber	7 days Ext/40 days Analyze
Physiologically Available Cyanide	MADEP draft	pH>12 NaOH, 4° C	N/A	1 L HDPE	14 days
Priority Pollutant Metals (13 Metals)	200.7/AA, 200 Series	pH<2 HNO3, 4° C	N/A	1 L HDPE	28 days (Hg), 6 mos. (others)
Purgeable Halocarbons & Aromatics	601/602	pH 2 HCl, Cool 4° C	N/A	40 mL Glass Vial	14 days
RCRA Metals (8 Metals)	200.7/AA, 200 Series	pH<2 HNO3, 4° C	N/A	1 L HDPE	28 days (Hg), 6 mos. (others)
Sulfate	300.0, 375	Cool 4° C	N/A	250 mL HDPE	28 days
Sulfide	376	pH>9 NaOH, Zn Acetate, Cool 4° C	N/A	1 L HDPE	7 days
Sulfite	377.1	None Required	N/A	125 mL HDPE	Analyze Immediately
Total Cyanide	335	pH>12 NaOH, Cool 4° C	N/A	1 L HDPE	14 days
Total Dissolved Solids (TDS)	209	Cool 4° C	N/A	250 mL HDPE	7 days
Total Organic Carbon (TOC)	415	pH<2 HCl or H2SO4, Cool 4° C, Dark	N/A	40 mL Amber	28 days
Total Organic Halogen (TOX)	506	pH<2 HNO3, 4° C	N/A	1 L Amber	check with lab
Total Phenolics	420.1	pH<2 H2SO4, Cool 4° C	N/A	1 L Amber	28 days
Total Phosphorus	365	pH<2 H2SO4, Cool 4oC	N/A	125 mL HDPE	28 days
Total Solids (TS)	160.3	Cool 4° C	N/A	250 mL HDPE	7 days
Total Suspended Solids (TSS)	160.2	Cool 4° C	N/A	250 mL HDPE	7 days
Volatile Organics	624	pH 2 HCl, Cool 4° C	N/A	40 mL Glass Vial	14 days
Weak and Dissociable Cyanide	Std. Mth. 412 H.	pH>12 NaOH, Cool 4° C	N/A	1 L HDPE	14 days
DRINKING WATER ANALYSIS					
Volatile Organics	502.2 or 524.2	pH 2 HCl, Cool 4° C	N/A	40 mL Glass Vial	14 days
MICROBIOLOGY					
Fecal Coliform	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours
Standard Plate Count	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours
Total Coliform	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours
Yeast and Mold	STDMTH	Cool 4o C	N/A	sterile, 125 mL	6 hours

SOIL/SEDIMENTS/WATER

Analysis Description	Method No.	Solids (S) / Liquids (L) Preservative	Solid Sample Volume/Container	Liquid Sample Volume/Container	Holding Time
Acid Extractables/Base/Neutral Extractables	8270	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Amenable Cyanide	-	S: 4° C / L: pH>12 NaOH, 4° C	4 oz. CWM	1 L HDPE	14 days
Chromium, Hexavalent	3060A/7196	S/L: Cool 4° C	8 oz. CWM	1 L HDPE	24 hours
Extractable Hydrocarbons	8015B	S: Cool 4° C / L: pH<2 HCl, 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Herbicides	8150	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Non-Halogenated Organics	8015B	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. CWM	40 mL Glass Vial	14 days
PAH (low level)	8310 or GC/MS SIM	S/L: Cool 4° C	8 oz. AWM	1 L Amber	7 days Ext/40 days Analyze
Paint Filter Liquids Test	9095	S: Cool 4° C	8 oz. CWM	1 L Amber	Analyze ASAP
PCBs	8082	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Pesticides	8081	S/L: Cool 4° C	8 oz. CWM	1 L Amber	7 days Ext/40 days Analyze
Physiologically Available Cyanide	MADEP draft	S: 4° C / L: pH>12 NaOH, 4° C	4 oz. CWM	1 L HDPE	14 days
Priority Pollutant Metals(13 Metals)	6010&7000	S: 4° C / L: pH<2 HNO3, 4° C	8 oz. CWM	1 L Amber	28 days (Hg), 6 mos. (others)
RCRA Metals (8 Metals)	6010&7000	S: 4° C / L: pH<2 HNO3, 4° C	8 oz. CWM	1 L Amber	28 days (Hg), 6 mos. (others)
Total Cyanide	9010	S: 4° C / L: pH>12 NaOH, 4° C	4 oz. CWM	1 L HDPE	14 days
Volatile Hydrocarbons	8015B	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. CWM	40 mL Glass Vial	14 days
Volatile Organics	8260B, 8021	S: methanol/$NaHSO_4$, 4° C / L: pH<2 HCl, 4° C	4 oz. CWM	40 mL Glass Vial	14 days
RCRA HAZARDOUS WASTE CHARACTERIZATION					
Corrosivity (pH only)	SW846-7.2	S: Cool 4° C	4 oz. CWM	check with lab	Analyze ASAP
Ignitability/Flashpoint	SW846-7.1	S: Cool 4° C	4 oz. CWM	check with lab	Analyze ASAP
Reactivity (CN-/S2-)	SW846-7.3	S: Cool 4° C	4 oz. CWM	check with lab	Analyze ASAP
TCLP (RCRA 8) Metals (check for mercury)	1311	S: Cool 4° C	16 oz. CWM	check with lab	6 mos. Ext/6 mos. Analyze
TCLP Pesticides/Herbicides	1311	S: Cool 4° C	16 oz. CWM	check with lab	14 days Ext/40 days Analyze
TCLP Semivolatiles	1311	S: Cool 4° C	16 oz. CWM	check with lab	14 days Ext/40 days Analyze
TCLP Volatiles	1311	S: Cool 4° C	8 oz. CWM	check with lab	14 days Ext/14 days Analyze
HYDROCARBON OIL & GREASE ANALYSIS					
MADEP EPH Method	MADEP REV. 0	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. Amber	1 L Amber	S:7 days Ext / L:14 days Ext
MADEP EPH Method (C-Ranges only)	MADEP REV. 0	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. Amber	1 L Amber	S:7 days Ext / L:14 days Ext
MADEP VPH Method	MADEP REV. 0	S: methanol, 4° C / L: pH<2 HCl, 4° C	40 mL+2 oz. CWM.	40 mL Glass Vial	S: 28 days / L: 14 days
MADEP VPH Method (C-Ranges only)	MADEP REV. 0	S: methanol, 4° C / L: pH<2 HCl, 4° C	40 mL+2 oz. CWM.	40 mL Glass Vial	S: 28 days / L: 14 days
MADEP EPH Method - with selected PAHs (including acenaphthene, naphthalene, 2-methylnaphthalene, and phenanthrene	MADEP REV. 0	S: Cool 4° C / L: pH<2 HCl, 4° C	4 oz. Amber	1 L Amber	S:7 days Ext / L:14 days Ext
Petroleum Identification	ASTM D3328				
Quantitative (include Chromatograms		S: Cool 4° C / L: pH<2 H_2SO_4, 4° C	4 oz. CWM	1 L Amber	S: 7 days / L: 28 days
Total Petroleum Hydrocarbons (Infrared	418.1	S: Cool 4° C / L: pH<2 H_2SO_4, 4° C	4 oz. CWM	1 L Amber	S: 7 days / L: 28 days

AIR METHODS

Analysis Description	Method No.	Preservative	Sample Volume/Container		Holding Time
Volatile Organic Compounds	EPA T01/T02	tubes: 4° C; Tedlar Bags: dark	N/A	N/A	tube: 14 days; bag: 72 hours
Volatile Organic Compounds	EPA T014	check with lab	N/A	N/A	can: 14 days; bag: 72 hours
VPH in air	EPA T01/T02	tubes: 4° C; Tedlar Bags: dark	N/A	N/A	tube: 14 days; bag: 72 hours
VPH in air	EPA T014	check with lab	N/A	N/A	can: 14 days; bag: 72 hours

This table is offered for informational purposes only and is intended to be followed and used by persons having related technical skills and at their own discretion and risk. Since conditions and the manner of use are outside of Haley & Aldrich's control, we make no warranties, express or implied, and accept no liability in connection with any use of this information. IT IS THE USER'S RESPONSIBILITY TO VERIFY THE SUITABILITY OF USE AND CORRECTNESS OF THE INFORMATION SUPPLIED.

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SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

Weather _____ **Temperature** _____

Ground surface Conditions ☐ Dry ☐ Wet ☐ Damp ☐ Standing Water ☐ Snow (_____in) ☐ Other_____

Comments _____

SOIL SAMPLING AND SURFACE WATER SAMPLING INFORMATION

Sample No.	Location	Depth (ft)	Time	Sample Description	Sampling Device	Cleaning Prodedure	Container Type

General Comments: (ie: field filtrations, persons communicated with at site, etc.)

Form 3004

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GROUNDWATER SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

GROUNDWATER SAMPLING INFORMATION

Well No.							
Water Depth (ft)							
Time							
Product							
Depth Of Well (ft)							
Inside Diameter (in)							
Standing Water Depth (ft) (1)							
Volume Of Water In Well (gal)							
Purging Device							
Volume of Bailer/Pump Capacity							
Cleaning Procedure							
Bails Removed/ Volume Removed							
Time Purging Started							
Time Purging Stopped							
Sampling Device							
Cleaning Procedure							
TIME SAMPLES TAKEN	VOA						
	ABN						
	Metals						
PARAMETERS	Color						
	Odor						
	pH						
	Conductivity						
	Turbidity						
	Dissolved Oxygen						
	Temp, ^{0} C						
	Salinity						

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

1. Standing Water Depth = Depth of Well - Water Depth

Form 3005

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MONITORING WELL DEVELOPMENT REPORT

Well No.

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP.	
CONTRACTOR		DATE	
ELEVATION SUBTRAHEND			

Estimated Volume of Water Lost During Drilling: _____ gallons

Comments: _____

Depth to Water Before Development: _____ feet

Comments: _____

Depth to Well Bottom Before Development: _____ feet

Comments: _____

Turubitiy of Water Before Development: _____ NTU

Comments: _____

Volume of Water Removed: _____ gallons

Comments: _____

Method of Removal (bailing, pumping): _____

Comments: _____

Depth to Well Bottom After Development: _____ feet

Comments: _____

Depth to Water After Development: _____ feet

Comments: _____

Turubitiy of Water After Development: _____ NTU

Comments: _____

OPERATING PROCEDURE: OP3018

VERTICAL PROFILING OF GROUNDWATER USING DIRECT PUSH TECHNOLOGY

LEVEL II Interim

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP3018

VERTICAL PROFILING OF GROUNDWATER USING DIRECT PUSH TECHNOLOGY

1. PURPOSE

Direct push systems (i.e. GeoProbe® or equivalent) can be mounted on a variety of vehicles, (e.g. trucks, vans, all-terrain vehicles (ATVs), etc.). They use hydraulics to drive hollow steel probes into the subsurface to collect samples of various media (e.g. soil, groundwater, soil-vapor). The individual probe sections (i.e., rods) are approximately 3 ft. long; and are threaded together before being driven into the subsurface.

The following operating procedure describes the use of direct push technology to install vertical water quality profilers, and the techniques used to collect groundwater samples from them.

2. EQUIPMENT & SUPPLIES

- Personal protective equipment (as required by the Health and Safety Plan)
- Cleaning equipment (as required in the Equipment Cleaning Procedures)
- Weighted Tape or Water Level Indicator
- Pocket knife
- Digital Camera
- Coolers with ice
- Appropriate sample containers, labels and forms
- Field notebook
- Haley & Aldrich Form 3005- Groundwater Sampling Record
- Vertical Profiler such as:
  - Hydropunch® by QED.
  - Groundwater Profiler by GeoProbe®.
  - Screenpoint 15 by GeoProbe®.
  - Waterloo Profiler® by Solinst®.
- Peristaltic pump
- Silicon tubing (i.e. Masterflex®)
- Polyethylene tubing (i.e. Waterra®)
- Check valve
- Bailer
- Drive Point (device specifications in Attachment D).

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3. PROCEDURE

Procedures used in conjunction with direct push drill rigs (i.e. GeoProbe® or equivalent) should be implemented in conjunction with those followed by the drilling subcontractor, and are not intended to serve as guidance or instruction for the operation of such a drill rig. Haley & Aldrich employees will not operate drill rigs.

The following procedures describe the use of several devices for the purpose of collecting groundwater samples. In addition, several relevant Haley & Aldrich Operating Procedures (OPs) are listed here:

Decontaminate reusable equipment as described in Haley & Aldrich Operating Procedure OP3027 Decontamination Procedure.

Disposed of excess purge water as described in Haley & Aldrich Operating Procedure OP3028 Investigation Derived Wastes.

3.1 Pre-sampling Observations, and Required Data Entries

A number of field measurements and observations should be made in the field when sampling groundwater. This information is listed below and will be recorded on a Groundwater Sampling Record. The following list of measurements and observations represents a minimum requirement for groundwater samples.

- Location ID
- Static water level (depth to water)
- Time
- Depth to product (if applicable)
- Depth to bottom of the well
- Inside diameter of well
- Calculated well volume
- Purging device
- Volume of bailer/Pump capacity [Note: This is “Continuous” for peristaltic, Grundfos® and Whale® pumps]
- Cleaning procedure
- Bails removed/volume removed
- Time purging started
- Time purging stopped
- Sampling device [Note: For pumps, this is “Waterra Tubing” or equivalent]
- Cleaning procedure [Note: If applicable, this is “Dedicated”]
- Time samples taken
- Sample Characteristics: pH, Conductivity, Dissolved Oxygen, Temperature, Preservative(s)
- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory)

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- Description of the Sample Location
- Photograph details (i.e. Picture number, orientation, subject matter, etc.)
- Latitude/Longitude (using GPS, collect Waypoint as well).
- Observable Physical Characteristics - Odor, Color, Cloudiness.
- Evidence of Stressed Vegetation, Wildlife, or Dumping.
- Ambient Weather Conditions during Sampling - Air Temperature, Atmospheric Conditions, Recent Precipitation or Drought.
- Samples Collected (enter all sample numbers collected at this location)

All entries will be made as described in Haley & Aldrich Level III Operating Procedure OP3029- Field Data Recording.

3.2 Hydropunch® and Screenpoint 15®

1. Drive device to desired sampling depth using direct push drill rig (i.e. GeoProbe® or equivalent).
2. Retract outer driving rods to expose inner screened portion.
3. Sample as described in Haley & Aldrich Operating Procedure OP3010- Groundwater Sampling.
4. Withdraw probe from ground and decontaminate.
5. Reinsert probe into ground, and drive to next desired depth.

3.3 Groundwater Profiler

1. Drive 6-inch or 12-inch sections of exposed screen to the desired depth
2. Circulate deionized water through the screen and into the formation during advancement to prevent screen clogging or entry of unwanted groundwater from non-target zones.
3. Sample as described in Haley & Aldrich Operating Procedure OP3010- Groundwater Sampling.
4. Leave probe in ground and advance to next sampling depth.

3.4 Waterloo® Sampler

1. Connect sample withdrawal tubing to screened ports in the probe. The tubing should be strung through the drive rods.
2. Drive probe to desired depth using direct push drill rig (i.e. GeoProbe® or equivalent)
3. Pump deionized water through the tubing and into the formation during probe advancement to minimize clogging of the sampling ports.
4. Sample as described in Haley & Aldrich Operating Procedure OP3010- Groundwater Sampling.
5. Leave probe in ground and advance to next sampling depth.

3.5 Drive Point Sampler

Please refer to Haley & Aldrich Operating Procedure OP3011- Groundwater Sampling using Direct Push Technology

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APPENDIX A
RELATED HALEY & ALDRICH PROCEDURES

Haley & Aldrich Operating Procedure OP3011- Groundwater Sampling using Direct Push Technology
Haley & Aldrich Operating Procedure OP3012- Low Stress/Low Flow Groundwater Sample Collection Procedure
Haley & Aldrich Operating Procedure OP3027- Decontamination Procedure
Haley & Aldrich Operating Procedure OP3028- Investigation Derived Wastes
Haley & Aldrich Operating Procedure OP3001- Preservation and Shipment of Environmental Samples, for naming, labeling, handling, and shipping information

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APPENDIX B
FORMS

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GROUNDWATER SAMPLING RECORD

Page of

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	

GROUNDWATER SAMPLING INFORMATION

Well No.							
Water Depth (ft)							
Time							
Product							
Depth Of Well (ft)							
Inside Diameter (in)							
Standing Water Depth (ft) (1)							
Volume Of Water In Well (gal)							
Purging Device							
Volume of Bailer/Pump Capacity							
Cleaning Procedure							
Bails Removed/ Volume Removed							
Time Purging Started							
Time Purging Stopped							
Sampling Device							
Cleaning Procedure							
TIME SAMPLES TAKEN	VOA						
	ABN						
	Metals						
PARAMETERS	Color						
	Odor						
	pH						
	Conductivity						
	Turbidity						
	Dissolved Oxygen						
	Temp, ^{0} C						
	Salinity						

Remarks: (ie: field filtrations, persons communicated with at site, etc.)

1. Standing Water Depth = Depth of Well - Water Depth

Form 3005

SOP #	**OP3023**
Task	**Air Sample Collection with Tedlar Bags**
Author	**Denis Conley**
Revision/Date	**Rev 1/January 2011**

Required Equipment

1-Liter Tedlar bags, Vac-U-Chamber

Procedure

Vapor samples are collected from sample ports installed in the treatability study tank while operating under typical conditions. Vapor samples will be analyzed on-site using an indicator tube or at H&A laboratory using a gas chromatograph equipped with a flame ionization detector (GC/FID). Confirmation analyses may also be performed at Alpha Analytical's Westborough, MA Laboratory using a GC interfaced with a mass spectrometer (MS) in accordance with EPA Method TO+15.

Vapor Sample Collection

Tank vapor samples will be collected according to the following procedures:

- Label the sample bag with the following information: sample ID (sample port-DDMMYY), date, time, airflow (acfm), temperature, sampler's initials and analysis requested.
- Open the sample port valve and purge the line for 20-30 seconds. If necessary use a purge bag allowing any condensate to evacuate from the sample port.
- Vapor samples are collected directly into 1-Liter Tedlar bags using an air sample pump and vacuum chamber.
    - Open valve on tedlar bag a maximum of one turn.
    - Connect bag to the interior tubing of the Vac-U-Chamber and close and secure latches. Make sure decompression valve located below handle is closed.
    - Connect air pump to Vac-U-Chamber using the connection tubing with male (quick disconnect) to pump inlet.
    - Connect sample port tubing to Vac-U-Chamber.
    - Open sample port valve.
    - Turn on air sampling pump to collect sample.
    - Fill the Tedlar bag to approximately 80% capacity, turning off pump when 80% capacity is reached.
    - Close sample port valve.
    - Bring Vac-U-Chamber back to atmospheric pressure by opening the decompression valve slightly, thereby releasing the vacuum.
    - Open the Vac U Chamber
    - Close the valve on the bag and disconnect from the tubing inlet.
- Place the sample into a cardboard box or cooler to protect from sunlight and transport for analysis.
- Protect sample from sunlight and temperature extremes, (i.e. <10 C or >30C).

OPERATING PROCEDURE: OP3026

CHAIN OF CUSTODY

LEVEL II (Interim)

Haley & Aldrich

PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP3026

CHAIN OF CUSTODY

1. PURPOSE

A chain-of-custody (COC) record will be completed at the time of sample collection and will accompany each shipment identifying the contents of the shipment to the laboratory. The field personnel collecting the samples will be responsible for the custody of the samples until the samples are relinquished to the laboratory. Sample transfer will require the individuals relinquishing and receiving the samples to sign, date and note the time of sample transfer on the COC record.

Custody is one of several factors necessary for the integrity of environmental data. Custody procedures help to satisfy the two major requirements for assuring sample integrity: relevance and authenticity. Custody of a sample begins when it is collected by or transferred to an individual and ends when that individual relinquishes or disposes of the sample. A sample is under your custody if:

- the item is in actual possession of a person;
- the item is in the view of the person after being in actual possession of the person;
- the item was in actual possession but is stored to prevent tampering; or
- the item is in a designated and identified secure area.

2. EQUIPMENT & SUPPLIES

1. Haley & Aldrich, Inc. Form 3003- Chain of Custody Record [Appendix C]

2. Indelible ink pen

3. List of analytes

3. PROCEDURE

Field personnel will keep written records of field activities on applicable preprinted field forms. The written records provide the means of recording data collecting activities. These records will be written legibly in ink and will contain pertinent field data and observations. Entry errors or changes will be crossed out with a single line, dated and initialed by the person making the correction.

Samples will be shipped or delivered to the laboratory so that holding-times and/or analysis times as prescribed

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by the methodology can be met.

Samples will be transported in containers (coolers) which will maintain the refrigeration temperature for those parameters for which refrigeration is required in the prescribed preservation protocols. Water samples will be placed in bubble wrap bags and placed in the sample cooler. Sample bags for volatile organic compound (VOC) analysis will contain no more than three (3) containers per bag while soil VOC samples will be placed in individually sealed sample pouches. Samples in polyethylene containers will be placed directly in the sample cooler. All samples will be placed in an upright position and limited to one layer of samples per each cooler. Additional bubble wrap or packaging material will be added to fill the cooler. Shipping containers will be secured with strapping tape and custody tape for shipment to the laboratory.

If samples are sent by a commercial carrier, a bill of lading will be used. A copy of the bill of lading will be retained as part of permanent documentation. (Note: Commercial carriers will not sign the custody record as the custody record will be sealed inside the sample cooler and the custody tape remains intact.

Samples will be picked up by a laboratory courier or transported overnight by a courier to the laboratory within 48 hours of collection. Ice will be added to the cooler as needed to maintain proper preservation temperatures.

Each sample cooler shipped to the laboratory will contain a chain-of-custody form. The chain-of-custody form will consist of four (4) copies which will be distributed as follows: The shipper will maintain a copy while the other three copies will be enclosed in a waterproof envelop within the cooler with the samples. The cooler will then be sealed properly for shipment. The laboratory, upon receiving the samples, will complete the three (3) remaining copies. The laboratory will maintain one copy for their records. One copy will be returned to the Field QA/QC Officer upon receipt of the samples by the laboratory. One copy will be returned with the laboratory data deliverables package. Chain-of-custody (COC) records are legal documents.

The following list provides guidance for the completion and handling of all COCs.

1. COCs used can be project specific forms or supplied by the project analytical laboratory.

2. COCs must be completed in indelible permanent ink only.

3. COCs must be completed neatly using printed text.

4. If a simple mistake is made, correct with a single line and initial and date the entry.

5. If numerous repetitive entries must be made in the same column, place a continuous vertical arrow between the first entry and the next different entry.

6. When more than one COC form is used for a single shipment, each form must be consecutively numbered using the "Page ___ of ___" format.

7. If necessary, place additional instructions directly onto the COC. Do not enclose separate instructions.

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8. Include a contact name and phone number on the COC in case there is a problem with the shipment.

9. Do not indicate the source of the sample as this may produce a biased lab result.

10. Before using an acronym on a COC, define clearly the full interpretation of your designation [i.e., Polychlorinated Biphenyls - (PCBs)].

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APPENDIX A
FORMS

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Haley & Aldrich, Inc.
465 Medford St.,
Suite 2200,
Boston, MA 02129-1400

CHAIN OF CUSTODY RECORD

Phone (617) 886-7400
Fax (617) 886-7700

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H&A FILE NO.		LABORATORY		DELIVERY DATE	
PROJECT NAME		ADDRESS		TURNAROUND TIMI	
H&A CONTACT		PROJECT MANAGER		DELIVERY DATE	

Sample No.	Date	Time	Depth	Type	Container Size	No. of Containers	Analysis Requested	Preservatives	Comments - (special instructions, precautions, additional method numbers, etc.)

Sampled and Relinquished by	Received by	PRESERVATION KEY	Sampling Comments
Sign	Sign	A Sample chilled	
Print	Print	B Sample filtered	
Firm	Firm	C NaOH	
Date Time	Date Time	D HNO_3	
Relinquished by	**Received by**	E H_2SO_4	
Sign	Sign	F HCL	
Print	Print	G Methanol	
Firm	Firm	H Sodium Bisulfate	
Date Time	Date Time	I	
Relinquished by	**Received by**	**Evidence samples were tamperd with?** YES NO	
Sign	Sign	**If YES, please explain in section below.**	
Print	Print		
Firm	Firm		
Date Time	Date Time		

WHITE - Laboratory **CANARY** - Project Manager **PINK** - Haley & Aldrich Laboratory **GOLDENROD** - Haley & Aldrich Contact

Form 3002

APPENDIX B
GLOSSARY

COC – Chain of Custody
OP – Operating Procedure
PCB – Polychlorinated Biphenyl
QA/QC – Quality Assurance/Quality Control
VOC – Volatile Organic Compound

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OPERATING PROCEDURE: OP3027

DECONTAMINATION PROCEDURE

LEVEL II (Interim)

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OPERATING PROCEDURE: OP3027

DECONTAMINATION PROCEDURE

1. PURPOSE

This procedure describes decontamination of field equipment potentially exposed to contaminants. Proper decontamination is required to minimize the potential for cross-contamination that would compromise sample quality. The degree of decontamination required will be dependent on the nature of the activity, equipment used and on the amount of exposure to contaminants.

2. EQUIPMENT & SUPPLIES

Decontamination equipment and solutions are generally selected based on ease of decontamination and disposability.

- Polyethylene sheeting;
- Metal racks to hold deconned equipment;
- Soft-bristle scrub brushes or long-handle brushes for removing gross contamination and scrubbing with wash solutions;
- Large galvanized wash tubs, stock tanks, or wading pools for wash and rinse solutions;
- Plastic buckets or garden sprayers for rinse solutions;
- Large plastic garbage cans or other similar containers lined with plastic bags can be used to store contaminated clothing;

Contaminated liquids and solids should be segregated and containerized in DOT-approved plastic or metal drums, appropriate for offsite shipping/disposal if necessary.

3. PROCEDURE

Decontamination activities must be performed in a controlled contaminant reduction area outside any exclusion zones established on the site. Care must be taken to minimize the potential for transfer of contaminated materials to the ground or onto other materials. Regardless of the size or nature of the equipment being decontaminated, the process will utilize a series of steps that involve removal of gross material (dirt, grease, oil etc.), washing with a detergent, and multiple rinsing steps. In lieu of a series of washes and rinse steps, steam cleaning with low-volume, high-pressure equipment (i.e. steam cleaner) is acceptable.

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Drill rigs, backhoes and other exploration equipment must be decontaminated prior to initiating site activities, in-between exploration locations to minimize cross- contamination potential, and prior to mobilizing off site after completion of site work. Heavy equipment is generally decontaminated with a combination of steam-cleaning equipment and manual scrubbing. Particular attention should be paid to parts in direct contact with contaminants, e.g. shovels, tires, augers, drilling decks, etc.

A decontamination pad must be constructed that is appropriate for the size and type of equipment being decontaminated for control and containerization of all decontamination fluids.

At a minimum, the decontamination pad will have the following elements:

- an impermeable barrier capable of containing decontamination fluids;
- a low point where fluids will collect and can be pumped into appropriate containers;
- durability to withstand equipment such as vehicle and foot traffic;
- appropriate ancillary equipment such as racks to place decontaminated equipment to drain without further exposure to contaminated fluids;
- Labels to alert personnel as to the potential presence of contaminated materials.

3.1 Decontamination of Sampling Equipment

All equipment that comes in contact with the sampling media (i.e. Surface Water, Sediment, etc.) must be decontaminated as specified below. An alternative approach is to have multiple pieces of equipment, and a centralized decontamination location where the procedures below can be reproduced in a grouped setting.

Stainless steel samplers used for the collection of samples for chemical analysis will be cleaned prior to use and between each sampling point in accordance with the following procedure:

- brush with soapy (phosphate-free soap) water; and
- rinse with de-ionized water provided by the laboratory.

The peristaltic pump used for surface water purging and sampling and/or pond sediment sampling will be decontaminated prior to use and between each location according to the following procedures:

- spray the discharge tubing, with de-ionized water (provided by the laboratory) to rinse off particulates;
- pump soapy (phosphate-free soap) water solution through the pump and;
- circulate potable water through the pump and discharge tubing until all traces of soap are gone; and
- pump de-ionized water (provided by the laboratory) through the pump and tubing.

NOTE: If the tubing is dedicated to each monitoring location and disposed of after sampling is completed, decontamination will be not required.

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3.2 Decontamination of Monitoring Equipment

Because monitoring equipment is difficult to decontaminate, care should be exercised to *prevent* contamination. Sensitive monitoring instruments should be protected when they are at risk of exposure to contaminants. This may include enclosing them in plastic bags allowing an opening for the sample intake. Ventilation ports should not be covered.

If decontamination is required, wipe the instruments down with detergent-wetted wipes or sponges, and wiped with de-ionized water-wetted wipes or sponges.

3.3 Disposal of Wash Solutions and Contaminated Equipment

All decontamination fluids such as wash water, rinsates, solids and materials used that cannot be effectively decontaminated (such as polyethylene sheeting) will be containerized and labeled with an indelible marker as to contents and date of placement in the container, and any appropriate stickers required. Storage of decontamination wastes on site will not exceed 90 days under any circumstances. Characterization of wastes for proper disposal will be performed immediately upon completion of the investigation to minimize storage time on site.

Please refer to Haley & Aldrich Operating Procedure OP3028-Investigation Derived Wastes for a complete discussion of handling and disposal of these materials.

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APPENDIX A
REFERENCES

ASTM D5088 - Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites

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OPERATING PROCEDURE: OP3028

INVESTIGATION DERIVED WASTES

LEVEL II (Interim)

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OPERATING PROCEDURE: OP3028

INVESTIGATION DERIVED WASTES

1. PURPOSE

This procedure applies to the management and characterization of investigation soils and/or groundwater as required in accordance with the Remedial Design Work Plan. In some areas and/or sections within the Site it is permitted to return soil cuttings/test pit soils and groundwater to the source area. In other areas it may not be practical to return cutting/soils to their origin, and they are better handled by this characterization/disposal procedure. These practices are consistent with USEPA procedure for IDW at RCRA facilities and CERCLA sites (reference 1, 2, 3). Typically, investigative derived wastes are dealt with following "Best Management Practices"; and are not handled under RCRA regulations until proven to be listed and/or identified as characteristically hazardous waste (reference 1). Investigative soils and groundwater often cannot be considered a listed waste due to the lack of generator knowledge concerning chemical source, chemical origin, and timing of chemical introduction to the subsurface. Consequently, waste sampling and characterization is performed to determine if the wastes exhibit a characterization of hazardous waste. Once the IDW characterization is complete, RCRA regulations apply if determined hazardous; if determined to be non-hazardous solid wastes, best management /solid waste handling practices apply. The disposal of soil cuttings, test pit soils and/or purged groundwater must be reviewed on a case by case basis prior to initiation of field activities. Two scenarios typically exist:

1. No Disposal/No Containerization Required - When sufficient Site information exists that allows investigative soils, cuttings, and/or purged groundwater to be placed back into the borehole or spread on the ground surface. This may be employed when it is believed that the area of concern will require a final remedy involving in-situ treatment, or an off-Site disposal removal effort is likely required, or no chemical impact is evident; and the material replacement does not pose a health threat or contaminate new areas.

   Alternatively, no information may be available in the area of activity or investigation, and impacted media/soils are identified. Activities such as new construction and /or maintenance works below grade may encounter environmental conditions that were unknown. Again it is logistically practical to complete the activity, employ health and safety measures appropriate to the conditions identified, and evaluate the extent and magnitude of the impact. Timely notification to the client would be required to formulate a course of action, and collect chemical samples from the area of concern (if warranted). Investigative works maybe conducted in areas where it is not known if impacted soils/groundwater exist, and the presence of hazardous constituents is not known. Again RCRA guidance permits Best Management Practices of keeping media on-Site (reference 2).

2. Disposal Required/Containerization Required – When sufficient facility and/or Site information regarding the investigative Site conditions warrant that all materials handled will be contained and disposed of.

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Investigation results may dictate that all IDW be recovered and contained. This approach may be performed to facilitate quick closure/allow access quickly back into the investigative area regardless of environmental impact or not.

If a known listed hazardous and/or characteristically hazardous waste/contaminated environmental media is being handled, then handling must be performed in accordance with RCRA Subtitle C (reference 2).

The following procedure describes the techniques for characterization of investigation derived waste (IDW) for disposal purposes. IDW may consist of soil cuttings (augering, boring, well installation soils, test pit soils), rock core or rock flour (from coring, reaming operations), groundwater (from well development, purging and sampling activities), personal protective equipment (PPE), and disposal equipment (DE).

2. EQUIPMENT & SUPPLIES

- Sample spoons, trowel, auger.
- Sample mixing bowl.
- Sampling bailer, or pump.
- Sample glassware.
- Ratchet to open drums.

3. PROCEDURE

The procedures for handling and characterization of field activity generated wastes are:

1. Soil/Rock Cuttings - Soils removed from boring activities and well construction tasks (including rock flour from bedrock coring) will be contained within an approved container, suitable for transportation and disposal.

2. Once placed into the approved container, any free liquids (i.e., groundwater) will be poured off for disposal as waste fluids. No free liquid as determined by the "paint filter test" (reference 5) shall be present.

3. Contained soils will be screened for the presence of Volatile Organic Compounds VOCs), using a Flame-ionization detector (FID); this data will be logged for future reference.

4. Once screened, full and closed; the container will be labeled in accordance with the Project Specific label and placed into the temporary container storage area. At a minimum, the following information will be shown on each container label: date and time of filling/generation, Site name, source of soils

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(i.e., borehole or well), and Site contact information. If necessary, the exterior of the container will be cleaned to remove any lose soil/cuttings.

5. Prior to container closure, representative samples from the containers will be collected for waste characterization purposes and submitted to the project laboratory.

6. Alternatively, it maybe practical to collect waste characterization samples as the containers are filled. The waste characterization sampling scheme will be dictated by the Remedial Design Work Plan and establish the volume of soils required for analysis (depending on parameters required), the number of containers considered representative, the homogenization procedure, volatile analysis collection procedure (if required), and preparation handling requirements. Typically at a location where an undetermined site specific parameter group exists, sampling and analysis may consist of the full RCRA Waste Characterization (ignitability, corrosivity, reactivity, toxicity), or a subset of the above based upon data collected, historical information, and generator knowledge.

7. Groundwater from well construction development, purging, and sampling requires disposal and shall be contained.

   Containment may be performed in 55-gallon drums, tanks suitable for temporary storage (i.e., nalgene) or if large volumes of groundwater are anticipated, tanker trailers (5,000 to 10,000 gallons ±), or drilling "Frac" tanks may be utilized
   (20,000 gallons ±). In all cases the container/tank used for groundwater storage must be clean before use such that cross-contamination does not occur.

8. Decontamination Water/Fluids - Decon water and/or fluids will be segregated, contained, and disposed accordingly.

   Decontamination waters may be disposed of with the contained groundwater once analytical results have been acquired. Depending on the analytical results, it may be appropriate to discharge the decontamination water to the Publicly Owned Treatment Works (POTW); or discharge to an On-Site treatment system; or off-Site for treatment.

9. Personal Protective Equipment (PPE) – A number of disposal options exists for spent PPE generated from investigation tasks. The options typically employed are:

   a. Immediately disposed of within on-site dumpster/municipal trash; or
   b. If known to be contaminated with RCRA hazardous waste, dispose off-Site at a RCRA-Subtitle C facility; or alternatively decontaminate PPE/DE and dispose on-site within dumpster/municipal trash.

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3.1 Waste Characterization Procedure

The Remedial Design Work Plan will identify the appropriate sampling strategy and analytes required to determine the IDW characteristics and disposal requirements. USEPA SW-846 (reference 4) describes the rationale for sampling plan development and sampling procedures. Generally random sampling and preparation of a composite sample of the media is employed for most investigative programs. Often a minimum of 4 representative samples is required to gain valid waste characteristic data to determine the disposal option applicable (if statistics are employed). Sampling procedures for IDW are:

Solid Wastes –Grab sampling using pre-cleaned sample spoons from bulk piles, lugger boxes, or as drums are being filled. In some instances when sufficient media mixing is evident, drum sampling from a random number of drums by accessing only the top solids may be permitted. In other instances where stratification is evident, a sample trowel/hand auger or device to collect from the entire vertical profile is required. Typically, a composite sample(s) from representative areas of the container(s) is homogenized and submitted for analysis. If VOCs are being evaluated, compositing and homogenization is not permitted. Individual grab samples are typically required.

- Waste Waters – Grab sampling techniques using pre-cleaned bailers or sampling pumps are typically employed. Waters in bulk are typically sampled once using a bailer or pump. The Remdial Design Work Plan will outline the appropriate sample frequency and analytes necessary to adequately characterize the contained waters. Facility sewer discharge permit parameters will be evaluated when disposal to the POTW is being considered.

- PPE – Depending on presence of contamination with RCRA hazardous waste, use D) above.

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APPENDIX A
REFERENCES

1. USEPA RCRA - Guidance and Policies: Management of Remediation Waste Under RCRA (October 1998).

2. USEPA RCRA - Management of Contaminated Media (October 1998).

3. USEPA CERCLA Guidance (Options Relevant to RCRA Facilities): Guide to Management of Investigation - Derived Wastes (January 1992).

4. USEPA Office of Solid Waste- SW846 Chapter 9 Sampling Plan, Chapter 10 Sampling Methods (September 1986).

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APPENDIX B
FORMS

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DRUM WASTE RECORD

Page of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	

Drum Number	Boring Identification	Drill Cuttings/Wash Water		Date Generated	Comments
		Solid	Liquid		

Location of Drums:

* Please attach a site plan showing the drum locations

Notes:

APPENDIX C
GLOSSARY

DE – Disposal Equipment
IDW – Investigation Derived Wastes
PPE – Personal Protective Equipment
POTW – Publicly Owned Treatment Works
USEPA – United States Environmental Protection Agency
RCRA – Resource Conservation and Recovery Act
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

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OPERATING PROCEDURE: OP3029

FIELD DATA RECORDING

LEVEL II (Interim)

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.1	RWS 4/5/08	DMC 04/06/08	JBB 04/07/08		

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OPERATING PROCEDURE: 3029

FIELD DATA RECORDING

1. PURPOSE

This procedure describes protocol for documenting standard investigation activities in the field. Field data recording for an environmental project provides site characterization information and supporting data for additional phases of investigation or remedial design activities. Recorded defensible field data includes proper and appropriate recording of field data as it is obtained in a manner that will preserve it for future use. This procedure provides guidelines for accurate, thorough collection and preservation of written and electronic field data.

2. EQUIPMENT & SUPPLIES

- 5” by 7” National 407 Field Book, with high-grade 50% rag paper with water resistant surface, hard-cover, or equivalent;
- Appropriate field log forms;
- Indelible pen (do not use “rollerball” or felt-tip style pens);
- Straight edge;
- Pocket calculator;
- Laptop computer (if required).

3. PROCEDURE

Typical field data to be recorded generally includes, but is not limited to, the following:

- general field observations;
- numeric field measurements and instrument readings;
- quantity estimates;
- sample locations and corresponding sample numbers;
- relevant comments and details pertaining to the samples collected;
- documentation of activities, procedures and progress achieved;
- contractor pay item quantities; such as number of borings, footage of pipe, number of samples collected, etc.;
- weather conditions;
- a listing of personnel involved in site-related activities;
- a log of conversations, site meetings and other communications; and

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- work plan deviations with pertinent information associated with the deviations.

3.1 Written Field Data

Written field data is generally recorded on one of two media: A standardized, preprinted field form, or a bound field log book. In general, use of standardized field forms is preferable as it prompts field personnel to record observations and data in a standardized format. This promotes completeness and consistency between field events and individuals. In the absence of a standardized pre-printed field form, the data should be recorded in an organized and structured manner in a dedicated project field logbook. Logbooks must be bound so that pages cannot be added or removed, and should be made from a high grade (50%) rag paper with a water-resistant surface.

The following are guidelines for use of field forms and logbooks:

1. Information must be factual, complete and without abbreviations.

2. All entries must be written legibly in indelible ink. (Do not use "rollerball" or felt tip-style pens, since the water-soluble ink can run or smear in the presence of moisture.)

3. All pages in a logbook and field forms must be consecutively numbered.

4. Each day's work must use a new log book page or field form.

5. At the end of each day, the current logbook page and /or field form must be *signed and dated* by the field personnel making the entries.

6. Make data entries immediately upon obtaining the data. Do not make temporary notes in other locations for later transfer to log forms or log books; this only increases the potential for error or loss of data.

7. Data entry corrections must be crossed out with a single line, dated and initialed by the person making the correction.

8. Do not leave blanks on log forms, if no entry is applicable for a given data field, indicate with a "NA" for *not applicable*.

9. At the earliest practical time, photocopies of field forms and log book pages should be scanned and placed in the electronic project file as a backup in the event the book or forms are damaged.

10. Logbooks should be dedicated to the project and the individual, (i.e. do not record data from multiple projects in one log book.)

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3.2 Electronic Data

Electronic data recording is widely used in environmental investigation and remediation projects. In general, it involves electronic measurement of field information through the use of monitoring instruments, sensors, gauges, and equipment controls. The following is a list of guidelines for proper recording and management of electronic field data:

1. Use only instruments calibrated in accordance with manufacturer's recommendations.

2. Usage of instruments, controls and computers for the purpose of obtaining field data should only be performed by personnel properly trained and experienced in the use of the equipment and software.

3. Use only fully licensed software on PCs and laptops. (Software piracy, even if unintentional, *is a felony* and exposes the client, its contractors, and their employees to severe criminal and financial penalties.)

4. Every effort should be made to back up electronic files obtained in the field as soon as practical. A backup file will be placed on a computer disk and kept in a separate location from the original to minimize the potential for loss of critical project information.

5. Electronic files, once transferred from field instruments or laptops to office computers, should be protected if possible to prevent unwanted or inadvertent manipulation or modification of data. Several levels of protection are usually available for spreadsheets, including making a file "read-only" or assigning a password to access the file.

6. Protect floppy disks from exposure to moisture, excessive heat or cold, magnetic fields, or other potentially damaging conditions.

7. Remote monitoring is often used to obtain stored electronic data from site environmental systems. A thorough discussion of this type of electronic field data recording is beyond the scope of this SOP. Users must remotely access the monitoring equipment files via modem or other access, and download the data. In order to minimize the potential for loss of data, access and downloading of data should be performed frequently enough to insure the data storage capacity of the remote equipment is not exceeded.

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OPERATING PROCEDURE: OP3030

FIELD INSTRUMENTS – USE AND CALIBRATION

LEVEL II (Interim)

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE 3030

FIELD INSTRUMENTS – USE AND CALIBRATION

1. PURPOSE

A significant number of field activities involve usage of electronic instruments to monitor environmental conditions and for health and safety purposes. It is imperative the instruments are used and maintained properly to obtain accurate data and to insure safe working conditions.

This OP provides guidance on the usage, maintenance and calibration of electronic field equipment, owned by the Contractor, or obtained from an equipment rental agency.

2. PROCEDURE

- All monitoring equipment will be in proper working order, and operated in accordance with the manufacturer's recommendations.
- A copy of the Operating Instructions, Maintenance and Service manual for each instrument used on a project will be kept on site at all times.
- Instruments will be operated only by personnel trained in the proper usage and calibration. In the event certification of training is required, personnel will have documentation of such certification with them on site at all times.
- Field personnel will be responsible for insuring the equipment is maintained in the field, or returned for office or manufacturer maintenance or calibration if warranted. Calibration is discussed in greater detail below.
- Instruments will be operated within the range of conditions such as temperature and humidity specified by the manufacturer unless authorized by the Project Manager and/or Health and Safety supervisor as appropriate.
- Instruments that contain radioactive source material, such as x-ray fluorescence analyzers or moisture-density gauges require specific transportation, handling and usage procedures that are generally associated with a license from the Nuclear Regulatory Commission (NRC) or an NRC-Agreement State. Under no circumstance will operation of such instruments be allowed on site unless by properly authorized and trained personnel, using the proper personal dosimetry badges or monitoring instruments.

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2.1 Calibration

Calibration of an electronic instrument is critical to insure it is operating properly for its intended use. Such instruments are often sensitive to changes in temperature or humidity, or chemical vapors in the working atmosphere.

Calibration of instruments shall be performed in accordance with the manufacturer's recommendations. This includes the following parameters:

- Frequency
- Use of proper Calibration Gases or Chemical Standards
- Requirements for Factory Calibration

2.1.1 Calibration Gas Safety

Several instruments such as photo-ionization detectors (PID), flame ionization detectors (FID), oxygen meters, explosimeters, and combustible gas indicators require the use of calibration gas contained in compressed gas cylinders. Many of these gases are combustible or explosive. Care shall be taken to minimize the potential for injury from the use of such compressed gases. Transport, handling and storage of cylinders, where necessary, shall be performed in accordance with applicable DOT regulations and site requirements.

Calibration will only be performed in areas free of sources of spark, flame or excessive heat. Smoking will not be allowed in the vicinity of calibration gas usage areas.

2.1.2 Documentation of Calibration

Instrument Calibration activities will be documented on the Instrument Calibration Form.

2.2 Intrinsically Safe Requirements

Certain work locations may be such that dangerous, ignitable or explosive conditions exist. In such cases, it may be necessary to utilize only equipment that is rated as "Intrinsically Safe." Intrinsically safe instrumentation is designed with limited electrical and thermal energy levels to eliminate the potential for ignition of hazardous mixtures.

For site work requiring operation of monitoring instruments in Class I, Division I locations (as defined by the National Fire Protection Agency (NFPA)) only instrumentation rated as Intrinsically Safe will be used. Such equipment (including all accessories and ancillary equipment) must be rated to conform to Underwriter's Laboratories (UL) Standard 913, for use in a Class I, Division 1 Groups A, B, C, and D locations. It is also recommended the equipment conform with CSA Standard 22.2, No. 157-92.

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- Upon completion of the field activities, equipment shall be returned to the possession of the Consultant, Contractor or Rental Agency accompanied by a written summary of any problems encountered with its use or calibration.

- Equipment shall be properly prepared for shipping, including insuring that residual gases (if applicable) are removed from the instrument, and accompanying containers of compressed gases or fluids are properly labeled and sealed.

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APPENDIX A
REFERENCES

1. Underwriter's Laboratories, Inc. (http://www.ul.com/hazloc/define.htm) Standard UL 913.

2. National Fire Protection Agency (http://www.nfpa.org/index.html)

3. Canadian Standards Association (CSA) (http://www.csa.ca) Standard 22.2 No.157

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APPENDIX B
FORMS

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Instrument Calibration Log

Project	**Surface Water Monitoring**	**Report No.**	
Location	**IndustriPlex Superfund Site**	**Date**	
Client	**de maximis**	**File No.**	**33020-030**
Contractor		**Field Rep.**	
Weather		**Outdoor Temp**	

Standard Reference Material _____

Certified Concentration _____

Expiration Date _____

NIST Traceability _____

DATE	DEVICE	TECH	CALS PERFORMED

Iron, Ferrous

DOC316.53.01049

1-10 Phenanthroline Method[1]

Method 8146

0.02 to 3.00 mg/L

Powder Pillows or AccuVac® Ampuls

Scope and Application: For water, wastewater and seawater

[1] Adapted from *Standard Methods for the Examination of Water and Wastewater*, 15th ed. 201 (1980)

Test preparation

How to use instrument-specific information

The *Instrument-specific information* table displays requirements that may vary between instruments. To use this table, select an instrument then read across to find the corresponding information required to perform this test.

Table 1 Instrument-specific information

Instrument	Powder pillows			AccuVac Ampuls	
	Sample cell	Cell orientation	Adapter	Sample cell	Adapter
DR 5000	2495402	Fill lines face user	A23618	2427606	A23618
DR 2800	2495402	Fill lines face right		2122800	LZV584 (C)
DR 2700	2495402	Fill lines face right		2122800	LZV584 (C)
DR/2500	2401906	—	—	2401906	—
DR/2400	2401906	—	—	2401906	—

Before starting the test:

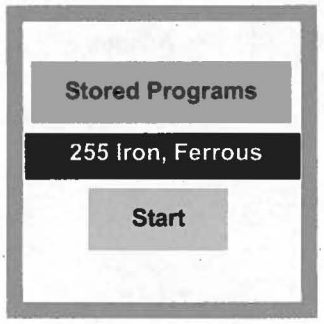
For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water instead of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust.
Analyze samples as soon as possible to prevent air oxidation of ferrous iron to ferric iron, which is not determined.
If ferrous iron is present, an orange color will form after adding the reagent.

Collect the following items:

Description	Quantity
Powder Pillow Test:	
Ferrous Iron Reagent Powder Pillows	1
Sample Cells (see *Instrument-specific information*)	2
AccuVac Test:	
Ferrous Iron Reagent AccuVac® Ampuls	1
Beaker, 50-mL (AccuVac test)	1
Sample Cell (see *Instrument-specific information*)	1

See *Consumables and replacement items* for reorder information.

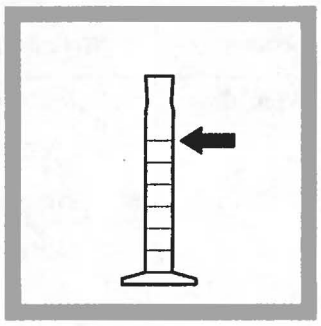
1-10 Phenanthroline method for powder pillows



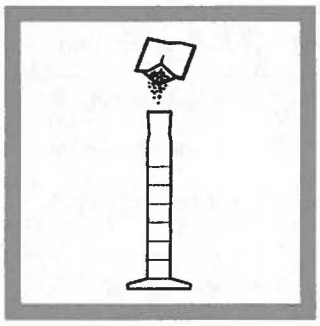
1. Select the test.

Insert an adapter if required (see *Instrument-specific information*).

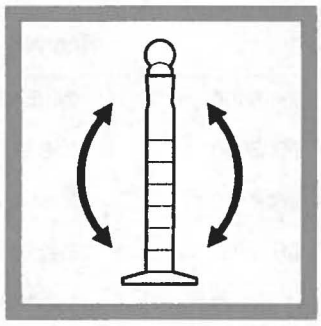
Refer to the user manual for orientation.



2. Fill a clean graduated mixing cylinder with 25 mL of sample.



3. Prepared Sample: Add the contents of one Ferrous Iron Reagent powder pillow to the cylinder.



4. Insert a stopper and invert to mix. Undissolved powder does not affect accuracy.

5. Start the instrument timer.

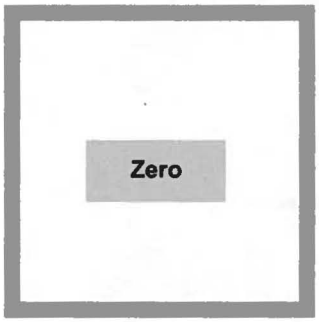
A three-minute reaction period will begin.

6. Blank Preparation: Fill a sample cell with 10 mL of sample.

7. Fill a second sample cell with the prepared sample from the mixing cylinder in step 4.

8. When the timer expires, insert the blank into the cell holder.

1-10 Phenanthroline method for powder pillows (continued)

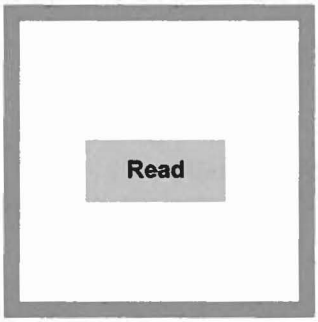


9. ZERO the instrument.

The display will show:

0.00 mg/L Fe2+

10. Insert the prepared sample into the cell holder.



11. READ the results in mg/L Fe2+.

1-10 Phenanthroline method for AccuVac® Ampuls

1. Select the test.

Insert an adapter if required (see *Instrument-specific information*).

Refer to the user manual for orientation.

2. Blank Preparation: Fill a round sample cell with 10 mL of sample.

3. Prepared Sample: Fill a Ferrous Iron Reagent AccuVac® Ampul with sample from the beaker. Keep the tip immersed while the Ampul fills completely.

4. Quickly invert the Ampul several times to mix.

5. Start the instrument timer.

A three-minute reaction period will begin.

6. Wipe the blank and insert it into the cell holder.

ZERO the instrument.

The display will show:

0.00 mg/L Fe2+

7. Wipe the Ampul and insert it into the cell holder.

READ the results in mg/L Fe2+.

Sample collection, preservation and storage

- Collect samples in plastic or glass bottles.
- Analyze samples as soon as possible after collection.

Accuracy check

Standard solution method

Note: *Refer to the instrument user manual for specific software navigation instructions.*

Required for accuracy check:

- Ferrous Ammonium Sulfate, hexahydrate, 0.7022 g
- 1-L Class A volumetric flask
- 100-mL Class A volumetric flask
- Deionized water
- Analytical balance
- 2-mL Class A volumetric pipet and pipet filler

1. Prepare a 100-mg/L Fe2+ ferrous iron stock solution as follows:
   a. Dissolve 0.7022 grams of Ferrous Ammonium Sulfate, hexahydrate, in deionized water.
   b. Dilute to one liter in a Class A volumetric flask.
   c. In a 100-mL Class A volumetric flask, dilute 2.00 mL of this solution to 100 mL with deionized water to make a 2.0-mg/L standard solution. Prepare this solution immediately before use.
2. Follow the *1-10 Phenanthroline method for powder pillows* or the *1-10 Phenanthroline method for AccuVac® Ampuls* test procedure.
3. To adjust the calibration curve using the reading obtained with the 2.00-mg/L Standard Solution, navigate to Standard Adjust in the software.

Instrument	Navigate to:
DR 5000	**OPTIONS>MORE>STANDARD ADJUST**
DR 2800	**OPTIONS>MORE>STANDARD ADJUST**
DR 2700	**OPTIONS>MORE>STANDARD ADJUST**
DR/2500	**OPTIONS>STANDARD ADJUST**
DR/2400	**OPTIONS>STANDARD ADJUST**

4. Turn on the Standard Adjust feature and accept the displayed concentration. If an alternate concentration is used, enter the concentration and adjust the curve to that value.

Method performance

Program	Instrument	Standard	Precision 95% Confidence Limits of Distribution	Sensitivity Concentration change per 0.010 Abs change
255	DR 5000	2.00 mg/L Fe2+[1]	1.99–2.01 mg/L Fe2+	0.021 mg/L Fe2+
	DR 2800			
	DR 2700			
	DR/2500		0.99–1.01 mg/L Fe2+	0.028 mg/L Fe2+
	DR/2400			
257			1.98–2.02 mg/L Fe2+	0.023 mg/L Fe2+
			0.98–1.02 mg/L Fe2+	0.023 mg/L Fe2+

[1] 1.00 mg/L on DR/2400 and DR/2500

Summary of method

The 1-10 phenanthroline indicator in the Ferrous Iron Reagent reacts with ferrous iron (Fe2+) in the sample to form an orange color in proportion to the iron concentration. Ferric iron (Fe3+)does not react. The ferric iron (Fe3+) concentration can be determined by subtracting the ferrous iron concentration from the results of a total iron test. Test results are measured at 510 nm.

Consumables and replacement items

Required reagents

Description	Quantity/Test	Unit	Catalog number
Ferrous Iron Reagent Powder Pillows	1	100/pkg	103769
OR			
Ferrous Iron Reagent AccuVac® Ampuls	1	25/pkg	2514025

Required apparatus (AccuVac)

Description	Quantity/Test	Unit	Catalog number
Beaker, 50-mL	1	each	50041H

Recommended standards and apparatus

Description	Unit	Catalog number
Balance, analytical, 80 g x 0.1 mg 115 VAC	each	2936701
Ferrous Ammonium Sulfate, hexahydrate, ACS	113 g	1125614
Flask, volumetric, 1000 mL	each	1457453
Pipet filler, safety bulb	each	1465100
Pipet, volumetric, 2.00 mL	each	1451535
Water, deionized	4 L	27256
Wipers, disposable	280/pkg	2097000

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PROCEDURES AND CRITERIA
ANALYSIS OF FLUORESCEIN, EOSINE, RHODAMINE WT, SULFORHODAMINE B, AND PYRANINE DYES IN WATER AND CHARCOAL SAMPLERS

August 22, 2003

Thomas Aley, PHG 179
President
Ozark Underground Laboratory, Inc.

PROCEDURES

Introduction

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or up-graded. A summary of changes in standard procedures and criteria is maintained by the Ozark Underground Laboratory.

Dye Nomenclature

Fluorescein is C.I. Acid yellow 73, Color Index Number 45350. Rhodamine WT is Acid Red 388; there is no assigned Color Index Number for this dye. Eosine (sometimes called eosin) is Acid Red 87, Color Index Number 45380. Sulforhodamine B is C.I. Acid Red 52, Color Index Number 45100. Pyranine is Solvent Green 7 (also called D&C Green 8), Color Index Number 59040.

Description of the Samplers

The charcoal samplers are packets of fiberglass screening partially filled with approximately 4.25 grams of activated coconut charcoal. The charcoal used by the Ozark Underground Laboratory is Barnebey and Sutcliffe coconut shell carbon, 6 to 12 mesh, catalog type AC.

The most commonly used samplers are about 4 inches long by two inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1 inch diameter wells); this is a special order item and should be specifically requested when it is needed. All of the samplers are closed by heat sealing.

Placement of Samplers

Samplers (also called charcoal packets) are placed so as to be exposed to as much water as possible. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than being flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are placed in sample holders made of PVC pipe fittings. Brass hose fittings are installed at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose.

The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consists of 1.5 inch diameter pipe and pipe fittings.

Charcoal packets can also be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Some sort of weight should be added near the charcoal packet to insure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with narrow wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a stainless steel weight may be added to the top of the disposable bailer. We have had good success with two to three ounce segments of stainless steel pipe which have an outside diameter of 1.315 inches and an inside diameter of 1.049 inches; such pipe weighs about 1.7 pounds per linear foot. The weight of the stainless steel is approximately 497 pounds per cubic foot. The pipe segments can be attached over the anchoring cord at the top of the bailer. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

Placement of samplers requires adjustment to field conditions. The above placement comments are intended as guidance, not firm requirements.

Rinsing of Charcoal Packets Prior to Sampling

Charcoal packets routinely contain some fine powder which washes off rapidly when they are placed in water. Since such material could remain in monitoring wells, charcoal packets to be placed in such wells are triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach, approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

Collection and Replacement of Samplers

Samplers are routinely collected and replaced from each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of

travel. As an illustration, we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled. This is typically not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak bags are ideal). The bag is labeled on the outside with a permanent type felt marker pen. Use only pens that have black ink; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels are not inserted inside the sample bags.

For most projects the Ozark Underground Laboratory supplies the Whirl-Pak bags. Prior to use, 1% of the new bags are randomly selected. Each bag is soaked in the standard eluting solution and then analyzed for the presence of any of the tracer dyes being used.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. We prefer (and in some studies require) that samples be placed on "blue ice" or ice upon collection and that they be shipped refrigerated with "blue ice" by overnight express. Do not ship samplers packed in ice since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration, yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

Water samples are often collected. They should be collected in either glass or plastic; the Ozark Underground Laboratory routinely uses 50 ml research grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. The vials should be placed in the dark and refrigerated immediately after collection. They should be refrigerated until shipment. For most projects the Ozark Underground Laboratory supplies the vials. Prior to use, 1% of the new vials are randomly selected. Each vial is soaked in the standard eluting solution and then analyzed for the presence of any of the tracer dyes being used.

When water or charcoal samplers are collected for shipment to the Ozark Underground Laboratory they should be shipped promptly. We receive good overnight and second day air service from both UPS and Fed Ex; Airborne Service is excessively slow, and the Postal Service does not provide next day service to us.

Each shipment of charcoal samplers or water samples must be accompanied by a sample tracking sheet. These sheets (which bear the title "Samples for Fluorescence Analysis") are provided by the Ozark Underground Laboratory and summarize placement and collection data. These sheets can be augmented by a client's chain of custody forms or any other relevant documentation. Figure 1 is one of our blank sample forms.

Receipt of Samplers

Samplers shipped to the Ozark Underground Laboratory are refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number. All samples are logged in upon receipt and are recorded in a bound journal.

It sometimes occurs that there are discrepancies between the chain-of-custody sheets and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. A copy of this form is enclosed as Figure 2. The purpose of the form is to help resolve discrepancies, even when they may be minor.

Cleaning of Samplers

Samplers are cleaned by spraying them with jets of clean water. At the Laboratory we use unchlorinated water for the cleansing to minimize dye deterioration. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

After washing, the packets are shaken to remove excess water. Next, the packets are cut open and the charcoal is emptied into a new disposable plastic beaker. The beaker has been pre-labeled with the laboratory identification number. The charcoal is now ready for elution. The emptied fiberglass screen packet is discarded. At stations where two or more charcoal packets are collected, one is selected for analysis and the other is frozen and retained until the end of the study. In some studies the analysis protocol stipulates that a fixed percentage (often 5%) of the samples should be duplicates; in these cases the second charcoal packet is separately analyzed. Note that these are duplicate samples, not replicate samples since each packet is, of necessity, placed in a somewhat different location and is therefore exposed to somewhat different conditions.

Cleaning of Glassware

Most of our work uses disposable plastic containers. A small amount of glassware is occasionally used for preparation of standards. It is dedicated to this use. In the event that any glassware does come in contact with tracer dyes it will be carefully cleaned before re-use. To do this cleaning, containers are rinsed several times in clean water. Glassware which may be contaminated with dyes is washed with detergent, and then again rinsed. Next, the glassware is soaked for one hour or more in a bleach and water solution. Upon removal from this soaking, the glassware is rinsed again and allowed to air dry.

Figure 1. Sample Collection Data Sheet

OZARK UNDERGROUND LABORATORY, INC.

1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 email: oul@tri-lakes.net

SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

Project:_____**Week No:**_____ **Samples Collected By:**_____

Samples Shipped By:_____**Samples Received By:**_____

Date Samples Shipped:____/____/___ **Date Samples Received:**____/____/___ **Time Samples Received:**____:____ **Return Cooler? Yes**_____**No**_____

Bill to:_____**Send Results to:** _____

Analyze for: Fluorescein_____**Eosine**_____**Rhodamine WT**_____**Other**_____**Ship cooler to:** _____

OUL use only		***Please indicate stations where dye was visible in the field*** *for field technician use - use black ink only*						*OUL use only*
# CHAR REC'D	**LAB NUMBER**	**STATION NUMBER** 1-4 Numbers	**STATION NAME**	**PLACED**		**COLLECTED**		**# WATER REC'D**
				DATE	**TIME**	**DATE**	**TIME**	

COMMENTS:_____

_____

This sheet filled out by OUL staff? Yes_____**No**_____**Charts for samples on this page proofed by OUL:**_____

Page _____ **of** _____

Figure 2. Discrepancy Sheet

OZARK UNDERGROUND LABORATORY, INC.

DISCREPANCIES BETWEEN CHAIN-OF-CUSTODY SHEETS AND ACTUAL SAMPLES RECEIVED **Page _____ of _____**

Company & Project Name: **Date Rec'd by OUL:** **Wk # _____**

Lab #	Sta #	Station Name	Date Pulled	Problem	Solution

Comments:

Elution of the Charcoal

There are various eluting solutions which can be used for the recovery of tracer dyes. The solutions typically include an alcohol, some water, and a strong basic solution such as aqueous ammonia.

The standard elution solution now used at the Ozark Underground Laboratory is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide flakes to saturate the solution. The isopropyl alcohol is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution we use will elute fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in some samplers.

Fifteen ml of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded.

Analysis on the Shimadzu RF-5000U or RF-5301

The Laboratory uses two Shimadzu spectrofluorophotometers. One is a model RF-5000U, and the other is a model RF-5301. Both of these instruments are capable of synchronous scanning. The RF-5301 is the primary instrument used; the RF-5000U is primarily used as a back-up instrument except for tracing studies which were begun using this instrument. The OUL also owns a Shimadzu RF-540 spectrofluorometer which is occasionally used for special purposes.

A sample of the elutant is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 ml of the elutant is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 ml. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The spectral range of the cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5000U or the RF-5301. Both instruments are controlled by a programmable computer. Each instrument is capable of conducting substantial data analysis.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of the instruments and a training session on the use of spectrofluorophotometers was provided by Delta Instrument Company.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes, the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "very fast" on the RF-5000U; it is “fast” on the RF-5301. The typical sensitivity setting used on both instruments is "high."

Our typical analysis of an elutant sample where pyranine dye may be present includes a synchronous scanning of excitation and emission spectra with a 35 nm separation between excitation and emission wavelengths. For this dye, the excitation scan is from 360 to 600 nm; the emission scan is from 395 to 635 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "very fast" on the RF-5000U; it is “fast” on the RF-5301. The typical sensitivity setting on both instruments is "high."

Excitation and emission slit width settings vary between the two instruments. The widths vary with the dyes for which we are sampling and for the matrix in which the dyes may be present. Excitation and emission slit width settings are summarized in Table 1.

Table 1. Excitation and emission slit width settings routinely used for dye analysis. Units are nanometers (nm)

Parameter	**RF5000U**	**RF5301**
Excitation slit for Eos, Fl, RWT, and SRB in elutant	5	3
Emission slit for Eos, Fl, RWT, and SRB in elutant	3	1.5
Excitation slit for Eos, Fl, RWT, and SRB in water	5	5
Emission slit for Eos, Fl, RWT, and SRB in water	10	3
Excitation slit for Pyranine in elutant	5	5
Emission slit for Pyranine in elutant	3	3
Excitation slit for Pyranine in pH adjusted water	5	5
Emission slit for Pyranine in pH adjusted water	3	3

Eos = Eosine. Fl = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

A plot of the synchronous scan for each sample is produced by the instrument; the plot shows emission fluorescence only. It is photocopied as a part of the final record. The synchronous scans are subjected to computer peak picks; peaks are picked to the nearest

0.1 nm. All samples run on the RF-5000U and RF-5301 are stored on disk and printed on normal typing paper with a laser printer; sample information is printed on the chart.

Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes. Dye quantities are expressed in microgram per liter (parts per billion; ppb). On the RF-5000U and RF-5301 the dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

Where there are multiple fluorescence peaks it is sometimes necessary to calculate dye concentrations based upon the height of the fluorescence peak rather that the area. The heights of the peaks are also proportional to dye concentrations.

We run dye concentration standards each day the machine is used. Ten separate standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
4) 10 ppb pyranine in well water from the Jefferson City-Cotter Formation. A sample of the standard is placed for at least two hours in a high ammonia atmosphere to adjust the pH to a value of 9.5 or greater.
5) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
6) 10 ppb eosine in elutant.
7) 100 ppb sulforhodamine B in elutant.
8) 10 ppb pyranine in elutant.

Preparation of Standards

Dye standards are prepared as follows:

Step 1. A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to insure that all dye is fully dissolved.

Step 2. One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein, rhodamine WT, eosine, sulforhodamine B, and pyranine. The resulting solutions contain

100 mg/l dye (100 parts per million dye). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 ml. of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 ml at intervals of 0.005 ml. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 ml, 0.90%

At 0.300 ml, 0.28%

At 1.000 ml, 0.30%

The Step 2 solution is called the long term standard. Ozark Underground Laboratory experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

Step 3. A series of intermediate-term dye solutions are made. Approximately 45 ml. of each intermediate-term dye solution is made. All volume measurements of less than 5 ml are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 ml. capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) A solution containing 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.

2) A solution containing 1 ppm eosine.

3) A solution containing 10 ppm sulforhodamine B dye.

4) A solution containing 1 ppm pyranine.

Step 4. A series of eight short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the Ozark Underground Laboratory these standards have a useful shelf life in excess of one week. However, in practice, they are kept under refrigeration and new standards are made weekly.

Dilution of Samples

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilution is 100 fold. One part of the test sample is combined with 99 parts of water (if the test sample is water) or with 99 parts of the standard elutant (if the test sample is elutant). Typically, 0.300 ml of the test solution is combined with 29.700 ml of water (or elutant as appropriate) to yield a new test solution. All volume

measurements of less than 5 ml are made with a digital Finnpipette. which is capable of measuring volumes between 0.200 and 1.000 ml at intervals of 0.005 ml. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 ml, 0.90%

At 0.300 ml, 0.28%

At 1.000 ml, 0.30%

All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 ml. capacity pump dispenser which will pump within plus or minus 1% of the set value.

Quality Control

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds which might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing typically includes approximately 1% of materials used.

Reports

Reports are provided in accordance with the needs of the client. At a minimum we provide copies of the analysis graphs and a listing of stations and samples where dye was detected. The reports indicate dye concentrations.

Work at the Ozark Underground Laboratory is directed by Mr. Thomas Aley. Mr. Aley has 36 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #179) by the American Institute of Hydrology. Mr. Aley has 34 years of professional experience in groundwater tracing with fluorescent tracing agents.

CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

Normal Emission Ranges and Detection Limits

The OUL has established normal emission fluorescence wavelength ranges for each of the five dyes. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically centrifuged or, if this is not effective, diluted prior to analysis.

Table 2 provides normal emission wavelength ranges and detection limits for the five dyes when analyzed on the OUL's RF-5000U spectrofluorophotometer. Table 3 provides similar data for the OUL's RF-5301. As indicated earlier in Table 1, the analytical protocols used on the two instruments are somewhat different, especially in regard to the widths of excitation and emission slit settings.

Table 2. RF-5000U Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes in water and elutant samples. Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Eosine in Elutant	533.0 to 539.6	0.035
Eosine in Water	529.6 to 538.4	0.008
Fluorescein in Elutant	510.7 to 515.0	0.010
Fluorescein in Water	505.6 to 510.5	0.0005
Pyranine in Elutant	500.4 to 504.6	0.055
Pyranine in Water*	501.2 to 505.2	0.030
Rhodamine WT in Elutant	561.7 to 568.9	0.275
Rhodamine WT in Water	569.4 to 574.8	0.050
Sulforhodamine B in Elutant	567.5 to 577.5	0.150
Sulforhodamine B in Water	576.2 to 579.7	0.040

* pH adjusted water with pH of 9.5 or greater.

Note: The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in the table.

Table 3. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes in water and elutant samples. Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Eosine in Elutant	535.2 to 541.8	0.050
Eosine in Water	532.1 to 540.9	0.015
Fluorescein in Elutant	513.6 to 517.9	0.025
Fluorescein in Water	506.9 to 509.9	0.002
Pyranine in Elutant	502.1 to 508.1	0.015
Pyranine in Water*	504.1 to 510.1	0.010
Rhodamine WT in Elutant	566.6 to 573.8	0.170
Rhodamine WT in Water	572.0 to 576.3	0.015
Sulforhodamine B in Elutant	570.8 to 580.8	0.080
Sulforhodamine B in Water	579.7 to 583.2	0.008

* pH adjusted water with pH of 9.5 or greater.

Note: The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in the table.

Criteria for Determining Positive Dye Recoveries

The following sections identify normal criteria used by the OUL for determining positive dye recoveries. Beginning January 1, 2001, the primary analytical instrument in use at the OUL was the RF-5301; the RF-5000U was the principal backup instrument. Studies which were in progress prior to January 1, 2001 continued to have samples analyzed on the RF-5000U.

Except for pyranine dye, the analytical protocol used for the RF-5301 provides for the use of narrower excitation and/or emission slit settings than the RF-5000U protocol. This enhances our ability to discriminate between dyes and other fluorescent compounds. The protocol which is possible with the RF-5301 (as contrasted with the RF-5000U) also provides for a better balance in the sizes of the fluorescence peaks associated with an equal concentration of all of the dyes.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive <u>Eosine</u> Dye Recoveries <u>in Elutants</u> from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of eosine dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be eosine dye.

Criterion 1. There must be at least one fluorescence peak at the station in question in the range of 535.2 to 541.8 nm for samples analyzed by the RF-5301. The range must be 533.0 to 539.6 nm for samples analyzed by the RF-5000U.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. For the RF-5301, the eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb. For the RF-5000U the eosine detection limit in elutant samples is 0.035 ppb, thus this dye concentration limit equals 0.105 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive <u>Eosine</u> Dye Recoveries <u>in Water</u> Samples.

There is generally little or no detectable fluorescence background in the general range of eosine dye encountered in most groundwater tracing studies. The following three criteria are used to identify fluorescence peaks which are deemed to be eosine dye.

Criterion 1. The associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. For samples analyzed on the RF-5301, the fluorescence peak should generally be in the range of 532.1 to 540.9 nm. For samples analyzed on the RF-5000U, the fluorescence peak should generally be in the range of 529.6 to 538.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples analyzed on the RF-5301 is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb. For samples analyzed on the 5000U the detection limit is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Fluorescein Dye Recoveries in Elutants from Charcoal Samplers.

There is often some fluorescence background in the range of fluorescein dye present at some of the stations used in groundwater tracing studies. We routinely conduct background sampling prior to the introduction of any tracer dyes to characterize this background fluorescence and to identify the existence of any tracer dyes which may be present in the area. The fact that a fluorescence peak is identified in our analytical results is not proof that it is fluorescein dye or that it is fluorescein dye from the trace of concern. The following 4 criteria are used to identify fluorescence peaks which are deemed to be fluorescein dye recoveries from our tracing work.

Criterion 1. There must be at least one fluorescence peak at the station in question in the range of 513.6 to 517.9 nm for samples analyzed by the RF-5301. The range must be 510.7 to 515.0 for samples analyzed by the RF-5000U.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. For the RF-5301, the fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb. For the RF-5000U, the fluorescein detection limit in elutant samples is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Fluorescein Dye Recoveries in Water Samples.

There is commonly some fluorescence background in the general range of fluorescein dye at some sampling stations used in groundwater tracing studies. The following criteria are used to identify fluorescence peaks which are deemed to be fluorescein dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. For samples analyzed on the RF-5301, the fluorescence peak should generally be in the range of 506.9 to 509.9 nm. For samples analyzed on the RF-5000U, the fluorescence peak should generally be in the range of 505.6 to 510.5 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples analyzed on the RF-5301 is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb. For the RF-5000U the detection limit is 0.0005 ppb, thus this dye concentration limit equals 0.0015 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Rhodamine WT Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of Rhodamine WT dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be Rhodamine WT.

Criterion 1. For samples analyzed on the RF-5301, there must be at least one fluorescence peak at the station in question in the range of 566.6 to 573.8 nm. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 561.7 to 568.9 nm.

Criterion 2. The dye concentration associated with the Rhodamine WT peak must be at least 3 times the detection limit. For the RF-5301, the detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb. For the RF-5000U, the detection limit in elutant samples is 0.275 ppb, thus this dye concentration limit equals 0.825 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of Rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Rhodamine WT Dye Recoveries in Water Samples.

The following criteria are used to identify fluorescence peaks which are deemed to be Rhodamine WT dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain Rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be Rhodamine WT dye from the tracing work under investigation. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 572.0 to 576.3 nm. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 569.4 to 574.8 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our Rhodamine WT detection limit in water samples analyzed on the RF-5301 is 0.015 ppb, thus this dye concentration limit is 0.045 ppb. For samples analyzed on the RF-5000U the detection limit is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Sulforhodamine B Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of sulforhodamine B dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be sulforhodamine B.

Criterion 1. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 567.5 to 577.5 nm. The acceptable range for samples analyzed on the RF-5301 is 570.8 to 580.8 nm.

Criterion 2. The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. For the RF-5000U, the detection limit in elutant samples is 0.150 ppb, thus this dye concentration limit equals 0.450 ppb. For the RF-5301, the detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Sulforhodamine B dye Recoveries in Water Samples.

The following criteria are used to identify fluorescence peaks which are deemed to be sulforhodamine B dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 576.2 to 579.7 nm. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 579.7 to 583.2 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. For samples analyzed on the RF-5301 the detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb. For samples analyzed on the RF-5000U the detection limit in water samples is 0.040 ppb, thus this dye concentration limit equals 0.120 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Pyranine Dye Recoveries in Elutants from Charcoal Samplers.

It must be remembered that the analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in this document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

There is often some detectable fluorescence background encountered in the general range of pyranine dye in groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be pyranine.

Criterion 1. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 500.4 to 504.6 nm. The acceptable range for samples analyzed on the RF-5301 is 502.1 to 508.1 nm.

Criterion 2. The dye concentration associated with the pyranine dye peak must be at least 3 times the detection limit. For the RF-5000U, the detection limit in elutant samples is 0.055 ppb, thus this dye concentration limit equals 0.165 ppb. For the RF-5301, the detection limit in elutant samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of pyranine dye. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Pyranine Dye Recoveries in Water Samples.

It must be remembered that the analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in this document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

The fluorescence of pyranine decreases below a pH of about 9.5. Prior to analysis water samples are placed in a high ammonia atmosphere for at least two hours. A pyranine dye in water standard is placed in the same atmosphere as the samples. Prior to analysis samples are tested to insure that their pH is 9.5 or greater. If pyranine dye concentrations in a sample are so great as to require dilution for quantification of the dye concentration the diluting water used is OUL reagent water which has been pH adjusted in a high ammonia atmosphere.

The following criteria are used to identify fluorescence peaks which are deemed to be pyranine dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain pyranine dye in accordance with the criteria listed earlier. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be pyranine dye from the tracing work under investigation. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 501.2 to 505.2 nm. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 504.1 to 510.1 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. For samples analyzed on the RF-5301 the detection limit in water is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb. For samples analyzed on the RF-5000U the detection limit in water samples is 0.030 ppb, thus this dye concentration limit equals 0.090 ppb.

ATTACHMENT C2

De-watering Testing Procedures (PDI-1)

EM 1110-2-5027
30 September 1987

US Army Corps
of Engineers

Confined Disposal of Dredged Material

ENGINEER MANUAL

material (passing the No. 200 sieve) should be used in the other characterization and consolidation tests if required. Grain size analyses should follow the procedures contained in EM 1110-2-1906. Hydrometer analyses can be used to define the grain size distribution of the fine-grained fraction if desired.

g. Plasticity Analyses. In order to evaluate the plasticity of fine-grained samples of sediment, the Atterberg liquid limit (LL) and plastic limit (PL) must be determined. The LL is that water content above which the material is said to be in a semiliquid state and below which the material is in a plastic state. Similarly, the water content that defines the lower limit of the plastic state and the upper limit of the semisolid state is termed the PL. The plasticity index (PI), defined as the numerical difference between the LL and the PL, is used to express the plasticity of the sediment. Plasticity analyses should be performed on the fine-grained fraction (<No. 200 sieve) of sediment samples. A detailed explanation of the LL and PL test procedures and apparatus can be found in Appendix III of EM 1110-2-1906.

h. Organic Content. A knowledge of whether significant organic matter is present is required. The following dry-combustion test procedure is recommended to determine the organic content expressed as the percentage of weight lost on ignition:

(1) Dry a 40-gram sample at 105° C until there is no further weight loss (usually 4 to 6 hours).

(2) Place it in a desiccator to cool for 15 minutes.

(3) Weigh the sample and place it in the oven at 440° C for 4 hours.

(4) Place it in the desiccator to cool for 15 minutes.

(5) Weigh the sample and determine the organic content by dividing the weight lost by the sample while in the oven at 440° C by the total weight of the sample at the time it was placed in the oven.

i. Specific Gravity. Values for the specific gravity of solids for fine-grained sediments and dredged material are required for determining void ratios, conducting hydrometer analyses, and consolidation testing. Procedures for conducting the specific gravity test are given in Appendix IV of EM 1110-2-1906.

j. USCS Classification. When classifying sediment samples, the fine-grained portion that passes the No. 200 sieve should be classified separately from the coarse-grained portion retained on the No. 200 sieve, regardless of which fraction comprises the greatest percentage by weight. Additional information regarding the USCS classification may be found in WES Technical Memorandum No. 3-357 (item 33).

3-3. Settling Tests. Dredged material placed in disposal areas by hydraulic dredges or pumped into disposal areas by pump-out facilities enters the disposal area as a slurry (mixture of dredged solids and dredging site water). Settling refers to those processes in which the dredged material slurry is separated into supernatant water of low solids concentration and a more

concentrated slurry. Laboratory sedimentation tests provide data for designing the containment area to meet effluent suspended solids criteria and to provide adequate storage capacity for the dredged solids.

a. Settling Processes.

(1) Settling types. The settling process can be categorized according to four basic classifications: discrete settling where the particle maintains its individuality and does not change in size, shape, or density during the settling process; flocculent settling where particles agglomerate during the settling period with a change in physical properties and settling rate; zone settling where the flocculent suspension forms a lattice structure and settles as a mass, the high solids concentration partially blocks the release of water and hinders settling of neighboring particles, and a distinct interface between the slurry and the supernatant water is exhibited during the settling process; and compression settling where settling occurs by compression of the lattice structure. All of the above sedimentation processes may occur simultaneously in a disposal area, and any one may control the design of the disposal area.

(2) Governing factors. Discrete settling describes the sedimentation of coarse particles. The important factors governing the sedimentation of fine-grained dredged material are the initial concentration of the slurry, salinity of the carrier water, and the flocculating properties of the solid particles. Because of the high influent solids concentration and the tendency of fine-grained particles to flocculate, either flocculent or zone settling behavior normally describes sedimentation in containment areas. Sedimentation of freshwater sediments at slurry concentrations of 100 grams per litre can generally be characterized by flocculent settling properties. As slurry concentrations or salinity is increased, the sedimentation process may be characterized by zone settling properties. Compression settling occurs in the lower layers of settled material for both the flocculent and zone settling cases. As more settled material accumulates, excess pore pressures develop in the lower layers and further consolidation occurs as water is expelled and the excess pore pressures dissipate.

(3) Zone versus flocculent settling as a function of salinity. The tendency of a fine-grained dredged material slurry to settle by zone or flocculent behavior in the initial stages of settling is strongly influenced by the presence of salt as a coagulant. If salinity is less than 1 part per thousand, indicative of freshwater conditions, flocculent processes normally describe the initial settling, and no clearly defined interface is seen. If salinity is greater than 1 part per thousand, indicative of brackish or saltwater conditions, zone settling processes normally describe the initial settling, and a clear interface between the clarified supernatant water and the more concentrated slurry is evident. For the zone settling case, some of the fine particles remain in the supernatant water as the interface falls. Flocculent processes then describe the settling of these fine particles from the supernatant.

b. Testing Equipment and Procedures.

(1) Test objective. The objective of running settling tests on sediments to be dredged is to define their settling behavior in a dredged material containment area. The tests provide numerical values for the design criteria that can be projected to the size and design of the containment area. Procedures for computer-assisted plotting and reduction of settling column data are available as discussed in Chapter 8.

(2) Settling column. The settling column shown in Figure 3-3 should be used for dredged material settling tests. The column is constructed of 8-inch-diameter plexiglas tubing and can be sectioned for easier handling and cleaning. Ports are provided for extraction of samples at various depths during sampling. A bottom-mounted airstone is also provided for agitation and mixing of slurries in the column by using compressed air. Shop drawings of the column with bills of materials are shown in Appendix B.

(3) Samples. Samples used to perform settling tests should consist of fine-grained (<No. 200 sieve) material. Any coarse-grained (>No. 200 sieve) material present in the sample would normally be hydraulically separated when the sample is mixed prior to sedimentation testing. A composite of several sediment samples may be used to perform the tests if this is thought to be more representative of the dredged material. Approximately 15 gallons of sediment is usually required for the tests. Water used to mix the slurries can be taken from the proposed dredging site or can be prepared by mixing tapwater and salt to the known salinity of the dredging site water.

(4) Pilot test. A pilot test conducted in a graduated cylinder (4 litres is satisfactory) is a useful method for determining if flocculent or zone process will describe the initial settling. The pilot test should be run at a slurry concentration of approximately 150 grams per litre. If an interface forms within the first few hours of the test, the slurry mass is exhibiting zone settling, and the fall of the interface versus time should be recorded. The curve will appear as shown in Figure 3-4. The break in the curve will define the concentration at which compression settling begins. Only lower concentrations should be used for the zone settling test in the 8-inch column. If no break in the curve is evident, the material has begun settling in the compression zone, and the pilot test should be repeated at a lower slurry concentration. It should be emphasized that use of a small cylinder as in the pilot test is not acceptable for use in design. Wall effects for columns of small diameter affect zone settling velocities, and data obtained using small-diameter columns will not accurately reflect field behavior. If no interface is observed in the pilot test within the first few hours, the slurry mass is exhibiting flocculent settling. In this case, the pilot test should be continued until an interface is observed between the turbid water above and more concentrated settled solids below. The concentration of the settled solids (computed assuming zero concentration of solids above) is an indication of the concentration at which the material exhibits compression settling.

(5) Required number of column loadings for tests. Three types of settling tests in the 8-inch column may be needed to fully define the settling properties of the dredged material. However, in most cases the 8-inch

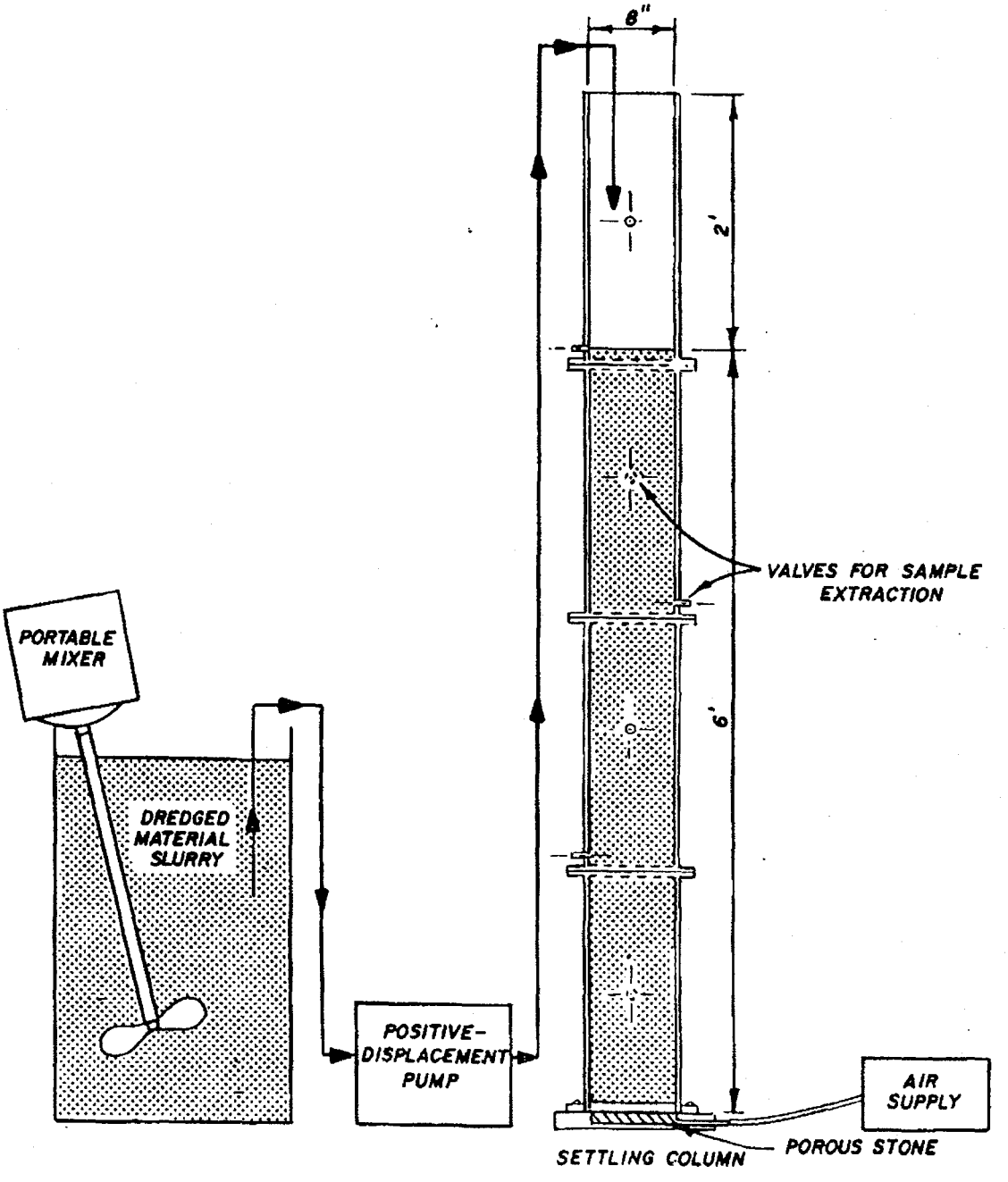

Figure 3-3. Schematic of apparatus for settling tests

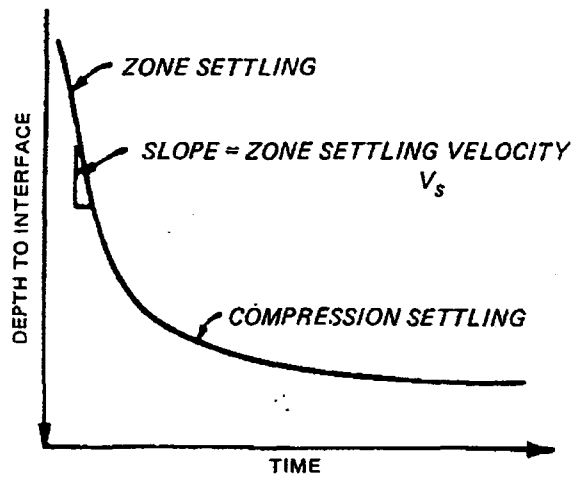

Figure 3-4. Conceptual plot of interface height versus time

settling column used for the settling tests, needs to be loaded with slurry only once. A compression settling test is needed to define the volume that will be occupied in the disposal area by a newly deposited dredged material layer at the end of the disposal operation. A flocculent settling test for either the slurry mass or for the supernatant water above any interface is required to predict effluent suspended solids concentrations. A zone settling test is required to define the minimum surface area needed for effective zone settling. These tests should be conducted at a slurry concentration equal to the expected influent concentration; therefore, only one loading of the test column would be required to collect data for all purposes.

c. Flocculent Settling Test.

(1) The flocculent settling test consists of measuring the concentration of suspended solids at various depths and time intervals in a settling column. If an interface forms near the top of the settling column during the first day of the test, sedimentation of the material below the interface is described by zone settling. In that case, the flocculent test procedure should be continued only for that portion of the column above the interface.

(2) Information required to design a containment area for the flocculent settling process can be obtained using the following procedure:

(a) A settling column such as shown in Figure 3-3 is used. The slurry depth used in the test column should approximate the effective settling depth of the proposed containment area. A practical limit on depth of test is 6 feet. The column should be at least 8 inches in diameter with sample ports at 0.5 foot intervals (minimum). The column should have provisions for slurry agitation with compressed air from the bottom to keep the slurry mixed during the column filling period.

(b) Mix the sediment slurry to a suspended solids concentration C equal to the expected concentration of the dredged material influent C_i. The

slurry should be mixed in a container with sufficient volume to fill the test column. Field studies indicate that for maintenance dredging of fine-grained material, the disposal concentration will average about 150 grams per litre. This concentration should be used in the test if better data are not available.

(c) Pump or pour the slurry into the test column using compressed air or mechanical agitation to maintain a uniform concentration during the filling period.

(d) When the slurry is completely mixed in the column, cut off the compressed air or mechanical agitation and immediately draw off samples at each sample port and determine their suspended solids concentration. Use the average of these values as the initial slurry concentration at the start of the test. The test is considered initiated when the first samples are drawn.

(e) If an interface has not formed on the first day, flocculent settling is occurring in the entire slurry mass. Allow the slurry to settle and withdraw samples from each sampling port at regular time intervals to determine the suspended solids concentrations. Substantial reductions of suspended solids will occur during the early part of the test, but reductions will lessen at longer retention times. Therefore, the intervals can be extended as the test progresses. Recommended sampling intervals are 1, 2, 4, 6, 12, 24, 48 hours, etc., until the end of the test. As a rule, a 50-millilitre sample should be taken from each port. Continue the test until an interface can be seen near the bottom of the column and the suspended solids concentration in the fluid above the interface is 1 gram per litre. Test data are tabulated and used to plot a concentration profile diagram as shown in Figure 3-5. Examples are shown in Appendix C.

(f) If an interface forms the first day, zone settling is occurring in the slurry below the interface, and flocculent settling is occurring in the supernatant water. For this case, samples should be extracted from all side ports above the falling interface. The first of these samples should be extracted immediately after the interface has fallen sufficiently below the uppermost port to allow extraction. This sample can usually be extracted within a few hours after the beginning of the test, depending on the initial slurry concentration and the spacing of ports. Record the time of extraction and port height for each port sample taken. As the interface continues to fall, extract samples from all ports above the interface at regular time intervals. As an alternative, samples can be taken above the interface at the desired depths using a pipette or syringe and tubing. As before, a suggested sequence of sampling intervals would be 1, 2, 4, 6, 12, 24, 48, 96 hours, etc. The samples should continue to be taken until the suspended solids concentration of the extracted samples shows no decrease. For this case, the suspended solids in the samples should be less then 1 gram per litre, and filtration will be required to determine the concentrations. The data should be expressed in milligrams per litre for these samples. Tabulate the data and plot a concentration profile diagram as shown in Figure 3-5. In reducing the data for this case, the concentration of the first port sample taken above the falling interface is considered the initial concentration C_o . Examples are shown in Appendix C.

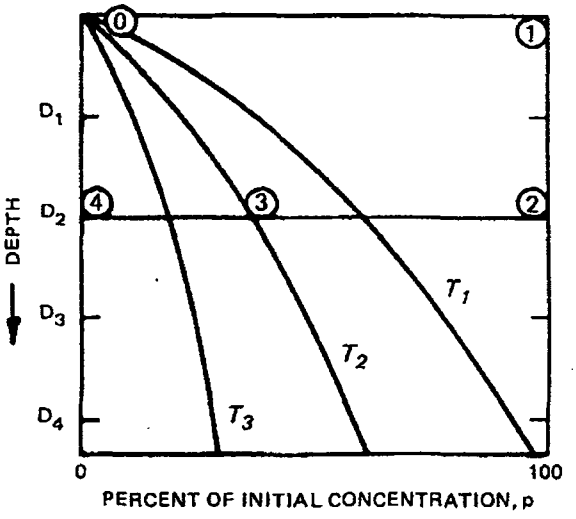

Figure 3-5. Conceptual concentration profile diagram

d. Zone Settling Test.

(1) The zone settling test consists of placing a slurry in a sedimentation column and reading and recording the fall of the liquid-solids interface with time. These data are plotted as depth to interface versus time. The slope of the constant velocity settling zone of the curve is the zone settling velocity, which is a function of the initial test slurry concentration. This test is required if the material exhibits an interface within the first day. The test should be run at the expected influent slurry concentration, or the highest expected to persist for several hours if a range is expected.

(2) Information required to design a containment area for the zone settling process can be obtained by using the following procedure:

(a) A settling column such as shown in Figure 3-3 is used. It is important that the column diameter be sufficient to reduce the "wall effect" and that the test be performed with a test slurry depth near that expected in the field. Therefore, a 1-litre graduated cylinder should never be used to perform a zone settling test for sediment slurries representing dredging disposal activities.

(b) Mix the slurry to the desired concentration and pump or pour it into the test column. Air may not be necessary to keep the slurry mixed if the filling time is less than 1 minute.

(c) Record the depth to the solid-liquid interface as a function of time. Readings must be taken at regular intervals to gain data for plotting the curve of depth to interface versus time as shown in Figure 3-4. It is important to take enough readings to clearly define this curve.

(d) Continue the readings until sufficient data are available to define the maximum point of curvature of the depth to interface versus time plot. The test may require from 8 to 48 hours to complete.

(e) Calculate the zone settling velocity v_s as the slope of the constant velocity settling zone, as shown in Figure 3-4 (straight-line portion of curve). The velocity should be in feet per hour.

(f) Compression Settling Test.

(1) A compression settling test must be run to obtain data for estimating the volume required for initial storage of the dredged material. For slurries exhibiting zone settling, the compression settling data can be obtained from the zone settling test with interface height versus time recorded. The only difference is that the test is continued for a period of 15 days, so that a relationship of log of concentration versus log of time in the compression settling range as shown in Figure 3-6 is obtained. For slurries exhibiting flocculent settling behavior, the test used to obtain flocculent settling data can be used for the compression settling test if an interface is formed after the first few days of the test. If not, an additional test is required with the slurry concentration for the test sufficiently high to initially induce compression settling. This concentration can be determined by the pilot test.

(2) Information required to design a containment area for the compression settling process can be obtained using the following procedures:

(a) Tabulate the interface height H_t for various times of observation during the 15-day test period.

(b) Calculate concentrations for various interface heights as follows:

$$C = \frac{C_o H_i}{H_t} \tag{3-11}$$

where

C = slurry concentration at time t, grams per litre

C_o = initial slurry concentration, grams per litre

H_i = initial slurry height, feet

H_t = height of interface at time, t, feet

Neglect solids in the water above the interface to simplify calculations.

(c) Plot concentration versus time on log-log paper as shown in Figure 3-6.

(d) Draw a straight line through the data points.

SECTION 4
BENTONITE

4.1 Description

a. Drilling grade bentonite is a naturally occurring clay containing the clay mineral smectite. It may also contain accessory minerals such as quartz, mica, feldspar, and calcite.

b. Drilling grade bentonite shall be deemed to meet this specification if a composite sample representing no more than one day's production conforms to the physical requirements of Table 4.1, represents the product produced, and is controlled by the manufacturer.

TABLE 4.1
BENTONITE PHYSICAL REQUIREMENTS

Requirement	Specification
Suspension Properties	
Viscometer Dial Reading at 600 rpm	30, minimum
Yield Point/Plastic Viscosity Ratio	3, maximum
Filtrate Volume	15.0 cm^3, maximum
Residue greater than 75 micrometers	4.0 wt. percent, maximum
Moisture	10.0 wt. percent, maximum

SUSPENSION PROPERTIES

4.2 Equipment

a. Thermometer: 32-220 ±1°F (0-105 ±0.5°C)

b. Balance: precision of ±0.01 g

c. Mixer (e.g., Multimixer Model 9B with 9B29X impellers or equivalent as shown in Fig. 2.1): Each spindle will be fitted with a single sine-wave impeller approximately one inch (25mm) in diameter mounted flash side up.

d. Container: approximate dimensions — 7 inches (180 mm) deep, 3-13/16 inch (97 mm) ID top, 2-3/4 inch (70 mm) ID bottom (e.g., Hamilton Beach mixer cup No. M110-D, or equivalent)

e. Spatula

f. Motor-Driven Direct Indicating Viscometer: as referenced in API RP 13B-1, 1st edition, June, 1990, Par. 2.4

g. Filter press: as referenced in API RP 13B-1, 1st edition, June, 1990, section 3.2

h. Graduated cylinder (TD): 500 ±5 cm^3

i. Deionized or distilled water

j. Container: about 500-cm^3 with lid

k. Timers: two interval, mechanical or electrical, precision of ±0.1 minute

l. Graduated cylinder (TC): 10 ±0.1 cm^3

4.3 Procedure — 600 rpm Reading, Plastic Viscosity, Yield Point

a. Prepare a suspension of the bentonite. Add 22.5 ±0.01 g of clay (as received) to 350 ±5 cm^3 of deionized water while stirring on the mixer.

b. After stirring five ±0.5 minutes, remove the container from mixer and scrape its sides with the spatula to dislodge any bentonite adhering to container walls. Be sure all bentonite clinging to the spatula is incorporated into the suspension.

c. Replace the container on the mixer and continue to stir. The container may need to be removed from the mixer and the sides scraped to dislodge any clay clinging to container walls after another 5 and 10 minutes. Total stirring time shall equal 20 ±1 minutes.

d. Age the bentonite suspension up to 16 hours in a sealed or covered container at room temperature. Record storage temperature and storage duration.

e. After aging bentonite suspension, shake well and then pour the suspension into the mixer container. Stir the suspension on the mixer for 5 ±0.5 minutes.

f. Pour the suspension into the viscometer cup provided with the direct indicating viscometer. The dial readings at 600 and 300 rpm rotor speed settings of the viscometer shall be recorded when a constant value for each rpm is reached. Readings shall be taken at a suspension test temperature of 77 ±2°F (25 ±1°C).

4.4 Calculation — Plastic Viscosity and Yield Point

Plastic Viscosity, cP =
[600 rpm reading] - [300 rpm reading] (a)

Yield Point, lb/100 ft^2 =
[300 rpm reading] - Plastic Viscosity (b)

Yield Point/Plastic viscosity ratio =
Yield point [Eq. 4.4(b)] ÷
Plastic viscosity [Eq. 4.4(a)] (c)

Record calculated values for plastic viscosity, yield point, and yield point/plastic viscosity ratio.

4.5 Procedure — Filtrate Volume

a. Recombine all of the suspension as prepared and tested in Par. 4.3 and stir in container for 1 ±0.5 minute on the mixer. Adjust suspension temperature to 77 ±2°F (25 ±1°C).

b. Pour the suspension into filter press cell. Before adding suspension, be sure each part of the filter cell is dry and that all gaskets are not distorted or worn. Pour the mud to within about 1/2 inch (13 mm) of the top of

the cell. Complete assembly of the filter press cell. Place filter cell in frame and close relief valve. Place a container under the drain tube.

c. Set one timer for 7.5 ±0.1 minutes and the second timer for 30 ±0.1 minutes. Start both timers and adjust pressure on cell at 100 ±5 psi (690 ±35 kPa). Both of these steps shall be completed in less than 15 seconds. Pressure shall be supplied by compressed air, nitrogen, or helium.

d. At 7.5 ±0.1 minutes on the first timer remove the container and any adhering liquid on the drain tube and discard. Place the dry 10-cm^3 graduated cylinder under the drain tube and continue collecting filtrate to the end of the second timer set at 30 minutes. Remove the graduated cylinder and record the volume of filtrate collected.

4.6 Calculation — Filtrate Volume

Calculate the filtrate volume of the clay suspension as:

$$\text{Filtrate vol., } cm^3 = 2 \times V_c \qquad \text{(a)}$$

where: V_c = volume filtrate collected between 7.5 and 30 minutes

Record calculated filtrate volume.

RESIDUE GREATER THAN 75 MICROMETERS

4.7 Equipment

a. Oven: regulated to 220 ±5°F (105 ±3°C)

b. Sodium hexametaphosphate (CAS #10124-56-8)

c. Balance: precision of ±0.01 g

d. Mixer (e.g., Multimixer Model 9B with 9B29X impellers or equivalent as shown in Fig. 2.1): Each spindle will be fitted with a single sine-wave impeller approximately one inch (25mm) in diameter mounted flash side up.

e. Container: approximate dimensions — 7 inches (180 mm) deep, 3-13/16 inch (97 mm) ID top, 2-3/4 inch (70 mm) ID bottom (e.g., Hamilton Beach mixer cup No. M110-D, or equivalent)

f. Spatula

g. A 75-micrometer sieve conforming* to the requirements of ASTM E11 Standard Specifications for Wire-Cloth Sieves for Testing Purposes, latest edition. Approximate dimensions are 3 in. (76mm) diameter, and 2.5 in. (69mm) from top of frame to wire cloth.

*NOTE: *Supplier's verification that sieve conforms to ASTM E11 is satisfactory evidence of compliance.*

h. Spray nozzle: 1/4 TT body (Spraying Systems Company, No. TG 6.5 tip with 1/4 TT body or equivalent) attached to water line with 90 degree elbow as shown in Fig. 2.2

i. Water pressure regulator capable of regulation to 10 ±1 psi (69 ±7 kPa)

j. Evaporating dish

k. Wash bottle

4.8 Procedure

a. Weigh 10 ±0.01 g of bentonite.

b. Add the weighed bentonite sample to approximately 350 cm^3 of water containing about 0.2 g of sodium hexameta-phosphate while stirring on the mixer.

c. Stir suspension on the mixer for 30 ±1 minutes.

d. Transfer the sample to the sieve. Use the wash bottle to remove all material from the container to the sieve. Wash the material on the sieve with water controlled to 10 ±1 psi (69 ±7 kPa) from the spray nozzle for two minutes ±15 seconds. While washing, hold the tip of the spray nozzle approximately in the plane of the top of sieve — move the spray of water repeatedly over the sample.

e. Wash the residue from the sieve into a tared evaporating dish and decant excess clear water.

f. Dry the residue in the oven to a constant weight. Record residue weight and total drying time.

4.9 Calculation

$$\text{Residue, wt. \% greater than 75 micrometers} = 100\frac{\text{(Weight residue, g)}}{\text{(Weight sample, g)}} - C_c{}^*$$

*where: C_c = calibration correction (Par. 12.5)

Record calculated value.

MOISTURE

4.10 Equipment

a. Oven: regulated to 220 ±5°F (105 ±3°C)

b. Balance: precision of ±0.01 g

c. Evaporating dish

d. Spatula

e. Desiccator with calcium sulfate (CAS #7778-18-9) desiccant, or equivalent

4.11 Procedure

a. Weigh 10 ±0.01 g of bentonite sample into a tared evaporating dish.

b. Dry sample in the oven to a constant weight. Record total drying time.

c. Cool to room temperature in desiccator.

d. Reweigh the evaporating dish containing the dry bentonite. Record weight.

4.12 Calculation

$$M = 100\,\frac{(W_1 - W_2)}{W_1} \qquad \text{(a)}$$

where: M = moisture, wt. percent

W_1 = original sample weight, g

W_2 = dry sample weight, g

Record calculated value.

SECTION 5
NONTREATED BENTONITE

5.1 Description

a. Drilling grade nontreated bentonite is dried and ground, but not chemically-treated clay, composed principally of the mineral smectite. It may also contain accessory minerals such as quartz, mica, feldspar, and calcite.

b. Drilling grade nontreated bentonite shall be deemed to meet this specification if a composite sample representing no more than one day's production conforms to the physical requirements of Table 5.1, represents the product produced, and is controlled by the manufacturer.

TABLE 5.1
NONTREATED BENTONITE
PHYSICAL REQUIREMENT

Requirement	Specification
Suspension Properties	
Yield Point/Plastic Viscosity Ratio	1.5, maximum
Dispersed Plastic Viscosity	10 cP, minimum
Dispersed Filtrate Volume	12.5 cm^3, maximum

SUSPENSION PROPERTIES

5.2 Equipment

a. Balance: precision of 0.01 g

b. Mixer (e.g., Multimixer Model 9B with 9B29X impellers or equivalent as shown in Fig. 2.1): Each spindle will be fitted with a single sine-wave impeller approximately one inch (25mm) in diameter mounted flash side up.

c. Container: approximate dimensions — 7 inches (180 mm) deep, 3-13/16 inch (97 mm) ID top, 2-3/4 inch (70 mm) ID bottom (e.g., Hamilton Beach mixer cup No. M110-D, or equivalent)

d. Motor-Driven Direct Indicating Viscometer: as referenced in API RP 13B-1, 1st edition, June, 1990, Par. 2.4

e. Filter press: as referenced in API RP 13B-1, 1st edition, June 1, 1990, Par. 3.2

f. Spatula

g. Thermometer: 32-220 ±1°F (0-105 ±0.5°C)

h. Deionized or distilled water

i. Graduated cylinder (TD): 500 ±5 cm^3

j. Container: about 500-cm^3 with lid

k. Syringe or pipette: 5 ±0.01 cm^3

l. Sodium hexametaphosphate (CAS #10124-56-8) solution: 10 ±0.5% by wt

m. Timers: two interval, mechanical or electrical, precision of 0.1 minute

n. Graduated cylinder (TC): 10 ±0.01 cm^3

5.3 Procedure — Yield Point/Plastic Viscosity Ratio

a. Prepare a suspension of nontreated bentonite. Add 25 ±0.01 g of clay (as received) to 350 ±5 cm^3 deionized water while stirring on the mixer.

b. After stirring 5 ±0.5 minutes, remove the container from mixer and scrape its sides with the spatula to dislodge any bentonite adhering to container walls. Be sure all bentonite clinging to the spatula is incorporated into the suspension.

c. Replace the container on the mixer and continue to stir. The container may need to be removed from the mixer and the sides scraped to dislodge any clay clinging to container walls after another 5 and 10 minutes. Total stirring time shall equal 20 ±1 minutes.

d. Age the bentonite suspension up to 16 hours in a sealed container at room temperature. Record storage temperature and storage duration.

e. After aging bentonite suspension, shake well and then pour the suspension into the mixer container. Stir the suspension on the mixer for 5 ±0.5 minutes.

f. Pour the suspension into the viscometer cup provided with the direct indicating viscometer. The dial readings at 600 and 300 rpm rotor speed settings of the viscometer shall be recorded when a constant value for each rpm is reached. Readings shall be taken at a suspension test temperature of 77 ±2°F (25 ±1°C).

5.4 Calculation — Plastic Viscosity and Yield Point

Plastic Viscosity, cP =
[600 rpm reading] -[300 rpm reading] (a)

Yield Point, lb/100 ft^2 = (b)
[300 rpm reading] - Plastic Viscosity

Yield Point/Plastic viscosity ratio =
Yield point [Eq. 5.4(b)] ÷
Plastic viscosity [Eq. 5.4(a)] (c)

Record calculated values for plastic viscosity, yield point, and yield point/plastic viscosity ratio.

5.5 Procedure — Dispersed Plastic Viscosity

a. Recombine all of the bentonite suspension as prepared and tested in Par. 5.3 and stir in container for 1 ±0.5 minute on the mixer.

b. Add 5 ±0.1 cm^3 of a 10% solution of sodium hexameta-phosphate to the suspension and stir for 3 ±0.5 minutes on the mixer.

c. Pour the suspension into the viscometer cup provided with the direct indicating viscometer. The dial readings at 600 and 300 rpm rotor speed settings of the viscometer shall be recorded when a constant value for each rpm is reached. Readings shall be taken at a suspension test temperature of 77 ±2°F (25 ±1°C).

d. Calculate and record the dispersed plastic viscosity as per Par. 5.4a.

5.6 Procedure — Dispersed Filtrate Volume

a. Recombine all of the suspension as prepared and tested in Par. 5.5 and stir in container for 1 ±0.5 minute on the mixer. Adjust suspension temperature to 77 ±2°F (25 ±1°C).

b. Pour the suspension into filter press cell. Before adding the suspension, be sure each part of the filter cell is dry and that all gaskets are not distorted or worn. Pour the suspension to within about 1/2 inch (13 mm) of the top of the cell. Complete assembly of the filter press cell. Place filter cell in frame and close relief valve. Place a container under the drain tube.

c. Set one timer for 7.5 ±0.1 minutes and the second timer for 30 ±0.1 minutes. Start both timers and adjust pressure on cell at 100 ±5 psi (690 ±35 kPa). Both of these steps shall be completed in less than 15 seconds. Pressure shall be supplied by compressed air, nitrogen, or helium.

d. At 7.5 ±0.1 minutes on the first timer remove the container and any adhering liquid on the drain tube and discard. Place dry 10-cm^3 graduated cylinder under the drain tube and continue collecting filtrate to the end of the second timer set at 30 minutes. Remove the graduated cylinder and record the volume of filtrate collected.

5.7 Calculation — Dispersed Filtrate Volume

Calculate the dispersed filtrate volume of the clay suspension as:

$$\text{Filtrate vol., } cm^3 = 2 \times V_c \qquad \text{(a)}$$

where: V_c = volume filtrate collected between 7.5 and 30 minutes

Record calculated filtrate volume.

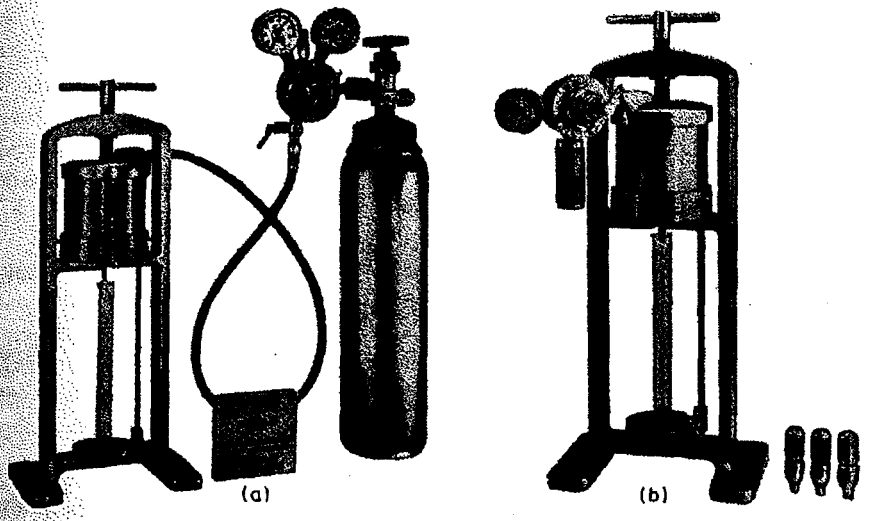

Fig. 4-21 Standard filter-press apparatus: (*a*) with nitrogen pressurization; (*b*) with carbon dioxide pressurization. (*NL Baroid/NL Industries, Inc.*)

situations the recommended allowable filtrate loss is from 15 to 25 cm^3 for a pressure of 100 lb/in^2. The author recommends an allowable loss from 12 to 15 cm^3 for a pressure of 3 kg/cm^2 (42.6 lb/in^2) and a maximum film thickness less than 2 mm.

4-6 MATERIALS USED IN SLURRIES

Among clay minerals bentonite and attapulgite are finely dispersed and therefore are suitable for slurries. Most illite clays exhibit nonswelling behavior, whereas members of the kaolinite group produce nonexpandable minerals; hence these materials tend to remain aggregated in the suspension. Furthermore, at concentrations showing satisfactory gel strength the plastic viscosity is too high, and treatment in this case is not always possible.

Bentonite as the Main Colloid Solid

Bentonite is produced from natural clays containing the montmorillonite mineral and resembles a gray powder. Different grades are available, better ones attaining the proper mixing levels and flow properties at lower concentrations. The selection of a suitable bentonite must be based on the conditions to be contended with but is also governed by local availability and cost.

As mentioned earlier, montmorillonite displays the highest surface activity and capacity to expand. This mineral constitutes the largest part of naturally occurring bentonite clays derived from the alteration of volcanic dust and ash deposits.

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Technical Note

Geotextile tube assessment using a hanging bag test

George R. Koerner*, Robert M. Koerner

Geosynthetic Institute, Folsom, PA, USA

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Abstract

This paper describes the field performance of three geotextile tube case histories contrasted to the results from 12 hanging bag tests (four different geotextiles at each site). The geotextile tubes were used in three different applications: (i) shoreline protection using a sand infill, (ii) dewatering of dredged harbor sediment, and (iii) dewatering of lagooned industrial ash. The "hanging bag test" (or HBT) was used as a comparative assessment method. Each of the site soils were used with four different geotextiles commonly used in geotextile tube fabrication. In all cases, the properties of the geotextiles and the soils are contrasted against the overall performance of the particular geotextile used for the tubes. The field performance of the geotextile tubes was mixed. One site performed well, the second fair, and the third poor. Findings presented in this paper show that the hanging bag test is a reasonable predictor of actual field performance. However, the test results do not correlate well with the opening size characteristics of the fabrics. It is hoped that this work will lead to the development of a standard test method that can be used by engineers to select or approve fabrics for optimal geotextile tube field performance.
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Keywords: Geotextile tube; Geotextile; Permeability; Flow rate; Soil retention; Hanging bag test

1. Introduction

The use of fabrics to make small sandbags has been practiced for hundreds of years, (Sprague, 1997; Miki et al., 1996). Rather than making the bags from degradable natural fibers, however, the use of UV-stabilized polymeric fibers has added greatly to the performance of such installations. With controlled strength and deformation, the bags can be filled with sand, grout or any dredged material and specifically tuned to the particular application at hand. When used for erosion control work, as they often are, a high-strength fabric sewn together into a large bag is an effective solution. The bags are placed in a staggered pattern and weigh many tons when filled (Leshchinsky et al., 1996; Pilarczyk, 2000).

Rather than using discrete bags of short length in forming erosion-control barriers, however, tubes of unlimited length can also be used. Flexible sand-filled tubes were made as early as 1957, but they were not very successful. Eventually in 1967, a patent was granted to a Danish firm, Aldek A. S., in conjunction with the Danish Institute of Applied Hydraulics. The tubes were 1.0 m in diameter or smaller (Koerner and Koerner, 1996). Subsequently, the tubes were made considerably larger reaching the present status of tubes being up to 4.5 m in diameter; approximately 14 m in circumference. (Geotextile tubes are commonly referenced by their circumference since they are elliptic shaped when filled rather than circular).

Geotextile tubes are factory assembled from conventional fabrics, sewn together, and include fill ports at discrete intervals per the project specifications. They are made from high strength woven fabrics and a generic fabric specification for different survivability conditions is available as GRI-GT10.

Brought to the job site, the tubes are hydraulically filled with sand (when used for shoreline erosion control) or fines (when used for dewatering of fine soils and sludges) by attaching an inlet pipe to one end and regulating a slurry flow through a valved opening. Typically, a dredge pumps the slurry into the tubes at a controlled rate. Materials ranging from coarse gravels to fine silts and clays have been

*Corresponding author.
E-mail address: gkoerner@dca.net (G.R. Koerner).

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successfully pumped. The operation and layout of a geotextile tube is shown in Fig. 1 for shoreline protection and in Fig. 2 for dewatering purposes. References in this regard are plentiful. See, for example, (Bishop et al., 1994; Fowler et al., 1997; Harris, 2003; Liu and Silverter, 1977; Moo-Young et al., 2002; Pilarczyk, 2000; Sprague, 1997; Yee, 2002).

When filling a geotextile tube with granular sands or gravels, as in shoreline protection, the process of draining the slurry water through the fabric is quite rapid. Conversely, when filling a geotextile tube with fine grained soil or sludges, as in dewatering, the process of draining water is very slow. This is due to the buildup of a filter cake of fine sediment on the inside surface of the fabric. Depending on the permeability of the filter cake, higher filling pressures and/or repeated sequences of filling become necessary. Fundamentally, the fabric must act successfully as a "filter", allowing water to pass but retaining the contained soil particles. Flow through the filter cake and fabric (see Fig. 3 for an example) is obviously critical to both the success of the installation and its economic viability.

In order to optimize water drainage from the infilling material, the opening size of the fabric being considered is important. If too open, soil particles will be lost. Conversely, if too tight, excessive pressure might be required which could exceed the fabric or seam strength and result in a failure. The nature of the filter cake is a complicating factor. As a precursor indication to determine if a particular fabric will be successful using a specific type of soil or sludge infill, the hanging bag test (HBT) will be described and then used in conjunction with the following three case histories.

2. Field sites

Site no. 1 was located at a beach resort adjacent to the Atlantic Ocean. Construction took place in September 1999. As can be seen from the photographs of Fig. 4a and b, the project utilized geotextile tubes for shoreline protection transitioning from the beach to the boardwalk. The infill soil for this project was a poorly graded sand classified as "SP". Other soil properties of the site are given in Table 1. The fabric used in construction of the primary geotextile tube was a woven polyester with properties that are summarized in Table 2 under the designation "Fabric A-1".

The geotextile tube worked very well in this application. The sand within the tube dewatered quickly and the tubes were brought to final elevation within days of the start of

Fig. 3. Photograph of filter cake built up on the inside of the fabric during pumping of fines and sludges in geotextile tubes.

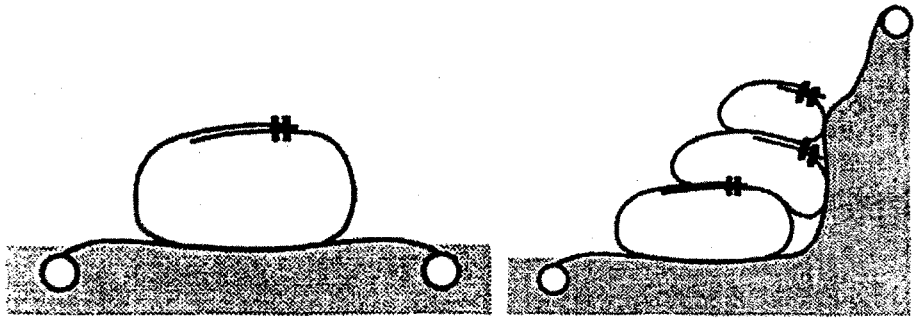


Fig. 1. Single and multiple geotextile tubes used for shoreline protection.

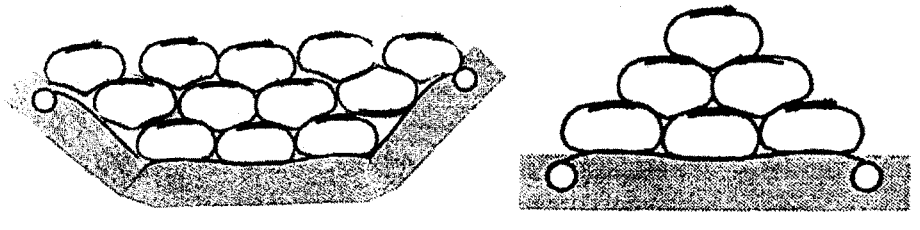
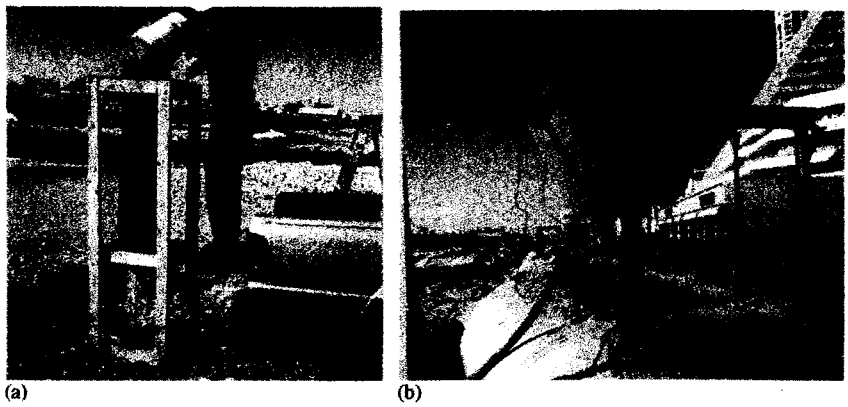


Fig. 2. Geotextile tubes in a basin and in a heap used for dewatering fine soils and sludges.



(a) (b)

Fig. 4. (a) Hanging bag test at site no. 1; (b) Geotubes at site no. 1.

Table 1
Soil properties at various field sites

Properties	Test method (ASTM)	Units	Site no. 1	Site no. 2	Site no. 3
Water content (w)	D2216	%	35	150	250
Percent Solids (w_s)	D2216	%	40	20	30
Degree of Saturation (S)	D2216	%	100	100	100
Organic content (O)	D2974	%	0	7	3
Specific gravity of solids (G_s)	D854	dimensionless	2.65	2.6	2.2
Liquid limit (LL)	D4318	%	0	45	32
Plastic limit (PL)	D4318	%	0	39	30
Plasticity index (PI)	D4318	%	0	6	2
Percent passing no. 200 sieve	D422	%	0	50	40
60% Finer (d_{60})	D422	mm	0.3	0.09	0.25
30% Finer (d_{30})	D422	mm	0.25	0.05	0.04
10% Finer (d_{10})	D422	mm	0.15	0.02	0.0
$C_u = D_{60}/D_{10}$	D422	dimensionless	2	4.5	33
$C_c = (D_{30})^2/D_{60}D_{10}$	D422	dimensionless	1.4	1.4	1
Unif. soil class sys.	n/a	n/a	SP	ML	SW
Permeability (k)	D4323	cm/s	1.2×10^{-2}	3.8×10^{-5}	3.1×10^{-3}

construction. There was so much water emerging from the tube that the tubes were set on a sacrificial sheet of plastic so as to direct the water from undermining the tube. A scour apron and anchor tube were included in a manner similar to that illustrated in Fig. 1. A sand layer was placed over the tube and then the dunes were seeded with dune grass. As of Fall of 2003 the tubes are working well. They have withstood both Hurricanes Floyd and Isabelle and are servicing this shore community well.

Site no. 2 was located inland from the Atlantic coastline at a marina. Construction took place in December 1999. As can be seen from the photographs of Fig. 5a and b, the project utilized geotextile tubes for dewatering silts and clays that had silted up the marina. The soil for this project was a silt of low plasticity, classified as "ML". Other soil properties of the site are given in Table 1. The fabric used in construction of the geotextile tube was a woven polypropylene designated Fabric A-2 and its properties are summarized in Table 2.

The geotextile tube worked poorly in this application. The dredged soil was fine grained and had a permeability of 3.8×10^{-5} cm/s. In addition to its low permeability it had an oily consistency which caused rapid formation of a filter cake on the inside of the fabric. After this cake was established, dewatering slowed considerably and the soil infill remained at high water content. As the remedy to the situation, more tubes were needed to dewater the contracted amount of dredged material. Flocculants were also needed so as to increase the performance of the tube. Both of these measures added time and expense to the project.

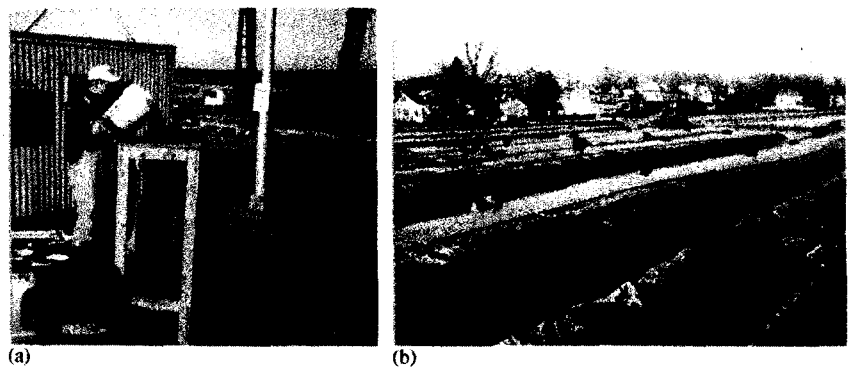
Site no. 3 was located at an industrial site near the Great Lakes. Construction took place in the Summer of 2000. As can be seen from the photographs of Fig. 6a and b, the project utilized geotextile tubes for dewatering, in this case lagooned ash. The material was classified as well graded sandy silt and designated "SW". Other properties of the infilled material appear in Table 1. The fabric used in

Table 2
Fabric properties used in hanging bag tests and at various field sites[1,2]

Property	Test method	Units	Fabric A-1	Fabric A-2	Fabric B-1	Fabric B-2
Fabric type and yarn resin	n/a	n/a	Woven polyester	Woven polypropylene	Woven polypropylene	Woven polypropylene
Weave	n/a	n/a	Diamond	Twill	Basket	Bias
Mechanical						
Strength	ASTM D4595	KN/m	104 × 193	61 × 88	70 × 114	142 × 161
Strain	ASTM D4595	%	18 × 20	32 × 35	21 × 29	27 × 23
Seam Strength	ASTM D4884	KN/m	107	51	49	63
Trapezoidal Tear	ASTM D4533	KN	1.9 × 2.1	1.7 × 1.8	0.9 × 1.4	1.5 × 1.9
Puncture Strength	ASTM D4833	KN	2.9	1.9	1.8	2.6
Hydraulic						
AOS	ASTM D4751	mm	0.21	0.43	0.43	0.43
POA	COE CW02215	%	1.5	3	3.5	2.5
Permittivity	ASTM D4491	s^{-1}	0.3	0.7	0.5	1.0
Endurance						
UV Resistance (strength retained after 150 h)	ASTM D4355	%	80	70	70	70

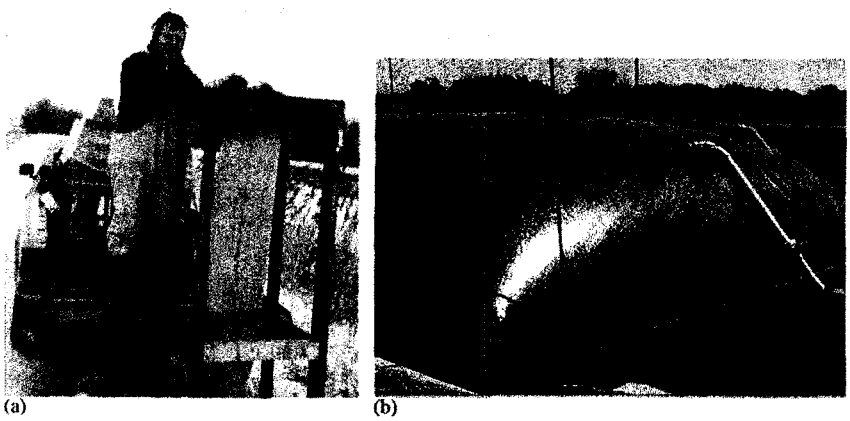
Notes:

1. All four fabrics were used for hanging bag tests at each field site.
2. Fabrics used for the geotextile tubes at the respective field sites were as follows:
   - Site no. 1 used Fabric A-1
   - Site no. 2 used Fabric A-2
   - Site no. 3 used Fabric B-1



(a) (b)

Fig. 5. (a) Hanging bag test at site no. 2; (b) Geotubes at site no. 2.



(a) (b)

Fig. 6. (a) Hanging bag test at site no. 3; (b) Geotubes at site no. 3.

construction of the geotextile tubes was a woven polypropylene designated as Fabric B-1 with properties that are summarized in Table 2.

The geotextile tubes worked from good to fair in this application depending upon who was interviewed. The well-graded coarse ash within the tube dewatered at a steady rate, however, the tube did not reach a final moisture content of below 30% as originally anticipated. The installation season was unusually wet and hampered dewatering. As the strength of the material within the tubes was not sufficient to support stacking of tubes, the layout of the project needed to be changed. The project transitioned from a stacked geotextile tube project to a large area stabilization project where ash lagoons were stabilized with geotextiles and soil berms built above, see (Koerner et al., 1987) and (Guglielmetti et al., 1996).

3. Hanging bag test

Having available the three case histories just described, it was decided to use a test procedure available in the literature to evaluate the suitability of various fabrics with respect to each of the site-specific soil infills. The four different fabrics listed in Table 2 were tested with all the soils in Table 1. Thus, there are 12 hanging bag tests reported in this paper.

The proposed test method is an extension of one proposed by Fowler et al. (1994) for the US Army Corps of Engineers at Vicksburg, Mississippi. While the physical concept remains the same in this paper, the measurement method is quite different. Called the HBT, this test method is used to determine the flow rate of water passing through the fabric as well as any sediment passing through over a specific time period. It is also used to evaluate the properties of the dewatered infill material as well as examine the nature of the filter cake, if one exists. The test method is intended as a performance test for the in situ evaluation of a specific fabric for a specific infilled material. The intent is that a designer or contractor perform the test to design or approve a particular fabric prior to fabrication for a particular site.

The apparatus used for this test is as shown in Fig. 7. A large bag is fabricated by sewing a fabric along its sides and bottom to form an enclosure that will support and contain a measured amount of saturated infill material. The volume of the bags used in this study is approximately 175 L (40 gal). The bag opening is fitted with eight evenly spaced metal grommets around its upper perimeter. It is hung from the inside of a wooden frame. A pan is placed under the container to collect sediment that passes through the bag. Ten, five gallon buckets, stop watch, balance and tape measure are needed for the test. Moisture contents of the soil retained within the bag and particle size of the soil passing through the bag can be conducted back at the laboratory.

The HBT as used in this study is conducted in the following manner:

1. The geotextile bag is pre-wet by soaking the fabric in the proposed dredge area or containment pond.
2. The wet bag is attached to the frame by way of the attached grommets and frame hooks. The bottom of the bag should have a clearance of no more than 200 mm (8 in.) from the pan sitting on the platform floor of the frame.
3. After the bag has drained itself of free water, a shallow 75 mm (3 in.) deep 60 cm (24 in.) diameter aluminum metal collection pan (for example, a hot water heater drip pan) is placed under the bag to collect passing fines during the test.

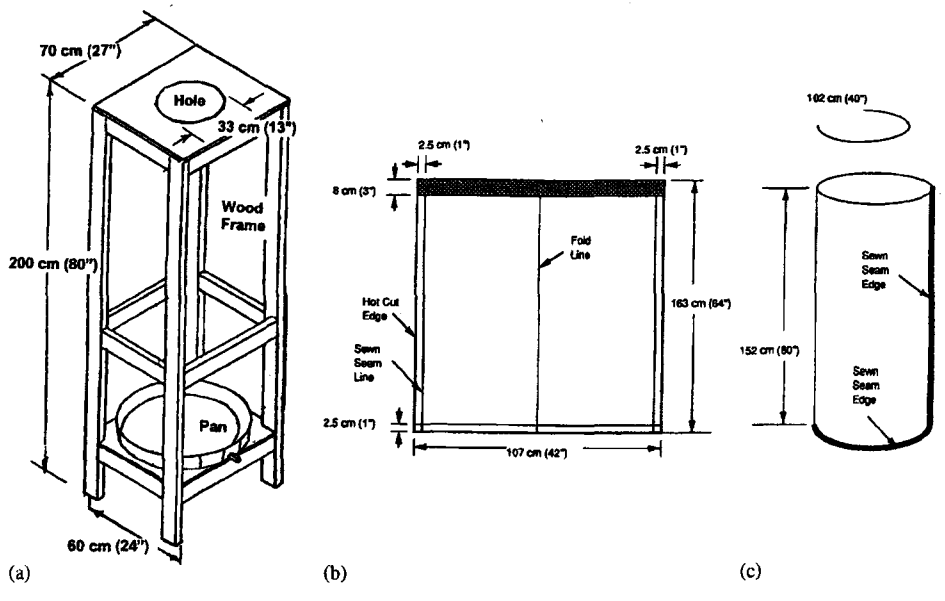


Fig. 7. Hanging bag test apparatus and geotextile before and after fabrication.

4. Next 38 L (10 gal) of site specific material is obtained in two 19 L (5 gal) containers. Also 151 L (40 gal) of site water is obtained in eight 19 L (5 gal) containers. The soil material is mixed with the water in an evenly distributed manner. This process will displace some water and will result in a mess. This is why the test should be conducted in the field, working from a platform typically on back of a pick-up truck as shown in the photographs of Figs. 4a, 5a and 6a.
5. In a safe and controlled manner, lift the premixed buckets of 20% soil slurry to the back bed of the pick-up truck or working platform. Thoroughly agitate the soil materials with a stirrer to mix the soil and water to obtain a uniform consistency that would be representative of the site material. Immediately pour these buckets into the fabric bag and start the stopwatch. Dump as much of the premixed slurry as needed into the tube until it is filled to the top and overflows. Record the time it took to fill the bag. This is time zero. Next, record the time it takes for the water level to drop 75 mm (3 in.). Continue to record the incremental time it takes for additional 75 mm (3 in.) increments until the water level reaches the top of the sediment. (This is the end of the flow rate portion of the test.) Record the time for the liquid level to drop from the upper rim of the bag to 7.5 cm (3 in.), 15 cm (6 in.), 22.5 cm (9 in.), 30 cm (12 in.), 37.5 cm (15 in.), 45 cm (18 in.), 52.5 cm (21 in.) and 60 cm (24 in.).

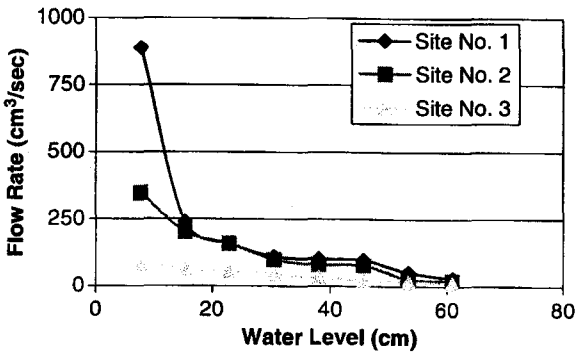


Fig. 8. Hanging bag test results for geotextile "A-1".

6. Continue to let the bag hang free until water stops draining from the bag. Sediment passing the fabric should be collected from the shallow aluminum pans at the base of the hanging bag for the entirety of the test.
7. At the conclusion of the test, remove the pan from under the bag decanting any free water from the sediment. With the aid of a spoon, brush and squirt bottle transfer the sediment to a stainless steel drying dish. Bring the drying dish back to the lab and dry the sediment in an oven. Determine the dry mass of sediment.
8. If desired, determine the mass of the sediment contained within the bag by cutting the bag free of the hanger and weighting it. Also obtain a representative sample from within the bag for a moisture content determination back in the lab. Carefully examine the inside of the fabric to note if a filter cake has formed. If so, characterize it as much as possible.
9. Calculate the discharge flow rate at each water level increment for elapsed time (t_e) for the slurry level to drop 7.5 cm (3.0 in.). The elapsed time (t_e) has to be converted into an initialized time (t_i) by subtracting the time to fill the bag (t_o) from the elapsed time as follows:

$$t_i = t_e - t_o. \tag{1}$$

Sequentially, the incremental times (t_δ) are calculated by subtracting successive initialized times from one another in the following manner:

$$t_{\delta(0-7.5)} = t_{i(0-7.5)} - t_{i(0)}, \tag{2}$$

$$t_{\delta(7.5-15)} = t_{i(7.5-15)} - t_{i(0-7.5)}, \tag{3}$$

$$t_{\delta(15-22.5)} = t_{i(15-22.5)} - t_{i(7.5-15)} \text{ etc.} \tag{4}$$

Assuming that the bag is cylindrical and that the volume in each increment of the bag is equal to approximately 6200 cm^3, the discharge flow rate can be calculated at each of the eight 7.5 cm (3 in.) increments by dividing the constant volume (6200 cc) by the respective increment time (t_δ). The discharge flow rate versus liquid level from top of bag should be plotted for each test.

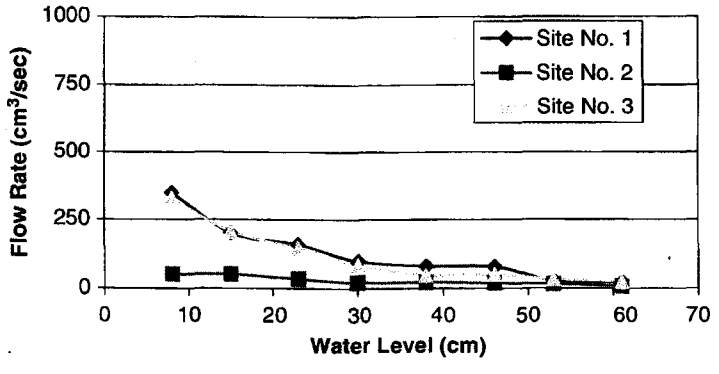


Fig. 9. Hanging bag test results for geotextile "A-2".

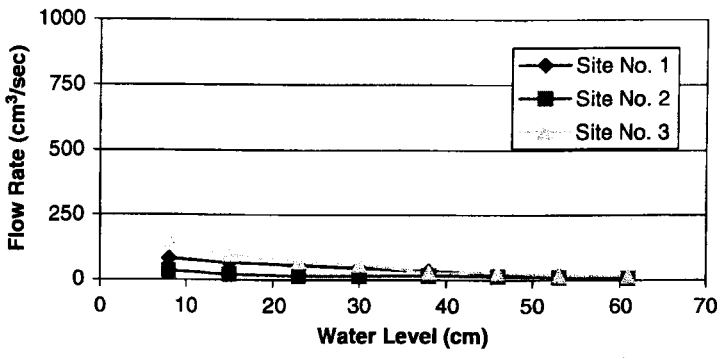


Fig. 10. Hanging bag test results for geotextile "B-1".

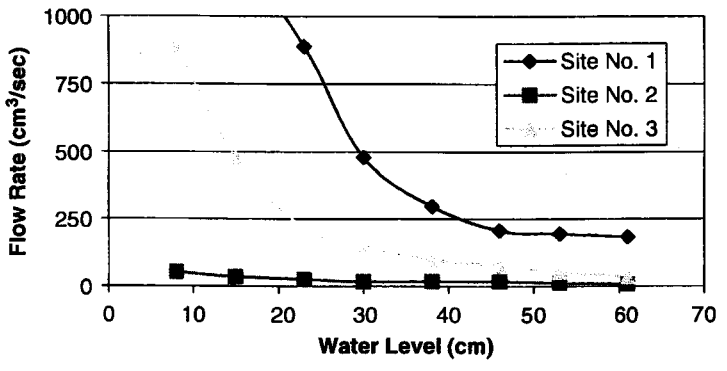


Fig. 11. Hanging bag test results for geotextile "B-2".

In addition, the dry mass of solids that passed through the fabric should be measured and recorded. Properties of the stabilized mass within the tube can also be sampled for moisture content and density, if desirable.

10. Examples of discharge flow rate versus liquid level from top of bag are shown in Figs. 8–11.

4. Discussion

The four fabrics listed in Table 2 were used in the above manner with the site-specific materials of the three sites listed in Table 1. Figs. 8–11 present the water flow rates out of the four fabrics, respectively, for each of the three site conditions described. The water levels referred to on the abscissa of these graphs refer to "0" as slurry being at the top of the bag decreasing to approximately 60-cm below the top of the bag where the water level subsides beneath the top of the soil at which point the water level could no longer be visually observed. Thus the curves refer to decreasing water levels within the bag in even 7.5 cm (3.0 in.) increments.

In all cases, flow rates at Site no. 2 were the lowest. This is understandable since the site soil was the finest, with the highest plasticity index, and created the thickest and densest filter cake on the inside of the fabrics. The filter cake shown in Fig. 3 was developed at this particular site. While a plasticity index of six (6) is not particularly high in a clay-soil context, it is high considering individual soil particles in suspension are being pressurized through a relatively thick, three-dimensional, fabric in a dewatering manner.

The highest flow rates were generally associated with the soil at Site no. 1, although for Fabrics A-2 and B-1 they were approximately the same as the results at Site no. 3. While expected for the Site no. 1 soil, which was a granular beach sand, the flow rates of the Site no. 3 soil were unexpectedly high. The ash material appeared to act as a well graded sandy soil. Unfortunately, the flow rates were not high enough for the design scheme that was under consideration.

The behavior of these flow rates is further evidenced by the permeability of the three soils (see Table 1) in that:

$$k_{\text{Site no. 1}} > k_{\text{Site no. 3}} > k_{\text{Site no. 2}} \quad (5)$$

Not shown graphically is the amount of soil passing through the respective bags in conducting the tests. In all cases, so little soil (or sediment) passed through the fabrics that graphing was not possible. This was somewhat of a surprise since Site no. 2 soil had 50% passing the No. 200 Sieve (0.075 mm), and Site no. 3 soil had 40% passing. The AOS of the four fabrics was considerably higher, i.e., 0.21–0.43 mm, than the fines contained in these soils. This apparent lack of correlation of in-fill sediment particle size with fabric opening size is somewhat disconcerting.

5. Summary

Design engineers and contractors involved with geotextile tubes are focused on the dewatering flow rate with respect to time response of geotextile tubes since it is an important consideration in how the particular fabric will function. Good prediction of performance is an integral part of designing and selecting fabrics for geotextile tubes for both shore line protection and dewatering; particularly the latter. While the HBT was a successful precursor test for these three case histories, it has several draw backs.

- Results from the HBT can be somewhat variable. Important variables include nonrepresentative fill materials, water content variations, specific filling procedure, orientation effects and differing ambient conditions.
- The HBT is both hard work and time consuming. It is possible for a single test to take an entire day. The process of sample supply, test set-up, fabricating the bag, running the test with varying dewatering periods and data analysis result in a test that is neither simple nor easy.
- Hanging bag testing is cumbersome, uses large quantities of site specific materials and can require establishment of several appropriate safety and health practices prior to use.
- The HBT is not a manufacturing quality control test. Geosynthetic manufacturers do not routinely conduct this test. Manufacturers rely on other material performance parameters such as AOS, and permittivity to control the filtration characteristics of the fabric being manufactured into the completed geotextile tube.
- Large HBT samples are used to simulate near field gradients.

Regardless of the above drawbacks, however, the HBT is crucial to a successful project. No geotextile tube project should be designed without having conducted at least one HBT under simulated site-specific conditions. If the HBT does show slow drainage, a designer then has the opportunity to design flocculants, change the geotextile, alter the geotextile tubes geometry, etc. In short, the HBT results supersede the manufacturer's quality control data for the prediction of compatibility of a fabric to a specific infill. Geotextile tubes work well for dewatering. An owner and/or designer, however, must have confidence in success by addressing factors affecting the process prior to construction. The HBT is the tool that the owner/designer needs so as to answer site specific questions about fabric-to-infill material compatibility.

6. Conclusion

Geotextile tubes are excellent design strategies for both shoreline protection and dewatering of fine materials. They provide containment while still allowing water to pass through them. A difficulty with regard to designing geotextile tubes is the matching of the appropriate fabric with the site-specific infilled material. Each site presents different challenges in this regard. This investigation looked at four different geotextiles and how they interacted with three different infill materials. The two critical findings from this study are as follows:

(i) The flow rates for all the tests were *directly proportional* to the permeability of the soil contained within the tube. In this regard the HBT results adequately predicted the field performance in all three case histories.
(ii) The performance of the fabric bags *was not dependent* on any conventional parameters, including the fabric AOS-values. In this regard the HBT results were superior to fabric properties in assessing the performance of the various fabrics to site specific infilled materials.

Acknowledgements

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DRAFT

ATTACHMENT C3

Bench Test Study of Tracer Dye Performance in Waters From the HBHA Pond Area, Industriplex Site, Woburn, MA, by Ozark Underground Laboratory, Inc.

Ozark UNDERGROUND LABORATORY 1572 Aley Lane • Protem, MO 65733 • (417) 785-4289 • fax (417) 785-4290 • contact@ozarkundergroundlab.com

BENCH TEST STUDY OF TRACER DYE PERFORMANCE IN WATERS FROM THE HBHA POND AREA, INDUSTRI-PLEX SITE, WOBURN, MA.

April 29, 2009

Thomas Aley, PG & PHG
Senior Hydrogeologist and President
President, Ozark Underground Laboratory, Inc.

An investigation and report prepared for Haley and Aldrich, Inc., 465 Medford Street, Suite 2200, Boston, MA 02129-1400

Table 1.	Charcoal bench test results for the Haley & Aldrich, Industri-Plex OU2 Site				
OUL #	Description of sample	Date/Time Placed	Date/Time Recovered	Dye Results	
				Peak nm	Conc. ppb
	RMI-50 Water				
S8291	**100ppb Eosine in RMI-50 Water**	**4/7/09 1410**	**4/7/09 1510**	**540.4**	**63.7**
S8301	10ppb Eosine in RMI-50 Water	4/7/09 1428	4/7/09 1530	540.6	2.50
S8310	1ppb Eosine in RMI-50 Water	4/7/09 1448	4/7/09 1550	ND	
S8294	**100ppb Fluorescein in RMI-50 Water**	**4/7/09 1416**	**4/7/09 1517**	**515.1**	**212**
S8304	10ppb Fluorescein in RMI-50 Water	4/7/09 1435	4/7/09 1537	515.2	17.6
S8313	1ppb Fluorescein in RMI-50 Water	4/7/09 1453	4/7/09 1555	515.7	1.66
S8297	**1000ppb Rhodamine WT in RMI-50 Water**	**4/7/09 1422**	**4/7/09 1523**	**567.8**	**544**
S8307	200ppb Rhodamine WT in RMI-50 Water	4/7/09 1442	4/7/09 1544	566.8	143
S8316	20ppb Rhodamine WT in RMI-50 Water	4/7/09 1459	4/7/09 1602	567.8	14.2
	RMI-300 Water				
S8292	**100ppb Eosine in RMI-300 Water**	**4/7/09 1412**	**4/7/09 1513**	**540.5**	**57.0**
S8302	10ppb Eosine in RMI-300 Water	4/7/09 1430	4/7/09 1532	539.2	3.94
S8623	10ppb Eosine in RMI-300 Water	4/14/09 0900	4/15/09 0900	540.9	22.1
S8311	1ppb Eosine in RMI-300 Water	4/7/09 1450	4/7/09 1552	ND	
S8626	1ppb Eosine in RMI-300 Water	4/14/09 0900	4/15/09 0906	ND	
S8295	**100ppb Fluorescein in RMI-300 Water**	**4/7/09 1418**	**4/7/09 1519**	**515.3**	**182**
S8305	10ppb Fluorescein in RMI-300 Water	4/7/09 1438	4/7/09 1540	515.4	19.5
S8624	10ppb Fluorescein in RMI-300 Water	4/14/09 0900	4/15/09 0902	515.6	39.8
S8314	1ppb Fluorescein in RMI-300 Water	4/7/09 1455	4/7/09 1557	517.2	2.99
S8627	1ppb Fluorescein in RMI-300 Water	4/14/09 0900	4/15/09 0908	515.8	6.98
S8298	**1000ppb Rhodamine WT in RMI-300 Water**	**4/7/09 1424**	**4/7/09 1525**	**567.8**	**605**
S8308	100ppb Rhodamine WT in RMI-300 Water	4/7/09 1444	4/7/09 1546	566.6	60.5
S8625	100ppb Rhodamine WT in RMI-300 Water	4/14/09 0900	4/15/09 0904	567.0	247
S8317	10ppb Rhodamine WT in RMI-300 Water	4/7/09 1502	4/7/09 1605	ND	
S8628	10ppb Rhodamine WT in RMI-300 Water	4/14/09 0900	4/15/09 0910	567.5	34.9
	Halls Brook Water				
S8293	**100ppb Eosine in Halls Brook Water**	**4/7/09 1414**	**4/7/09 1515**	**540.3**	**43.4**
S8303	10ppb Eosine in Halls Brook Water	4/7/09 1433	4/7/09 1534	541.2	2.55
S8312	1ppb Eosine in Halls Brook Water	4/7/09 1452	4/7/09 1553	ND	
S8296	**100ppb Fluorescein in Halls Brook Water**	**4/7/09 1420**	**4/7/09 1521**	**515.1**	**213**

OUL #	Description of sample	Date/Time Placed	Date/Time Recovered	Dye Results	
				Peak nm	Conc. ppb
S8306	10ppb Fluorescein in Halls Brook Water	4/7/09 1440	4/7/09 1542	515.3	20.9
S8315	1ppb Fluorescein in Halls Brook Water	4/7/09 1457	4/7/09 1600	516.6	2.20
S8299	**1000ppb Rhodamine WT in Halls Brook Water**	**4/7/09 1426**	**4/7/09 1527**	**567.4**	**607**
S8309	100ppb Rhodamine WT in Halls Brook Water	4/7/09 1446	4/7/09 1548	567.1	57.7
S8318	10ppb Rhodamine WT in Halls Brook Water	4/7/09 1505	4/7/09 1607	568.4 *	4.41

Footnotes: ND = No dye detected

* = A fluorescence peak is present that does not meet all the criteria for a positive dye result. However, it has been calculated as the tracer dye.

Introduction

This bench test was designed to verify that the three potential tracer dyes planned for use in hydrodynamic modeling studies, HBHA Pond, Industri-Plex Site, Woburn, MA, will perform adequately in various waters present at the site. The waters tested were:

1. RMI-50 water from the pond. This water is from the epilimnium zone.
2. RMI-300 water from the pond. This water is from the hypolimnium zone.
3. Halls Brook water.

The waters were collected on April 1, 2009 between 1545 and 1600 hours by personnel from Haley and Aldrich and were shipped to the Ozark Underground Laboratory (OUL) where they arrived on April 3, 2009. The shipped water bottles were labeled RMI-50, RMI-300, and Halls Brook. These names were used throughout the study to identify the particular waters.

Upon arrival at the OUL all waters had a pH of approximately 7.0. No pH adjustments of the waters were made during the bench test.

This bench test followed a study plan prepared by the Ozark Underground Laboratory (OUL) dated April 5, 2009 and entitled "Study plan; bench test of eosine, fluorescein and rhodamine WT dyes in selected waters from the HBHA Pond area, Industri-Plex, Woburn, MA."

The three dyes tested in this bench test were:

1. **Eosine**. The Color Index Name is Acid Red 87, and its Color Index Number is 45380. This dye is also known as Eosin and Eosine OJ. Its CAS Number is 17372-87-1. The dye mixture used is approximately 75% dye equivalent and 25% diluent (starch).
2. **Fluorescein**. The Color Index Name is Acid Yellow 73, and its Color Index Number is 45350. This dye is also known as Uranine, Uranine C, and Sodium Fluorescein. Its CAS Number is 518-47-8. The dye mixture used is approximately 75% dye equivalent and 25% diluent (starch).
3. **Rhodamine WT**. The Color Index Name is Acid Red 388. It has no assigned Color Index Number. This dye is sometimes sold as Acid Red. Its CAS Number is 37299-86-8. The dye mixture used is approximately 20% dye equivalent and 80% diluent (water).

For this study all dye concentrations were based upon the as-sold weight of the dye mixtures (which include the diluent). All dye analysis work was conducted in accordance with the OUL's current Procedures and Criteria document dated December 15, 2008. A copy of this document is included as Appendix A in this report.

Basic Dye Solutions

The following 27 dye solutions were prepared. Each bottle contained approximately 900 ml of final dye solution.

- 1, 10, and 100 ppb eosine dye mixture in RMI-50, RMI-300, and Halls Brook water. This totaled 9 bottles of water.
- 1, 10, and 100 ppb fluorescein dye mixture in RMI-50, RMI-300, and Halls Brook water. This totaled 9 bottles of water.
- 10, 100, and 1000 ppb rhodamine WT dye mixture in RMI-300 and Halls Brook water. This totaled 6 bottles of water.
- 20, 200, and 1000 ppb rhodamine WT dye mixtures in RMI-50 water. This totaled 3 bottles of water.

The study design intended that the rhodamine WT mixtures in RMI-50 water be 10, 100, and 1000 ppb rhodamine WT. However, the 100 ppb mixture was accidentally double spiked thus yielding a 200 ppb solution. Some of this solution was used to spike the next solution and it thus became 20 ppb rather than the intended 10 ppb. The error was not discovered until one day after the study was started so it was not reasonable to remix all dye solutions and re-start the bench test. The purpose of the bench test was to test the performance of the three tracer dyes at three different concentrations in the three different waters so the error did not adversely affect the study and its results.

The study was designed to verify that activated carbon samplers could effectively adsorb the dyes and then release them to eluting solutions in the laboratory (the charcoal [activated carbon] tests) and to assess the stability of the dyes in the different waters (the water tests). Each of these two tests is discussed separately.

The Charcoal (Activated Carbon) Tests

One-Hour Test

On the day that the test mixtures were prepared 425 ml of each of the 27 dye mixtures was poured into a new clean glass bottle. The weigh of activated carbon in the carbon samplers is 4.25 grams, so the weight of the dyed water was 100 times that of the carbon sampler. An activated carbon sampler was then placed in each of the bottles and allowed to remain for approximately one hour (the times placed in the water and removed from the water are recorded in Table 1 where the results are shown). After the one-hour immersion period the charcoal samplers were removed from the water, washed in a strong jet of dye-free water, and then eluted following the standard OUL protocol (see Appendix A). The dye concentration in the 15 ml of eluting solution was then determined.

Table 1 presents data from the one-hour test arranged by type of water and then type and concentration of dye. In the RMI-50 water the only dye type and concentration that was not detectable using the carbon samplers was the 1 ppm solution of eosine. In the RMI-300 water the only dye types and concentrations that were not detectable using the carbon samplers were 1 ppb eosine and 10 ppb rhodamine WT. In the Halls Brook water the only dye types and concentrations that were not detectable was 1 ppb eosine, although the 10 ppb rhodamine WT peak shape was of poor quality and did not meet all the criteria for a positive detection.

The one-hour test demonstrates that carbon samplers in water containing fluorescein dye were several times more effective in adsorbing dye and then releasing the dye to the eluting solution than was the case for carbon samplers in water containing eosine dye. For 100 ppb solutions the performance of eosine and rhodamine WT was similar with rhodamine WT possibly being slightly superior to eosine dye.

Table 2 compares dye concentrations in the charcoal packet elutants for the two higher concentrations tested for all three dyes in all three waters. It shows that while the concentrations vary, the charcoal samplers provide generally similar performance for any particular dye regardless of the type of water involved. The variations noted can be attributed to the nature of the carbon and the sorption and elution of the dyes. During fieldwork when duplicate carbon samplers are placed in the same water mean relative percent differences are commonly about 40%. The relative percent difference (RPD) is calculated by dividing the difference between two values by the mean of the values.

Table 2 shows that the mean RPD value for fluorescein was 16.4% and was 16.2% for rhodamine WT. In contrast, the mean RPD value for eosine was 41.3%. This indicates that measured concentrations of fluorescein and rhodamine WT in charcoal sampler elutants will be more accurate than measurements of eosine in the elutants. This observation may affect the sites selected for the introduction of particular dyes.

Table 3 compares activated carbon sampler results for the one-hour test for the two stronger concentrations of dye in each of the three types of water. If the ability of the carbon to adsorb and then release a tracer dye were directly proportional to the dye concentration then measured dye concentrations for carbon samplers placed in a dye concentration of 100 ppb should be approximately 10 times greater than the measured dye concentrations for samplers placed in a dye concentration of 10 ppb. Table 3 shows that this relationship was approximately met for fluorescein and rhodamine WT dye in all three of the waters tested. However, the measured dye concentration in carbon samplers left in eosine-spiked water at a 100 ppb concentration averaged 16.6 times greater than the concentrations in eosine-spiked water at a 10 ppb concentration. However, since the two spiked concentrations differed by an order of magnitude, the results for eosine do not appreciably reduce the utility of this tracer dye for the planned studies.

Table 2. Comparison of dye concentrations in carbon sampler elutants left in test waters for one hour. Relative Percent Difference (RPD) is calculated for highest and lowest values in each group of three samples.

Dye mixture	Water type	Dye concentration in elutant (ppb)	RPD for highest and lowest values in group
100 ppb eosine	**RMI-50**	**63.7**	
ditto	RMI-300	57.0	
ditto	Halls Brook	43.4	37.9%
100 ppb fluorescein	**RMI-50**	**212**	
ditto	RMI-300	182	
ditto	Halls Brook	213	15.7%
1,000 rhodamine WT	**RMI-50**	**544**	
ditto	RMI-300	605	
ditto	Halls Brook	607	10.9%
10 ppb eosine	**RMI-50**	**2.50**	
ditto	RMI-300	3.94	
ditto	Halls Brook	2.55	44.7%
10 ppb fluorescein	**RMI-50**	**17.6**	
ditto	RMI-300	19.5	
ditto	Halls Brook	20.9	17.1%
200 ppb rhodamine WT	**RMI-50**	**143**	
100 ppb rhodamine WT	RMI-300	60.5	
100 ppb rhodamine WT	Halls Brook	57.7	21.4%*

* Calculation assumes that 100 ppb rhodamine WT in RMI-50 water would have had an elutant concentration of 71.5 ppb (this is half of the 200 ppb value).

Mean RPD Values:
Eosine = 41.3%
Fluorescein = 16.4%
Rhodamine WT = 16.2%

Table 3. Comparison of dye concentrations in elutants of carbon samplers exposed to 425 ml of dyed water for one hour. Concentrations are in ppb.

(1) Dye Type	(2) Water Type	(3) Dye concentration in carbon sampler elutant exposed to 100 ppb dye solution	(4) Dye concentration in carbon sampler elutant exposed to 10 ppb dye solution	Factor; Column 3 divided by Column 4.
Eosine	RMI-50	63.7	2.50	18.2
Eosine	RMI-300	57.0	3.94	14.5
Eosine	Halls Brook	43.4	2.55	17.0
Mean		***54.7***	***3.00***	***16.6***
Fluorescein	RMI-50	212	17.6	12.0
Fluorescein	RMI-300	182	19.5	9.3
Fluorescein	Halls Brook	213	20.9	10.2
Mean		***202***	***19.3***	***10.5***
		(3) Dye concentration in carbon sampler elutant exposed to 1000 ppb dye solution	**(4) Dye concentration in carbon sampler elutant exposed to 100 ppb dye solution**	
Rhodamine WT	RMI-50	544	71.5*	7.6
Rhodamine WT	RMI-300	605	60.5	10.0
Rhodamine WT	Halls Brook	607	57.7	10.5
Mean		***585***	***63.2***	***9.4***

* Rhodamine WT concentration in the tested water had a concentration of 200 ppb and yielded a concentration in the carbon sampler elutant of 143 ppb. This value is divided by 2 to yield an estimated value for a tested water concentration of 100 ppb.

24-Hour Test

Activated carbon samplers were placed in a few of the bottles of water spiked with the three dyes. The water samples used for this test had been kept in the dark for 7 days after spiking with the tracer dyes. Each water sample bottle contained 425 ml of water. The carbon samplers were allowed to sit in the water bottles for 24 hours and then were removed, washed in strong jets of dye-free water, and analyzed in accordance with the normal OUL protocol (See Appendix A). The only waters tested with activated carbon for 24 hours were those shown in Table 4.

Table 4. Comparison of dye concentrations in carbon sampler elutants left in test waters for one hour with those left for 24 hours.

Dye mixture	Water type	Dye concentration in elutant (ppb) 1 hour test	Dye concentration in elutant (ppb) 24 hour test
1 ppb eosine	RMI-300	ND	ND
1 ppb fluorescein	RMI-300	2.00	6.98
10 ppb rhodamine WT	RMI-300	ND	34.9

A carbon sampler in a jar of water continues to adsorb any tracer dye present, but as the adsorption continues the dye concentration in the jar decreases and thus the rate at which dye can be adsorbed decreases. The data in Table 4 show that a carbon sampler in a 1 ppb eosine solution did not adsorb and then released to the eluting solution enough eosine to be detectable. Eosine was detectable in carbon sampler elutants in place in 10 ppb solutions of the dye. In contrast, while carbon samplers in a 10 ppb rhodamine WT solution for one hour did not result in detectable dye in the carbon sampler elutant, leaving a sampler in this solution for 24 hours did yield detectable rhodamine WT dye in the carbon sampler elutant.

A test that was not included in the study plan was to measure the dye concentration remaining in the 425 ml of water after a carbon sampler had been left in it for 24 hours. Six water samples were analyzed for dye concentrations on Day 8 after charcoal samplers had been removed. The data are shown in Table 5.

Table 5. Dye removed from 425 ml of water in which an activated carbon sampler had been left for 24 hours. All samples in RMI-300 water.

Dye Solution	Measured Dye Concentration in Water, Day 7. ppb	Measured Dye Concentration in Water, Day 8. ppb	Estimated Percent of Dye Removed
10 ppb eosine	9.64	6.41	33.5
1 ppb eosine	ND	ND	
10 ppb fluorescein	9.00	3.86	57.1
1 ppb fluorescein	0.891	0.473	46.9
100 ppb rhodamine WT	83.1	36.3	56.3
10 ppb rhodamine WT	7.85	ND	100

Water Sample Tests

The "Basic Dye Solutions" portion of this report identified the 27 dye solutions prepared. The water sample testing removed a 10 ml sample from each of the 27 dye solutions at 1, 2, 3, 4, and 7 days after the dye solutions were mixed. Upon removal the samples were chilled to 4 degrees C. prior to dye analysis. Table 6 presents the sample analysis results.

The fluorescence intensity of tracer dyes in water (and thus their measured concentrations) can be less than the as-mixed solutions due to the nature of the water used, its pH, and the clarity of the water sample. The waters used in this study had a pH of approximately 7. Fluorescein does not reach maximum fluorescence intensity at pH 7. Kass (1998, p. 97) presents a graph indicating that the fluorescence intensity of fluorescein (known as uranine in this reference) at pH 7 is about 75% of its intensity at pH 8.1 or greater. Eosine reaches maximum fluorescence at a pH of about 6.3 or greater. We have not found literature indicating the pH at which rhodamine WT reaches maximum fluorescence intensity, but in our experience the value is at about pH 7.3.

In our normal laboratory protocol when analyzing water samples for the presence of fluorescein dye we pH adjust the samples to a pH of 9.5 or greater by placing them in open vials in a high ammonia environment for a period of time necessary to reach pH 9.5 or greater. This can be accomplished by leaving the samples in this environment overnight. In this bench test we did not pH adjust samples since the objective was to determine relative dye concentrations under natural conditions in the various waters at 1, 2, 3, 4, and 7 days after the dye solutions were mixed. The pH adjusting of samples would have offset the results by a day, and, in view of the objectives of the bench test, was neither necessary nor desirable.

Table 6.	Water bench test results for the Haley & Aldrich, Industri-Plex OU2 Site				
OUL #	Description of sample	Date/Time Analyzed	Dye Results		Comments
			Peak nm	Conc. ppb	
	RMI-50 Water				
S8319	**100ppb Eosine in RMI-50 Water**	**4/8/09 0835**	**534.1**	**80.6**	
S8378	100ppb Eosine in RMI-50 Water	4/9/09 0833	533.7	72.9	
S8407	100ppb Eosine in RMI-50 Water	4/10/09 0825	533.9	76.4	
S8517	100ppb Eosine in RMI-50 Water	4/11/09 0900	533.7	75.2	
S8594	100ppb Eosine in RMI-50 Water	4/14/09 0820	533.9	75.8	
S8329	**10ppb Eosine in RMI-50 Water**	**4/8/09 0847**	**534.1**	**7.10**	
S8388	10ppb Eosine in RMI-50 Water	4/9/09 0843	533.7	6.81	
S8416	10ppb Eosine in RMI-50 Water	4/10/09 0835	533.5	6.79	
S8527	10ppb Eosine in RMI-50 Water	4/11/09 0911	533.7	7.08	
S8604	10ppb Eosine in RMI-50 Water	4/14/09 0829	533.5	7.00	
S8604R	10ppb Eosine in RMI-50 Water	4/14/09 0829	533.7	7.02	
S8338	**1ppb Eosine in RMI-50 Water**	**4/8/09 0902**	**533.7**	**0.547**	
S8397	1ppb Eosine in RMI-50 Water	4/9/09 0852	534.0	0.687	
S8426	1ppb Eosine in RMI-50 Water	4/10/09 0844	534.0	0.656	
S8536	1ppb Eosine in RMI-50 Water	4/11/09 0922	534.8	0.602	
S8613	1ppb Eosine in RMI-50 Water	4/14/09 0838	533.8	0.776	
S8323	**100ppb Fluorescein in RMI-50 Water**	**4/8/09 0839**	**509.0**	**114**	**Off scale, 1:10 dilutions**
S8382	100ppb Fluorescein in RMI-50 Water	4/9/09 0836	508.2	112	Off scale, 1:10 dilutions
S8410	100ppb Fluorescein in RMI-50 Water	4/10/09 0828	508.3	121	Off scale, 1:10 dilutions
S8521	100ppb Fluorescein in RMI-50 Water	4/11/09 0903	508.5	117	Off scale, 1:10 dilutions
S8597X	100ppb Fluorescein in RMI-50 Water	4/14/09 0823	508.5	124	Off scale, 1:10 dilutions
S8332	**10ppb Fluorescein in RMI-50 Water**	**4/8/09 0851**	**508.3**	**7.80**	
S8391	10ppb Fluorescein in RMI-50 Water	4/9/09 0846	507.8	7.65	
S8419	10ppb Fluorescein in RMI-50 Water	4/10/09 0838	507.4	7.86	
S8530	10ppb Fluorescein in RMI-50 Water	4/11/09 0914	508.2	7.81	
S8607	10ppb Fluorescein in RMI-50 Water	4/14/09 0832	507.8	7.99	
S8607R	10ppb Fluorescein in RMI-50 Water	4/14/09 0832	507.8	7.91	
S8342	**1ppb Fluorescein in RMI-50 Water**	**4/8/09 0906**	**508.2**	**0.692**	
S8401	1ppb Fluorescein in RMI-50 Water	4/9/09 0855	508.0	0.677	
S8429	1ppb Fluorescein in RMI-50 Water	4/10/09 0847	508.2	0.688	

OUL #	Description of sample	Date/Time Analyzed	Dye Results Peak nm	Dye Results Conc. ppb	Comments
S8539	1ppb Fluorescein in RMI-50 Water	4/11/09 0925	507.9	0.660	
S8616	1ppb Fluorescein in RMI-50 Water	4/14/09 0841	507.8	0.706	
S8326	**1000ppb Rhodamine WT in RMI-50 Water**	**4/8/09 0843**	**574.2**	**916**	**Off scale, 1:10 dilutions**
S8385	1000ppb Rhodamine WT in RMI-50 Water	4/9/09 0840	572.8	865	Off scale, 1:10 dilutions
S8413	1000ppb Rhodamine WT in RMI-50 Water	4/10/09 0831	573.0	807	Off scale, 1:10 dilutions
S8524	1000ppb Rhodamine WT in RMI-50 Water	4/11/09 0907	572.7	785	Off scale, 1:10 dilutions
S8601	1000ppb Rhodamine WT in RMI-50 Water	4/14/09 0826	572.8	785	Off scale, 1:10 dilutions
S8335A	**200ppb Rhodamine WT in RMI-50 Water**	**4/8/09 0856**	**574.2**	**279**	**Background present, but**
S8394A	200ppb Rhodamine WT in RMI-50 Water	4/9/09 0849	573.0	239	undiluted samples gave the
S8423A	200ppb Rhodamine WT in RMI-50 Water	4/10/09 0841	573.0	237	best results
S8533A	200ppb Rhodamine WT in RMI-50 Water	4/11/09 0918	573.0	194	
S8610A	200ppb Rhodamine WT in RMI-50 Water	4/14/09 0835	572.6	188	Used 1:10 dilutions
S8610R	200ppb Rhodamine WT in RMI-50 Water	4/14/09 0835	572.4	174	Used 1:10 dilutions
S8345	**20ppb Rhodamine WT in RMI-50 Water**	**4/8/09 0910**	**574.2**	**24.7**	
S8404	20ppb Rhodamine WT in RMI-50 Water	4/9/09 0858	572.6	20.1	
S8432	20ppb Rhodamine WT in RMI-50 Water	4/10/09 0850	572.6	20.9	
S8543	20ppb Rhodamine WT in RMI-50 Water	4/11/09 0928	573.0	18.1	
S8619	20ppb Rhodamine WT in RMI-50 Water	4/14/09 0844	572.5	20.8	
	RMI-300 Water				
S8321X	**100ppb Eosine in RMI-300 Water**	**4/8/09 0837**	**534.0**	**92.6**	**Background present, and**
S8379X	100ppb Eosine in RMI-300 Water	4/9/09 0834	533.9	68.2	1:10 dilutions gave best
S8408X	100ppb Eosine in RMI-300 Water	4/10/09 0826	533.8	73.1	results.
S8518X	100ppb Eosine in RMI-300 Water	4/11/09 0901	533.8	76.4	
S8595X	100ppb Eosine in RMI-300 Water	4/14/09 0821	533.9	70.3	
S8330	**10ppb Eosine in RMI-300 Water**	**4/8/09 0848**	**533.7**	**8.0**	**Background present, and**
S8389X	10ppb Eosine in RMI-300 Water	4/9/09 0844	534.4	6.72	1:10 dilutions gave best
S8417X	10ppb Eosine in RMI-300 Water	4/10/09 0836	533.8	8.34	results.
S8528X	10ppb Eosine in RMI-300 Water	4/11/09 0912	533.4	8.05	
S8605X	10ppb Eosine in RMI-300 Water	4/14/09 0830	533.8	7.45	
S8605R	10ppb Eosine in RMI-300 Water	4/14/09 0830	534.0	7.73	
S8716X	10ppb Eosine in RMI-300 Water	4/15/09 0915	534.4	6.41	
S8339	**1ppb Eosine in RMI-300 Water**	**4/8/09 0903**	**ND**		**Background present,**

OUL #	Description of sample	Date/Time Analyzed	Dye Results		Comments
			Peak nm	Conc. ppb	
S8398	1ppb Eosine in RMI-300 Water	4/9/09 0853	ND		could not detect dye.
S8427	1ppb Eosine in RMI-300 Water	4/10/09 0845	ND		
S8537	1ppb Eosine in RMI-300 Water	4/11/09 0923	ND		
S8614	1ppb Eosine in RMI-300 Water	4/14/09 0839	ND		
S8719	1ppb Eosine in RMI-300 Water	4/15/09 0918	ND		
S8324	**100ppb Fluorescein in RMI-300 Water**	**4/8/09 0840**	**509.0**	**110**	**Off scale, 1:10 dilutions**
S8383	100ppb Fluorescein in RMI-300 Water	4/9/09 0837	508.3	103	Off scale, 1:10 dilutions
S8411	100ppb Fluorescein in RMI-300 Water	4/10/09 0829	508.3	111	Off scale, 1:10 dilutions
S8522	100ppb Fluorescein in RMI-300 Water	4/11/09 0905	508.5	108	Off scale, 1:10 dilutions
S8598	100ppb Fluorescein in RMI-300 Water	4/14/09 0824	508.5	109	
S8333X	**10ppb Fluorescein in RMI-300 Water**	**4/8/09 0853**	**508.9**	**7.67**	**Background present,**
S8392X	10ppb Fluorescein in RMI-300 Water	4/9/09 0847	508.2	8.12	1:10 dilutions gave best
S8421X	10ppb Fluorescein in RMI-300 Water	4/10/09 0839	508.7	8.63	results
S8531X	10ppb Fluorescein in RMI-300 Water	4/11/09 0915	508.6	8.72	
S8608X	10ppb Fluorescein in RMI-300 Water	4/14/09 0833	508.7	8.89	
S8608R	10ppb Fluorescein in RMI-300 Water	4/14/09 0833	508.7	9.00	
S8717X	10ppb Fluorescein in RMI-300 Water	4/15/09 0916	508.9	3.86	
S8343	**1ppb Fluorescein in RMI-300 Water**	**4/8/09 0907**	**509.2**	**0.657**	**Background present, but**
S8402	1ppb Fluorescein in RMI-300 Water	4/9/09 0856	508.6	0.653	generally 1:10 dilutions
S8430	1ppb Fluorescein in RMI-300 Water	4/10/09 0848	508.6	0.708	gave the best results
S8541X	1ppb Fluorescein in RMI-300 Water	4/11/09 0926	509.5	0.780	
S8617X	1ppb Fluorescein in RMI-300 Water	4/14/09 0842	509.5	0.891	
S8721	1ppb Fluorescein in RMI-300 Water	4/15/09 0919	509.6	0.473	
S8327	**1000ppb Rhodamine WT in RMI-300 Water**	**4/8/09 0844**	**574.5**	**917**	**Off scale, 1:10 dilutions**
S8386	1000ppb Rhodamine WT in RMI-300 Water	4/9/09 0841	572.9	792	Off scale, 1:10 dilutions
S8414	1000ppb Rhodamine WT in RMI-300 Water	4/10/09 0832	572.7	756	Off scale, 1:10 dilutions
S8525	1000ppb Rhodamine WT in RMI-300 Water	4/11/09 0908	573.0	810	Off scale, 1:10 dilutions
S8602	1000ppb Rhodamine WT in RMI-300 Water	4/14/09 0827	572.8	711	
S8336X	**100ppb Rhodamine WT in RMI-300 Water**	**4/8/09 0858**	**575.2**	**107**	**Background present,**
S8395X	100ppb Rhodamine WT in RMI-300 Water	4/9/09 0850	573.0	75.6	1:10 dilutions gave best
S8424X	100ppb Rhodamine WT in RMI-300 Water	4/10/09 0842	572.9	83.7	results. Peaks had
S8534X	100ppb Rhodamine WT in RMI-300 Water	4/11/09 0919	573.0	80.2	slightly abnormal shapes.

OUL #	Description of sample	Date/Time Analyzed	Dye Results		Comments
			Peak nm	Conc. ppb	
S8611X	100ppb Rhodamine WT in RMI-300 Water	4/14/09 0836	572.9	83.1	
S8718X	100ppb Rhodamine WT in RMI-300 Water	4/15/09 0917	572.9	36.3	
S8346	**10ppb Rhodamine WT in RMI-300 Water**	**4/8/09 0912**	**576.2**	**11.5**	**Could draw these**
S8405X	10ppb Rhodamine WT in RMI-300 Water	4/9/09 0859	576.6	9.00	peaks only because dye
S8433	10ppb Rhodamine WT in RMI-300 Water	4/10/09 0851	576.6	8.42	was known to be in the
S8544	10ppb Rhodamine WT in RMI-300 Water	4/11/09 0929	575.8	7.53	water.
S8621	10ppb Rhodamine WT in RMI-300 Water	4/14/09 0845	575.2	7.85	
S8722	10ppb Rhodamine WT in RMI-300 Water	4/15/09 0920	ND		
	Halls Brook Water				
S8322	**100ppb Eosine in Halls Brook Water**	**4/8/09 0837**	**534.1**	**80.6**	
S8381	100ppb Eosine in Halls Brook Water	4/9/09 0835	533.5	73.1	
S8409	100ppb Eosine in Halls Brook Water	4/10/09 0827	533.6	74.3	
S8519	100ppb Eosine in Halls Brook Water	4/11/09 0902	533.8	76.2	
S8596	100ppb Eosine in Halls Brook Water	4/14/09 0822	533.7	75.4	
S8331	**10ppb Eosine in Halls Brook Water**	**4/8/09 0849**	**534.1**	**7.33**	
S8390	10ppb Eosine in Halls Brook Water	4/9/09 0845	533.5	7.08	
S8418	10ppb Eosine in Halls Brook Water	4/10/09 0837	533.6	7.11	
S8529	10ppb Eosine in Halls Brook Water	4/11/09 0913	533.7	7.28	
S8606	10ppb Eosine in Halls Brook Water	4/14/09 0831	533.5	7.11	
S8341	**1ppb Eosine in Halls Brook Water**	**4/8/09 0904**	**533.8**	**0.602**	
S8399	1ppb Eosine in Halls Brook Water	4/9/09 0854	533.6	0.721	
S8428	1ppb Eosine in Halls Brook Water	4/10/09 0846	533.8	0.645	
S8538	1ppb Eosine in Halls Brook Water	4/11/09 0924	534.0	0.730	
S8615	1ppb Eosine in Halls Brook Water	4/14/09 0840	534.0	0.742	
S8325	**100ppb Fluorescein in Halls Brook Water**	**4/8/09 0842**	**509.1**	**103**	**Off scale, 1:10 dilutions**
S8384	100ppb Fluorescein in Halls Brook Water	4/9/09 0839	508.3	102	Off scale, 1:10 dilutions
S8412	100ppb Fluorescein in Halls Brook Water	4/10/09 0830	508.3	92.3	Off scale, 1:10 dilutions
S8523	100ppb Fluorescein in Halls Brook Water	4/11/09 0906	508.5	111	Off scale, 1:10 dilutions
S8599	100ppb Fluorescein in Halls Brook Water	4/14/09 0825	508.5	116	Off scale, 1:10 dilutions
S8334	**10ppb Fluorescein in Halls Brook Water**	**4/8/09 0854**	**508.2**	**9.00**	
S8393	10ppb Fluorescein in Halls Brook Water	4/9/09 0848	508.2	8.71	
S8422	10ppb Fluorescein in Halls Brook Water	4/10/09 0840	507.4	8.56	

OUL #	Description of sample	Date/Time Analyzed	Dye Results		Comments
			Peak nm	Conc. ppb	
S8532	10ppb Fluorescein in Halls Brook Water	4/11/09 0916	508	8.92	
S8609	10ppb Fluorescein in Halls Brook Water	4/14/09 0834	507.7	9.14	
S8609R	10ppb Fluorescein in Halls Brook Water	4/14/09 0834	507.8	9.14	
S8344	**1ppb Fluorescein in Halls Brook Water**	**4/8/09 0909**	**508.4**	**0.792**	
S8403	1ppb Fluorescein in Halls Brook Water	4/9/09 0857	507.8	0.799	
S8431	1ppb Fluorescein in Halls Brook Water	4/10/09 0849	507.4	0.811	
S8542	1ppb Fluorescein in Halls Brook Water	4/11/09 0927	508.1	0.822	
S8618	1ppb Fluorescein in Halls Brook Water	4/14/09 0843	507.0	0.828	
S8328	**1000ppb Rhodamine WT in Halls Brook Water**	**4/8/09 0845**	**574.4**	**879**	**Off scale, 1:10 dilutions**
S8387	1000ppb Rhodamine WT in Halls Brook Water	4/9/09 0842	572.6	846	Off scale, 1:10 dilutions
S8415	1000ppb Rhodamine WT in Halls Brook Water	4/10/09 0833	572.7	809	Off scale, 1:10 dilutions
S8526	1000ppb Rhodamine WT in Halls Brook Water	4/11/09 0910	572.7	832	Off scale, 1:10 dilutions
S8603	1000ppb Rhodamine WT in Halls Brook Water	4/14/09 0828	572.6	810	Off scale, 1:10 dilutions
S8337	**100ppb Rhodamine WT in Halls Brook Water**	**4/8/09 0900**	**574.4**	**111**	
S8396	100ppb Rhodamine WT in Halls Brook Water	4/9/09 0851	572.9	89.1	
S8425	100ppb Rhodamine WT in Halls Brook Water	4/10/09 0843	572.6	90.9	
S8535	100ppb Rhodamine WT in Halls Brook Water	4/11/09 0921	573	78.5	
S8612	100ppb Rhodamine WT in Halls Brook Water	4/14/09 0837	572.7	88.8	
S8347	**10ppb Rhodamine WT in Halls Brook Water**	**4/8/09 0914**	**574.3**	**10.1**	
S8406	10ppb Rhodamine WT in Halls Brook Water	4/9/09 0900	572.6	8.21	
S8434	10ppb Rhodamine WT in Halls Brook Water	4/10/09 0852	572.9	8.27	
S8545	10ppb Rhodamine WT in Halls Brook Water	4/11/09 0930	572.7	7.01	
S8622	10ppb Rhodamine WT in Halls Brook Water	4/14/09 0846	572.2	8.26	

Footnotes: ND = No dye detected

The RMI-300 water had a distinct brown color that reduced clarity. The RMI-50 water had a faint brown color, and the Halls Brook water was very clear. In our experience the amount of color in the water would not substantially reduce the apparent concentration of any of the three dyes in the water, although some reduction in the RMI-300 water should be expected.

All three of the waters tested have the ability to quench some of the fluorescence intensity of the dyes tested. The percent of quenching (expressed as the percent difference between the calculated dye concentration and the measured dye concentration) generally increases slightly as dye concentrations decrease. Table 7 shows the mean percent of quenching for the three dyes; values for the three types of water are averaged. The 100 ppb fluorescein solutions were no quenches since analysis of these samples required an order of magnitude dilution and this dilution used OUL reagent water with a pH of 9.5 or greater.

Table 8 shows mean measured dye concentrations for all dyes in all waters. Day 0 (April 7, 2009) was the day on which the dye mixture was made. When made, the calculated dye concentration was the standard concentration shown in the first column of Table 8. Days 1 through 4 were April 8 though 11. Day 7 was April 14, 2009. Table 8 also indicates the day when the highest and lowest concentrations were measured as indicated by the letter H for highest and L for lowest concentration. In one case two days had identical lowest concentration values; both dates are indicated with the letter L. Where replicate samples were analyzed on the same day the mean of the two values was used in Table 8.

Table 7. Percent of dye quenching for the three tested dyes. The percent of quenching is based upon the mean measured dye concentration during the seven-day analysis period for each of the dye types and concentrations. Values for all three types of water are averaged. The value for the 10 and 100 ppb rhodamine WT solutions in RMI-50 water is assumed to equal the 20 and 200 ppb solutions measured.

Dye Mixture	As Mixed Concentration (ppb)	Percent Quenched
Eosine	100	23.9
Eosine	10	27.1
Eosine	1	32.9*
Fluorescein	100	Not quenched; enhanced by 10.3
Fluorescein	10	16.3
Fluorescein	1	25.6
Rhodamine WT	1,000	17.9
Rhodamine WT	100	1.8
Rhodamine WT	10	0.8

*Based on results from RMI-50 and Halls Brook waters. Dye was not detectable in RMI-300 water.

Table 8. Mean dye concentrations in water samples and dates when highest (H) and lowest (L) concentrations were measured. HB = Halls Brook water

Dye Mixture	Water Type	Mean Conc. ppb	Day 1 4/8/09	Day 2 4/9/09	Day 3 4/10/09	Day 4 4/11/09	Day 7 4/14/09
100 ppb Eos	RMI-50	76.2	H	L			
10 ppb Eos	RMI-50	6.96	H		L		
1 ppb Eos	RMI-50	0.654	L				H
100 ppb Eos	RMI-300	76.1	H	L			
10 ppb Eos	RMI-300	7.71		L	H		
1 ppb Eos	RMI-300	ND	ND	ND	ND	ND	ND
100 ppb Eos	HB	75.9	H	L			
10 ppb Eos	HB	7.18	H	L			
1 ppb Eos	HB	0.688	L				H
100 ppb Fl	RMI-50	118		L			H
10 ppb Fl	RMI-50	7.81		L			H
1 ppb Fl	RMI-50	0.685				L	H
100 ppb Fl	RMI-300	108	L		H		
10 ppb Fl	RMI-300	8.42	L				H
1 ppb Fl	RMI-300	0.738		L			H
100 ppb Fl	HB	105			L		H
10 ppb Fl	HB	8.87			L		H
1 ppb Fl	HB	0.810	L				H
1000 ppb RWT	RMI-50	832	H			L	L
200 ppb RWT	RMI-50	227	H				L
20 ppb RWT	RMI-50	20.9	H			L	
1000 ppb RWT	RMI-300	797	H				L
100 ppb RWT	RMI-300	85.9	H			L	
10 ppb RWT	RMI-300	8.86	H			L	
1000 ppb RWT	HB	835	H		L		
100 ppb RWT	HB	91.7	H			L	
10 ppb RWT	HB	8.37	H			L	

Based upon the data in Table 8 most of the highest eosine dye concentrations occurred on Day 1, and most of the lowest concentrations occurred on Day 2. For fluorescein almost all of the highest concentrations occurred on Day 7 with most of the lowest concentrations spread through the rest of the sampling period. For rhodamine WT all of the highest concentrations occurred on Day 1 and most of the lowest concentrations occurred on Day 4. Except for the lowest concentrations tested (1 ppb for eosine and fluorescein and 10 ppb for rhodamine WT), dye concentrations did not vary greatly during the 7 day period of repeated analysis. This is indicated by Table 9 where we have presented the mean and the standard deviations for water samples analyzed five times

during the study period. Where duplicate samples were analyzed we have used only the original sample analysis in the calculation of the mean and standard deviation.

Table 9. Mean and standard deviations for water samples analyzed one to seven days after preparation. All concentrations in parts per billion

Dye Mixture	Water Type	Mean	Standard Deviation	Standard Deviation as % of Mean
100 ppb Eos	RMI-50	76.18	2.80	3.7
10 ppb Eos	RMI-50	6.96	0.15	2.2
1 ppb Eos	RMI-50	0.654	0.087	13.3
100 ppb Eos	RMI-300	76.12	9.71	12.8
10 ppb Eos	RMI-300	7.71	0.63	8.2
1 ppb Eos	RMI-300	ND	---	---
100 ppb Eos	HB	75.92	2.86	3.8
10 ppb Eos	HB	7.18	0.11	1.5
1 ppb Eos	HB	0.688	0.061	8.7
Eos Mean				***6.8%***
100 ppb Fl	RMI-50	117.6	4.9	4.2
10 ppb Fl	RMI-50	7.82	0.12	1.5
1 ppb Fl	RMI-50	0.685	0.017	2.5
100 ppb Fl	RMI-300	108.2	3.1	2.9
10 ppb Fl	RMI-300	8.41	0.50	5.9
1 ppb Fl	RMI-300	0.738	0.100	13.6
100 ppb Fl	HB	104.86	9.10	8.7
10 ppb Fl	HB	8.87	0.23	2.6
1 ppb Fl	HB	0.810	0.015	1.9
Fl Mean				***4.9%***
1000 ppb RWT	RMI-50	831.6	57.4	6.9
200 ppb RWT	RMI-50	227.4	37..3	16.4
20 ppb RWT	RMI-50	20.92	2.39	11.4
1000 ppb RWT	RMI-300	797.2	76.9	9.7
100 ppb RWT	RMI-300	85.92	12.21	14.2
10 ppb RWT	RMI-300	8.86	1.58	17.8
1000 ppb RWT	HB	835.2	29.0	3.5
100 ppb RWT	HB	91.66	11.86	12.9
10 ppb RWT	HB	8.37	1.11	13.3
RWT Mean				***11.8%***

Replicate Water Samples

As a quality control step we analyzed six replicate water samples so that the results could be compared with the initial water sample. The data are shown in Table 10. The difference in emission wavelength peaks between the samples and their replicates were 0.2 nm or less. Relative percent differences average 2.3% and the largest RPD value was 7.7%. Four of the seven pairs of samples had RPD values of 1.2% or less. The replicate water samples show that sample analysis results are of good quality.

Table 10. Analysis results for replicate water samples.

Sample Number	Nominal Dye Concentration and Water Type	Emission Fluorescence Peak (nm)	Dye Concentration (ppb)	Relative Percent Difference (RPD)
S8604	10 ppb Eosine in RMI 50 Water	533.5	7.00	
S8604R	ditto	533.7	7.02	0.3%
S8607	10 ppb Fluorescein in RMI-50 Water	507.8	7.99	
S8607R	ditto	507.8	7.91	1.0%
S8610A	100 ppb Rhodamine WT in RMI-50 Water	572.6	188	
S8610R	ditto	572.4	174	7.7%
S8605X	10 ppb Eosine in RMI-300 Water	533.8	7.45	
S8605R	ditto	534.0	7.73	3.7%
S8608X	10 ppb Fluorescein in RMI-300 Water	508.7	8.89	
S8608R	ditto	508.7	9.00	1.2%
S8609	10 ppb Fluorescein in Halls Brook Water	507.7	9.14	
S8609R	ditto	507.8	9.14	0.0%
Mean				2.3%

Conclusions

1. Table 2 compares dye concentrations in the charcoal packet elutants for the two higher concentrations tested for all three dyes in all three waters. It shows that while the concentrations vary, the charcoal samplers provide generally similar performance for any particular dye regardless of the type of water involved. The mean RPD value for fluorescein in carbon sampler elutants was 16.4% and was 16.2% for rhodamine WT. In contrast, the mean RPD value for eosine in carbon sampler elutants was 41.3%. This indicates that measured concentrations of fluorescein and rhodamine WT in charcoal sampler elutants will be more accurate than measurements of eosine in the elutants. This observation may affect the sites selected for the introduction of particular dyes.

2. If the ability of the activated carbon to adsorb and then release a tracer dye is directly proportional to the dye concentration then measured dye concentrations for carbon samplers placed in a dye concentration of 100 ppb should be approximately 10 times greater than the measured dye concentrations for samplers placed in a dye concentration of 10 ppb. Table 3 showed that this relationship was approximately met for fluorescein and rhodamine WT dye in all three of the waters tested. However, the measured dye concentration in carbon samplers left in eosine-spiked water at a 100 ppb concentration averaged 16.6 times greater than the concentrations in eosine-spiked water at a 10 ppb concentration. However, since the two spiked concentrations differed by an order of magnitude, the results for eosine do not appreciably reduce the utility of this tracer dye for the planned studies.

3. The following dye concentrations yielded acceptable dye adsorption onto activated carbon samplers and subsequent laboratory elution when samplers were left in these test water for approximately one hour:

- 10 and 100 ppb eosine dye solutions in all three waters.
- 1, 10, and 100 ppb fluorescein dye solutions in all three waters.
- 20 ppb rhodamine WT dye solutions in RMI-50 waters. This concentration was not tested in other waters.
- 100 and 1,000 ppb rhodamine WT dye solutions in RMI-300 and Halls Brook waters.
- 200 ppb rhodamine WT dye solutions in RMI-50 waters. This concentration was not tested in other waters.

4. It is our conclusion that activated carbon samplers will adequately adsorb (and release to elution in the laboratory) the following dyes in all of the tested waters if the samplers are left for periods of one hour or more in ponded waters containing the following mean dye concentrations:

- At least 1 ppb fluorescein dye mixture
- At least 10 ppb eosine dye mixture
- At least 100 ppb rhodamine WT dye mixture

5. Based upon the bench test and our experience, if carbon samplers are left in place for more than one hour (for example, for 24 hours) the performance of the samplers will be substantially enhanced and smaller concentrations of eosine and rhodamine WT mixtures will produce adequate results. If samplers were left in place for 24 hours mean dye concentrations in the tested waters should be:

- At least 1 ppb fluorescein dye mixture
- At least 5 ppb eosine dye mixture
- At least 20 ppb rhodamine WT dye mixture.

6. The bench test demonstrated that all of the tested waters have some ability to quench the fluorescence of all three of the tracer dyes. However, this does not significantly reduce the utility of the dyes for the planned tracing work in these waters.

7. Over a period of 8 days (the approximate duration of the planned tracer study) all of the tracer dyes were reasonably stable in all three of the test waters. This shown by data in Tables 8 and 9 and the associated discussions.

References

Aley, Thomas. 2002. The Ozark Underground Laboratory's groundwater tracing handbook. Ozark Underground Laboratory, Protem, MO. 35p.

Kass, Werner. 1998. Tracing technique in geohydrology. A.A. Balkema, Rotterdam and Brookfield. 581p.

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APPENDIX A

PROCEDURES AND CRITERIA DOCUMENT

Ozark UNDERGROUND LABORATORY 1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 oul@tri-lakes.net

PROCEDURES AND CRITERIA
ANALYSIS OF FLUORESCEIN, EOSINE, RHODAMINE WT, SULFORHODAMINE B, AND PYRANINE DYES IN WATER AND CHARCOAL SAMPLERS

December 15, 2008

Thomas Aley, PHG 179
President
Ozark Underground Laboratory, Inc.

PROCEDURES

Introduction

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or up-graded. The Ozark Underground Laboratory maintains a summary of changes in standard procedures and criteria.

Dye Nomenclature

Fluorescein is C.I. Acid yellow 73, Color Index Number 45350. Rhodamine WT is Acid Red 388; there is no assigned Color Index Number for this dye. Eosine (sometimes called eosin) is Acid Red 87, Color Index Number 45380. Sulforhodamine B is C.I. Acid Red 52, Color Index Number 45100. Pyranine is Solvent Green 7 (also called D&C Green 8), Color Index Number 59040.

Description of the Samplers

The charcoal samplers are packets of fiberglass screening partially filled with approximately 4.25 grams of activated coconut charcoal. The charcoal used by the Ozark Underground Laboratory is Calgon 207C coconut shell carbon, 6 to 12 mesh.

The most commonly used samplers are about 4 inches long by two inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1 inch diameter wells); this is a special order item and should be specifically requested when it is needed. All of the samplers are closed by heat sealing.

Placement of Samplers

Samplers (also called charcoal packets) are placed so as to be exposed to as much water as possible. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than being flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are placed in sample holders made of PVC pipe fittings. Brass hose fittings are installed at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose. The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consists of 1.5 inch diameter pipe and pipe fitting.

Charcoal packets can also be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Some sort of weight should be added near the charcoal packet to insure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a white or uncolored plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. Do not use colored cord. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with small diameter wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a stainless steel weight may be added to the top of the disposable bailer. We have had good success with two to three ounce segments of stainless steel pipe which have an outside diameter of 1.315 inches and an inside diameter of 1.049 inches; such pipe weighs about 1.7 pounds per linear foot. The weight of the stainless steel is approximately 497 pounds per cubic foot. The pipe segments can be attached over the anchoring cord at the top of the bailer. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

Placement of samplers requires adjustment to field conditions. The above placement comments are intended as guidance, not firm requirements.

Rinsing of Charcoal Packets Prior to Sampling

Charcoal packets routinely contain some fine powder that washes off rapidly when they are placed in water. Since such material could remain in monitoring wells, charcoal packets to be placed in such wells are triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach, approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

Collection and Replacement of Samplers

Samplers are routinely collected and replaced from each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of travel. As an illustration,

we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled. This is typically not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak bags are ideal). The bag is labeled on the outside with a permanent type felt marker pen. Use only pens that have black ink; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels must not be inserted inside the sample bags.

For most projects the Ozark Underground Laboratory supplies the Whirl-Pak bags. Prior to use, 1% of the new bags are randomly selected. Each bag is soaked in the standard eluting solution and then analyzed for the presence of any of the tracer dyes being used.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. We prefer (and in some studies require) that samples be placed on "blue ice" or ice upon collection and that they be shipped refrigerated with "blue ice" by overnight express. Do not ship samplers packed in ice since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration, yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

Water samples are often collected. They should be collected in either glass or plastic; the Ozark Underground Laboratory routinely uses 50 ml research grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. We need no more than 30 ml of water. The vials should be placed in the dark and refrigerated immediately after collection. They should be refrigerated until shipment. For most projects the Ozark Underground Laboratory supplies the vials. Prior to use, 1% of the new vials are randomly selected. Each vial is soaked in the standard eluting solution and then analyzed for the presence of any of the tracer dyes being used.

When water or charcoal samplers are collected for shipment to the Ozark Underground Laboratory they should be shipped promptly. We receive good overnight and second day air service from both UPS and Fed Ex; the Postal Service does not provide next day service to us. DHL works adequately for international shipments.

Each shipment of charcoal samplers or water samples must be accompanied by a sample tracking sheet. These sheets (which bear the title "Samples for Fluorescence Analysis") are provided by the Ozark Underground Laboratory and summarize placement and collection data. These sheets can be augmented by a client's chain of custody forms or any other relevant documentation. Figure 1 is one of our blank sample forms.

Figure 1. Sample Collection Data Sheet

OZARK UNDERGROUND LABORATORY, INC.

1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 email: oul@tri-lakes.net

SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

Project:_____ Week No:_____ Samples Collected By:_____

Samples Shipped By:_____ Samples Received By:_____

Date Samples Shipped:___/___/___ Date Samples Received:___/___/___ Time Samples Received:____:____ Return Cooler? Yes_____No__

Bill to:_____Send Results to: _____

Analyze for: Fluorescein_____Eosine_____Rhodamine WT____Other_____Ship cooler to: _____

OUL use only		*Please indicate stations where dye was visible in the field* *for field technician use - use black ink only*						*OUL use only*
# CHAR REC'D	LAB NUMBER	STATION NUMBER 1-4 Numbers	STATION NAME	PLACED		COLLECTED		# WATER REC'D
				DATE	TIME	DATE	TIME	

COMMENTS:_____

This sheet filled out by OUL staff? Yes_____No_____Charts for samples on this page proofed by OUL:_____

Page _____ of_____

Digital cameras can provide an independent verification of the date and time of sample collection. A digital photo can be taken of each sampling location during each sample collection. The photo file has a date and time created. If the camera's clock is set correctly, the photo provides an independent reference of the date and time the sample was collected. It is critical that the photos be taken in the order of sampling; that is, if one has forgotten to take a photo of the previous station and remembers at the current sampling station, do not go back and take the previous station photo.

When we are using a digital camera for sampling documentation we initially take a high resolution photo of each station that shows its context broadly enough for an observer to distinguish it from other sampling station, but narrow enough not to include another sampling station. Subsequently, we download he high-resolution photos into a reference folder and rename the photos to the station number and name. We also make a copy of the photo to another folder and digitally draw arrows to the exact locations of the samplers. During subsequent sampling events a low-resolution digital photo is taken of each sampling station in the order they are visited. It is best to establish a routine of taking the photo upon arrival at the station. We then download these photos into a folder whose name indicates the dates of the photos. We do not rename these photos.

Some sites do not permit cameras. An alternative is to collect a Global Positioning System (GPS) location during each visit. GPS records the date and time each point (sampling station) is visited. While these files are not as easy to review as photographs, they can be used with a base map to show which locations were visited at which dates and times.

Receipt of Samplers

Samplers shipped to the Ozark Underground Laboratory are refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number. All samples are logged in upon receipt.

It sometimes occurs that there are discrepancies between the chain-of-custody sheets and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. A copy of this form is enclosed as Figure 2. The purpose of the form is to help resolve discrepancies, even when they may be minor.

Cleaning of Samplers

Samplers are cleaned by spraying them with jets of clean water. At the Laboratory we use unchlorinated water for the cleansing to minimize dye deterioration. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

Figure 2. Discrepancy Sheet

OZARK UNDERGROUND LABORATORY, INC.

DISCREPANCIES BETWEEN CHAIN-OF-CUSTODY SHEETS AND ACTUAL SAMPLES RECEIVED Page _____ of _____

Company & Project Name: Date Rec'd by OUL: Wk # _____

Lab #	Sta #	Station Name	Date Pulled	Problem	Solution

Comments:

Elution of the Charcoal

There are various eluting solutions that can be used for the recovery of tracer dyes. The solutions typically include an alcohol, some water, and a strong basic solution such as aqueous ammonia.

The standard elution solution now used at the Ozark Underground Laboratory is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide flakes to saturate the solution. The isopropyl alcohol solution is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution we use will elute fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in some samplers.

Fifteen ml of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded.

Analysis on the Shimadzu RF-5000U or RF-5301

The Laboratory uses two Shimadzu spectrofluorophotometers. One is a model RF-5000U, and the other is a model RF-5301. Both of these instruments are capable of synchronous scanning. The RF-5301 is the primary instrument used; the RF-5000U is primarily used as a back-up instrument except for tracing studies which were begun using this instrument. The OUL also owns a Shimadzu RF-540 spectrofluorometer which is occasionally used for special purposes.

A sample of the elutant is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 ml of the elutant is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 ml. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The spectral range of the cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5000U or the RF-5301. Both instruments are controlled by a programmable computer. Each instrument is capable of conducting substantial data analysis.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of the instruments and a training session on the use of spectrofluorophotometers was provided by Delta Instrument Company.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes, the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "very fast" on the RF-5000U; it is "fast" on the RF-5301. The typical sensitivity setting used on both instruments is "high."

Our typical analysis of an elutant sample where pyranine dye may be present includes a synchronous scanning of excitation and emission spectra with a 35 nm separation between excitation and emission wavelengths. For this dye, the excitation scan is from 360 to 600 nm; the emission scan is from 395 to 635 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is "very fast" on the RF-5000U; it is "fast" on the RF-5301. The typical sensitivity setting on both instruments is "high."

Excitation and emission slit width settings vary between the two instruments. The widths vary with the dyes for which we are sampling and for the matrix in which the dyes may be present. Excitation and emission slit width settings are summarized in Table 1.

Table 1. Excitation and emission slit width settings routinely used for dye analysis. Units are nanometers (nm)

Parameter	RF5000U	RF5301
Excitation slit for Eos, Fl, RWT, and SRB in elutant	5	3
Emission slit for Eos, Fl, RWT, and SRB in elutant	3	1.5
Excitation slit for Eos, Fl, RWT, and SRB in water	5	5
Emission slit for Eos, Fl, RWT, and SRB in water	10	3
Excitation slit for Pyranine in elutant	5	5
Emission slit for Pyranine in elutant	3	3
Excitation slit for Pyranine in pH adjusted water	5	5
Emission slit for Pyranine in pH adjusted water	3	3

Eos = Eosine. Fl = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

The instrument produces a plot of the synchronous scan for each sample; the plot shows emission fluorescence only. The synchronous scans are subjected to computer peak picks; peaks are picked to the nearest 0.1 nm. All samples run on the RF-5000U and

RF-5301 are stored on disk and printed on normal typing paper with a laser printer; sample information is printed on the chart.

All samples analyzed are recorded in a bound journal.

Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes. Dye quantities are expressed in microgram per liter (parts per billion; ppb). On the RF-5000U and RF-5301 the dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

Where there are multiple fluorescence peaks it is sometimes necessary to calculate dye concentrations based upon the height of the fluorescence peak rather that the area. The heights of the peaks are also proportional to dye concentrations.

We run dye concentration standards each day the machine is used. Ten separate standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
4) 10 ppb pyranine in well water from the Jefferson City-Cotter Formation. A sample of the standard is placed for at least two hours in a high ammonia atmosphere to adjust the pH to a value of 9.5 or greater.
5) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
6) 10 ppb eosine in elutant.
7) 100 ppb sulforhodamine B in elutant.
8) 10 ppb pyranine in elutant.

Preparation of Standards

Dye standards are prepared as follows:

Step 1. A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to insure that all dye is fully dissolved.

Step 2. One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein,

rhodamine WT, eosine, sulforhodamine B, and pyranine. The resulting solutions contain 100 mg/l dye (100 parts per million dye). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 ml. of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 ml at intervals of 0.005 ml. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 ml, 0.90%

At 0.300 ml, 0.28%

At 1.000 ml, 0.30%

The Step 2 solution is called the long term standard. Ozark Underground Laboratory experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

Step 3. A series of intermediate-term dye solutions are made. Approximately 45 ml. of each intermediate-term dye solution is made. All volume measurements of less than 5 ml are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 ml. capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) A solution containing 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.

2) A solution containing 1 ppm eosine.

3) A solution containing 10 ppm sulforhodamine B dye.

4) A solution containing 1 ppm pyranine.

Step 4. A series of eight short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the Ozark Underground Laboratory these standards have a useful shelf life in excess of one week. However, in practice, they are kept under refrigeration and new standards are made weekly.

Dilution of Samples

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilution is 100 fold. One part of the test sample is combined with 99 parts of water (if the test sample is water) or with 99 parts of the standard elutant (if the test sample is elutant). Typically, 0.300 ml of the test solution is combined with 29.700 ml

of water (or elutant as appropriate) to yield a new test solution. All volume measurements of less than 5 ml are made with a digital Finnpipette. which is capable of measuring volumes between 0.200 and 1.000 ml at intervals of 0.005 ml. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 ml, 0.90%

At 0.300 ml, 0.28%

At 1.000 ml, 0.30%

All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 ml. capacity pump dispenser which will pump within plus or minus 1% of the set value.

The water used for dilution is from a carbonate aquifer. All dilution water is pH adjusted to greater than pH 9.5 by holding it overnight in open containers in a high ammonia concentration chamber.

Quality Control

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds that might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing typically includes approximately 1% of materials used.

Reports

Reports are provided in accordance with the needs of the client. We typically provide copies of the analysis graphs and a listing of stations and samples where dye was detected. The reports indicate dye concentrations.

Work at the Ozark Underground Laboratory is directed by Mr. Thomas Aley. Mr. Aley has 45 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #179) by the American Institute of Hydrology. Mr. Aley has 40 years of professional experience in groundwater tracing with fluorescent tracing agents.

CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

Normal Emission Ranges and Detection Limits

The OUL has established normal emission fluorescence wavelength ranges for each of the five dyes. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 2 provides normal emission wavelength ranges and detection limits for the five dyes when analyzed on the OUL's RF-5000U spectrofluorophotometer. Table 3 provides similar data for the OUL's RF-5301. As indicated earlier in Table 1, the analytical protocols used on the two instruments are somewhat different, especially in regard to the widths of excitation and emission slit settings.

Table 2. **RF-5000U Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes in water and elutant samples.** Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Eosine in Elutant	533.0 to 539.6	0.035
Eosine in Water	529.6 to 538.4	0.008
Fluorescein in Elutant	510.7 to 515.0	0.010
Fluorescein in Water	505.6 to 510.5	0.0005
Pyranine in Elutant	500.4 to 504.6	0.055
Pyranine in Water*	495.5 to 501.5	0.030
Rhodamine WT in Elutant	561.7 to 568.9	0.275
Rhodamine WT in Water	569.4 to 574.8	0.050
Sulforhodamine B in Elutant	567.5 to 577.5	0.150
Sulforhodamine B in Water	576.2 to 579.7	0.040

* pH adjusted water with pH of 9.5 or greater.

Note: The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in the table.

Table 3. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, sulforhodamine B, and pyranine dyes in water and elutant samples. Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Eosine in Elutant	538.1 to 543.9	0.050
Eosine in Water	533.4 to 537.9	0.015
Fluorescein in Elutant	514.0 to 518.1	0.025
Fluorescein in Water	508.0 to 511.7	0.002
Pyranine in Elutant	502.1 to 508.1	0.015
Pyranine in Water*	498.4 to 504.4	0.010
Rhodamine WT in Elutant	565.4 to 572.0	0.170
Rhodamine WT in Water	572.7 to 578.0	0.015
Sulforhodamine B in Elutant	572.8 to 579.6	0.080
Sulforhodamine B in Water	580.1 to 583.7	0.008

* pH adjusted water with pH of 9.5 or greater.

Note: The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in the table.

Criteria for Determining Positive Dye Recoveries

The following sections identify normal criteria used by the OUL for determining positive dye recoveries. Beginning January 1, 2001, the primary analytical instrument in use at the OUL was the RF-5301; the RF-5000U was the principal backup instrument. Studies which were in progress prior to January 1, 2001 continued to have samples analyzed on the RF-5000U.

Except for pyranine dye, the analytical protocol used for the RF-5301 provides for the use of narrower excitation and/or emission slit settings than the RF-5000U protocol. This enhances our ability to discriminate between dyes and other fluorescent compounds. The protocol which is possible with the RF-5301 (as contrasted with the RF-5000U) also provides for a better balance in the sizes of the fluorescence peaks associated with an equal concentration of all of the dyes.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Eosine Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of eosine dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be eosine dye.

Criterion 1. There must be at least one fluorescence peak at the station in question in the range of 538.1 to 543.9 nm for samples analyzed by the RF-5301. The range must be 533.0 to 539.6 nm for samples analyzed by the RF-5000U.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. For the RF-5301, the eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb. For the RF-5000U the eosine detection limit in elutant samples is 0.035 ppb, thus this dye concentration limit equals 0.105 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Eosine Dye Recoveries in Water Samples.

There is generally little or no detectable fluorescence background in the general range of eosine dye encountered in most groundwater tracing studies. The following three criteria are used to identify fluorescence peaks which are deemed to be eosine dye.

Criterion 1. The associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. For samples analyzed on the RF-5301, the fluorescence peak should generally be in the range of 533.4 to 537.9 nm. For samples analyzed on the RF-5000U, the fluorescence peak should generally be in the range of 529.6 to 538.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples analyzed on the RF-5301 is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb. For samples analyzed on the 5000U the detection limit is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Fluorescein Dye Recoveries in Elutants from Charcoal Samplers.

There is often some fluorescence background in the range of fluorescein dye present at some of the stations used in groundwater tracing studies. We routinely conduct background sampling prior to the introduction of any tracer dyes to characterize this background fluorescence and to identify the existence of any tracer dyes which may be present in the area. The fact that a fluorescence peak is identified in our analytical results is not proof that it is fluorescein dye or that it is fluorescein dye from the trace of concern. The following 4 criteria are used to identify fluorescence peaks which are deemed to be fluorescein dye recoveries from our tracing work.

Criterion 1. There must be at least one fluorescence peak at the station in question in the range of 514.0 to 518.1 nm for samples analyzed by the RF-5301. The range must be 510.7 to 515.0 for samples analyzed by the RF-5000U.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. For the RF-5301, the fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb. For the RF-5000U, the fluorescein detection limit in elutant samples is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Fluorescein Dye Recoveries in Water Samples.

There is commonly some fluorescence background in the general range of fluorescein dye at some sampling stations used in groundwater tracing studies. The following criteria are used to identify fluorescence peaks which are deemed to be fluorescein dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. For samples analyzed on the RF-5301, the fluorescence peak should generally be in the range of 508.0 to 511.7 nm. For samples analyzed on the RF-5000U, the fluorescence peak should generally be in the range of 505.6 to 510.5 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples analyzed on the RF-5301 is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb. For the RF-5000U the detection limit is 0.0005 ppb, thus this dye concentration limit equals 0.0015 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Rhodamine WT Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of Rhodamine WT dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be Rhodamine WT.

Criterion 1. For samples analyzed on the RF-5301, there must be at least one fluorescence peak at the station in question in the range of 565.4 to 572.0 nm. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 561.7 to 568.9 nm.

Criterion 2. The dye concentration associated with the Rhodamine WT peak must be at least 3 times the detection limit. For the RF-5301, the detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb. For the RF-5000U, the detection limit in elutant samples is 0.275 ppb, thus this dye concentration limit equals 0.825 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of Rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Rhodamine WT Dye Recoveries in Water Samples.

The following criteria are used to identify fluorescence peaks which are deemed to be Rhodamine WT dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain Rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be Rhodamine WT dye from the tracing work under investigation. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 572.7 to 578.0 nm. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 569.4 to 574.8 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our Rhodamine WT detection limit in water samples analyzed on the RF-5301 is 0.015 ppb, thus this dye concentration limit is 0.045 ppb. For samples analyzed on the RF-5000U the detection limit is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Sulforhodamine B Dye Recoveries in Elutants from Charcoal Samplers.

There is generally little or no detectable fluorescence background in the general range of sulforhodamine B dye encountered in most groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be sulforhodamine B.

Criterion 1. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 567.5 to 577.5 nm. The acceptable range for samples analyzed on the RF-5301 is 572.8 to 579.6 nm.

Criterion 2. The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. For the RF-5000U, the detection limit in elutant samples is 0.150 ppb, thus this dye concentration limit equals 0.450 ppb. For the RF-5301, the detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Sulforhodamine B dye Recoveries in Water Samples.

The following criteria are used to identify fluorescence peaks which are deemed to be sulforhodamine B dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 576.2 to 579.7 nm. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 580.1 to 583.7 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. For samples analyzed on the RF-5301 the detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb. For samples analyzed on the RF-5000U the detection limit in water samples is 0.040 ppb, thus this dye concentration limit equals 0.120 ppb.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Pyranine Dye Recoveries in Elutants from Charcoal Samplers.

It must be remembered that the analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in this document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

There is often some detectable fluorescence background encountered in the general range of pyranine dye in groundwater tracing studies. The following four criteria are used to identify fluorescence peaks which are deemed to be pyranine.

Criterion 1. For samples analyzed on the RF-5000U, there must be at least one fluorescence peak at the station in question in the range of 500.4 to 504.6 nm. The acceptable range for samples analyzed on the RF-5301 is 502.1 to 508.1 nm.

Criterion 2. The dye concentration associated with the pyranine dye peak must be at least 3 times the detection limit. For the RF-5000U, the detection limit in elutant samples is 0.055 ppb, thus this dye concentration limit equals 0.165 ppb. For the RF-5301, the detection limit in elutant samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of pyranine dye. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the Ozark Underground Laboratory for Determining Positive Pyranine Dye Recoveries in Water Samples.

It must be remembered that the analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in this document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

The fluorescence of pyranine decreases below a pH of about 9.5. Prior to analysis water samples are placed in a high ammonia atmosphere for at least two hours. A pyranine dye in water standard is placed in the same atmosphere as the samples. Prior to analysis samples are tested to insure that their pH is 9.5 or greater. If pyranine dye concentrations in a sample are so great as to require dilution for quantification of the dye concentration the diluting water used is OUL reagent water which has been pH adjusted in a high ammonia atmosphere.

The following criteria are used to identify fluorescence peaks which are deemed to be pyranine dye in water.

Criterion 1. The associated charcoal samplers for the station should also contain pyranine dye in accordance with the criteria listed earlier. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be pyranine dye from the tracing work under investigation. For samples analyzed with the RF-5000U, the fluorescence peak should generally be in the range of 495.5 to 501.5 nm. For samples analyzed with the RF-5301, the fluorescence peak should generally be in the range of 498.4 to 504.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. For samples analyzed on the RF-5301 the detection limit in water is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb. For samples analyzed on the RF-5000U the detection limit in water samples is 0.030 ppb, thus this dye concentration limit equals 0.090 ppb.

ATTACHMENT C4

Lantec Q-PAC Product Information

LANTEC

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Q-PAC® for Trickling Filters and Bioreactors

Q-PAC® is a state-of-the-art medium for microorganism growth in trickling filters and other fixed-film bioreactors for wastewater treatment.

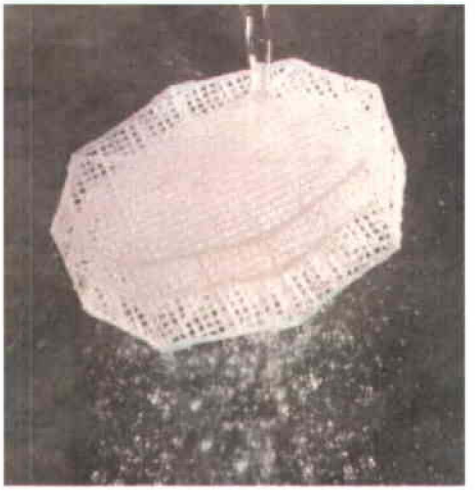
Its rod structure with multiple drip points provides a large available surface area for biofilm growth. QPAC's effective surface area actually increases as biomass grows (Figures 1 and 2). QPAC's high void fraction makes it resistant to plugging, and the uniform distribution of the surface ensures that there are no tight corners where biomass gets trapped and can't fall off. This helps avoid the formation of "dead zones"—anaerobic pockets that can cause odor problems.

Q-PAC is a random packing, and is easier to install than structured media that have to be placed by hand and cut to fit the periphery of a filter. In large filters, the savings in installation time and labor can be considerable.

Q-PAC® Advantages

- Fast, easy random installation
- High available surface area
- Uniform biomass growth
- Resistant to plugging and odors
- Easy sloughing of excess biomass
- Corrosion- and degradation-resistant
- Competitively priced

Q-PAC® Specifications	
Material	Polypropylene (specific gravity 0.90~0.91) UV-stabilized, resistant to acids, alkalis and microbes
Size	Diameter 11 in., height 3 in.
Specific Surface Area	30 ft^2/ft^3 clean, 60~90 ft^2/ft^3 with biofilm
Void Fraction	96.1%
Bulk Density	2.2 lb/ft^3 (clean)
Piece Count	5 / ft^3
Compressive Strength	960 lb/ft^2, suitable for filters up to 35 ft tall



Lantec Products, Inc. 5302 Derry Ave., Unit G Agoura Hills, CA 91301 818-707-2285 (fax) 707-9367 engineering@lantecp.com

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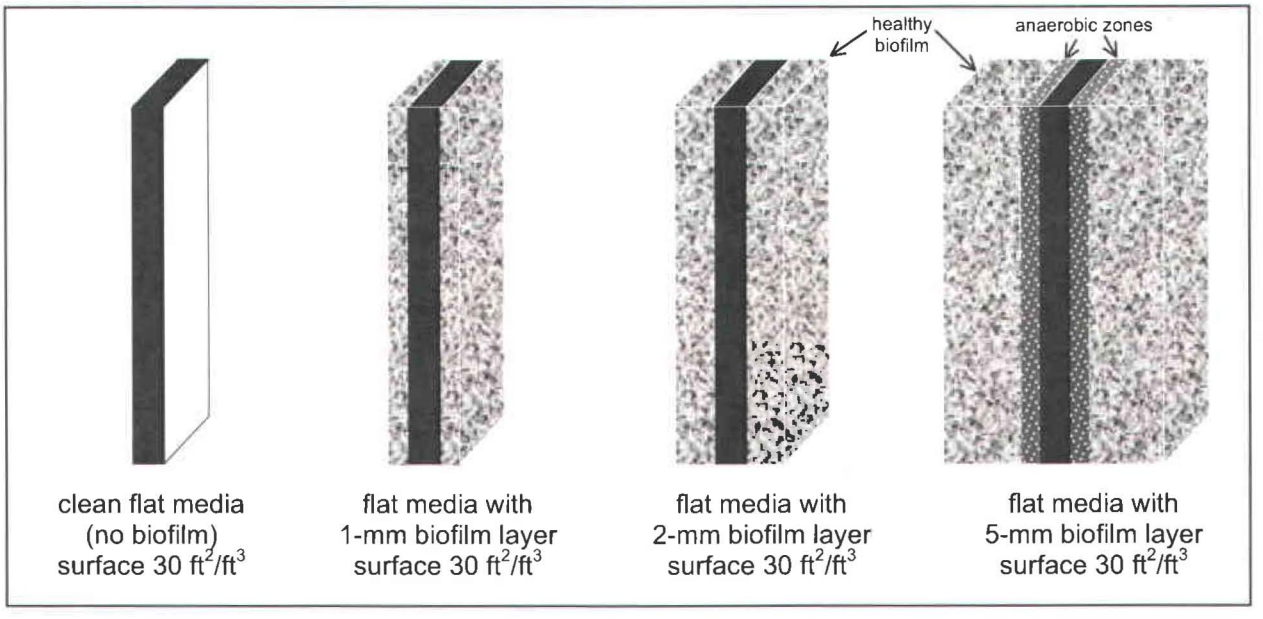
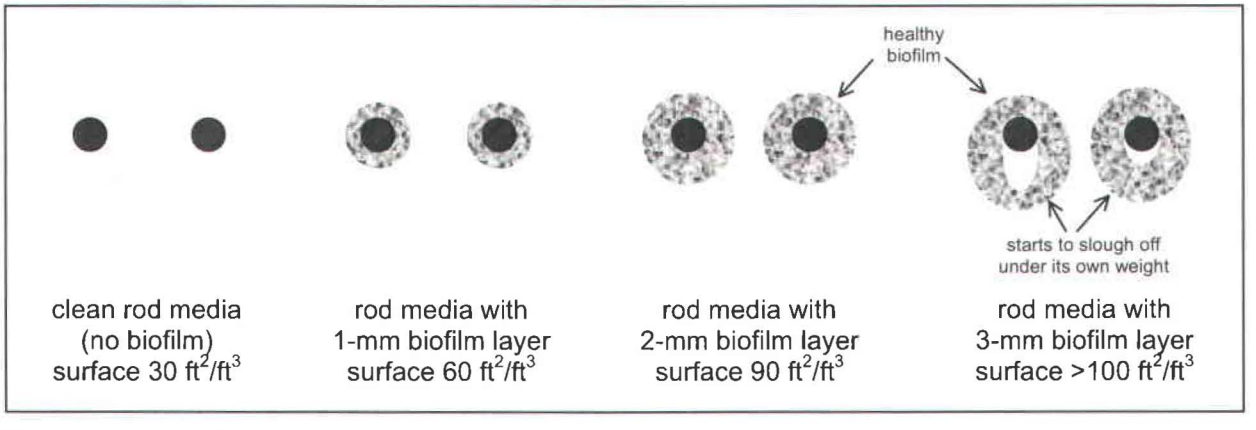
Figure 1. Biofilm Growth on Flat or Extended-Surface Media



When plastic media has extended flat or curved surfaces, the biofilm surface area in contact with the wastewater remains essentially constant as the microbes grow. Chunks of biomass are attached to the media over a wide area, so the biofilm can grow quite thick. Sometimes it won't slough off until microbes at the base of the biofilm die off due to lack of oxygen. When anaerobic conditions develop in the deepest layer of the biofilm, sulfate-reducing bacteria can grow there, producing H_2S gas—and odor complaints.

Figure 2. Biofilm Growth on Rod-Shaped Media



When plastic media consists mainly of small-diameter rods or bars, the biofilm surface area in contact with wastewater increases as the microbes grow. Growing biomass is attached to the media over a limited area of sharply curving surface, so it cannot adhere very firmly and tends to fall off under its own weight before becoming thick enough for anaerobic conditions to develop.

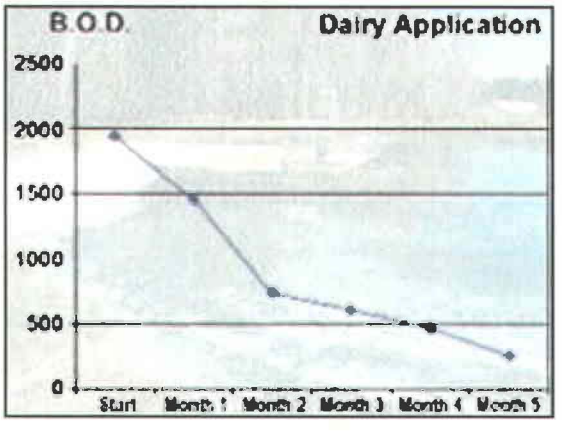
Patented Bioreactor uses Q-PAC Randomly Packed Media and Application-Specific Bacterial Cultures for Treating High Strength Industrial Waste for BOD and Odor Reduction in a Cheese Manufacturing Plant

Jim Hyzy PhD, Microbiologist, Waste Stream Technology,
Volker Hausin, TVT US Corp., and Lantec Products, Inc.

A cheese manufacturer in Upstate New York with one three million gallon lagoon is testing a bioreactor (TVT-BIO 32) from TVT US Corporation. The concept is essentially the same as bacteria eating an oil spill. However, the difference is that the TVT-BIO system is an active one versus other processes, which are passive. The field research goal is to determine how much odor control and BOD reduction can be achieved with this equipment during winter and summer conditions.

The bioreactor is filled with Q-PAC polypropylene packing media, which act as a substrate for biofilm growth. The TVT Bio-Boost System acts as a bioreactor by providing optimum conditions for rapid continuous growth of application specific microbial cultures. Appropriate cultures are combined to act on the target contaminate (high strength waste water).

The bacteria chosen for production are target specific, not pathogenic, and are proven safe. Repeated applications will lead to their dominance, outgrowing indigenous species, including pathogens. The resulting enhancement leads to the rapid breakdown of undesireable BOD and malodorous compounds, converting them to CO_2 and H_2O, thereby decreasing the residual sludge formation by as much as 50%. The bacterial cultures and microbial activity can be tracked throughout the bio-remediation process, and can be correlated with contaminant degradation.



The three million gallon lagoon has two five horsepower splashers operating during the Department of Environmental Conservation (DEC) Summer Permit discharge conditions from May to November. During the summer, the undiluted whey-waste water in the lagoon is drawn down and sprayed onto the adjacent meadow, which is owned by the cheese manufacturer.

One splasher near the discharge pipe into the lagoon has been replaced with the Oxy-BIO-32™ Bioreactor. Within the bioreactor, continuous aeration and re-circulation of the whey-waste-water creates a biofilm on the media, which eat the whey-waste. The Oxy-BIO™ process continually regenerates application specific bacterial cultures at a high rate, which slough off the mature bacteria into the lagoon, thereby also discharging the sludge for constant re-circulation. This enables sludge reduction within the lagoon system.

The round pin-like elements on the Q-PAC media provide a surface geometry on which the constantly thickening biofilm can provide an increasing surface in contact with the waste water. As the biofilm increases in mass, it will eventually slough off the small diameter plastic needles before the biofilm is too thick to facilitate oxygen transfer to the microbes at the plastic-biofilm interface.

The second splasher located at the far end of the lagoon remained for additional continuous aeration and agitation. Typically the lagoon establishes an active dark green algae population during summer operations. During winter operations, the capacity of the lagoon allows for no discharge until next summer season.

The whey collection tank in the factory has fluctuating BOD loadings from 3,860 up to 10,600. In 1999 the pH in the collection tank ranged from 9.8 up to 11.6. At this range no microbiology exists. The periodic, undiluted discharge from the tank into the lagoon averaged 6,000 GPD. During winter operations the lagoon has no aeration treatment as is completely covered by ice. Aeration treatment startup in Spring regularly created odor until sufficient aeration has transferred oxygen into the whey-waste treatment lagoon.

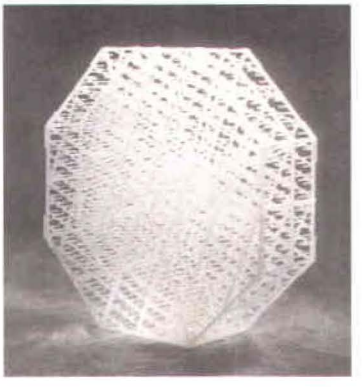
The TVT-BIO 32 was installed on February 26, 1999 and field commissioned on March 8, 1999. The initial lab tests from Waste Stream Technology yielded the following grab sample from the lagoon: BOD at 1,950, oil and grease at 71.5, pH at 6.22, and a lagoon temperature of 34°F.

As the warmer weather comes to Upstate New York, the severe but typical odor problem develops. The TVT Bio 32 Bioreactor's enhanced the oxygen transfer into the lagoon waste water until July 2nd (summertime in New York). Not only were all odors absent but the third party independent laboratory tests showed a 90% reduction in BOD levels.

The lab tests from July 2nd, 1999 show: BOD of 463, oil and grease of 11.5, and a pH of 7.71 at the TVT-BIO 32 location in the lagoon (see chart on front). The final lab test on July 21 showed BOD of 251.

The initial result of the TVT-BIO 32 Bioreactor is the reduction of the ice cover in the lagoon by two thirds, and odor removal (Oxygen transfer) started even during cold water temperatures. Under the previous year's lagoon operations, when the ice cover had melted, and two five horsepower splashers had been re-installed in May, odor would persist for several weeks. For the first time during the operation of this lagoon, with the new system, there was no odor.

On April 5th, 1999 the temperatures in the lagoon exceeded 55°F and TVT augmented 100 pounds of Application Specific Bacteria for the lagoon, based on the recommendation from Dr. Jim Hyzy. Another 50 pounds during May, and a final 50 pounds were added in June to establish application specific dominant bacterial cultures.



Between June 7-11, 1999 it became visible that the dominant existing green algae in the lagoon had been replaced by the application specific bacterial cultures from Waste Steam Technologies and converted the lagoon into a secondary aerated treatment lagoon. The change in color was dramatic. From the first day, a light beige color transformed to a saturated brown activated sludge by the fifth day.

The plastic Q-PAC biofilm substrate has 30 ft^2/ft^3 of round surface area when new. As biofilm builds up on the Q-PAC, the round surfaces of the biofilm in contact with the wastewater increase geometrically with the thickness of the biofilm. This enlarged surface can expand the effective surface of the Q-PAC to 60 to 90 ft^2/ft^3. As the mass of the biofilm increases, it will eventually slough off the Q-PAC elements, aided by the laminar flow streams inside the bioreactor and the action of the air bubbles created by the aeration system.

A by-product of oxygenated, activated, flocculation and activated sludge is retention of valuable solids as fertilizer, which stay within the root zone instead of percolating down into the ground water below.

Conclusion:
The concept of combining oxygen enriched wastewater grown on an extended surface plastic substrate (Q-PAC) in a bioreactor with application specific bacteria increased operational efficiencies in this test up to 73%.

Additional benefits of the TVT-BIO 32 include:

- Installation in existing lagoons without cranes or special equipment.
- Operation with minimum monthly maintenance.
- Controlling nitrification.
- Increasing dissolved oxygen to meet the biological oxygen demand.
- Controlling of odor.
- Controlling of fats, oils, and grease (FOG)
- Improvement of settling ability of the sludge
- Reduction of operational costs.

ATTACHMENT C5

HBHA Pond Aeration Pilot Test Contingency Plan (PDI-15)

DRAFT

Attachment C5 - HBHA Pond Aeration Pilot Test Contingency Plan (PDI-15)

Industri-Plex OU2 Site
Remedial Design Work Plan
Woburn, Massachusetts

In the unlikely event that conditions occur in the upper layer of the water column during PDI-15: HBHA Pond Aeration Pilot Test, such as significant increase in turbidity, arsenic, benzene, or ammonia concentrations, or other deleterious conditions noted in the FSP, the aeration device will be shut down while the conditions are further evaluated and allowed to approach a more stable state. Pending the outcome of the evaluation, PDI-15 may continue. To mitigate the potential for deleterious conditions caused by the test, water quality will be monitored for adverse conditions as described in the FSP. Four potential concerns include:

- Increase in suspended solids
- Sulfide oxidation
- Sediment resuspension
- Ephemeral anoxia

The following subsections describe each of these in more detail, the likelihood these impacts could occur during PDI-15, and contingency measures to be taken in the event they do occur.

A. Increase in Suspended Solids

When dissolved iron and arsenic are exposed to an oxidizing environment, iron (hydr)oxide solids are formed. These solids will be subject to settling and sedimentation. During the start up of the aerator device, oxygen will be incrementally distributed in the water column as described in the FSP. The addition of oxygen could potentially promote the formation of iron (hydr)oxide suspended solids in the water column. It is important to note that once the system is fully operational and the system is performing as intended, we anticipate that arsenic will be sequestered deeper in the water column or near the sediment-surface water interface, and thus suspended solids formation will not likely be of concern.

In an effort to assess the suspended solids formation before the pilot test, a water sample from the anoxic zone (if it exists) will be collected and allowed to oxygenate to evaluate the potential for particulate formation. Such evaluation will be completed prior to PDI-15 field implementation (likely integrated with other ongoing PDIs).

During the pilot test, turbidity in the water column will be monitored at the monitoring stations described in the FSP. The formation of suspended solids results in increased turbidity. To mitigate migration of suspended solids, a silt curtain will be deployed across the southern end of the Pond to act as settling baffle, as shown on Figure 3.1.12.4-1 of the FSP.

B. Sulfide Oxidation with Release of Contaminants

The aeration approach being pilot tested is anticipated to increase oxygen levels in the Pond and create an oxidizing environment that will result in the precipitation of iron (hydr)oxides containing arsenic. Under reducing conditions found in organic-rich sediments, arsenic can also be sequestered via sulfate

reduction and the formation of iron monosulfides. Ford (2005a) has concluded that both reactions are occurring in the Pond and are contributing to arsenic sequestration.

The sediment on the bottom of the Pond represents an anoxic, strongly reducing environment. The iron (hydr)oxides that form in oxidizing environments contain adsorbed arsenic, and settle to the bottom of the Pond (below the chemocline). Due to the reducing conditions below the chemocline, the iron (hydr)oxides will go back into solution and the arsenic will be released and could be re-precipitated as an impurity in iron sulfide(s) that form under sulfate reducing conditions, assuming sufficient sulfur is present.

Generalized equations to represent these reactions are:

- Sulfate reduction: $SO_4^{2-} + 9H^+ + 8e^- = HS^- + 4H_2O$

- Reduction of arsenic-bearing iron (hydr)oxides:
  $Fe(OH)^3$ (solid, with adsorbed arsenic) $+ e^- = Fe^{2+} + 3OH^- +$ As (aq)

- Precipitation sulfides with arsenic:
  $Fe^{2+} + HS^- +$ As (aq) = solid Fe(As, S) $+ H^+$

The arsenic will remain immobilized in the reduced iron sulfide unless these minerals are oxidized, in which case the iron, sulfur, and arsenic may be released to the pore water of the sediments or water column.

Based on this conceptual model from Ford (2005a), sulfide oxidation could theoretically occur during PDI-15 implementation, but should not play a significant role in the fate of arsenic in the Pond. Deeper in the sediments or in an isolated area of the north basin where sulfur is present in sufficient amounts, sulfide deposition plays a role in sequestration of arsenic. Ford observed iron (hydr)oxide deposits existing in the anoxic, reducing, portions of the Pond, counter to the thermodynamic predictions, and cites other cases (Kostka and Luther, 1994) where this phenomenon was observed.

Based on the analysis presented by Ford (2005a), it appears that sulfide formation was limited to the amount of available sulfur and sulfate reduction. As such, sulfide deposition in shallow sediments was focused over a small area in the northeast portion of the Pond. Sulfide deposition may play a larger role deeper within the sediment column. Figure ATT C5-1 (from Ford, 2005a) is a conceptual model that shows the following:

- Iron oxidation and reducing conditions dominate in the water column and shallow sediment

- Sulfate reduction occurs mainly at depth in the sediment column and PDI-15 is not designed or intended to deliver oxygen to these deeper sediments.

Figure ATT C5-2 (derived from Ford, 2005a) shows arsenic enriched in the Pond water below the chemocline relative to sediment pore water (i.e., groundwater). This observation indicates that the arsenic in solution in the anoxic bottom waters is not effectively being sequestered by sulfides, but rather remains in solution until it reaches oxic water near the chemocline. Sulfides do play a role in

sequestering arsenic, but based on Ford's analysis, our mass balance calculations, and the internal cycling that is occurring, it appears that iron oxidation and iron reducing conditions play a more dominant role in controlling the fate of arsenic.

It is believed that the aeration approach being pilot tested will promote oxidizing conditions through a larger portion of the water column and possibly at the sediment-surface water interface. In the same way, this approach would not eliminate sulfide precipitation from occurring, but would cause sulfate reducing conditions to occur deeper in the sediment column.

Although we believe oxidation of sulfides will not result in significant releases of arsenic from the sediment into the water column, dissolved arsenic will be monitored during PDI-15. If, after oxidizing conditions have been established within a greater portion of the Pond water column, there is an increase in arsenic concentrations in the water column, the system will be shut down as described in the FSP and the possible role of sulfide oxidation will be evaluated further.

C. Sediment Resuspension

The SolarBee® aeration equipment operates by drawing in water with dissolved oxygen (DO) levels below saturation from depth, routing the water to the surface through an intake tube, and discharging it to the surface where re-aeration occurs. The SolarBee® aeration device is equipped with an intake plate that promotes lateral inflow of the bottom water and will be set above the sediment-surface water interface at an appropriate distance to avoid scouring sediment near the intake. The final depth of the intake tube will be established in the field, and will be raised if sediment resuspension is observed. In addition, as described in the start-up sequence in the FSP, the intake tubes will be lowered through the water column at staggered intervals to circulate the water column. Time intervals for lowering the intake will be based on water quality monitoring results. Therefore, increases in turbidity that result from sediment resuspension will be observed, and will trigger shutdown of the system. In addition, a silt curtain will be installed during PDI-15 as a supplemental contingency measure.

D. Ephemeral Anoxia during Pilot Start Up

The process of aerating the water column may circulate ammonia-rich water, potentially increasing the nitrogenous oxygen demand (NOD) in the water column associated with nitrification. Therefore, the concern is that once the water column is mixed, the oxygen may be consumed, resulting in ephemeral anoxia that could result in detrimental effects on the lake ecosystem, including fish kills. As described in the pilot start-up sequence in the FSP, the aeration equipment will be started in a sequential manner to reduce abrupt changes to water quality and reduce the potential for pond–wide anoxia. The intake tubes will also be lowered at each location in a phased approach with rigorous monitoring of the water column geochemistry. Lastly, testing is proposed in localized areas of the Pond so that large areas are not affected if the devices change Pond chemistry abruptly. If the water column DO concentration drops below 2 mg/L and persists in the upper 5 ft of the water column, the system will be shut down in accordance with the performance criteria described in Table 3.1.12.7-1 of the FSP. These criteria apply to the upper 5 ft of the water column, as the bottom waters are anoxic under typical current conditions.

REFERENCES

1. Ford, Robert (EPA). 2005. "Field Study of the Fate of Arsenic, Lead, and Zinc at the Ground-Water/Surface-Water Interface," dated December 2005.

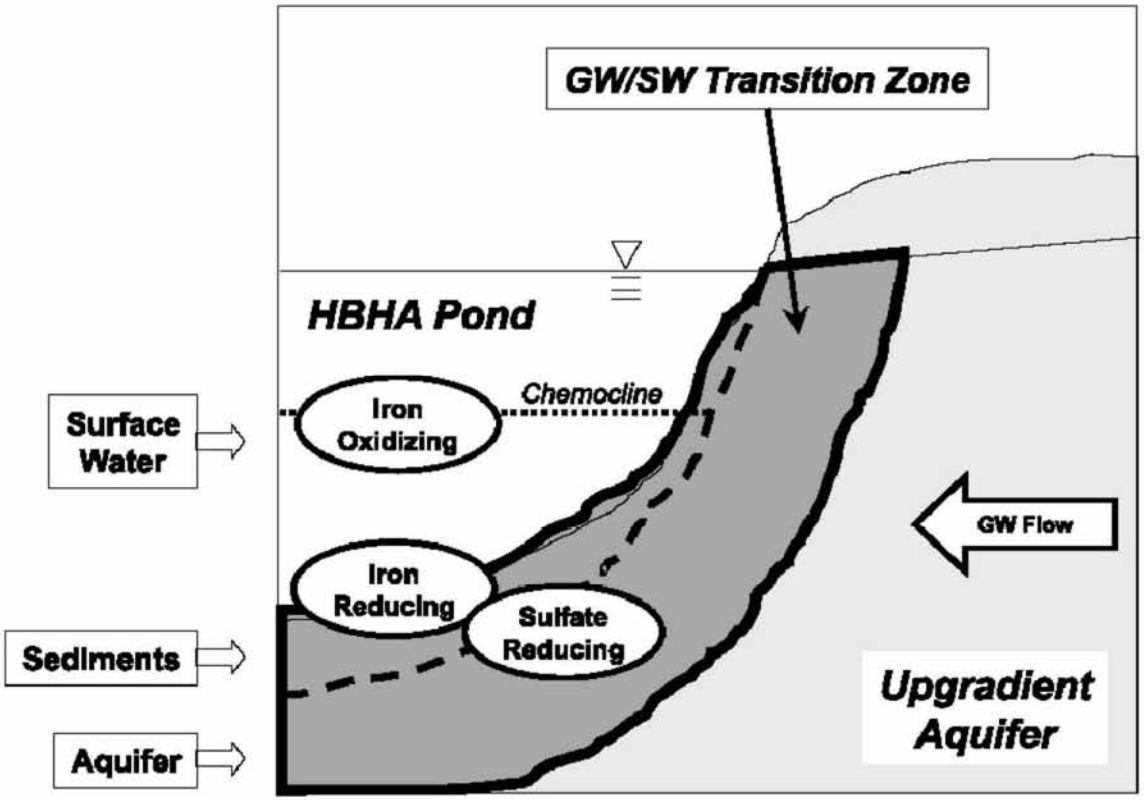
Cited by Ford, 2005:

2. Kostka, J.E., and G.W. Luther III. Partitioning and speciation of solid phase iron in saltmarsh sediments. Geochimica et Cosmochima Acta 56: 1701-1710 (1994).

SUPPLEMENTS

Figure ATT C5-1: PDI-15: Conceptual Model of the Groundwater-Surface Water Transition Zone
Figure ATT C5-2: PDI-15: Water Chemistry Profile at NML Sampling Station

22 March 2010
G:\33020\031\FSP\Revised per EPA_Feb 2010\Attachments\Attach C5_PDI-15\2010-0303-HAI-PDI-15ContingencyAttachment.doc



Iron Oxidizing Zone
Oxidation-precipitation of ferrous iron leading to the production of iron (hydr)oxides that sequester arsenic from solution

Iron Reducing Zone
Reductive dissolution of settling iron (hydr)oxides coupled with release of arsenic to solution

Sulfate Reducing Zone
Precipitation of iron sulfides that sequester a fraction of arsenic derived from ground-water discharge and dissolution of settling iron (hydr)oxides

NOTE:

1. FROM FORD, ROBERT. "FIELD STUDY OF THE FATE OF ARSENIC, LEAD, AND ZINC AT THE GROUND-WATER/SURFACE-WATER INTERFACE," DATED DECEMBER 2005.

DRAFT

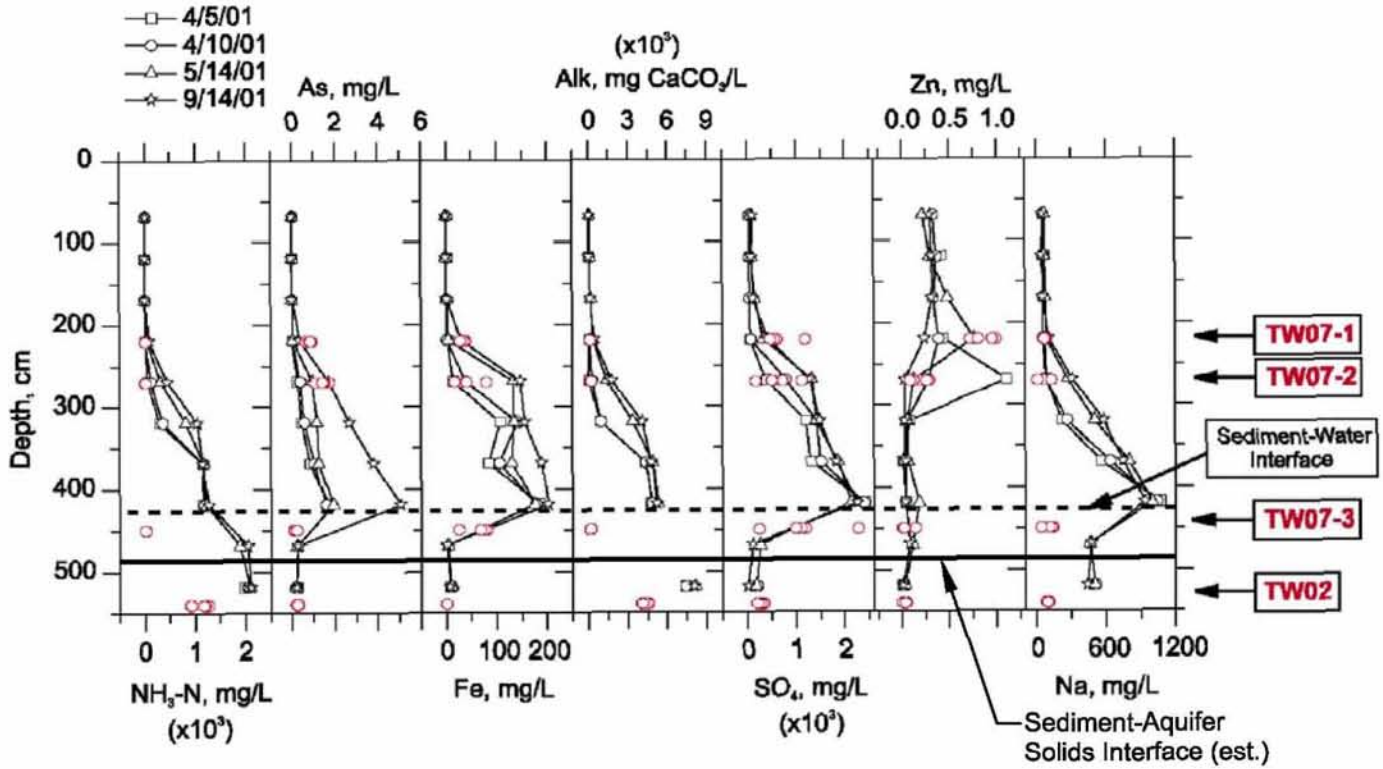
HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-15: CONCEPTUAL MODEL OF THE GROUNDWATER-SURFACE WATER TRANSITION ZONE

SCALE: NONE
MARCH 2010

FIGURE ATT C5-1



Temporal trends in water chemistry for the NML sampling station and adjacent ground-water monitoring locations (TW07 and TW02). NML data are shown as open black symbols connected with lines for multiple sampling dates during the period of April 5, 2001, to September 14, 2001; adjacent ground-water data for locations TW07-1, TW07-2, TW07-3, and TW02 are shown as open red symbols for multiple sampling dates during the period of April 6, 2000, to September 11, 2001. Arsenic data for the NML sampling station are from Ford (2005).

Adapted based on Ford (2004, 2005)

HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PDI-15: WATER CHEMISTRY PROFILE AT NML SAMPLING STATION

DRAFT

SCALE: NONE
MARCH 2010

FIGURE ATT C5-2

DRAFT

ATTACHMENT C6

Screening Level Microcosm Work Plan

ATTACHMENT C6

SCREENING LEVEL MICROCOSM WORK PLAN

Industri-plex Operable Unit 2
Woburn, Massachusetts

Prepared by:

Colorado School of Mines
1500 Illinois Street
Golden, Colorado 80401

Haley & Aldrich, Inc.
465 Medford Street
Boston, Massachusetts 02129

March 2011

Screening Level Microcosm Work Plan:

Pre-Design Investigation

Colorado School of Mines (CSM) will provide support for a portion of the Pre-Design Investigation (PDI) work described in the Remedial Design Work Plan (RDWP) (e.g., PDI-4B), related to evaluating the role of microbial nitrification (aerobic), denitrification (anaerobic), and anammox (anaerobic ammonia oxidation) in the removal of ammonia present in the Halls Brook Holding Area (HBHA) Pond portion of the Industri-plex Superfund Site, Operable Unit (OU) 2 (hereinafter the Pond). The screening level tests proposed in this portion of the PDI are intended to offer insight into the potential microbial conversion of ammonia through metabolic pathways such as aerobic oxidation and the anaerobic ammonia oxidation (anammox) process.

The primary goals of this screening level microcosm study are to:

1. Improve understanding of ammonia transformation such as, but not limited to, adding greater weight of evidence to which processes (nitrification, denitrification and/or anammox) are occurring and the possible rate-limiting reactions.
2. Based on this improved understanding, determine what factors could be detrimental or beneficial to ammonia degradation in the Pond and assess potential methods to overcome limitations to biodegradation and thus establish possible enhancements of such processes and incorporate relevant information into other PDIs and the design of remediation system(s).

The objectives and approach to this microcosm study are further described below.

Introduction

Data collected to date indicates the presence (at high cell counts) of anammox bacteria. In addition, aerobic ammonia oxidizing bacteria (AOB) were also identified at high cell counts. See Appendix A. The presence of bacteria relevant to ammonia transformation provides an initial screening-level assessment of the possible ammonia transformation pathways that may be occurring in the Pond. This microcosm study is designed to build and expand on these data to further ascertain the potential rate-limiting reactions that may be affecting natural transformation processes. This base understanding of the microbial community and its impact on ammonia transformation can be considered in the PDIs described in the RDWP and in the remedy design process, e.g., to assess potential advantages and disadvantage of attempting to enhance one particular pathway (aerobic over anaerobic, or vice versa) through remediation methods.

As described below, it appears that ammonia is being converted to nitrogen gas in the Pond. There is no known <u>single</u> metabolic pathway capable of this transformation. Our proposed conceptual model of ammonia transformation in the pond (outlined below) hypothesizes, based on recent data collected by the Settling Defendants, a potentially complex interaction between metabolic processes occurring at the interface between the hypolimnion and epilimnion portions of the Pond. If this hypothesis is proven, a RD/RA process undertaken without any general understanding of this interaction runs the risk of reducing, rather than enhancing, the effectiveness with which the Pond attenuates ammonia. However, other than the indirect evidence of bacterial counts and ammonia and nitrate concentration profiles, there is no direct evidence to support this belief. Due to the unique chemical conditions in the Pond, it is possible that an alternate metabolism, such as anaerobic oxidation of ammonia using sulfate as an electron acceptor, is occurring in concert with the processes of nitrification, denitrification and anammox. By performing the proposed experiments in a carefully controlled manner, mass balances on nitrogen will provide insight into the processes occurring in the Pond.

Based on gross mass balance calculations, it appears that ammonia is being removed (converted to di-nitrogen gas) in the Pond, either above, below, or at the chemocline, or in some combination of these compartments. This conversion is likely accomplished via several microbial metabolic pathways. In aerobic environments certain consortiums of bacteria are capable of oxidizing ammonia to nitrate [ammonia oxidizing bacteria (AOB), aka nitrifiers], utilizing inorganic carbon (e.g., HCO_3^-) as a carbon source. This occurs in two steps; one group of bacteria (i.e., nitroso-bacteria) oxidizes the ammonia to nitrite (NO_2^-) and a separate group (nitro-bacteria) oxidizes the nitrite to nitrate (NO_3^-). The overall stoichiometry is approximated by the following equation:

$$NH_4^+ + 1.83\ O_2 + 1.98\ HCO_3^- \Rightarrow 0.021\ C_5H_7NO_2 + 0.98\ NO_3^- + 1.04\ H_2O + 1.88\ H_2CO_3 \quad (1)$$

(Ahn 2006)

where $C_5H_7O_2N$ represents bacteria cell mass. Because nitrate is not accumulating in the Pond, other processes must be occurring in combination with AOB. One possibility is an anaerobic process referred to as denitrification, where a consortium of bacteria (e.g., from the genera of *Pseudomonas, Alcaligenes, Bacillus, Agrobacterium, etc.*) convert nitrate to nitrogen gas in a two-step process:

$$NO_3^- \Rightarrow NO_2^- \Rightarrow N_{2(g)}$$

A representative overall stoichiometry is shown in the following equation:

$$NO_3^- + 1.08\ CH_3OH + 0.24H^+ \Rightarrow 0.056\ C_5H_7O_2N + 0.47\ N_{2(g)} + 1.68\ H_2O + 0.76\ HCO_3^- \quad (2)$$

(Ahn 2006)

Data collected to date in the Pond shows the presence in high cell counts of a type of bacteria capable of ammonia transformation anaerobically (anammox, through quantitative PCR analyses). This data suggests that another possible pathway of significance, specifically anaerobic ammonia oxidation (anammox), may be occurring in the Pond, converting ammonia and nitrite to nitrogen gas and nitrate as shown in the following equation:

$$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+ \Rightarrow$$
$$1.02\ N_2 + 0.26\ NO_3^- + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O \quad (3)$$

where $CH_2O_{0.5}N_{0.15}$ is a different formulation for bacterial cell mass (Kuenen 2008). Bacteria species known to perform anammox have been detected in the Pond at high cell/gene concentrations (Haley & Aldrich, 2009; see Attachment A); it is likely that the anammox process is occurring in the Pond[1]. Ammonia oxidizing bacteria have also been detected in the Pond indicating that both processes are likely occurring simultaneously. It is also possible that denitrification is occurring. In fact, because the anammox process is typically dependent on a source of nitrite, the first steps of nitrification or denitrification must be occurring if a nitrite-dependent pathway is active and dominant. Additionally, because nitrate is a product of both nitrification and anammox, but is not accumulating in the Pond, denitrification must be occurring.

[1] As noted above, one of the primary goals of this study is to further improve the understanding of ammonia transformation. To this end, the microcosm study is intended to supplement the genetic data, which provides a gross cell/gene concentration that could include dead cells, and provide a more direct indication of the active transformation process(es) for ammonia in the Pond.

The concurrent occurrence of multiple microbial nitrogen metabolic pathways has been documented. Sliekers et al. (2002) have demonstrated ammonia removal under oxygen-limited conditions in a reactor dominated by two groups of bacteria. One group (*Nitrosomonas* species) oxidized ammonia to nitrite and planctomycete-like organisms were simultaneously converting ammonia and nitrite to nitrogen gas and nitrate. No aerobic nitrite oxidizers were detected in the oxygen-limited environment indicating the anammox process consumed the nitrite formed by the AOB. This process has been patented and called the CANON process (completely autotrophic nitrogen removal over nitrite). Going one step further, Chen et al. (2009), observed aerobic ammonia oxidation, anammox and anaerobic denitrification ($NO_3^- \Rightarrow NO_2^- \Rightarrow N_{2(g)}$) occurring simultaneously in a bioreactor fed with ammonia, organic carbon and limited amounts of oxygen (DO = 0.5 – 0.7 mg/L). The bioreactor removed both nitrogen and organic matter and they called the process "simultaneous partial nitrification, anammox and denitrification" (SNAD).

The main purpose of this bench scale study is to add more weight of evidence regarding the three processes – nitrification, denitrification and anammox – occurring in the Pond, and through the experimental design understand the interaction between these processes and investigate which of them may be rate limiting. The conceptual model of the Pond that was considered when designing this microcosm study is illustrated on Figure 1 (attached).

Figure 1 includes depth profiles of ammonia, dissolved oxygen, nitrite and nitrate and the proposed nitrogen metabolic pathways that would produce such profiles. The chemical profiles indicate that the region surrounding the chemocline is host to nitrification, denitrification and possibly anammox. Products of nitrification (nitrite and/or nitrate) feed into the anammox and denitrification pathways and the nitrate produced by anammox would feed the denitrification cycle. The previous detection of anammox bacteria in the Pond adds evidence that anammox is occurring. The detections of ammonia oxidizing bacteria add evidence of aerobic ammonia oxidation.

This study is designed to build on the existing data showing presence of relevant ammonia transforming bacteria in high cell counts (the Early Action genetic work) to further evaluate the potential rate-limiting process so that further PDI studies, including those conducted directly in and/or with water recirculated from/to the Pond (e.g., PDI-5: Tank Treatability Studies), could build upon the results from the Early Action genetic work and this microcosm work. Failure to fully understand the processes at work in the Pond could result in pond remediation efforts that upset the balance of interacting metabolic pathways that we currently believe are removing nitrogen, and that result in a process that is less satisfactory than the current situation.

To evaluate the nitrogen removal processes occurring in the Pond, we propose to perform three classes of microcosm experiments using water (and sediment in select experiments) from the Pond that will simulate the three main compartments of the Pond; 1) the upper aerobic section, 2) chemocline, and 3) lower anoxic/anaerobic section.

Class 1: Aerobic. Purpose: Determine if the epilimnion[2] portion (above the chemocline) of the Pond is conducive (proper conditions and organisms) to nitrification. One set of microcosms (one condition, two replicates) will utilize water collected from above the chemocline containing 5 - 6 mg/L ammonia on average, which is typical of the ambient average ammonia concentration in this vertical interval (if samples do not contain ammonia when received, they will be amended with approximately 5 mg/L ammonia). When and if the ammonia concentrations subsequently drop below 0.5 mg/L, the microcosms will be amended with 20 mg/L ammonia to verify that ammonia is being oxidized to nitrite and/or nitrate

[2] For brevity, the term "epilimnion" is operationally defined as the portion of the water column above the chemocline, whereas the "hypolimnion" is operationally defined as the portion of the water column below the chemocline.

and to more closely simulate the interface between the epilimnion and the chemocline, where the ammonia concentrations are higher. These microcosms will be maintained in an aerobic condition.

Class 2: Anoxic/Anaerobic. Purpose: Determine if the hypolimnion (below the chemocline) portion of the Pond is conducive (proper conditions and organisms) to denitrification and/or anammox. Four experimental conditions (as described below), will be set up to simulate conditions below the chemocline in the Pond to determine the potential metabolic pathways that can occur. Conditions 2 and 3 will be set up both with and without sediment as an inoculum source, using duplicates in each instance.

Condition 1: This portion of the microcosm study will be conducted with water collected below the chemocline (i.e., hypolimnion water) and pond sediment and will be kept anaerobic. This set of microcosms will be used to determine if ammonia transformations are occurring in the anaerobic portion of the Pond, independent of interactions with the chemocline. Condition 1 will also serve as a control for Conditions 2 to 4 described below.

Because anammox requires nitrite and there will be no source of nitrite in the anaerobic microcosms (in the Pond, nitrite could diffuse from the epilimnion/chemocline interface to the chemocline/hypolimnion interface), nitrite and nitrate will be added to the Condition 2 and 3 microcosms (respectively) to determine if anammox could occur.

Condition 2: This portion of the microcosm study will be performed with hypolimnion water and pond sediment, and will be amended with nitrite. If the nitrite is consumed but the ammonia level stays constant, only denitrification is likely occurring. However, if both nitrite and ammonia decrease, anammox is most likely occurring. Nitrogen mass balance calculations will be performed to apportion nitrogen conversion between denitrification and anammox because each pathway has a unique stoichiometry. This condition will be duplicated in a set of microcosms that will not be inoculated with sediment.

Condition 3: This study will be performed using hypolimnion water and pond sediment that are amended with nitrate. If the nitrate is consumed but the ammonia level stays constant, only denitrification is likely occurring. However, if both nitrate and ammonia decrease, both partial denitrification and anammox are most likely occurring. Again, nitrogen mass balance calculations will be performed to apportion between denitrification and anammox. This condition will be duplicated in a set of microcosms that will not be inoculated with sediment.

Condition 4: This set of microcosms will be performed using hypolimnion water, pond sediment and amended with additional sulfate (circa 500 mg/L) and will be kept anaerobic. The added sulfate will test whether sulfate may be acting as an electron acceptor driving ammonia removal via the anammox pathway. Sulfate has been proposed (but not proven) as a potential electron acceptor for the anammox process (F. Fdz-Polanco et al. 2001). Sulfate has been observed below the chemocline at concentrations ranging up to 2,200 mg/L (Haley & Aldrich; RM-1 on 3 November 2009 monitoring event). Amending the microcosm with more sulfate is designed to identify the effect, if any, of this constituent.

The total microcosm (bottle) count for the Class 2 experiments will be 12: this count includes duplicates, as well as performing Class 2, Condition 2 and 3 both with and without sediment inoculum. The following is a brief discussion of our sediment inoculum philosophy. To increase the likelihood that we

have a representative and viable consortium, Class 2 microcosms include testing with sediment included in the bottles. Sampling of the water column may miss key components of the microbial community due to mixing in the water column (induced by the sampling or of natural causes) or unrepresentative sample collection. Additionally, the stress of sampling and shipping (unintended introduction of oxygen, temperature changes, starvation, etc.) may adversely affect the microbial population of the water column. Sediment samples are considerably more robust in terms of microbial survival (e.g., even autoclaving does not ensure the sterility of a sediment sample). Microorganisms from the sediment are likely to be continuously introduced into the water column by the groundwater flow. It is unlikely that there are organisms in the sediment that have not been introduced to the overlying water in the Pond. Notwithstanding these considerations, Class 2, Conditions 2 and 3 described above will be replicated without sediment to address concerns expressed by EPA.

Chemocline processes:

It is unlikely that processes in the hypolimnion and epilimnion (below and above the chemocline, respectively) are occurring independently of each other. If only aerobic ammonia oxidation was occurring, nitrate would accumulate. However, analytical data indicates nitrate is not accumulating. Denitrification is unlikely to occur in the isolated hypolimnion water below the chemocline because there is no source of nitrate. Diffusional processes are likely providing nitrate from the upper zones to the lower zones of the Pond, however this is most likely occurring in a fairly narrow zone centered around the chemocline. Likewise, denitrification and/or anammox are unlikely to occur in the isolated hypolimnion water because there is no source of nitrate and nitrite. One qualification to this statement is the proposition that sulfate can act as a potential electron acceptor for the anammox process as noted above.

Dissolved oxygen and ammonia profiles from the Pond suggest that the interface (chemocline) between the epilimnion and the hypolimnion is the site of active ammonia conversion. Nitrite and nitrate production in the epilimnion could feed anammox and/or denitrification in the hypolimnion. Kuenen (2008) hypothesizes that this could occur not only in specialized bioreactors but also in natural environments such as stratified water bodies. To test this proposition, we propose to initiate a third class of microcosms.

Class 3: Microaerophilic. Purpose: Determine if the chemocline portion of the Pond is conducive (proper conditions and organisms) to nitrification, denitrification and/or anammox. Three sets (three conditions, two replicates each) of microcosms will be set up to simulate conditions in the chemocline portion of the Pond to determine the potential metabolic pathways that can occur. This portion of the microcosm study will be performed using water collected from the chemocline (inoculated with 20 mL of epilimnion water and 20 mL of hypolimnion water to ensure all requisite microbial species are present) and will be fed with limited quantities of oxygen to simulate the chemocline environment. If the resulting mixture has an ammonia concentration less than 100 mg/L (the approximate average concentration of ammonia observed proximate to the chemocline), additional ammonia will be added to bring the concentration up to 100 mg/L. If the water collected from the chemocline has more than 100 mg/L, it will be diluted with water collected above the chemocline to reach the targeted concentration. To test the capacity of the chemocline to convert ammonia at the higher concentrations, additional ammonia will be added to a set of microcosms to bring the concentration up to 450 mg/L, which is approximately the average for the hypolimnion. Average ammonia concentration from the North Station above the chemocline is estimated at 6.4 mg/L, while average ammonia concentration below the chemocline is 453 mg/L (Haley & Aldrich data collected through December 2009).

The amount of oxygen added to these microcosms will be the amount necessary to oxidize approximately one-half of the ammonia present to nitrite or about 1.3 mg of O_2 for every mg of NH_4^+ present in each microcosm. This should supply enough nitrite to allow anammox to remove 75% of the remaining

ammonia. The oxygen will be added to the headspace of the microcosms (relying on diffusion for mass transfer between the gas and liquid phase) over the two-month period that the microcosms are operated so that oxygen levels in the microcosms do not exceed 0.5 mg/L and anammox is not inhibited. It is possible that oxygen will be consumed by microbial processes other than nitrification (e.g., oxidation of organic carbon) so that the above amounts of oxygen are insufficient to drive substantial nitrogen conversion. Oxygen and nitrogen levels will be monitored during the test and oxygen feed rates will be adjusted if necessary.

If the hypothesis that oxygen from above the chemocline drives the nitrogen removal process is correct, the rate of nitrogen removal in these microcosms should be related to the oxygen flux. This will be tested by operating two sets of Class 3 microcosms containing 100 mg/L ammonia at two different oxygen flux rates. If it is verified that the ammonia removal rate is dependent on the oxygen flux, the ammonia removal rate in the Pond could be estimated by calculating the flux of oxygen into the Pond, which in turn could be used to support the design of an appropriate remedy for ammonia removal.

The frequency of oxygen additions will depend on how quickly oxygen is consumed. Initially enough oxygen will be added to bring the aqueous DO concentration up to 0.5 mg/L. For the high oxygen rate microcosms (Class 3, Conditions 1 and 3), when the oxygen level drops below 0.1 mg/L, enough oxygen will be added to bring the level back up to 0.5 mg/L. For the low oxygen rate (Class 3, Condition 2), oxygen will be added at one-third the rate as in the high rate microcosms.

To summarize, there will be three Class 3 conditions; all done in duplicate for a total of six Class 3 microcosms.

Condition 1: Low ammonia, high oxygen rate
Condition 2: Low ammonia, low oxygen rate
Condition 3: High ammonia, high oxygen rate

Because the chemical profiles suggest that the bulk of the microbial activity is taking place in the area surrounding the chemocline, a sample of water from the chemocline interface will be collected and used to inoculate the Class 3 microcosms to increase the likelihood that a representative consortium of microorganisms will be present in these microcosms.

Nitrogen balances will be calculated by measuring ammonia, nitrite, nitrate and TN (organic nitrogen + ammonia, nitrate and nitrite) in all of the microcosms. Nitrogen gas will be measured in all of the microcosms except those in the Class 1 experiments. It will not be possible to measure the production of nitrogen gas in the Class 1 microcosms because they will be open to the atmosphere. The nitrogen, oxygen and carbon mass balances should enable us to allocate nitrogen conversion to the three pathways shown in equations 1–3. For example, if more than 50% of the ammonia in the Class 3 microcosms is transformed (given that enough oxygen is added (and consumed) to oxidize 50% of the ammonia to nitrite), we anticipate being able to deduce that anammox is occurring. The process of appropriating nitrogen to the different metabolic pathways will be accomplished by solving the mass balances on equations 1-3 simultaneously (Equations 1 and 2 will be defined in two steps so that the nitrite balance is explicitly defined). However, as mentioned above, if oxygen is being consumed in microbial mediated aerobic organic carbon oxidation (which produces inorganic carbon), there may not be a unique solution to the mass balances. This is the reason that the Class 2, Condition 2 and 3 microcosms are included.

Experimental Setup

The microcosm experiments will be conducted in glass serum bottles with a nominal volume of 1,150 mL to accommodate sampling requirements. Each condition will be run in duplicate. One liter of pond water from the appropriate compartment of the Pond will be added to each microcosm. Pond water for the initial

microcosm will be collected during the spring/summer timeframe to represent warmer water conditions. The elevation of the chemocline varies with pond conditions, and sampling depth will influence what active microbial populations are collected to evaluate degradation/transformation processes in laboratory microcosms. The position of the chemocline will be identified immediately prior to water sample collection by vertical profiling with a YSI sonde (or similar instrument; collect data on DO, temperature, pH, specific conductance, ORP) in order to insure that sample collection targets the desired depth. If necessary, an additional microcosm may be performed with water representing colder water conditions collected during the fall/winter time-frame. Five (5) grams of pond sediment will be added to the appropriate microcosms (see description above). Sterile (autoclaved and added sodium azide) controls will be included to monitor for abiotic ammonia conversion or loss. The microcosms will be incubated at a temperature that is representative of the Pond. The Class 2 and 3 microcosms will be flushed with argon gas and sealed with butyl rubber stoppers to prevent subsequent gas transfer. The Class 1 microcosms will be capped with a capillary tube to allow gas transfer in a manner that will minimize evaporation of the water in the microcosms. Class 1 and 3 microcosms will be mixed on an orbital shaker. Class 2 microcosms will be mixed by manual shaking once a day for the first week and then at decreasing intervals.

Liquid and gas samples will be withdrawn from the microcosms for analyses using a syringe needle so that the appropriate conditions will be maintained in the microcosms (e.g., microaerophilic, anaerobic).

Process Parameters

This section will define the operational parameters for the microcosm work and the rationale behind each of the parameters.

- *Water quality:* To determine the preferred conditions for the anammox transformation pathway, two water quality conditions and two oxygen flux scenarios will be evaluated in the Class 3 microcosms. Water quality conditions will be established at 100 mg/L and 450 mg/L ammonia. The average ammonia concentration at RM-1 above the chemocline is 6.4 mg/L, while the average ammonia concentration below the chemocline is 453 mg/L (Haley & Aldrich data collected through December 2009).

- *Evaluation time frame:* The anammox pathway is expected to require longer retention times than aerobic biological process, therefore assessment of ammonia transformation pathways in microcosms will utilize a total evaluation period of 8 weeks.

- *Oxygen flux:* Oxygen flux into the microcosms will be controlled by injecting oxygen directly into the headspace. Anammox is favored under low dissolved oxygen concentration. A headspace oxygen concentration ≤ 1% will limit the dissolved oxygen concentration to < 0.5 mg/L.

- *Temperature:* Chemical data suggests ammonia transformation may be occurring in the vicinity of the chemocline, therefore all three classes of microcosms will be conducted at a temperature that is representative of the chemocline. Specifically, operating the microcosms at a temperature representative of average summer conditions near the chemocline (~15 C).

Sampling

Water analyses shall be performed at the following times:

- *Initial Basis:* Each microcosm will be sampled and analyzed when it is started to provide an assessment of baseline water quality and initial conditions for each test.

- *Periodic time intervals:* Liquid and gas samples will be taken from each microcosm to measure the net change in the microcosms relative to the baseline conditions.

Sampling time intervals will be an initial basis sampling plus five (5) periodic sampling events at elapsed times of 3 days, 1, 2, 4, and 8 weeks, for a total of six (6) events. The parameters that will be measured during each sampling event are outlined below.

Chemical Analysis

The following parameters will be measured:

- Conventional (Real-time) Parameters:
  - pH - EPA 150.1 (every sampling period)
  - Temperature – NIST traceable glass thermometer (every sampling period)
  - Oxidation-Reduction Potential (ORP) - Standard Methods for the Examination of Water and Wastewater (Section 2580 B) (first, fourth and last sampling periods)
  - DO –measured with a Hansatech Oxyview meter using a Clark type oxygen electrode disk (first, fourth and last sampling periods). Where appropriate, additional DO measurements more frequent than the sampling events noted above will be made in select microcosms to verify certain thresholds are maintained.

- Laboratory Analytical Parameters:
  - Ammonia/ammonium** HACH Method 10031 (every sampling period)
  - Nitrite** HACH Method 10019 (every sampling period)
  - Nitrate** HACH Method 10020 (every sampling period)
  - TN (total nitrogen) – HACH Persulfate Digestion Method 10072 (every sampling period)
  - Ferrous iron HACH Method 8112 (first and last sampling periods)
  - Total Organic Carbon (TOC) – measured on Shimadzu TOC 5000 calibrated with purchased TOC standards (first, fourth and last sampling periods)
  - Total Inorganic Carbon (TIC) - measured on Shimadzu TOC 5000 calibrated with prepared TIC standards (first, fourth and last sampling periods)
  - ICP analysis for metals (As, Fe, Mg, Mn, P, and S) (first and last sampling periods)
  - IC for sulfate and phosphate – based on EPA method 300.1 (first and last sampling periods)

Note: the high salinity and DOC content of the water may interfere with some measurements. Attachment B includes a description of CSM's standard operating procedures (SOPs) for the listed analyses.

The parameters noted with ** are key parameters that will be submitted for confirmation at a frequency of one sample to Alpha per ten analyzed by CSM (Alpha is the commercial lab used in other PDIs). Given that the experiments will be starting with at least 100 mg/L ammonia, the following acceptance criteria should be achievable and still ensure the data is of sufficient quality for the purposes of this study. The following confirmation sample acceptance criteria will be used to evaluate samples analyzed at Alpha:

- ammonia: < +/- 5.0 mg/L or RDP < 30%, whichever is greater
- nitrite: < +/- 0.1 mg/L or RDP < 30%, whichever is greater
- nitrate: < +/- 1.0 mg/L or RDP < 30%, whichever is greater

Supplemental Chemical Analysis

While not the focus of this Microcosm Work Plan, arsenic (dissolved and total) and benzene will be analyzed in select samples. More specifically, benzene will be measured during the following events:

1. At the time of sampling in the HBHA Pond
2. When received by CSM (to measure potential losses in transit, if any)
3. At the conclusion of the test

For events 1 and 2 above, benzene sampling will involve pulling an aliquot from water representing the three zones/compartments (below the chemocline, above the chemocline, and at the chemocline) shipped in large sample containers (three samples per event, for a total of six from Events 1 and 2). For Event 3, one sample will be collected from one of the bottles in each microcosm class (a total of three samples), i.e., one from each of the three microcosm classes (Class 1, 2, and 3). In total, nine samples will be submitted for benzene analysis at Alpha.

Arsenic (total and dissolved) will be analyzed by CSM from the first and last sampling event from each microcosm as described above.

Gas Testing

In addition, gas samples shall be taken from the headspace in the microcosms at the 2, 4 and 8-week sampling events. These gas samples will be analyzed with a gas chromatograph to assess the production of carbon dioxide, methane and nitrogen gas species.

Test Sequence and Phases

While it is difficult to predict the amount of time required for a biological system to be established, time frames are estimated to provide an overview of the testing procedure, and thus may be adjusted accordingly.

Biological Analytical Parameters

Additional supporting information regarding the microbial community will be performed on select microcosms by Haley & Aldrich's subcontracted laboratory. Specific analyses include using qPCR for functional genes related to AOB and anaerobic ammonia oxidation bacteria (anammox) for qualitative comparison of the microbial community, and total 16SrDNA which provides an estimated quantity of total cells. Samples for the above mentioned parameters will be collected from all microcosm bottles, but microbial analyses will be performed only on the microcosms where the geochemical data warrants.

Quality Assurance and Data Quality Objectives

The primary component of this microcosm work plan includes collection of data from test vessels containing water representing various redox compartments in the Pond to identify the ammonia fate and transformation pathway(s) and identify possible rate limiting steps.

The key decision will be evaluated by collecting the following information:

- Identification of the ammonia transformation pathway by compartment using various analytical tests to determine which pathways are involved in ammonia transformation.

The limits on decision errors for this study include the following:

- ***Type I decision error (false rejection error):***

  Conclude through testing that ammonia transformation is occurring through one particular pathway, when in fact it may not be occurring through that pathway to a measurable degree.

  Minimize the potential for above error by optimizing the field sampling design and utilizing input from expert subcontractors:
  - Ensure microcosms are prepared and maintained according to directions and standard practice
  - Ensure that personnel performing microcosm study, including associated analytical testing, follow appropriate procedures and personnel are properly trained in those procedures
  - Verify bench-scale microcosms are performed consistent with the approved design and procedures

- ***Type II decision error (false acceptance error):***

  Conclude through testing that a particular ammonia transformation pathway is occurring through one particular pathway, when in fact it is not.

Minimize the potential for above errors by optimizing field sampling design, utilizing input from expert subcontractors, checking microcosm set-up, and verify procedures and qualifications of personnel performing key tests.

Method to optimize the design for obtaining data will include:

- Obtain field test data in accordance with the field sampling plan (FSP) and this work plan; double-check sampling devices and sample containers to ensure they are appropriate for the samples
- Conduct bench-scale tests with adequate number of duplicate samples, controls, and use of blanks

In addition to the above measures to optimize data collection via the microcosm, analytical work to support the microcosm will comply with relevant portions of the project Quality Assurance Project Plan (QAPP) submitted with the RDWP (22 March 2010). For example, QAQC testing includes:

1. Calibration
2. Check Standards
3. Result (for each sample run)
4. Blank
5. 1 in 20 samples will include a matrix spike where appropriate (see SOP). The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.
6. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run.
7. Second party confirmation for select key parameters for nitrogen balance noted in the text above is to be performed at a frequency of 10% of the samples analyzed by CSM (i.e., 1 in 10 samples).
8. Check standards will be procured from a certified EPA vendor where appropriate (see SOP). In general, if analysis of check standards is greater than 15% from the expected value, the cause will be investigated and rectified.

In addition, the analytical methods to be performed by CSM will be tested with Pond water before the microcosms are initiated to ensure there are no artifacts associated with matrix interference effects. Aliquots (0.5 L) of epilimnion and hypolimnion water will be shipped to CSM prior to collection of the Pond samples that will be used in the microcosm experiments. Using these pre-microcosm samples, CSM will analyze background levels and matrix spikes of ammonia, nitrate, nitrite, total nitrogen, ferrous iron, sulfate, phosphate, TOC, TIC and trace metals (Fe, As, S, Mg, Mn with the ICP-AES) to ensure the proposed analytical methods are appropriate. These measurements will be made in duplicate; the matrix spike recoveries shall be within 75-125% and the RPDs shall be ≤ 20%. If not, the cause will be investigated and rectified.

Attachments

Figure 1	Nitrogen Cycling Conceptual Model Proximate To HBHA Pond Chemocline
Attachment A	4 November 2009 Comparison of February 2009 and September 2009 Microbial Sampling of HBHA
Attachment B	Standard Operating Procedures related to Colorado School of Mines Analytical Work

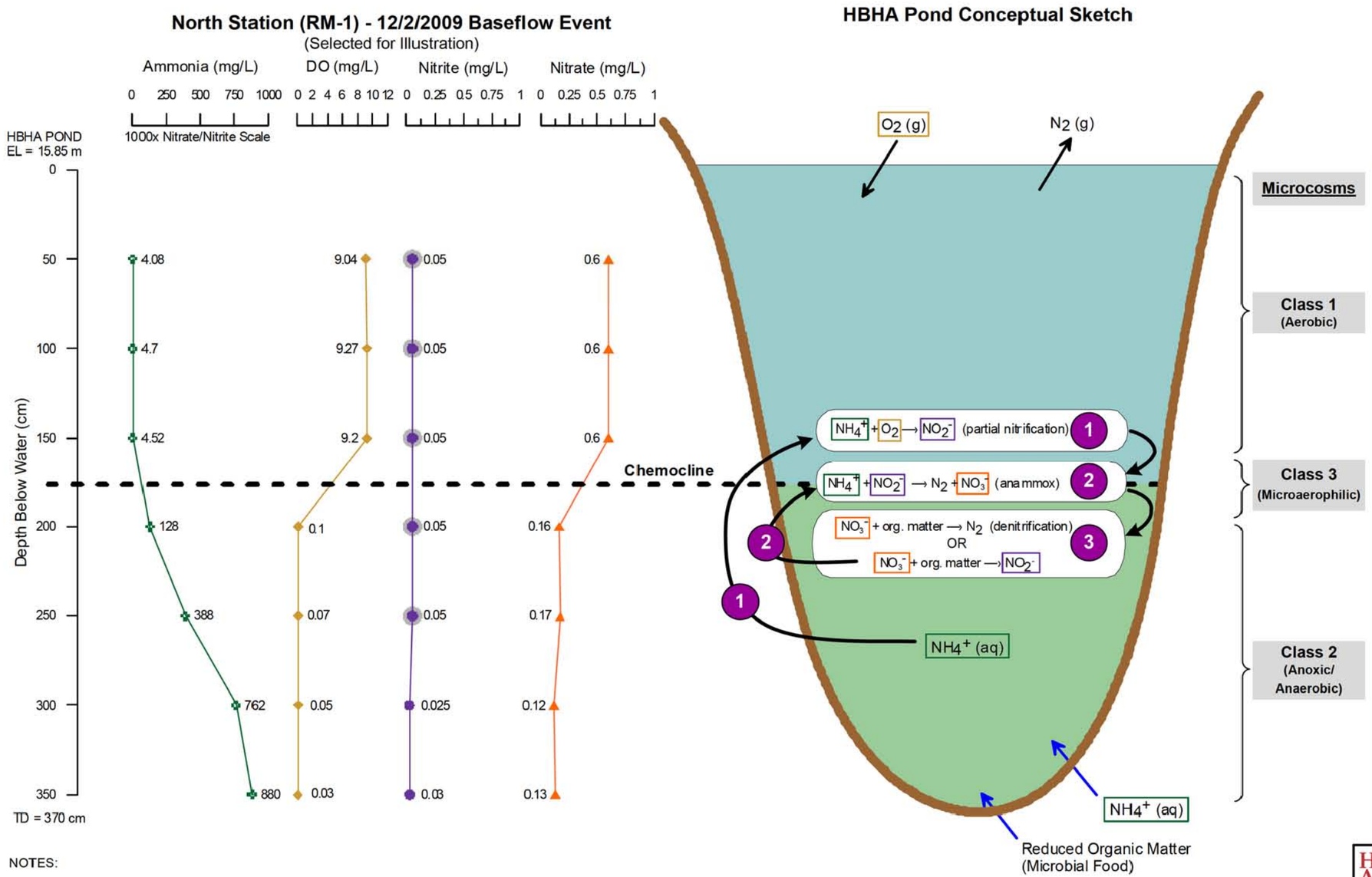
REFERENCES

1. Chen, H. et al., 2009. The development of simultaneous partial nitrification, ANAMMOX and denitrification (SNAD) process in a single reactor for nitrogen removal. *Bioresource Technology*, 100(4), 1548-1554.
2. Fdz-Polanco, F. et al., 2001. New process for simultaneous removal of nitrogen and sulphur under anaerobic conditions. *Water Research*, 35(4), 1111-1114.
3. Haley & Aldrich, 2009. HBHA Microbial Technical Results Memos February 23, 2009 and November 3, 2009.
4. Kuenen, J.G., 2008. Anammox bacteria: from discovery to application. *Nat Rev Micro*, 6(4), 320-326.
5. Sliekers, A.O. et al., 2002. Completely autotrophic nitrogen removal over nitrite in one single reactor. *Water Research*, 36(10), 2475-2482.

Figure 1

Nitrogen Cycling Conceptual Model Proximate to HBHA Pond Chemocline

Conceptual Model: Conceptual model of ammonia transformation in the HBHA Pond. Depth profiles of ammonia, dissolved oxygen, nitrite and nitrate in the Pond indicate that the majority of ammonia transformation is occurring at and immediately below the chemocline. The proposed nitrogen metabolic pathways that would produce such profiles are as follows:



"Near" Chemocline Processes

1. NH_4^+ diffusing toward zone above the chemocline drives partial nitrification (oxidation) of NH_4^+ to NO_2^-

   Ammonia diffusing from the bottom of the pond to the chemocline where oxygen is present drives partial nitrification, converting ammonia to nitrite

2. NH_4^+ & NO_2^- drives anammox

   In the presence of ammonia and nitrite, anammox can occur, producing nitrogen gas and some nitrate

3. NO_3^- from anammox drives denitrification (or partial denitrification)

   In the low oxygen environment immediately below the chemocline, the nitrate produced by anammox (and/or nitrification) and organic matter from the groundwater is driving denitrification, producing nitrogen gas and/or nitrite which could be feeding into the anammox process.

* All three processes (nitrification, anammox, & denitrification) are interdependent

This type of symbiotic process has been documented (Kuenen, 2008, Chen et al., 2009). It is also possible that an alternate process such as anaerobic oxidation of ammonia using sulfate as an electron acceptor is occurring.

NOTES:

1. GRAY SHADING INDICATES "U" VALUE = NOT DETECTED AT REPORTING LIMIT (REPORTING LIMIT SHOWN).
2. FIXED LAB ANALYSIS FOR AMMONIA REPORTED IN mg N/L AND CONSISTS OF SUM OF BOTH AMMONIA AND AMMONIUM SPECIES.
3. HBHA POND ELEVATION ESTIMATED FROM WATER LEVEL AT BECO CULVERT, HBHA POND LEVELLOGGER, AND MERIDIAN LAND SERVICE'S 2000 SURVEY READINGS. THE ELEVATION SHOWN REPRESENTS TOP OF WATER.

DRAFT

HALEY & ALDRICH

REMEDIAL DESIGN – SCREENING LEVEL MICROCOSM WORK PLAN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

NITROGEN CYCLING CONCEPTUAL MODEL PROXIMATE TO HBHA POND CHEMOCLINE

SCALE: NONE
AUGUST 2010

FIGURE 1

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Attachment A

4 November 2009 Comparison of February 2009 and September 2009 Microbial Sampling of HBHA

Haley & Aldrich, Inc.
465 Medford St.
Suite 2200
Boston, MA 02129-1400

Tel: 617.886.7400
Fax: 617.886.7600
HaleyAldrich.com

MEMORANDUM

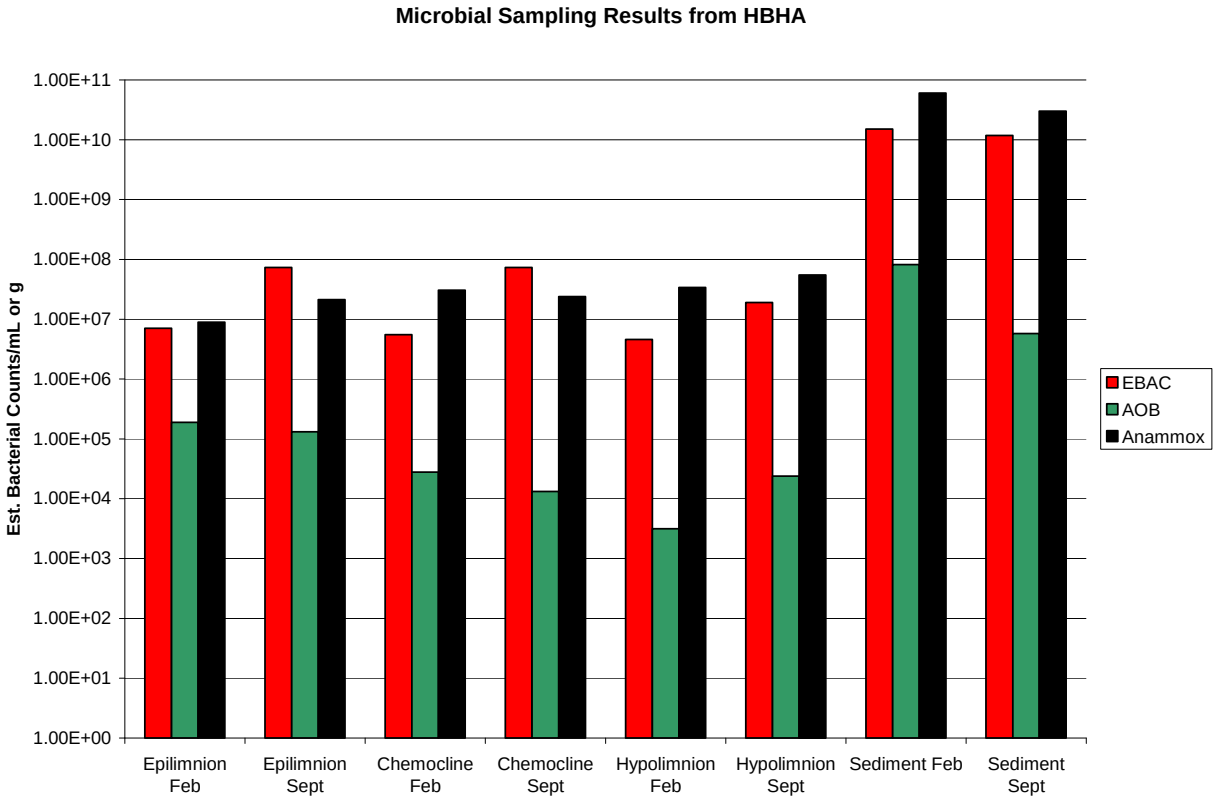
4 November 2009
File No. 33020-057

TO: de maximis, Inc.
Bruce Thompson; Todd Majer

FROM: Haley & Aldrich, Inc.
Russell Schuck; Tom Holden; Aaron Peacock

SUBJECT: Comparison of February 2009 and September 2009 Microbial Sampling of HBHA
Industri-plex OU2
Woburn, Massachusetts

Microbial sampling of HBHA was performed February 2 and 3, 2009 and again September 30, 2009. Along with the water chemistry the samples were analyzed using real-time quantitative polymerase chain reaction (qPCR) of DNA for total bacterial biomass (EBAC) and genes that code for enzymes that catalyze ammonia oxidation (AOB) and anaerobic ammonia oxidation (anammox). A quick comparison of the two sampling events showed that there was an increase of about one order of magnitude for total bacteria in the water column (epilimnion, chemocline and hypolimnion) from the February to September sampling event. There was no observed total bacterial biomass change observed in the sediment during that time. Ammonia oxidizing bacteria remained constant in the epilimnion and chemocline but showed an increase of an order of magnitude in the hypolimnion and a decrease of an order of magnitude in the sediment. Anammox numbers in the pond were roughly equivalent (no order of magnitude changes) at both sampling events in all compartments. The figure below displays the data from both sampling events.



Attachments

Summary of Surface Water Quality Results - Data to Support Microbial Sampling
Microbial Insights Laboratory Report – 3 February 2009 Samples
Microbial Insights Laboratory Report – 30 September 2009 Samples
Profiling Data with Microbial Testing Data, Date: 2/3/2009 (Baseflow Event)
Profiling Data with Microbial Testing Data, Date: 9/30/2009 (Baseflow Event)

G:\33020\057\2009-1103-Microbial Comparison Memo.doc

LOCATION SAMPLING DATE LAB SAMPLE ID	Units	EPILIMNION SURFACE WATER RM1100-093009-1100 9/30/2009 L0913811-01	Qual	EPILIMNION SURFACE WATER RM1100-101509-1315 10/15/2009 L0914693-12 L0914693-12 R1	Qual	CHEMOCLINE SURFACE WATER RM1195-093009-1220 9/30/2009 L0913811-02	Qual	CHEMOCLINE SURFACE WATER RM1200-101509-1345 10/15/2009 L0914693-14 L0914693-14 R1	Qual
General Chemistry - Westborough Lab									
Nitrogen, Ammonia	mg/l	-		8.31		-		201	
Nitrogen, Nitrite	mg/l	-		0.026	J	-		0.5	U
Nitrogen, Nitrate	mg/l	-		0.56		-		1	U
Nitrogen, Total Kjeldahl	mg/l	-		8.1		-		220	
Nitrogen, Total Organic	mg/l	-		0.3	U	-		19	
Alkalinity, Total	mg CaCO3/L	51		-		720		-	
Solids, Total Dissolved	mg/l	320		-		2000		-	
Solids, Total Suspended	mg/l	46		-		170		-	
Solids, Volatile Suspended	mg/l	11		-		10	U	-	
Chloride	mg/l	-		150		-		180	
Phosphorus, Total	mg/l	-		0.058		-		0.318	
Phosphorus, Orthophosphate	mg/l	-		0.005	U	-		0.004	J
Sulfate	mg/l	-		62		-		1200	
Chemical Oxygen Demand	mg/l	20	U	-		150		-	
BOD, 5 day	mg/l	2	U	-		15		-	
CBOD, 5 day	mg/l	2	U	-		9.5		-	
Total Organic Carbon	mg/l	-		5.7		-		44	
Dissolved Organic Carbon	mg/l	-		6.1		-		39	
Iron, Ferrous	mg/l	-		0.5	U	-		37	
MCP Dissolved Metals - Westborough Lab									
Arsenic, Dissolved	mg/l	-		0.006		-		0.269	
Iron, Dissolved	mg/l	-		0.1		-		86	
MCP Total Metals - Westborough Lab									
Arsenic, Total	mg/l	-		0.022		-		0.523	
Iron, Total	mg/l	-		1.2		-		100	
MCP Volatile Organics - Westborough Lab									
Benzene	mg/l	-		0.00032	J	-		0.17	
Percent Moisture	%								

NOTES
U = Not detected at reporting limit (reporting limit shown).
J = Estimated value.

LOCATION SAMPLING DATE LAB SAMPLE ID	Units	HYPOLIMNION SURFACE WATER RM1300-093009-1315 9/30/2009 L0913811-03	Qual	HYPOLIMNION SURFACE WATER RM1300-101509-1430 10/15/2009 L0914693-16 L0914693-16 R1	Qual	SEDIMENT RM1350-093009-1400 9/30/2009 L0913811-04	Qual
General Chemistry - Westborough Lab							
Nitrogen, Ammonia	mg/l	-		685		-	
Nitrogen, Nitrite	mg/l	-		0.5	U	-	
Nitrogen, Nitrate	mg/l	-		0.68	J	-	
Nitrogen, Total Kjeldahl	mg/l	-		760		-	
Nitrogen, Total Organic	mg/l	-		75		-	
Alkalinity, Total	mg CaCO3/L	3600		-	-	-	-
Solids, Total Dissolved	mg/l	3300		-	-	-	-
Solids, Total Suspended	mg/l	170		-	-	-	-
Solids, Volatile Suspended	mg/l	46		-	-	-	-
Chloride	mg/l	-		160		-	-
Phosphorus, Total	mg/l	-		3.31		-	-
Phosphorus, Orthophosphate	mg/l	-		0.009	J	-	-
Sulfate	mg/l	-		1600		-	-
Chemical Oxygen Demand	mg/l	480		-	-	-	-
BOD, 5 day	mg/l	61		-	-	-	-
CBOD, 5 day	mg/l	55		-	-	-	-
Total Organic Carbon	mg/l	-		120		370	
Dissolved Organic Carbon	mg/l	-		100		-	
Iron, Ferrous	mg/l	-		76		-	-
MCP Dissolved Metals - Westborough Lab							
Arsenic, Dissolved	mg/l	-		3.56		-	
Iron, Dissolved	mg/l	-		130		-	-
MCP Total Metals - Westborough Lab							
Arsenic, Total	mg/l	-		3.64		-	
Iron, Total	mg/l	-		130		-	
MCP Volatile Organics - Westborough Lab							
Benzene	mg/l	-		1.6		-	
Percent Moisture	%					96	

NOTES
U = Not detected at reporting limit (reporting limit shown).
J = Estimated value.

2340 Stock Creek Blvd.
Rockford TN 37853-3044
Phone: (865) 573-8188
Fax: (865) 573-8133
Email: info@microbe.com

DNA Analysis Report

Client: Russel Schuck
Haley & Aldrich,Inc.
465 Medford Street
Suite 2200
Boston, MA 02129

Phone: 617.886.7404

Fax: 617.886.7771

MI Identifier: 009GB **Date Rec:** 02/04/2009 **Report Date:** 03/04/2009

Client Project #: 33020-045 **Client Project Name:** Industri-Plex OU2

Purchase Order #: 33020-045

Analysis Requested: CENSUS, PLFA

Comments:

Reported By:

Reviewed By:

NOTICE: This report is intended only for the addressee shown above and may contain confidential or privileged information. If the recipient of this material is not the intended recipient or if you have received this in error, please notify Microbial Insights, Inc. immediately. The data and other information in this report represent only the sample(s) analyzed and are rendered upon condition that it is not to be reproduced without approval from Microbial Insights, Inc. Thank you for your cooperation.

MICROBIAL INSIGHTS, INC.

2340 Stock Creek Blvd. Rockford, TN 37853-3044
Tel. (865) 573-8188 Fax. (865) 573-8133

Q Potential (DNA)

Client: **Haley & Aldrich,Inc.**
Project: Industri-Plex OU2

MI Project Number: **009GB**
Date Received: 02/04/2009

Sample Information

Client Sample ID:		**RM1100-020309-1110**	**RM1185-020309-1215**	**RM1300-020309-1300**	**RM1-020309-1345**
Sample Date:		02/03/2009	02/03/2009	02/03/2009	02/03/2009
Units:		cells/mL	cells/mL	cells/mL	cells/g
Other Genera					
Anaeromyxobacter spp.	ANA	**7.23E+02**	**3.66E+02**	**2.21E+02**	**6.67E+06**
Phylogenetic Group					
Total Eubacteria	EBAC	**7.03E+06**	**5.55E+06**	**4.61E+06**	**1.51E+10**
Ammonia oxidizing bacteria	AOB	**1.9E+05**	**2.78E+04**	**3.15E+03**	**8.18E+07**
Anaerobic Ammonia oxidation	Anammox	**8.95E+06**	**3.04E+07**	**3.39E+07**	**6.06E+10**

Legend:
NA = Not Analyzed NS = Not Sampled J = Estimated gene copies below PQL but above LQL I = Inhibited
< = Result not detected

MICROBIAL INSIGHTS, INC.

2340 Stock Creek Blvd. Rockford, TN 37853-3044
Tel. (865) 573-8188 Fax. (865) 573-8133

PLFA

Client: **Haley & Aldrich,Inc.**
Project: Industri-Plex OU2

MI Project Number: **009GB**
Date Received: 02/04/2009

Sample Information

Sample Name:	**RM1100-020309 -1110**	**RM1185-020309- 1215**	**RM1300-020 309-1300**	**RM1-020309-1 345**
Sample Date:	02/03/2009	02/03/2009	02/03/2009	02/03/2009
Sample Matrix:	Water	Water	Water	Sediment

Biomass

Total Biomass (cells/mL)	**1E+05**	**1.36E+05**	**9.31E+05**	**- -**

Community Structure (% total PLFA)

Firmicutes (TerBrSats)	**3.16**	**8.47**	**21.02**	**12.67**
Proteobacteria (Monos)	**69.86**	**64.53**	**48.64**	**34.92**
Anaerobic metal reducers (BrMonos)	**1.01**	**1.33**	**1.81**	**7.66**
SRB/Actinomycetes (MidBrSats)	**0.63**	**1.96**	**4.44**	**1.35**
General (Nsats)	**15.83**	**17.71**	**18.57**	**30.26**
Eukaryotes (polyenoics)	**9.51**	**6.01**	**5.54**	**13.12**

Physiological Status (Proteobacteria only)

Slowed Growth	**0.04**	**0.04**	**0.14**	**0.28**
Decreased Permeability	**0.02**	**0.08**	**0.10**	**0.36**

Legend:
NA = Not Analyzed NS = Not Sampled

MICROBIAL INSIGHTS, INC.

2340 Stock Creek Blvd. Rockford, TN 37853-3044
Tel. (865) 573-8188 Fax. (865) 573-8133

PLFA

Client: **Haley & Aldrich,Inc.**
Project: Industri-Plex OU2

MI Project Number: **009GB**
Date Received: 02/04/2009

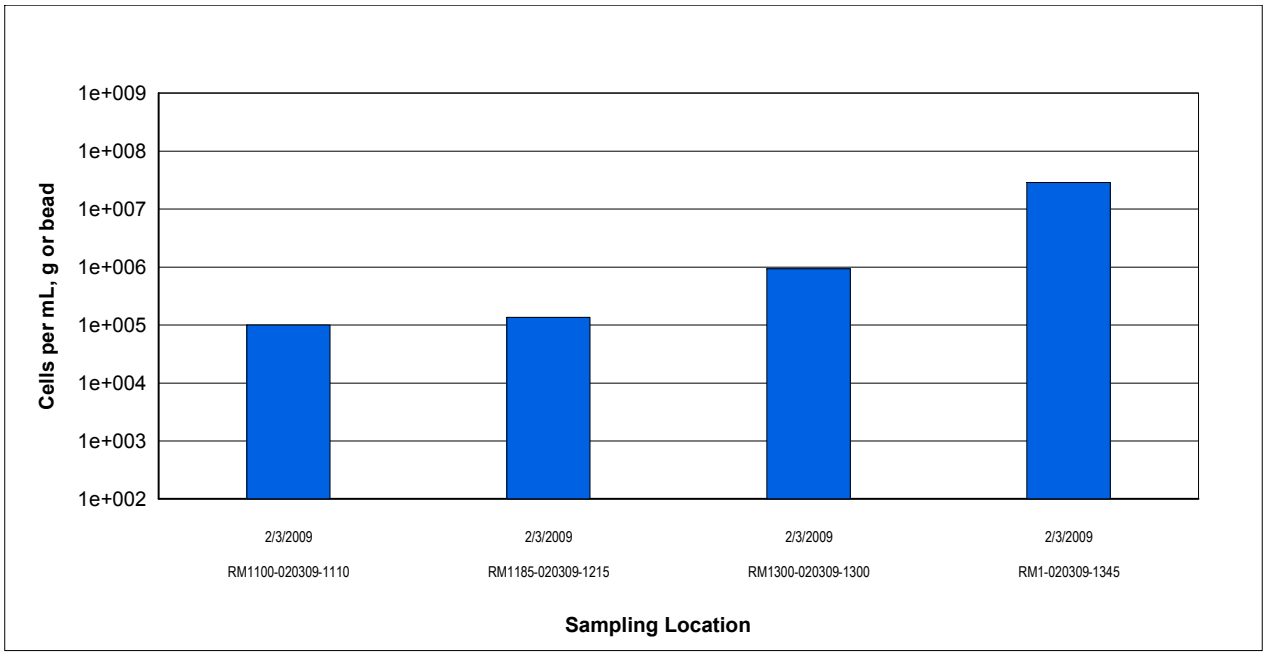


Figure 1. Biomass content is presented as a cell equivalent based on the total amount of phospholipid fatty acids (PLFA) extracted from a given sample. Total biomass is calculated based upon PLFA attributed to bacterial and eukaryotic biomass (associated with higher organisms).

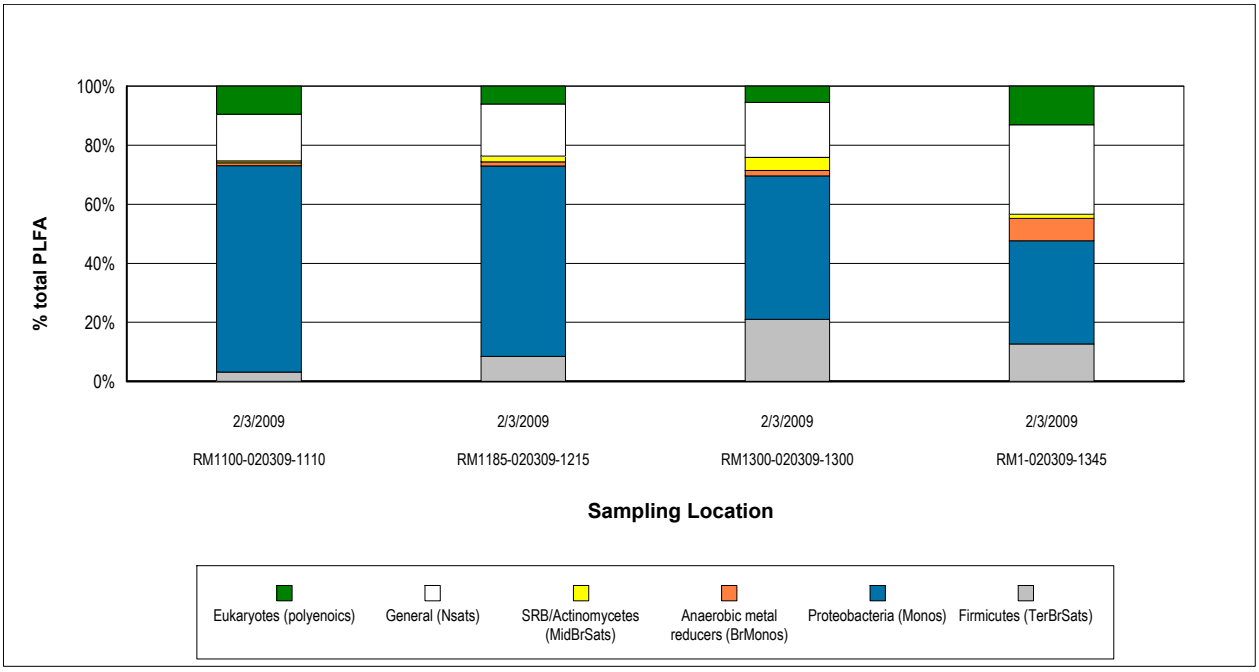


Figure 2. Relative percentages of total PLFA structural groups in the samples analyzed. Structural groups are assigned according to PLFA chemical structure, which is related to fatty acid biosynthesis.

REPORT TO:
Reports will be provided to the contact(s) listed below. Parties other than the contact(s) listed below will require prior approval.

Name: Russel Schuck
Company: Haley & Aldrich
Address: 465 Medford St. Suite 2200
Boston, MA 02129-1400

email: rschuck@haleyAldrich.com
Phone: (617) 886-7404
Fax: (617) 886-7771

Project Manager: Russel Schuck
Project Name: Industri-Plex OU2
Project No.: 33020-045

INVOICE TO:
For Invoices **paid by a third party** it is imperative that contact information & corresponding reference No. be provided.

Name: Accounts Payable
Company: Haley & Aldrich
Address: Same Address

email:
Phone: ( )
Fax: ( )

Purchase Order No. 33020-045
Subcontract No.

microbialinsights
2340 Stock Creek Blvd.
Rockford, TN 37853-3044
phone (865) 573-8188
fax: (865) 573-8133
email: info@microbe.com
www.microbe.com

Please Check One:
☐ More samples to follow
☒ No Additional Samples

Saturday Delivery
Please see sampling protocol for instructions

Report Type: ☒ Standard (default) ☐ Comprehensive (15% surcharge) ☐ Historical (30% surcharge)

Please contact us prior to submitting samples regarding questions about the analyses you are requesting at (865) 573-8188 (8:00 am to 4:00 pm M-F). After these hours please call (865) 300-8053.

Sample Information											CENSUS: Please select the target organism/gene																									
																				* See Arron Peacock *																
MI ID (Laboratory Use Only)	Sample Name	Date Sampled	Time Sampled	Matrix	PLFA	VFA	MF/E	DGGE+3ID	DGGE+5ID		qDHC (Dehalococcoides)	DHC Functional genes	qDHB (Dehalobacter)	qDSM (Desulfuromonas)	qDSB (Desulfiobacterium)	qEBAC (Total)	qDSR (SRBs only)	qSRB/IRB	qMGN (methanogens)	qMOB (methanotrophs)	qDNF (Denitrifying)	qAOB (ammonia oxidizing)	qPM1 (MTBE aerobic)	qTOD (Intial PAHs aerobic)	qCAT (Intermediate PAHs aerobic)	qBSS (Toluen/Xylene Anaerobic)	qNAH (Napthalene aerobic)	add. qPCR: AnAMMox	add. qPCR: NOB	add. qPCR:	RNA (Expression Option)*	Other:	Other:	Other:	Other:
009GB 1	RM1100-020309-1110	02/03/09	1110	Ag	X	X	X														*	X						X	X						
2	RM1185-020309-1215		1215	Ag	X																*	X						X	X						
3	RM1300-020309-1300		1300	Ag	X																*	X						X	X						
4	RM1-020309-1345		1345	SED	X																*	X						X	X						

Relinquished by: [signature] Date: 02-03-09 Received by: [signature] Date 2/4/09

In order for analysis to be completed correctly, it is vital that chain of custody is filled out correctly & that all relative information is provided. Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable. * additional cost and sample preservation are associated with RNA samples.

* Please Fax Signed Copy Upon Receipt to (617) 886.7771

2340 Stock Creek Blvd.
Rockford TN 37853-3044
Phone: (865) 573-8188
Fax: (865) 573-8133
Email: info@microbe.com

Client: Russel Schuck
Haley & Aldrich,Inc.
465 Medford Street
Suite 2200
Boston, MA 02129

Phone: 617.886.7404

Fax: 617.886.7771

Identifier: 002GJ **Date Rec:** 10/01/2009 **Report Date:** 11/03/2009

Client Project #: 33020-057 **Client Project Name:** Industri-Plex OU2

Purchase Order #: 33020-057

Analysis Requested: Cancelled, CENSUS

Reviewed By:

NOTICE: This report is intended only for the addressee shown above and may contain confidential or privileged information. If the recipient of this material is not the intended recipient or if you have received this in error, please notify Microbial Insights, Inc. immediately. The data and other information in this report represent only the sample(s) analyzed and are rendered upon condition that it is not to be reproduced without approval from Microbial Insights, Inc. Thank you for your cooperation.

MICROBIAL INSIGHTS, INC.

2340 Stock Creek Blvd. Rockford, TN 37853-3044
Tel. (865) 573-8188 Fax. (865) 573-8133

CENSUS

Client: **Haley & Aldrich, Inc.**
Project: Industri-Plex OU2

MI Project Number: **002GJ**
Date Received: 10/01/2009

Sample Information

Client Sample ID:	**RM1100-093009-1145**	**RM1195-093009-1248**	**RM1300-093009-1321**	**RM1350-093009-1415**
Sample Date:	09/30/2009	09/30/2009	09/30/2009	09/30/2009
Units:	cells/mL	cells/mL	cells/mL	cells/mL
Analyst:	ab	ab	ab	ab

Phylogenetic Group

Total Eubacteria	EBAC	**7.32E+07**	**1.91E+07**	**2.21E+07**	**1.18E+10**
Ammonia oxidizing bacteria	AOB	**1.32E+05**	**1.32E+04**	**2.39E+04**	**5.76E+06**
Anaerobic Ammonia oxidation	ANAMMOX	**2.13E+07**	**2.39E+07**	**5.49E+07**	**2.99E+10**

Legend:
NA = Not Analyzed NS = Not Sampled J = Estimated gene copies below PQL but above LQL I = Inhibited
< = Result not detected

2340 Stock Creek Blvd.
Rockford TN 37853-3044
Phone: (865) 573-8188
Fax: (865) 573-8133
Email: info@microbe.com

Identifier: 002GJ **Date Rec:** 10/01/2009 **Report Date:** 11/03/2009

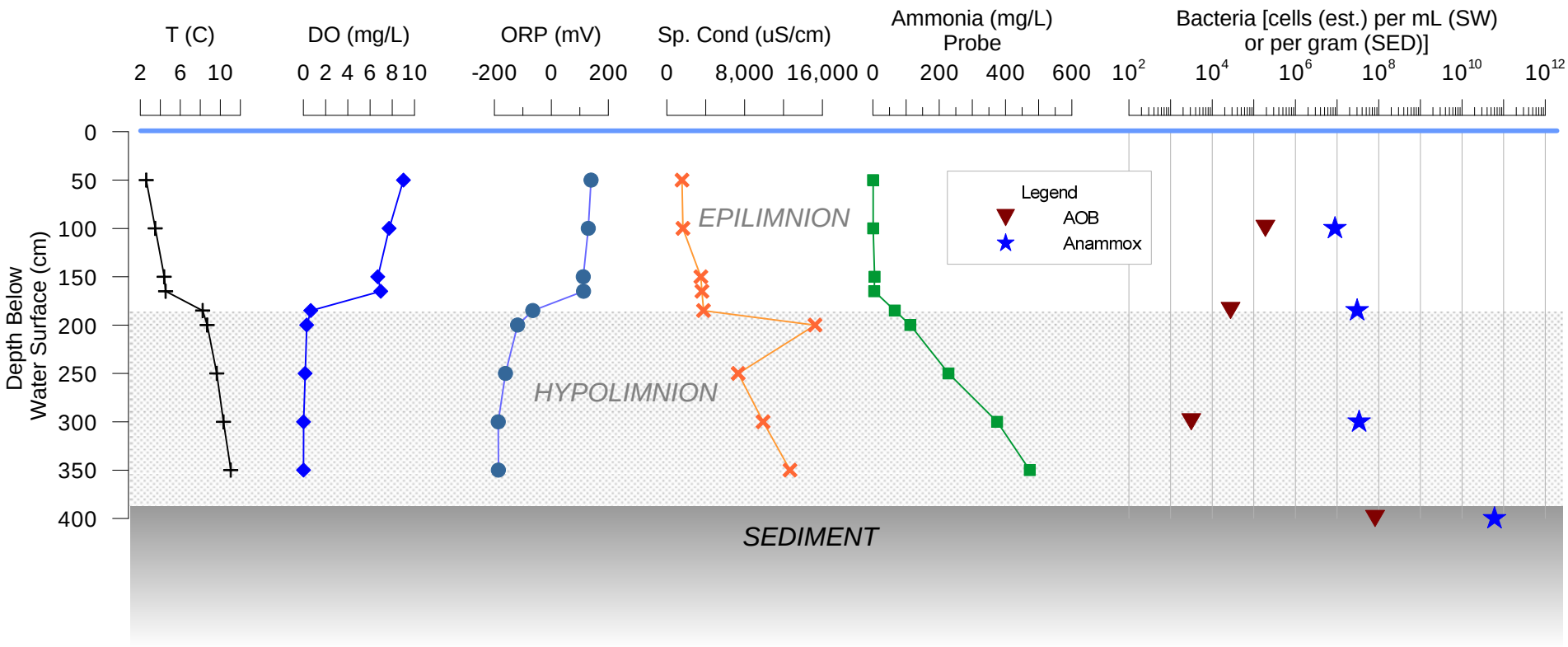
Client Project #: 33020-057 **Client Project Name:** Industri-Plex OU2

Purchase Order #: 33020-057

Comments:

G:\33020\010\Presentations\20May2009Pres\2009-0507-HAI-ProfileGraph_020309.grf

RM-1 WATER QUALITY PROFILE AND MICROBIAL DATA (2/3/09)



PRELIMINARY DRAFT

NOTES:

1. VALIDATED DATA PRESENTED.
2. SAMPLE COLLECTED AT 400 cm REPRESENTS A SEDIMENT SAMPLE SUBJECTED TO MICROBIAL TESTING ONLY; OTHER SAMPLE RESULTS REPRESENT ANALYSIS OF PARTICULATE MATTER IN SURFACE WATER (FILTER MEDIA).
3. PROBE RESULT CONSISTS OF SUM OF AMMONIA AND AMMONIUM READINGS ON THE YSI SONDE.
4. AOB = AEROBIC OXIDIZING BACTERIA; ANAMMOX = ANAEROBIC AMMONIA OXIDATION BACTERIA.

HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

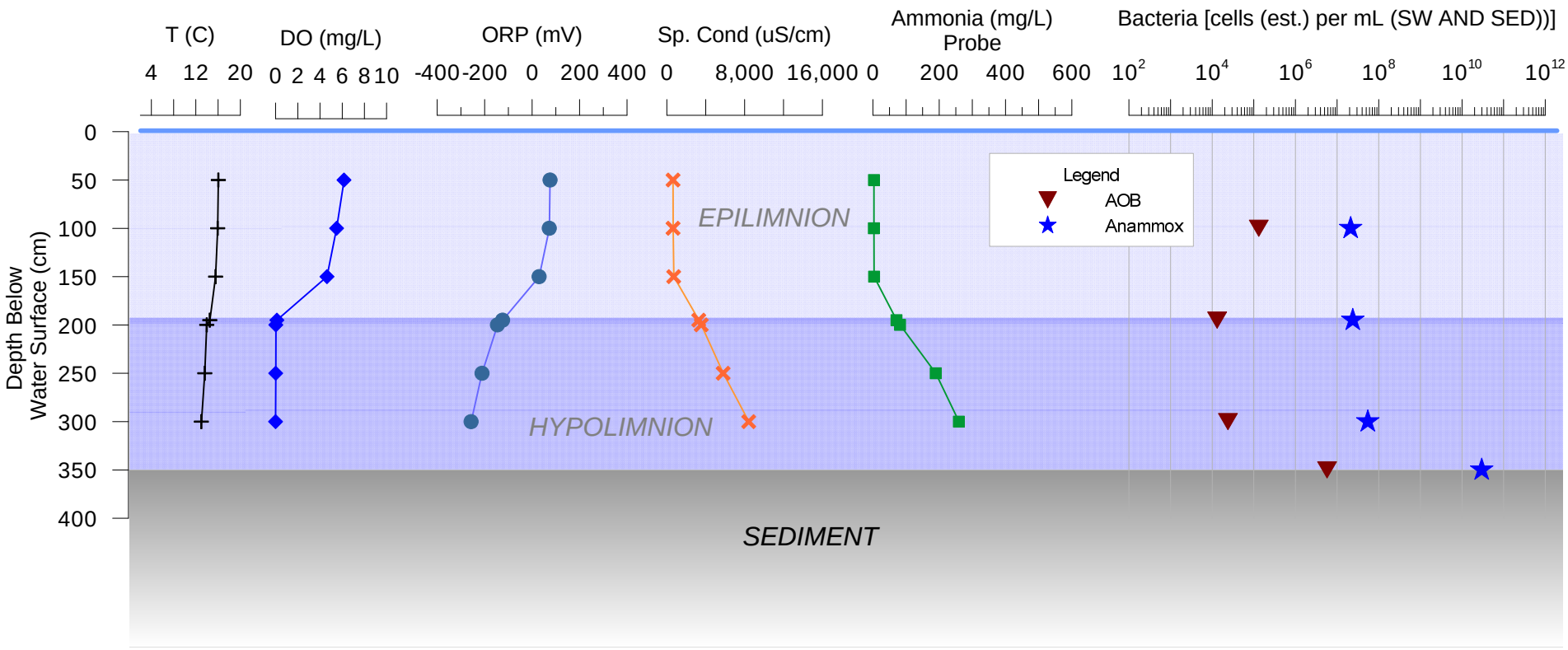
PROFILING DATA WITH MICROBIAL TESTING DATA
DATE: 2/3/09 (BASEFLOW EVENT)

SCALE: NONE
MAY 2009

FIGURE HBHA-17

G:\33020\100\Oct2009_Deliverables\2009-1103-HAI-ProfileGraph_0____9.grf

RM-1 WATER QUALITY PROFILE AND MICROBIAL DATA (9/30/09)



PRELIMINARY DRAFT

NOTES:

1. VALIDATED DATA PRESENTED.
2. SAMPLE COLLECTED AT 350 cm REPRESENTS A SEDIMENT SAMPLE SUBJECTED TO MICROBIAL TESTING ONLY; OTHER SAMPLE RESULTS REPRESENT ANALYSIS OF PARTICULATE MATTER IN SURFACE WATER (FILTER MEDIA).
3. PROBE RESULT CONSISTS OF SUM OF AMMONIA AND AMMONIUM READINGS ON THE YSI SONDE.
4. AOB = AEROBIC OXIDIZING BACTERIA; ANAMMOX = ANAEROBIC AMMONIA OXIDATION BACTERIA.

HALEY & ALDRICH

REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PROFILING DATA WITH MICROBIAL TESTING DATA
DATE: 9/30/09 (BASEFLOW EVENT)

SCALE: NONE
NOVEMBER 2009

FIGURE HBHA-17b

Attachment B

Standard Operating Procedures related to Colorado School of Mines Analytical Work

Colorado School of Mines
Standard Operating Procedures
For Screening Level Microcosm Work Plan

pH: (EPA method 150.1) The pH meter will be operated per the manufacturer's protocol. The pH meter will be calibrated daily with nominal pH buffers of 4.00, 7.00 and 10.00 that are stirred with a magnetic stir bar and stir-plate prior to measurement of pH. The pH probe will be rinsed with deionized water or equivalent between measurements. The pH 7 buffer is to be checked every 15 minutes and should be within 6.95 to 7.05, if not, recalibrate.

E_H (ORP): An E_H probe with a platinum electrode and a silver/silver-chloride reference electrode will be used to determine the E_H. The electrode will be verified using Zoebell's solution of known E_H. The measured Zoebell's E_H must be within ± 10 mV of the known solution value (-430 mV) and, if not, the probe will be subjected to cleaning and other required maintenance before recalibration. Hold probe in center of sample.

Temperature: The temperature of the incubator(s) will be checked with a NIST traceable glass thermometer.

Dissolved Oxygen (DO): DO will be measured in samples having an EH greater than 0 mV using a Hansatech Oxyview-1 system (Clark type oxygen electrode disk) is accordance with the manufacturer's directions. The system is prepared (electrode cleaned and new membrane installed) as per the manufacturer's instructions. The unit is calibrated daily using a zero-oxygen standard (sodium dithionite in DI water) and a DI water sample equilibrated with atmospheric oxygen (the oxygen value is calculated from the temperature and altitude of the laboratory).

Ammonia: Use HACH AmVer "Test N Tube" (catalog # 26069-45) and HACH salicylate method 10031 with HACH DR-5000 UV-Vis spectrophotometer. The instrument is calibrated using a blank sample and a 40.0 mg/L-N ammonia standard. If the ammonia concentration in the samples is above 50 mg/L-N, the samples are diluted appropriately using deionized water and a volumetric pipette to stay within the concentration range of the Test N Tube kit. A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run. 1 in 20 samples will include a matrix spike. The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.

Nitrite: Use HACH NitriVer "Test N Tube" (catalog # 26083-45) and HACH diazotization method 10019 with HACH DR-5000 UV-Vis spectrophotometer. The instrument is calibrated using a blank sample and a .015 mg/L-N nitrite standard. If the nitrite concentration in the samples is above 0.5 mg/L-N, the samples are diluted appropriately using deionized water and a volumetric pipette to stay within the concentration range of the Test N Tube kit. A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run. 1 in 20 samples will include a matrix spike. The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.

Nitrate: Use HACH NitraVer "Test N Tube" (catalog # 26053-45) and HACH chromotropic acid method 10020 with HACH DR-5000 UV-Vis spectrophotometer. The instrument is calibrated using a blank sample and a 10.0 mg/L-N nitrate standard. If the nitrate concentration in the samples is above 30 mg/L-N, the samples are diluted appropriately using deionized water and a volumetric pipette to stay within the concentration range of the Test N Tube kit. A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and

rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run. 1 in 20 samples will include a matrix spike. The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.

Total Nitrogen: Use HACH Total Nitrogen "Test N Tube" (catalog # 27141) and HACH persulfate digestion method 10072 with HACH DR-5000 UV-Vis spectrophotometer. The instrument is calibrated using a blank sample and a 100 mg/L-N ammonia standard. If the nitrogen concentration in the samples is above 150 mg/L-N, the samples are diluted appropriately using deionized water and a volumetric pipette to stay within the concentration range of the Test N Tube kit. A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run. 1 in 20 samples will include a matrix spike. The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.

Ferrous Iron: Use the HACH 1,10 phenanthroline method 8112 with HACH DR-5000 UV-Vis spectrophotometer. The instrument is calibrated using a blank sample and a 1.0 mg/L-N ferrous iron standard. If the ferrous iron concentration in the samples is above 1.8 mg/L, the samples are diluted appropriately using deionized water and a volumetric pipette to stay within the concentration range of the test (0 -1.8 mg/L). A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run. 1 in 20 samples will include a matrix spike. The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.

Inorganic Anions: (based on EPA method 300.1) Chloride, ortho-phosphate, bromide, fluoride, nitrate and sulfate are measured by ion chromatography (IC) using a Dionex ICS-90 Ion Chromatography System with a Dionex IonPakAS14A anion column. The eluents are 6 mM sodium carbonate and 1 mM sodium bicarbonate. The instrument uses ion suppression with 3 mM sulfuric acid as regenerant. A calibration curve is generated once a year using 6 standards between 1 and 300 mg/L for chloride and sulfate and 8 standards between 0.01 mg/L and 60 mg/L for the rest of the ions. Validation standards are run with all sample runs (100 mg/L for chloride and sulfate, 20 mg/L for all others). A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run. 1 in 20 samples will include a matrix spike. The MS recovery should be 75-125%. If not, investigate cause, rectify and re-run.

Metals: <u>Inductively Coupled Plasma Atomic Emissions Spectroscopy (ICP-AES)</u>
Approximately 10 ml of filtered sample is acidified with nitric acid. The samples are then analyzed on a Perkin Elmer Optima 3000 ICP-AES for the following 31 Elements: Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Sn, Sr, Ti, V, and Zn (only As, Fe, Mg, Mn, P, and S will be reported for this study). All results are given in mg/L.

ICP-AES Quality Assurance and Quality Control
Metals shall be measured in water solutions that have been filtered using 0.45 micrometer filters and acidified to below a pH of 2.0 using nitric acid (trace metal grade). For field samples, all efforts will be made to keep the samples refrigerated until analysis. All water samples will be analyzed within 30 days of collection. Metals analyses will be conducted by inductively coupled plasma emission atomic spectroscopy. A Perkin Elmer Optima Model 3000 radial viewing spectrometer is used. Typical detection limits are contained in a table at the end of this note. Because CSM is not a commercial laboratory and the instrument is not operated daily, not all elements of EPA Method 6010B can be conducted for metal analyses. The concentration of the following cations and metals will be reported: Arsenic, Iron, Phosphorus, Magnesium, Manganese and Sulfur. A scandium spike is added to all samples that are analyzed with the ICP spectrometer. This internal standard helps to account for fluctuations in the flame of the ICP. Results are rejected if scandium counts are 20% off of their true amount. A quality

control standard is analyzed before each batch of samples. If in this standard, the analytical results for Cd, Co, Cu, Fe, Pb, Mn, or Zn are more than 15 % different than the accepted value, then the analysis will be stopped, the reason for the discrepancy determined and corrected, and then the analysis will be resumed. If a water sample shows considerable precipitate, it will be acidified and refiltered before analysis. This can happen if the water sample has very high concentrations of natural organic matter. Typical detection limits and concentration values for check standards are given in Table 1

Table 1. Detection Limits (DL) and Concentration Check Values (CCV) for the Perkin Elmer Optima 3000

DL's 8/2/04		Known and analyzed values for the CCVs 8/2/04			
Analyte	DL (mg/l)	Known	Value (mg/l)	Rel. % Error	% RSD
Al 308.215	0.012296468	20	17.94714	-10.26	0.67
As 193.696	0.032565136	20	18.20882	-8.96	1.26
B 249.772	0.041403081	20	17.92461	-10.38	0.42
Ba 455.403	0.005319935	10	9.331006	-6.69	0.83
Be 313.107	0.000210298	10	9.401357	-5.99	1.11
Ca 317.933	0.023068921	20	18.50234	-7.49	0.20
Cd 214.440	0.000761947	10	9.100216	-9.00	0.68
Co 228.616	0.003318598	10	8.817492	-11.83	0.74
Cr 205.560	0.00426592	5	4.626522	-7.47	0.27
Cu 324.752	0.00283794	20	18.06499	-9.68	0.19
Fe 238.204	0.00475459	20	18.28628	-8.57	0.67
K 766.490	0.125389639	50	48.50625	-2.99	0.03
Li 670.784	0.00138925	20	18.47963	-7.60	0.11
Mg 279.553	0.002057754	20	18.67208	-6.64	1.15
Mn 257.610	0.000731167	10	9.113338	-8.87	0.15
Mo 202.031	0.003811713	20	17.31616	-13.42	0.71
Na 589.592	0.029116255	81	73.93728	-8.72	1.04
Ni 231.604	0.005351297	20	18.2202	-8.90	0.68
P 177.434	0.074996631	50	44.41629	-11.17	0.66
Pb 220.353	0.014197523	20	18.39187	-8.04	0.69
S 180.669	0.041198753	50	50.29261	0.59	0.42
Sb 217.582	0.010465244				
Se 196.026	0.055778925	20	18.00122	-9.99	0.92
Si 251.611	0.021988343	50	47.40869	-5.18	1.54
Sn 189.927	0.025984225				
Sr 421.552	0.000338655	20	saturated	saturated	saturated
Ti 334.940	0.000913515				
V 292.402	0.002053346	10	9.053521	-9.46	0.30
Zn 213.857	0.002256435	10	9.295377	-7.05	0.68

Because CSM is not a commercial laboratory and the instrument is not operated daily, not all elements of EPA Method 6010B are followed. Calibration standards are analyzed each run in triplicate. If the standard variation of the scandium in the calibration standard exceeds 10%, the calibration is re-run. CCV standards are run immediately after the calibration standards and after every ten (10) samples. Results are rejected if CCV standards are not within 20% of expected value. At least once every two weeks, NIST traceable standards (SRM-1640A and SRM-1643E) are analyzed and if results are more than 15% from expected values, the cause is investigated and rectified. 1 in 10 samples will be run in duplicate. The relative percent difference (RPD) shall be ≤ 20%. If not, investigate cause, rectify and re-run.

Total Organic Carbon (TOC)/Total Inorganic Carbon (TIC): TOC and TIC are measured using a Shimadzu TOC 5000 instrument. The instrument has two modules, one that measures total carbon (TC) by converting all carbon to CO_2 by heating the sample to 680 C in the presence of an oxidation catalyst. The generated CO_2 is then measured by a non-dispersive infrared gas analyzer (NDIR). The second module measures inorganic carbon by bubbling a carrier gas through a sample that is acidified in the reaction chamber. The CO_2 in the carrier gas is measured by the NDIR. TOC can then be calculated by subtracting TIC from TC.

Instructions:

Note: Please prepare your standard solutions and samples according to the instructions below. The measurement will be started by an authorized person. DO NOT START THE MEASUREMENT OR CHANGE ANY INSTRUMENT PARAMETERS BY YOURSELF.

TOC concentration range for measurement: 1-500 mg/L (1-500 ppm) TOC
The measurement error becomes smaller with increasing TOC concentrations. For concentrations below 1 ppm TOC use the Sievers TOC.

Volumes needed:
Samples: 5 – 6 mL for each replicate
Standard solutions: 30 – 40 mL for each standard concentration for calibration plus at least 5 - 6 mL for estimation of %error of the measurement (see below)

Preparation of standard solutions:

- Estimate the TOC concentration range of your samples, e.g. 0 – 20 ppm TOC.
- Decide on the TOC concentrations of the standard solutions for the calibration, multiple calibration curves are possible:
  e.g. calibration 1: 0, 1, 5, 10 ppm TOC; calibration 2: 5, 10, 50 ppm TOC.

(It is recommended to run a DI water blank (0 ppm TOC) with the calibration curve of the lowest concentrations.)

- Prepare TOC standard solutions using the potassium hydrogen phthalate (KHP) standard provided.
  Note: MW (KHP) = 204.23 g/mol $\Rightarrow$ 1 mol KHP = 204.23 g KHP = 96.088 g carbon
- Prepare TIC standards using sodium carbonate (Na_2CO_3).
- Fill standard solutions in big Shimadzu vials.
- Cover the vials with parafilm.

Preparation of samples:

- Fill small Shimadzu vials with sample.
- Cover the vials with parafilm.

To estimate %error of your measurement (as a function of TOC concentration):

- Run standard solutions as samples using the sample preparation described above.
- Run instrument blank with each batch of samples. The instrument blank should be below the reporting limit.
- Samples will be analyzed in duplicate; if the relative percent difference (RDP) is larger than 20% the sample will be re-analyzed.

A check standard will be analyzed each run and if the measured value is greater than ± 15% from the expected value, the cause will be investigated and rectified.

To avoid carry-over of TOC to samples (always do this, but especially in case of large TOC conc. differences):

- Put sample vials containing DI acidified water in between your sample vials during the measurement run.

Make sure your measurement is finished with an acidified DI water sample.

DRAFT

REMEDIAL DESIGN PROJECT OPERATIONS PLAN
APPENDIX D

SITE-SPECIFIC HEALTH & SAFETY PLAN

Industri-plex Operable Unit 2
(including Wells G& H Operable Unit 3) Superfund Site
Woburn, Massachusetts

Prepared by:

Haley & Aldrich, Inc.
465 Medford Street
Boston, Massachusetts 02129

March 2011

Haley & Aldrich, Inc.
Approvals:

Kristina M. Gross - Regional H&S Coordinator	29 March 2011 Date
Russell A. Schuck, PG - Site Project Manager	29 March 2011 Date
Scott A. Boston, CIH, CSP - Corporate H&S Manager	29 March 2011 Date

DRAFT

Disclaimer: This document is a DRAFT document prepared by the Settling Defendants under a government Consent Decree. This document has not undergone formal review by the U.S. Environmental Protection Agency or the Massachusetts Department of Environmental Protection. The opinions, findings, and conclusions, expressed are those of the author and not those of the U.S. Environmental Protection Agency or the Massachusetts Department of Environmental Protection.

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LIST OF ACRONYMS

Acronym	Agency/Organization/Definition
AAD	Atlantic Avenue Drainway
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, toluene, ethylbenzene, xylenes
CBCA	Cranberry Bog Conservation Area
CD	Consent Decree
CMR	Code of Massachusetts Regulations
COCs	Contaminants of Concern
CTD	Conductivity, Temperature & Depth
CRZ	Contaminant Reduction Zone
dBA	Decibel A-Weighted
DPT	Direct Push Technology
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FSP	Field Sampling Plan
GWTB	Groundwater Treatment Building
HASP	Site-specific Health & Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBHA	Halls Brook Holding Area
HR	Human Resources
LEL	Lower Explosive Limit
MassDEP	Massachusetts Department of Environmental Protection
MBTA	Massachusetts Bay Transportation Authority
MSDS	Material Safety Data Sheets
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OU2	Industri-plex Superfund Site Operable Unit 2
PAHs	Polycyclic Aromatic Hydrocarbons
PDIs	Pre-Design Investigations
PEL	Permissible Exposure Limits
PFD	Personal Flotation Device
PID	Photoionization Detector
POP	Project Operations Plan
PPE	Personal Protective Equipment
RD/RA	Remedial Design/Remedial Action
RDWP	Remedial Design Work Plan
REL	Recommended Exposure Limit
RHSC	Regional Health and Safety Coordinator
ROD	Record of Decision
ROW	Right of Way
SAIR	Supervisor Accident/Injury/Near Miss Report
SMP	Site Management Plan

LIST OF ACRONYMS
(Continued)

Acronym	Agency/Organization/Definition
SOW	Statement of Work
SSO	Site Safety Officer
SWMP	Surface Water Monitoring Plan
TCE	Trichloroethylene
TOU	Thermal Oxidizer Unit
TWA	Time-Weighted Average
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This Site-specific Health & Safety Plan (HASP) is submitted as Appendix D of the Remedial Design Work Plan (RDWP) Project Operations Plan (POP) pursuant to the Consent Decree (CD) for Remedial Design/Remedial Action (Civil Action No. 1:08-cv-10325) and the Remedial Design/Remedial Action (RD/RA) Statement of Work (SOW) for Operable Unit 2 (OU2) at the Industri-plex Superfund Site (including Operable Unit 3 of the Wells G&H Superfund Site) in Woburn, Massachusetts (hereinafter, "Industri-plex OU2 or Site"; see Figures 1-1 and 1-2), and on behalf of Pharmacia Corporation by its Attorney-in-Fact Monsanto Company and Stauffer Management Company LLC as litigation agent for Bayer CropScience (Settling Defendants).

1.1 Project Information and Emergency Resources

Project Name: Industri-plex Superfund Site, Operable Unit No. 2	**H&A File No.: 33020-030**
Location: Woburn, Massachusetts	
Client/Site Contact: Phone Number: Emergency Phone Number:	Bruce Thompson 860.298.0541 (office) 860.662.0526 (cell)
H&A Project Manager: Phone Number: Emergency Phone Number:	Russell Schuck 617.886.7404 (office) 857.498.1255 (cell)
Regional Health & Safety Coordinator: Emergency Phone Number:	Kristina Gross 617. 447.1193 (cell)
Nearest Hospital: Address: Phone Number:	Winchester Hospital 41 Highland Avenue, Winchester, MA 01890 781.729.9000
Nearest Occupational Clinic: Address: Phone Number: **WorkCare:**	Concentra 66B Concord Street, Wilmington, MA 01887 978.657.3826 888.449.7787
Emergency Response Number:	**911**
Other Local Emergency Response Number:	Woburn Police Department 25 Harrison Ave, Woburn, MA 01801 781.933.1212 (for officer) **911** (emergency)
Other Ambulance, Fire, Police, or Environmental Emergency Resources:	Woburn Fire Department 124 Main St, Woburn, MA 01801 781.932.4560 (business) 781.933.3131 / **911** (emergency)

1.2 Training, Initial and Site-specific

All Haley & Aldrich employees who participate in field activities must have completed Occupational Safety and Health Administration (OSHA)/ Hazardous Waste Operations and Emergency Response (HAZWOPER) 40-hour training and be current with 8-hour refresher courses. Competent Person Training is required by Haley & Aldrich employees participating in field activities where excavations and other ground penetrating operations (e.g., soil borings) are being conducted. Additional training will be evaluated by the Project Manager, and implemented as necessary.

1.3 Subcontractors to be involved in on-site activities

Various subcontractors will work on the Site throughout the duration of the project.
When on the Site, subcontractors are required to comply with this Site-specific HASP. If warranted and/or required by the Project Coordinator, Subcontractors may develop or provide their own HASPs to be reviewed by Haley & Aldrich and the Project Coordinator.

Projected Start Date: June 2010
Projected Completion Date: December 2012
Estimated Number of Months to Complete Field Work: 30 Months

1.4 Directions to the Nearest Hospital

The nearest hospital to the Site is:

Winchester Hospital
41 Highland Avenue
Winchester, MA 01890

Written directions from the Site office to Winchester Hospital accompanied by a map are presented in Attachment D1. The directions and map to the hospital shall be posted near the exit in the field office.

2.0 SITE DESCRIPTION

The following section provides general information on the classification and description of the site as well as a brief waste site background. The site plan and work areas are also discussed in this section.

2.1 Site Classification

☑ Industrial	☐ Commercial	☐ Other

2.2 General Description

Industri-plex OU2
Woburn, Middlesex County, Massachusetts

United States Environmental Protection Agency (EPA) Identification Numbers:
Industri-plex - MAD076580950
Wells G&H - MAD980732168

The general location of the Industri-plex OU2 is shown on Figure 1-1.

2.3 Site Background

The selected remedy for Industri-plex OU2 is structured to provide a comprehensive approach that utilizes source control, exposure control or prevention, and management of migration components to address the risks identified by EPA. The proposed remedy involves several media and areas of within Industri-plex OU2 and along the Aberjona River and addresses the following Contaminants of Concern (COCs): arsenic, ammonia; benzene, 1,2 – dichloroethane, trichloroethene, naphthalene, and benzo(a)pyrene. Based on previous studies performed at the Site, it is anticipated that arsenic, ammonia, and benzene will be of primary concern with regards to worker safety. Table 2.3-1 presents the estimated concentrations of these constituents based on previous data sets.

A major portion of the Industri-plex OU2 remedy relates to the Halls Brook Holding Area (HBHA). The HBHA consists of a pond and wetland area. The pond is a 4.6-acre storm water detention basin. Immediately south of the pond is the HBHA wetland, which covers approximately 10.6 acres. Surface water discharges into the pond from three main sources: Halls Brook (primary contributor under base flow), Atlantic Avenue Drainway (AAD), and Right of Way Number 9 (ROW No. 9) outfall. Water exits the pond from one outlet at its south end. The invert elevation of the outlet is approximately El. 50 ft.[1,2] Surface water in the HBHA wetlands discharges through a 60-in. diameter circular culvert/weir where the watercourse joins the Aberjona River. The Aberjona River flows south through box culverts, beneath Mishawum Road and Route 128. The invert elevation of this circular weir is El. 47.95 ft.

The water level in the pond was measured on 30 June 2000 at El. 51.2 ft. The 100-year flood elevation in the vicinity of HBHA Pond, as estimated by Federal Emergency Management Agency (FEMA), is approximately El. 55 ft[3] (5 ft above the invert elevation near the pond's outfall. The depth of the pond ranges up to approximately 16 ft (4.9 m) under normal stage height, although the majority of the pond

[1] Survey data from surface water gauging station SW-4.
[2] Datum: National Geodetic Vertical Datum of 1929.
[3] A more recent estimate of the 100-yr flood stage in the vicinity of the pond is El. 56.8 ft (VHB, 2003).

footprint is less than this depth. Sediment texture consists of loose, floc-like sediment overlying more dense, sand deposits. Based on existing data, the pond morphology is understood to include two main basins located in the northern and southern ends of the pond.

Additional information on the site history, property ownership, usage, etc. is provided in the Record of Decision (ROD), RD/RA CD and SOW and Administrative Record.

2.4 Site Status

The site is currently occupied by several commercial and industrial tenants, including the Massachusetts Bay Transportation Authority (MBTA) Anderson Regional Transportation Center for the commuter rail service. However, sampling and other field activities will be focused in areas that are generally unoccupied, some of which has restricted access (fencing, vegetation, etc.).

2.5 Site Plan

The Site Plan is presented as Figure 1-2.

2.6 Work Areas

Exclusion Zone. The Exclusion Zone isolates the area of contaminated media, and serves to restrict the potential spread of contamination from work areas of the Site to support areas and off-site locations. The Exclusion Zone will be demarcated by a tape line or physical barrier. Personnel entering the Exclusion Zone must:

- Enter through the CRZ
- Wear the prescribed level of PPE
- Be authorized to enter the Exclusion Zone

Any personnel, equipment, or materials exiting the Exclusion Zone must enter the Contaminant Reduction Zone (CRZ) where decontamination and disposal activities will occur. Decontamination will follow the guidance of Haley & Aldrich Operating Procedure OP3027-Decontamination. Disposable equipment and materials will be containerized according to Haley & Aldrich Operating Procedure OP3028-Investigation Derived Waste (Attachment D4).

Restricted areas for heavy machinery (i.e., excavators, drill rigs, etc.) use will be clearly marked and identified within the Exclusion Zone to ensure safe operation. Plans to provide emergency access to the Exclusion Zone are provided in the Contingency Plan described in Section 8.

Contaminant Reduction Zone. The CRZ is an area adjacent to the Exclusion Zone designated for decontamination and disposal activities associated with work conducted in the Exclusion Zone. Decontamination will follow the guidance of Haley & Aldrich Operating Procedure OP3027-Decontamination. Disposable equipment and materials will be containerized according to Haley & Aldrich Operating Procedure OP3028-Investigation Derived Waste (Attachment D4). After undergoing the decontamination process or containerization, personnel equipment or materials will be permitted to exit the CRZ.

Periodic assessments of the CRZ will be conducted to ensure that it maintains the proper level of housekeeping. The assessments will consist of visual determination. In the event of contamination of the CRZ, the SSO shall direct that the areas are brought up to the proper level of cleanliness and tailgate concerns to the site workers.

Support Zone. Support Zone(s) will be established at the areas within the Site boundaries not including the Exclusion Zone and the CRZ owned by the Settling Defendants on the Site [See Site Management Plan (SMP) for more detail]:

- The former Groundwater Treatment Building (GWTB) is adjacent to the southern portion of the MBTA Anderson Regional Transportation Center parking lot.
- The Thermal Oxidizer Unit (TOU) is located to the northeast of the MBTA Anderson Regional Transportation Center parking lot, adjacent to the Raytheon building.

These facilities will be used to support Site operations, general administrative tasks, and logistics. They will also serve as a centralized location for communication, storage of sampling equipment and PPE, and source of emergency assistance for operations in the Exclusion Zone and CRZ.

Periodic surveys of the Support Zone will be conducted in order to ensure that it remains free of contamination. The surveys will consist of air monitoring for Lower Explosive Limit (LEL) and Photoionization Detector (PID), visual determination, and field screening surfaces with a monitoring instrument or wipes. In the event of contamination of the Support Zone, the Contingency Plan will dictate an alternate, with priority given to existing buildings within the Support Zone.

3.0 SCOPE OF WORK

This Site-specific HASP addresses the health and safety practices and procedures that will be employed by all Haley & Aldrich employees participating in the site characterization of the Project Site. This HASP has been developed for the investigation phase of this project and will be continuously updated, as necessary, to be applicable to subsequent project phases including the design implementation phase. HASP update notification will be distributed when updates to the HASP requiring issuance of a HASP Amendment Form or reissuance of the HASP document are made. Haley & Aldrich will provide HASP update notifications to EPA, MassDEP, and de maximis within two (2) weeks of HASP updates or revisions.

This plan is based on an assessment of the site-specific health and safety risks by Haley & Aldrich and our experience with other project sites. Attachment D2 presents HASP Issuance and Compliance and Site Safety Officer Role and Responsibilities for the Site.

A series of Pre-Design Investigations (PDIs) will be conducted to provide data for the design of the remedy at the Site. This section presents a brief description of the tasks to be completed under the individual PDIs which require field investigations. Detailed descriptions of the field tasks required to complete each of the PDIs are described in the project Field Sampling Plan (FSP) and shall be referenced prior to completing the work. The tasks listed here are those which will be completed on the Site and fall under the jurisdiction of this HASP. Specific Standard Operating Procedures (SOPs) for the tasks listed below are included in the FSP. Table 3.1-1 summarizes the various tasks included as part of each PDI.

3.1 PDI-1: HBHA Pond Sediment Dredging

PDI-1: HBHA Pond Sediment Dredging provides information in support of the dredging, sediment dewatering, and disposal of sediment in the HBHA Pond. The field tasks that are included in the scope of PDI-1 are as follows:

- Bathymetric survey
- Sediment sampling
- Peat Probing
- Subsurface (pond) sampler and instrumentation deployment and collection (sediment traps)

3.2 PDI-2: Wells G&H and Cranberry Bog Conservation Area (CBCA) Wetlands Sediment Dredging/Excavation

PDI-2: Wells G&H and CBCA Wetlands Sediment Dredging/Excavation is designed to collect information in support of the removal, dewatering and disposal of wetlands soils/sediments. The field tasks included in the scope of PDI-2 are as follows:

- Accessibility survey
- Sediment sampling
- Wetland peat probing and soil boring

3.3 PDI-3: Groundwater Investigation

Information pertaining to the horizontal extent of groundwater plumes and groundwater discharge into the HBHA Pond and will be collected under the *PDI-3 Groundwater Investigation* series. The two subparts included in this section (*PDI-3A: Groundwater Discharge Evaluation to HBHA Pond and PDI-3B: Sitewide Groundwater Plume Investigation*) require the same field tasks to complete the individual scopes of work. Field tasks included in the scope of the PDI-3 series are as follows:

- Groundwater profiling using Direct Push Technology (DPT) and Low Flow Sampling
- Groundwater sampling
- Groundwater sampling from barge
- Drive point piezometer installation
- Water level measurement
- Monitoring well development
- Monitoring field explorations

3.4 PDI-4: HBHA Pond COC Transformation Processes & Studies

The four PDIs (PDI-4A through PDI-4D) included in the *PDI-4 HBHA Pond COC Transformation Processes & Studies* Series are designed to better understand the chemistry, hydrology and natural processes occurring in the HBHA Pond in order design an efficient treatment system in the Pond. The tasks involved in each of the PDIs under this series are listed below.

3.4.1 PDI-4A: Estimating Residence Times

Field tasks included in the scope of PDI-4A are as follows:

- Surface water sampling
- Surface water screening with full spectrum sonde
- Fluorescent dye study

3.4.2 PDI-4B: COC Transformation Processes

Field tasks included in the scope of PDI-4B are as follows:

- Surface water sampling
- Surface water screening with full spectrum sonde

3.4.3 PDI-4C: Surface Water Profiling

Field tasks included in the scope of PDI-4C are as follows:

- Surface water sampling
- Surface water screening with full spectrum sonde
- Meteorological monitoring
- Subsurface (pond) sampler and instrumentation deployment and collection (CTD sensors)

3.5 PDI-5: Tank Treatability Studies

The goal of this PDI is to investigate treatment components for the design of the treatment system in HBHA Pond. The field task associated with this PDI include the set-up and running of a tank treatability study. The studies consist of using tanks to model the processes occurring in HBHA Pond and altering conditions to test the natural processes occurring in the pond and to understand the appropriate way to

optimize these natural processes to enhance the remedy at the Site. The tank treatability studies will occur within a building on-Site.

3.6 PDI-6: Geotechnical Investigations

The three PDIs (PDI-6A through PDI-6C) included in the *PDI-6 Geotechnical Investigations* Series are designed to investigate subsurface conditions at different location of the Site to facility the construction of structures as needed to complete the remedy. The three PDIs included in this section (*PDI-6A: HBHA-4 Pond Cofferdam and Storm Flow Bypass, PDI-6B: Halls Brook Storm Bypass/Holding Dissipation Systems*, and *PDI-6C: AAD and BECO Drainway Storm Energy Dissipation Systems*) require the same field tasks to complete the individual scopes of work. These field tasks are as follows:

- Deep soil borings
- Soil borings and sampling
- Monitoring field explorations
- Identification and description of soils in the field
- Surficial soil sampling

3.7 PDI-9: West Hide Pile Investigations and Assessment

The PDI-9: West Hide Pile Investigations and Assessment series includes three subparts (*PDI-9A: WHP & EHP Investigations and Assessment, PDI-9B: WHP Enhanced Bioremediation Studies, and PDI-9C: Additional Actions to Address Unacceptable Risk(s)*) and involves field data collection to assess potential risks at this part of the Site. The field tasks that are necessary to complete the scope of the PDI-9 series are as follows:

- Sediment sampling
- Drive point piezometer installation
- Water level measurement
- Monitoring well development
- Groundwater sampling
- Surface water sampling
- Surface water screening with full spectrum sonde
- Monitoring field explorations

3.8 PDI-10: Impermeable Caps

Data collected under *PDI-10 Impermeable Caps* will be used to design the impermeable cap and to understand the hydraulic connection between surface water and groundwater in the area of the site drainage channels. The field tasks that are necessary to complete the scope of PDI-10 are as follows:

- Groundwater sampling
- Drive point piezometer installation
- Water level measurement
- Monitoring well development
- Surface water sampling
- Surface water screening with full spectrum sonde
- Monitoring field explorations

3.9 PDI-11: Permeable Caps

Data collected under *PDI-11: PDI-11 Permeable Caps* will be used to design the permeable cap for the AAD area. The field tasks that are necessary to complete the scope of PDI-11 are as follows:

- Soil borings and sampling
- Monitoring field explorations
- Identification and description of soils in the field
- Surficial soil sampling

3.10 PDI-12: Institutional Controls

Field data collection conducted under the *PDI-12: Institutional Controls* Series will provide information to delineate the extent and/or define the appropriate method of Institutional Controls needed at the Site. This PDI series is made up of five subparts, *PDI-12A: Soil Institutional Control Delineation, PDI-12B: Deeper Interior Sediment Institutional Control Delineation, PDI-12C: Groundwater Institutional Control Delineation, PDI-12D: Remedy Monitoring, Protection, and Permanent Access, and PDI-12E: Institutional Control Studies*. The field tasks that are necessary to complete the scope of the PDI-12 series are as follows:

- Groundwater profiling using DPT and Low Flow Sampling
- Groundwater sampling
- Surface water screening with full spectrum sonde
- Deep soil borings
- Soil borings and sampling
- Monitoring field explorations
- Identification and description of soils in the field
- Surficial soil sampling

3.11 PDI-14: Ammonia Background Investigation

The goal of PDI-14 Ammonia Background Investigation is to obtain groundwater data representative of background conditions and to identify other sources of ammonia that may be contributing to Industri-plex OU2. Surface water sampling was performed under Early Action Remedial Design Activities conducted in accordance with the 13 August 2008 letter submitted by de maximis Inc. to EPA under the 24 June 2008 Draft Health & Safety Plan. Since groundwater data from other PDIs (PDI-3, PDI-9, PDI-10, and PDI-12) and publically available information (Olin Chemical & Woburn Landfill wells) will be used to evaluate other sources of ammonia, no field tasks will be performed under PDI-14.

3.12 PDI-15: HBHA Pond Aeration Pilot Test

The results of PDI-15 will provide information regarding the efficiency and practicality of different types of aeration devices for possible use in the HBHA Pond treatment system. Test aeration devices will be installed by the device vendors. Precautions taken during the installation and maintenance of the devices will be consistent with working over water (see Section 4.5.5) and the manufacturers' safety precautions. The field tasks that are necessary to complete the scope of PDI-15 are as follows:

- Subsurface (pond) sampler and instrumentation deployment and collection (aeration devices)
- Surface water sampling
- Surface water screening with full spectrum sonde

3.13 PDI-16: Cofferdam Simulation Pilot Test

The goal of *PDI-16: Cofferdam Simulation Pilot Test* is to gather sufficient data to assess the option of using a synthetic, flexible curtain concept in the facilitation of the treatment system in HBHA Pond. The field tasks that are necessary to complete the scope of PDI-16 are as follows:

- Subsurface (pond) sampler and instrumentation deployment and collection (flexible curtain)
- Surface water sampling
- Surface water screening with full spectrum sonde
- Barrier system installation

4.0 HAZARD ASSESSMENT

Material Safety Data Sheets (MSDS) of hazardous materials used during the execution of work shall be available on site. MSDSs are required for chemicals used to prepare samples, calibration gases, etc. MSDSs are not required for waste materials. MSDSs are available in site field vehicles, at the Roland Street Laboratory, and are included in this HASP as Attachment D7. Copies of the HASP will be located in the primary field office, and in the site field vehicles.

The MSDSs for the chemicals listed below are provided in Attachment D7:

Decontamination Solutions:

- Alconox soap
- Distilled water
- Methanol
- Hexane

Sample Preservatives:

- Hydrochloric acid
- Nitric acid
- Sulfuric acid
- Sodium bisulfate
- Sodium hydroxide

Calibration Solutions:

- Isobutylene
- 4 pH buffer
- 7 pH buffer
- 10 pH buffer
- Conductivity solution (potassium chloride)
- ORP standard 100mV
- Ammonia standard (1, 10, 100 ppm as N)
- Mixed calibration gas [pentane 25% LEL, 19% O_2, 25 ppm hydrogen sulfide, 100 ppm carbon monoxide, and nitrogen (balance)]

Miscellaneous:

- Phosphorus (PDI-5)

4.1 Chemical Hazards

Chemical analysis data indicate that the site is contaminated. The potential physical state of the hazardous materials at the Site includes:

- Gas/Vapors
- Sludge
- Liquid
- Solid/Particulate

The anticipated or actual classes of compounds at the site are:

- BTEX (benzene, toluene, ethylbenzene, xylenes)
- Chlorinated Solvents
- Heavy Metals – Arsenic
- Inorganics – Ammonia
- Polycyclic Aromatic Hydrocarbons (PAHs) – Naphthalene, Benzo(a)pyrene

4.2 Impacted Environments

Contamination is expected in the following media:

- Groundwater – BTEX, chlorinated solvents, metals, naphthalene
- Surface water – ammonia
- Soil – BTEX, arsenic
- Sediment – arsenic, ammonia, benzo(a)pyrene

4.3 Major Chemicals

Table 4.3-1 summarizes the chemicals expected to be encountered by on-site personnel and the media within which these chemicals are expected to be present. These chemicals include the Site COCs as well as phosphorous, which will be brought on to the Site for use during the tank treatability studies conducted under PDI-5. While phosphorous is not found on-site, it has been added to this summary Table because workers may become exposed to this material while completing work.

4.4 Chemicals of Concern

The chemicals of concern at the Site are arsenic, ammonia, benzene, 1,2-dichloroethane, trichloroethene, naphthalene, and benzo(a)pyrene. For occupational exposure limits for these chemicals of concern, reference Table 4.4-1.

4.4.1 Arsenic

Breathing high levels of inorganic arsenic can cause a sore throat or irritated lungs. Ingesting very high levels of arsenic can result in death. Exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of “pins and needles” in hands and feet. Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small “corns” or “warts” on the palms, soles, and torso. Skin contact with inorganic arsenic may cause redness and swelling. Almost nothing is known regarding health effects of organic arsenic compounds in humans. Studies in animals show that some simple organic arsenic compounds are less toxic than inorganic forms. Ingestion of methyl and dimethyl compounds can cause diarrhea and damage to the kidneys.

OSHA has set limits of 10 microgram arsenic per cubic meter of workplace air (10 µg/m3) for 8-hour shifts and 40-hour work weeks. Since inorganic arsenic is a regulated carcinogen, OSHA has also established an Action Level at 5 µg/m3

4.4.2 Ammonia

Ammonia is often used for agricultural purposes, for refrigeration, and as a cleaner when dissolved in water. At room temperature it is a colorless, flammable gas with a pungent, suffocating odor. It becomes a clear, colorless liquid under increased pressure. Ammonia is usually shipped as a compressed liquid in

steel cylinders. Anhydrous ammonia is the form used primarily in refrigeration and agriculture. Ammonia dissolves in water to form ammonium hydroxide, a corrosive solution. Concentrations of ammonium hydroxide vary from 5 to 10% for household use and 25% or more for industrial use. No health effects have been found in humans exposed to typical environmental concentrations of ammonia. Exposure to high levels of ammonia in air may be irritating to skin, eyes, throat, and lungs and cause coughing and burns. Lung damage and death may occur after exposure to very high concentrations of ammonia. Some people with asthma may be more sensitive to breathing ammonia than others. Swallowing concentrated solutions of ammonia can cause burns in the mouth, throat, and stomach. Splashing ammonia into the eyes can cause burns and even blindness.

The OSHA permissible exposure limit for ammonia in air, based on an 8-hour Time-Weighted Average (TWA), is 50 parts per million (ppm). NIOSH has recommended a TWA of 25 ppm and a Short Term Exposure Limit (STEL) of 35 ppm.

4.4.3 Benzene

Benzene is a Volatile Organic Compound (VOC) and colorless liquid with a sweet odor. It evaporates into the air very quickly and dissolves slightly in water. It is highly flammable and is formed from both natural processes and human activities. Breathing very high levels of benzene can result in death, while high levels can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. Eating or drinking foods containing high levels of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, and death. The major effect of benzene from long-term exposure is on the blood. Benzene causes harmful effects on the bone marrow and can cause a decrease in red blood cells leading to anemia. It can also cause excessive bleeding and can affect the immune system, increasing the chance for infection. Some women who breathed high levels of benzene for many months had irregular menstrual periods and a decrease in the size of their ovaries, but we do not know for certain that benzene caused the effects. It is not known whether benzene will affect fertility in men.

The OSHA permissible exposure limit for benzene in air, based on an 8-hour Time-Weighted Average (TWA), is 1 part per million (ppm) and 5ppm as an STEL. Since benzene is a regulated carcinogen, OSHA has also established an Action Level at 0.5 ppm

4.4.4 1,2-Dichloroethane

1,2-dichloroethane, also known as Ethylene dichloride, is a VOC and a colorless liquid with a pleasant odor. While the major human exposure to 1,2-dichloroethane is through breathing low levels of the compound in the ambient air while working, workers can also be exposed by coming in contact with 1,2-dichloroethane in contaminated waters or soils. The latter route of exposure is not as common due to the volatile nature of the compound. 1,2-dichloroethane can be released into the environment during manufacturing, transporting, use and disposal of the compound. Nervous system disorders, liver and kidney diseases, and lung effects have been reported in humans ingesting or inhaling large amounts of 1,2-dichloroethane.

In laboratory animals, breathing or ingesting large amounts of 1,2-dichloroethane has also caused nervous system disorders and liver, kidney, and lung effects. Animal studies also suggest that 1,2-dichloroethane may damage the immune system. Kidney disease has also been seen in animals ingesting low doses of 1,2-dichloroethane for a long time. Studies in animals indicate that 1,2-dichloroethane does not affect reproduction.

The OSHA Permissible Exposure Limits (PEL) for 1,2-dichloroethane in air averaged over a normal 8-hour workday or a 40-hour workweek is 100 ppm, a ceiling concentration of 200 ppm and an STEL of 300 ppm for 5minutes in any three hour period.

4.4.5 Trichloroethene (TCE)

TCE is a colorless, nonflammable, non-corrosive liquid classified as a VOC and has a “sweet” odor characteristic of some chlorinated hydrocarbons. Breathing small amounts may cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing large amounts of trichloroethylene may cause impaired heart function, unconsciousness, and death. Breathing it for long periods may cause nerve, kidney, and liver damage. Drinking large amounts of trichloroethylene may cause nausea, liver damage, unconsciousness, impaired heart function, or death. Drinking small amounts of trichloroethylene for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear. Skin contact with trichloroethylene for short periods may cause skin rashes.

The OSHA PEL for TCE is 100 ppm as an 8-hour TWA; an acceptable ceiling concentration of 200 ppm; and an acceptable maximum peak ceiling of 300 ppm for no more than 5 minutes in any 2-hour period. The standard routes of entry in the body are through inhalation, percutaneous absorption, ingestion, skin and eye contact.

4.4.6 Naphthalene

Naphthalene is a PAH found in the solid form as a white powder and has a strong odor of mothballs. It is introduced into the environment through industrial processes; however, most naphthalene introduced into the environment is discharged into the air. Workers at hazardous waste sites can be exposed to Naphthalene by breathing ambient air while handling and disposing of contaminated waters and soils containing the compound. Workers can also be exposed to naphthalene by ingestion and dermal contact while working around the compound. Exposure to large amounts of naphthalene may damage or destroy red blood cells. This could cause a lack of red blood cells until the body is able to replace the destroyed cells. This condition is called hemolytic anemia. Some symptoms of hemolytic anemia are fatigue, lack of appetite, restlessness, and pale skin. Exposure to large amounts of naphthalene may also cause nausea, vomiting, diarrhea, blood in the urine, and a yellow color to the skin. Animals sometimes develop cloudiness in the eyes after swallowing high amounts of naphthalene. It is not clear whether this also develops in humans. Rats and mice that inhaled naphthalene vapors daily for a lifetime developed irritation and inflammation of their nose and lungs. It is unclear if naphthalene causes reproductive effects in animals; most evidence says it does not. There are no studies of humans exposed to 1-methylnaphthalene or 2-methylnaphthalene. Studies in which mice were fed food containing 1-methylnaphthalene and 2-methylnaphthalene for most of their lives found that portions of their lungs filled with an abnormal material.

The OSHA PEL for naphthalene in air is 50 mg/m^3 as an 8-hour TWA.

4.4.7 Benzo(a)pyrene

Benzo (a) pyrene is also classified as a PAH compound. PAHs are comprised of a group of many different chemical compounds that are formed during the incomplete combustion of organic fuels and substances. While PAHs can be natural in the environment, they are also introduced into the environment through the combustion process and/or are manufactured. PAHs exist as a colorless solid and can be found in coal tar, crude oil and creosote.
In the environment, PAHs are often found sorbed to soil/sediment particles due to the affiliation of PAHs to the organic carbon found in the soils/sediments, or in the atmosphere having volatilized from the water column. PAHs are not readily soluble in water. Workers can be exposed to PAHs including benzo(a)pyrene through inhalation, ingestion and dermal contact.

Short-term health effects can be a skin rash or eye irritation with redness and/or a burning sensation. Exposure to sunlight and the chemical together can increase these effects. Benzo[a]pyrene is a probable cancer-causing agent in humans. There is some evidence that it causes skin, lung, and bladder cancer in humans and in animals. If benzo(a)pyrene is on skin when during exposure to sunlight or ultraviolet light, there is an increased risk of skin cancer. Exposure to coal tar and pitch increases the likelihood of cancer. Repeated exposure to substances containing benzo[a]pyrene may cause the skin to thicken and darken, and for pimples to appear. Long-term skin changes include both loss of color and reddish areas, thinning of the skin and warts. Bronchitis may result from repeated exposure to mixtures containing benzo(a)pyrene.

The OSHA PEL for benzo(a)pyrene in air is 0.2 mg/m^3 as an 8-hour TWA measured as coal tar pitch volatiles.

4.5 Physical Hazards

Physical hazards include heavy equipment (i.e., drill rig, excavator), utilities, hoisting, noise, traffic, and chemical hazards associated with onsite contamination, fumes and dust. These Hazards are summarized in Table 4.5-1.

There are two main scenarios for working in the Pond during the cold weather months: 1) working over water from a boat; and 2) working over ice. Each of these two scenarios and the safety precautions associated with each are described below in Section 4.5.4.

4.5.1 Drilling Safety

[Please refer to Haley & Aldrich Operating Procedure OP1002-Drilling Safety (included in Attachment D4.)]

4.5.1.1 Heavy Equipment

Staff Members must be especially careful and alert when working with contractors who use heavy equipment, since equipment failure or breakage can lead to accidents and worker injury. Cranes and equipment for drilling, pile driving, test pitting and coring is of special concern. Should these devices fail during operation the likelihood of worker injury is high. Subcontractors will be responsible for visually inspecting and checking that their equipment is in proper working order prior to the commencement of field work. Subcontractors will also ensure that the operators of heavy equipment meet all of the requirements to operate heavy equipment. Inspections of equipment and operator licensure shall be addressed in the subcontractor's HASP. Haley & Aldrich, Inc. staff members that supervise projects or are associated with such high risk projects that involve digging should use due diligence when working with a subcontractor. Maintain visual contact with operators at all times and keep out of the strike zone whenever possible. Always approach heavy equipment with an awareness of the swing radius and traffic routes of each piece of equipment and never go beneath a hoisted load. High-visibility safety vests must be worn onsite at all times.

4.5.1.2 Noise

Site activities in proximity to heavy equipment often expose workers to excessive noise. It is anticipated that situations may arise when noise levels may exceed the OSHA Action Level of 85 Decibel Adjusted (dBA) in an 8-hour TWA. The SSO shall implement the requirements of OP1031-Hearing Conservation Program during site activities. As a general guideline, hearing protection should be worn if you have to raise your voice to speak to someone standing an arm's length away from you.

4.5.2 Site Security & Work Area Controls

Work areas will be cordoned off with traffic cones and caution tape during working hours. All borings will be backfilled, covered with the rig, or completed as wells during nonworking hours to prevent access. Additional Site security information is available in the SMP.

4.5.2.1 Special Precautions

All H&A personnel visiting the site will be given an orientation safety meeting. Daily tailgate safety meetings will be conducted and documented onsite following the requirements established in OP1033-Tailgate Safety Meetings. Site facilities personnel have been contacted to assist with location of underground utilities.

Housekeeping is essential to avoid creating a hazard to pedestrian and vehicular traffic. An exclusion zone will be set up using traffic cones or caution tape around work areas as necessary to protect passersby. High visibility safety vests required onsite for heavy equipment and traffic concerns. Avoid fumes created by heavy equipment exhaust.

4.5.2.2 Traffic

Work may occur near pedestrian and vehicular traffic. Work areas will be cordoned off with traffic cones and caution tape during working hours. All borings will be backfilled, covered with the rig, or completed as wells during.

4.5.2.3 Active Railroad Tracks

Some RD activities will be conducted adjacent to an active railway commuter line, such that there is a risk of injury to field personnel from moving trains. Massachusetts Bay Commuter Rail Company (MBCR) and Amtrak both utilize the railroad tracks located within or adjacent to the site. MBCR and Amtrak safety training will be required of all staff and subcontractors working in the right of way of the active railroad tracks. The training, as conducted by MBCR and Amtrak, will dictate which activities will require railway authorities are to be contacted, and to when the use of a flagman is required. The safety training will provide detailed risks and safety precautions related to working near or on active railroad tracks.

Proper attention and protection are essential to personal safety when working near railroad tracks. A few general safety precautions are listed below:

- Train or equipment movement should be expected on any track, in any direction, at any time.
- Work will not be performed at less than 25 ft from the centerline of any track unless a railroad representative has been notified or is present onsite.
- Do not walk between rails or foul track, except when duties require and proper protection is provided.
- When necessary to cross tracks, look in both directions and keep a minimum of 25 ft from the nearest end of stationary rail equipment.
- Stepping, walking, or sitting on the top of rail is prohibited; the railhead becomes very slick from oil buildup and presents a slipping hazard.
- Never sit or stand on other track components such as switch points, frogs, guard rails, derails, and wheel stops.
- When a train is approaching, staff or equipment working near the tracks should move as far away from the track as practical, until the entire train has passed.

- Never cross a track in front of oncoming traffic unless you are absolutely certain there is sufficient time and space to do so safely.
- Watch for protruding structures on passing equipment as well as other hazards.
- Violent arm, flag, or flashlight movement while trains are passing typically indicates an emergency (requires trains to stop) and must not be done unless an emergency exists.
- Do not lean on, climb on, or go under any on-track equipment unless your job requires it. Then do so only after all required safety procedures, such as lockout/tagout procedures have been put in place

Staff members shall adhere to safety procedures as directed by the MBCR and Amtrak safety training, at all times while working near or on active railroad tracks.

4.5.2.4 Environmental Controls (Erosion, Suspended Solids, Dust and Odor)

Adequate erosion controls shall be placed around work areas to minimize erosion during construction and prevent run-on and run-off from work areas. Adequate suspended solid controls shall be established for all in-water work activities to prevent downstream migration of suspended solids during construction. At a minimum, silt curtains shall be placed downstream of in-water work activities including dredging operations, cofferdam installation and wetlands restoration. Other appropriate suspended solids controls may be considered to prevent suspended solids migration. Dust controls and odor controls shall be established for the implementation of the remedial action. Dust controls shall be applied to any activity that has the potential to produce dust, and shall include, but not be limited to, the following: dust suppression water sprays and/or foams, applications of calcium carbonate, etc. Odor controls shall be applied to any activity that has the potential to produce unpleasant odors, and shall include, but not be limited to, the following: covering material with clean soils, odor suppression foams or masking agents, etc.

4.5.2.5 Environmental Monitoring (Surface Water, Dust and Odor)

Surface water monitoring and action levels shall be established for remedial action construction activities. Surface water quality shall be monitored daily to evaluate erosion controls and construction activities including water activities. If surface water conditions exceed surface water action levels, then further engineering controls shall be implemented immediately including: decreasing rate of/stopping construction activities, changing methods of construction, increasing erosion controls, etc. The primary considerations for establishing the surface water action levels shall be cleanup standards, ARARs, ensure workers, public and environmental are not at risk, and environmental conditions are not worsening downstream.

Air and dust monitoring and action levels shall be established for remedial action construction activities. Air and dust monitoring shall be implemented daily to evaluate air and dust controls and construction activities. If air or dust conditions exceed the action levels, then further engineering controls shall be implemented including: decreasing rate of/stopping construction activities, changing construction methods, increasing air/dust controls (e.g., water spraying and other dust suppression techniques), etc. The considerations for establishing the air and dust action levels shall be cleanup standards, ARARs, ensure workers, public and environmental are not at risk, and environmental conditions are not worsening downstream.

Odors shall be monitored by field personnel during all construction activities. Odors caused by construction activities shall be minimized by odor controls to ensure the protection of public health and welfare. In addition, any complaints regarding odor concerns associated with construction activities will be evaluated immediately and where appropriate, further controls shall be implemented to prevent/minimize these odors.

4.5.3 Working Outdoors

[Please refer to Haley & Aldrich Operating Procedures OP1003-Cold Stress & OP1015-Heat Stress (Attachment D4.)]

H&A employees and their subcontractors should be aware of potential health effects and/or physical hazards of working during inclement weather.

4.5.3.1 Cold Stress

Persons working outdoors in low temperatures, especially at or below freezing are subject to cold stress. Exposure to extreme cold for a short time may cause severe injury to the surface of the body, or result in profound generalized cooling, causing death. Areas of the body that have high surface area-to-volume ratio, such as fingers, toes, and ears, are the most susceptible.

Two factors influence the development of a cold injury: ambient temperature and the speed of the wind. Wind chill is used to describe the chilling effect of moving air in combination with low temperature. For instance, 10° F with a wind of 15 miles per hour (mph) is equivalent in chilling effect to still air at -18°F.

As a general rule, the greatest incremental increase in wind chill occurs when a wind of 5 mph increases to 10 mph. In addition, water conducts heat 240 times faster than air. Thus when chemical-protective equipment is removed the body cools suddenly if the clothing underneath is perspiration soaked. Warm, dry clothing must be available and donned as soon as possible when these conditions are present.

4.5.3.2 Frostbite

Local injury resulting from cold is included in the generic term frostbite. There are several degrees of damage. Frostbite of the extremities can be categorized into:

<u>Frost nip or incipient frostbite</u>: sudden blanching or whitening of the skin.

<u>Superficial frostbite</u>: skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.

<u>Deep frostbite</u>: tissues are cold, pale, and solid; extremely serious injury.

To administer first aid for frostbite, bring the victim indoors and heat the areas <u>quickly</u> in water between 102 and 105 degree F (39 and 41 degree C). Never place frostbitten tissue in hot water as the area will have a reduced heat awareness and such treatment could result in burns. Give a warm drink <u>not</u> coffee, tea or alcohol. The victim should not smoke. Keep the frozen parts in warm water or covered with warm clothes for 30 minutes, even though the tissue will be very painful as it thaws. Then elevate the injured area and protect it from injury. Do not allow blisters to be broken. Use sterile, soft, dry material to cover the injured areas. Keep victim warm and get immediate medical care.

After thawing, the victim should try to move the injured areas slightly, but no more than can be done alone, without help.

Do <u>not</u> rub the frostbitten area, use ice, snow, gasoline or anything cold on frostbite, use heat lamps or hot water bottles to re-warm the frostbitten area, place the frostbitten area near a hot stove.

4.5.3.3 Hypothermia

Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature. Its symptoms are usually exhibited in five stages:

- Shivering
- Apathy, listlessness, sleepiness, rapid cooling of the body to less than 95°F
- Unconsciousness, glassy stare, slow pulse, and slow respiratory rate
- Freezing of the extremities
- Death

The ultimate responsibility for postponing or delaying work at a site due to inclement weather rests with the Project Manager.

4.5.3.4 Heat Stress

Heat stress on hazardous waste sites or construction sites usually is a result of protective clothing decreasing natural body ventilation, although it may occur at any time work is being performed at elevated ambient temperatures. Because heat stress is one of the most common and potentially serious illnesses associated with hazardous waste site work, regular monitoring and other preventative measures are vital.

Site workers must learn to recognize and treat the various forms of heat stress.

The best approach is preventative heat stress management. In general:

- Workers should drink 16 ounces of water before beginning work, such as in the morning or after lunch. The water should be maintained at 50 to 60°F. Workers should drink one to two 4-ounce cups of water every 30 to 60 minutes. A cool area for rest breaks should be designated, preferably air-conditioned. The use of alcohol during non-working hours and the intake of caffeine during working hours can lead to an increase in susceptibility to heat stress. Monitor for signs of heat stress.
- Workers should acclimate to site work conditions by slowly increasing workloads, i.e., do not begin site work activities with extremely demanding activities. This acclimation process may require up to two weeks for completion.
- Cooling devices should be used to aid natural body ventilation. These devices, however, add weight, and their use should be balanced against worker efficiency. An example of a cooling aid is long cotton underwear, which acts as a wick to help absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing.
- Installed mobile showers and/or hose-down facilities should be used to reduce body temperature and cool protective clothing in serious heat stress situations.
- In hot weather, field activities should be conducted in the early morning or evening.
- Adequate shelter should be available to protect personnel from heat, as well as cold, rain, snow, etc., which can decrease physical efficiency and increase the probability of both heat and cold stress. Set up a command post in the shade or erect temporary shade at the workstation if practical.
- In hot weather, rotate shifts of workers with potential heat stress exposure.
- Good hygienic standards must be maintained by frequent changes of clothing and showering. Clothing should be permitted to dry during rest periods. Persons who develop skin problems should immediately consult medical personnel.

A. Heat Stress (Effects)

If the body's physiological process fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur ranging from mild (such as fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement) to fatal.

Heat-related problems are:

HEAT STROKE: An acute and dangerous reaction to heat exposure caused by failure of heat regulating mechanisms of the body; the individual's temperature control system that causes sweating stops working correctly. Body temperature rises so high that brain damage and death will result if the person is not cooled quickly.

Symptoms: Red, hot, dry skin, although person may have been sweating earlier; nausea; dizziness; confusion; extremely high body temperature; rapid respiratory and pulse rate; unconsciousness or coma.

Treatment: Cool the victim quickly and obtain immediate medical assistance. If the body temperature is not brought down fast, permanent brain damage or death may result. Soak the victim in cool but not cold water, sponge the body with rubbing alcohol or cool water, or pour water on the body to reduce the temperature to a safe level (102°F). Observe the victim and obtain medical help. Do not give coffee, tea or alcoholic beverages.

HEAT EXHAUSTION: A state of definite weakness or exhaustion caused by the loss of fluids from the body. This condition is much less dangerous than heat stroke, but it nonetheless must be treated.

Symptoms: Pale, clammy, moist skin, profuse perspiration and extreme weakness. Body temperature is normal, pulse is weak and rapid, and breathing is shallow. The person may have a headache, may vomit, and may be dizzy.

Treatment: Remove the person to a cool place, loosen clothing, and place in a head-low position. Provide bed rest. Consult physician, especially in severe cases. The normal thirst mechanism is not sensitive enough to ensure body fluid replacement. Have patient drink 1 to 2 cups water immediately and every 20 minutes thereafter until symptoms subside. Total water consumption should be 1 to 2 gallons per day.

HEAT CRAMPS: Caused by perspiration that is not balanced by adequate fluid intake. Heat cramps are often the first sign of a condition that can lead to heat stroke.

Symptoms: Acute painful spasms of voluntary muscles (e.g., abdomen and extremities).

Treatment: Remove the victim to a cool area and loosen clothing. Have the patient drink 1 to 2 cups water immediately, and every 20 minutes thereafter until symptoms subside. Total water consumption should be 1 to gallons per day.

HEAT RASH: Caused by continuous exposure to heat and humid air and aggravated by chaffing clothes. Decreases ability to tolerate heat.

Symptoms: Mild red rash, especially in areas of the body on contract with protective gear.

Treatment: Decrease amount of time in protective gear, and provide powder to help absorb moisture and decrease chaffing.

4.5.3.5 Lightning

- Always pay attention to the weather conditions. You are responsible for your own safety. Use common sense and do not feel pressure to continue to work if you feel there is a threat and others don't, such as contractors and co-workers.
- If you are using conductive tools and equipment, separate yourself from them as far as practical.
- If you are near a drilling rig, lower the mast and move away from the rig.
- Rule of thumb - wait until 30 minutes after the last observed lightning strike or thunderclap before resuming your outdoor activities, warns the National Lightning Safety Institute.
- Protect yourself by taking cover in the best shelter you can find.
- If you are in or near the water, go to land immediately and find shelter. Take extra precaution when on the water and in a boat.
- If choosing between a building and a car, choose the building.
- If choosing between a hardtop and a convertible, choose the hardtop.
- If you're in a car, keep the windows closed.
- If there is no shelter, find a low-lying, open place that is a safe distance from trees, poles, or metal objects that can conduct electricity. Make sure it is not likely to flood. Assume a tucked position: Squat low to the ground. Place your hands on your knees with your head tucked between them. Try to touch as little of your body to the ground as possible.
- Do not lie flat on the ground, as your fully extended body will provide a larger surface to conduct electricity. Stay in a tuck position well after the storm passes.
- Watch for local flooding you may have to move if water begins to accumulate.

If you feel your hair stand on end in a storm, drop into the tuck position immediately. This sensation means electric charges are already rushing up your body from the ground toward an electrically charged cloud. Minimize your contact with the ground to minimize your injury.

4.5.4 Water Safety (Work over Water from a Boat)

[The following guidelines are to be implemented alongside Haley & Aldrich Operating Procedure OP1008-Work Over, Near, or On Water (included in Attachment D4).]

There are three scenarios to the health and safety protocols while working over water from a boat:
1) Two workers sampling from a boat with a third person on shore for emergency rescue purposes.
2) Two workers sampling from a boat wearing full body cold weather insulated personal flotation devices (e.g., Mustang MS 2175 Class V PFD). 3) Working directly on thick ice, sampling through holes cut in the ice.

These scenarios differ in the type of required PPE number of personnel involved. Health and Safety protocols designed to deal with these scenarios are provided below.

Note: If ice exists on the pond, but is thin enough such that the boat can easily break it up to facilitate access using normal boat operation, then the water safety procedure for work over water in a boat can be utilized. If the ice cannot easily be broken, but is not sufficiently thick to enable work on ice, sampling will be postponed until the next safe opportunity.

A. Requirements When Third Person on Shore

Listed below are the minimum equipment requirements that H&A staff members must have prior to working on or near water in situations when personnel on shore available to call for help.

- USCG approved lifejacket, Personal Flotation Device (PFD) or buoyant work vest
- A 30-inch diameter ring buoy with 90 ft of line for emergency rescue operations
- At least one lifesaving skiff or boat immediately available for rescue services*
- For activities where personnel must board a vessel, an appropriate ramp gangway, ladder or Jacobs ladder must be available
- Appropriate illumination for activities that will occur at night or in reduced visibility. OSHA requires a minimum of five foot-candles measured in the working area
- A first aid kit shall be available on site or on the vessel
- No hazardous material in bulk (>55 U.S. gallons) shall be carried on board a vessel unless the vessel has been inspected and certified for that purpose by the USCG
- Appropriate firefighting equipment shall be provided on any vessel. Work areas shall be marked with "No Smoking" and other safety signs as may be required
- No plastics or other garbage shall be discharged overboard from any vessel. Any garbage that accumulates shall undergo proper disposal
- Equipment must be kept in good working condition and worn properly at all times
- Blankets and appropriate change of clothing for each person in the boat should be kept on-shore
- A lifesaving skiff or boat immediately available for rescuers

4.5.4.1 Requirements Without a Third Person on Shore (i.e., wearing "Mustang" cold weather suits)

In the event that water temperatures pose a potential exposure hazard, a cold water immersion suit must be available on the boat.

Listed below is the minimum equipment requirements that H&A staff members must ensure are provided prior to working on or near water under this scenarios.

- A one-piece worksuit with integrated PFD and cold water/weather hypothermia protection (e.g., Mustang MS 2175 Class V PFD)
- All other requirements as per above for work with a third person on shore

4.5.5 Working Over Ice

In the event the surface cover of the Pond is frozen and of sufficient strength to support the work activities and people, the following precautions shall be used to allow safe work practice.

1. Workers will wear a cold water immersion suit (e.g., Mustang MS 2175 Class V PFD).
2. The combined weight of workers (assume 2 @ 250lbs) and equipment (assume 300 lbs) shall not exceed 1 ton.
3. No vehicles (i.e., snowmobile, all-terrain vehicle, automobile) shall be used over the ice. A small sled may be used to transport equipment.
4. A minimum of 4 inches of solid ice is required for work over ice. No work shall be completed over ice during mixed ice (i.e., partially frozen pond) scenarios, however boat work may be completed per Haley & Aldrich's "Work over Water" operating procedure.
5. No vehicles will be driven on the pond.
6. No significantly large loads (>1 ton) will be brought on the ice.

7. All equipment will be removed from the ice immediately following the completion of sampling procedures.

Attachment D5 includes the U.S. Army Cold Regions Research & Engineering Laboratory's "Safety on Floating Ice Sheets" work guidance [from http://www.crrel.usace.army.mil/icejams/icesafety/]. This guidance document provides information on weight limits for various thicknesses of Ice and should be used as a reference. Contact the Project Manager immediately if there is there is any uncertainty regarding ice thickness, weigh capacity of the ice, or safety procedures for working on ice. Do not, under any circumstances, proceed to work on ice if the proper safety precautions have not been followed.

4.5.6 Drums

[Please refer to Haley & Aldrich Operating Procedure OP3028-Investigation Derived Waste for additional information]

Accidents may occur during handling of drums and other hazardous waste containers. Hazards include detonations, fires, explosions, vapor generation and physical injury resulting from moving heavy containers by hand and working around stacked drums, heavy equipment and deteriorated drums. While these hazardous are always present proper work practices can minimize risks to site personnel. Planned field activities under the RD do not anticipate investigating or encountering waste drums other than those provided for investigation derived waste disposal.

4.5.7 Rig Inspection and Set-Up

Each day, prior to the start of work, the driller will inspect the drill rig and associated equipment. The following checks will be made:

- Vehicle condition: Check proper operation of brakes, lights, steering mechanism, back-up alarms and horn. The operator shall also inspect the vehicles for fluid leaks. Under no circumstances will leaking equipment be allowed to be used or stored on-site.
- Equipment storage: All equipment such as auger flights, split spoon samplers, hammers, hand tools, etc. will be properly stored in an appropriate location and will be secured before moving the rig
- Wire rope, Cat Line: All wire rope, cable and Cat Line will be inspected for signs of wear such as broken wires, a reduction in rope diameter, abrasion, or signs of rust. Worn, frayed, or otherwise damaged wire, rope or cable will be replaced
- Safety equipment: Each rig will have at least one fire extinguisher (Type B/C) and one First Aid Kit

Each drill rig will be properly blocked and leveled prior to raising the derrick. The rig will be moved only after the derrick has been lowered. The leveling jacks will not be raised until the derrick has been lowered.

Blocking provides a more stable drilling structure by evenly distributing the weight of the rig. Proper blocking ensures that a differential settling of the rig does not occur. Wooden blocks, at least 12 by 12 inches and four to eight inches thick, are recommended and should be placed between the jack swivels and the ground. The emergency brake will be engaged and the wheels that are on the ground chocked.

Site drilling will comply with the following rules:

- Before drilling, the Contractor/Consultant Site Coordinator will ensure an adequate safety zone around the drill rig and associated operations

- Before drilling, the existence of underground utilities in the work area will be determined and conspicuously marked
- If drilling is conducted in the vicinity of overhead power lines, proper distance will be maintained between the drill rig and the lines as per OSHA 29 CFR 1926, Subpart N and as detailed in OP1020-Overhead Utilities. The proper distance or shielding technique will be determined prior to each field activity.

4.5.8 Biological Hazards

Biological Hazards exist at the Site. Potential biological hazards include exposure to:

- Poison ivy, poison oak, and poison sumac, which may be present along the stream banks at and downstream of Industri-plex OU2
- Ticks, bees, and wasps
- Snapping turtles
- Potentially poisonous snakes and potentially rabid stray or wild animals

4.6 Potential Activity Hazards and Hazard Controls

POTENTIAL ACTIVITY HAZARD		
Abrasions and Cuts ✓	Fueling and Fuel Storage ✓	Overloaded Equipment ✓
Access ✓	Fugitive Dust ✓	Oxygen Deficiency
Asphyxiation	Fumes ✓	Pinch Points ✓
Bacteria	Generated Wastes ✓	Poisonous Plants ✓
Biological Hazards ✓	Guards removed	Pressure
Bloodborne Pathogens	Hazardous Materials ✓	Pressurized Lines
Cave Ins	Heat Stress (cramps, exhaustion, stroke) ✓	Radiation
Chemical/Thermal Burns	Heavy Equipment Operation ✓	Repetitive Motion
Chemicals	Heavy Equipment/Stability ✓	Rigging - Improper ✓
Cold Stress ✓	Heavy Lifting ✓	Sharp Objects ✓
Compressed Gases	High crime area (violence)	Silicosis
Confined Spaces	High Winds	Slips, Trips, and Falls ✓
Congestion	Hoists, Rigging, Slings, Cables ✓	Sprains and Strains ✓
Defective Equipment	Housekeeping – Improper ✓	Steam
Dermatitis	Illumination - Poor	Sunburn ✓
Dropping Materials/Tools to Lower Levels	Impact	Surface Water Run-off ✓
Drowning or Flowing Water ✓	Inability to Maintain Communication	Toxicity
Electrical Shock	Inclement Weather ✓	Traffic ✓
Energized Equipment ✓	Inclines	Underground Utilities ✓
Equipment Misuse ✓	Insects/Reptiles ✓	Uneven Terrain ✓
Ergonomics ✓	Mold	Unsafe Atmosphere
Excavations ✓	Moving Equipment, Conveyors or Vehicles ✓	Vibration
Explosions	Muddy Site Conditions ✓	Visibility - Poor
Fatigue ✓	New Personnel ✓	Visitors Known/Unknown ✓
Fire	Noise ✓	VOC Emissions
Flammability	Odor ✓	Weight ✓
Flying debris	Overhead Utilities ✓	Work at Depth
Foreign Body in Eye	Overhead Work	Work at Heights
Frostbite/Cold ✓		Work over Water ✓
		Working on Ice ✓
HAZARD CONTROLS		
Air Monitoring ✓	Fall Protection	Manual Lifting Equipment
Appropriate Clothing/Monitoring of Weather ✓	Fire Extinguisher ✓	Police Detail
Appropriate Labels/Signage ✓	Flotation Devices/Lifelines✓	Proper Lifting Techniques ✓
Barricades/Fencing/Silt Fencing ✓	Gloves ✓	Proper Tool for Job ✓
Buddy System - Attendant ✓	Ground Fault Interrupter	Proper Work Position/Tools ✓
Chock Blocks	Grounded Hydraulic Attachments	Protective Equipment ✓
Confined Space Procedures	Grounded Equipment/Tanks ✓	Radio Communication
Decontamination Procedures ✓	Hand Signal ✓	Respirator, (Specify Type)
Derived Waste Management Plan ✓	Communication✓	Safety
Drinking Water/Fluids ✓	Hard Hat	Harness/Lanyard/Scaffold
Dust Abatement Measures ✓	Hazardous/Flammable Material Storage	Security Escort
Emergency Action Plan Procedures ✓	Hearing Protection	Sloping, Shoring, Trench Box
Equipment Inspection ✓	High Visibility Safety Vest ✓	Spill Prevention Measures
Equipment Manuals/Training ✓	Hoses, Access to Water ✓	Spill Kits
Exclusion/Work Zones ✓	Hotwork Procedures	Stormwater Control ✓
Exhaust Ventilation	Isolation of Energy Sources(Lockout/Tagout) ✓	Traffic Controls ✓
Eye Protection ✓	Machine/Equipment Guards	Procedures/Method s ✓
		Vehicle Inspection
		Visitor Orientation Escort ✓
		Window Cleaning/Defrost

4.6.1 Specific Activity Hazards and Precautions

Haley & Aldrich personnel should be cognizant of the intrinsic danger of working on ice and/or over water as discussed previously.

Hazards include drilling related physical hazards due to heavy equipment, utilities, hoisting, noise, traffic, and chemical hazards associated with onsite contamination, fumes and dust.

4.6.2 Safety Meetings

All H&A personnel visiting the site will be given an orientation safety meeting and are required to read and sign this HASP. Daily tail gate safety meetings will be conducted onsite and documented on a Health & Safety Tailgate Meeting Form.

4.6.3 Utility Locators and Underground Hazards

Prior to drilling or excavating, Haley & Aldrich staff members will ensure that permission has been gained from the property owner to access the property. Contact site facilities personnel to assist with location of underground utilities. Before marking any proposed exploration location, it is critical that all readily available information on underground utilities and structures be obtained. The estimated location of utility installations, such as gas, electric, fuel, steam, sewer, telephone, fiber optic, water, drainage or any other underground installation that may be expected to be encountered during drilling work, will be identified with the appropriate authority. Appropriate authorities include client representatives, utility companies, nonprofit organizations (e.g., "Dig-Safe), and others.

Note: It is important to note that not all utilities are participants in the "one-call" agency or process. As such, inquiries must be made with the "one-call" agency to determine which entities do not participate, so they can be contacted independently.

Also, most stake-outs or markings have a limited time period for which they remain valid, typically 2 to 3 weeks. It is critical that this time period be taken into account to prevent expiration of clearance prior to completion of the invasive activities, and the need to repeat the process.

Completion of the utility stake out is not a guarantee that the underground facilities will not be encountered in the boreholes; very few if any guarantee their work or accept the liability for damage or losses if one may occur. Accordingly, Haley & Aldrich field staff is expected to use extreme caution in the upper 4-5 ft in the event the clearance has failed to identify an existing facility. This may necessitate hand-excavation or probing to confirm the presence of shallow utilities.

When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours (unless a longer period is required by state or local law), or cannot establish the exact location of these installations, geophysical techniques, such as ground penetrating radar and/or magnetometery can be utilized to locate the potential underground hazards. Using any information that can be obtained, the site should be viewed in detail for physical evidence of buried lines or structures. Evidence of surface elements of buried utilities should be documented, such as manholes, gas or water valves, catch basins, etc.

No subsurface drilling activities will be allowed until "all" utilities have been properly located and marked.

Marking locations can be accomplished using spray paint on the ground, stakes, or other similar method. All markings of proposed locations shall be made in white, in accordance with the generally-accepted universal color code for facilities identification.

White:	Proposed excavation or drilling location
Pink:	Temporary Survey Markings
Red:	Electrical, Power Lines, Cables, Conduit, and Lightening Cables.
Yellow:	Gas, Oil, Steam, Petroleum, and Gaseous Materials.
Orange:	Communications, Alarm, or Signal Lines, Cables, and Conduits.
Blue:	Potable Water.
Purple:	Reclaimed Water, Irrigation, and Slurry Lines.
Green:	Sewers and Drain Lines.

The public and private utility entities generally only mark the locations of their respective underground facilities within public rights-of-way. Determination of the locations on private property will most likely be the responsibility of Haley & Aldrich or the contractor. In some cases, it may be necessary to put the ultimate responsibility back on the owner, to assist in the location of the utilities. It is incumbent on Haley & Aldrich and the Contractor to exercise caution and use good judgment when faced with uncertainty.

4.6.4 Overhead High Voltage Electric Transmission Lines

Maintain the following minimum clearances between mechanical equipment and electrical transmission lines:

Voltage	Distance
5-15 kV	10 ft.
23-34.5 kV	10 ft.
46-69 kV	10 ft. 8 in.
115 kV	12 ft. 4 in.
230 kV	16 ft.
345 kV	20 ft.
345-800 kV	21 ft.
Maintain 10 ft. of clearance from overhead lines for voltages of up to 50 kV. For voltages greater than 50 kV maintain 10 ft. of clearance plus an additional 4 in. for every 10 kV over 50 kV.	

4.6.5 Heavy Equipment

Staff Members must be especially careful and alert when working with contractors who use heavy equipment, since equipment failure or breakage can lead to accidents and worker injury. Cranes and equipment for drilling, pile driving, test pitting and coring is of special concern. Should these devices fail during operation the likelihood of worker injury is high. Subcontractors will be responsible for visually inspecting and checking that their equipment is in proper working order prior to the commencement of field work. Subcontractors will also ensure that the operators of heavy equipment meet all of the requirements to operate heavy equipment. Inspections of equipment and operator licensure shall be addressed in the subcontractor's HASP. Haley & Aldrich, Inc. staff members that supervise projects or are associated with such high risk projects that involve digging should use due diligence when working with a subcontractor.. Maintain visual contact with operators at all times and keep out of the strike zone whenever possible. Always approach heavy equipment with an awareness of the swing radius and traffic routes of each piece of equipment and never go beneath a hoisted load. High-visibility safety vests must be worn onsite at all times. Avoid fumes created by heavy equipment exhaust.

4.6.6 Noise Reduction

Site activities in proximity to heavy equipment often expose workers to excessive noise. It is anticipated that situations may arise when noise levels may exceed the OSHA Action Level of 85 dBA in an 8-hour TWA. An example of this possibility is working in close proximity to the subcontractor during drilling activities onsite. If excessive noise levels occur, efforts will be made to control this by issuance of earplugs to all personnel and by implementing a system of hand signals understood by all.

4.6.7 Work Site Access & Controls (Standard Precautions)

The work area is restricted to authorized personnel. Clearly define the work area before beginning activities for the day. Caution tape and safety cones must be provided as necessary for vehicular traffic concerns and to protect passers-by. Proper housekeeping is essential to avoid creating a hazard to pedestrian and vehicular traffic. Excavations in progress will not be left unattended at any time. Running equipment will not be left unattended at any time.

4.6.8 Site Security

Access to the Site is controlled during non-work hours with multiple locked gates and fences.

4.6.9 Hazard Communication

[Please refer to Haley & Aldrich Operating Procedure OP1014-Hazard Communication (included in Attachment D4.)]

4.6.10 Reporting Incidents

[The following guidelines are to be implemented alongside Haley & Aldrich Operating Procedure OP1016-Recordkeeping and Reporting (included in Attachment D4.)]

Detailed reporting procedures for work-related accidents and incidents involving H&A staff members consist of the following sequential steps:

1. Initial notification - The staff member who is injured or otherwise directly involved in a work-related incident is responsible for immediately notifying his/her supervisor (staff manager) of the event. Obviously, any other staff member present at the site may make the notification if the injury is serious and/or debilitating.

2. Secondary notifications - The staff manager shall notify his/her RHSC of the accident/incident as soon as possible after the initial response is completed. If a serious work-related injury occurs, the staff manager shall also directly notify the Corporate H&S Manager. The RHSC shall notify the Corporate H&S Manager in all minor cases. The Corporate H&S Manager will, in turn, be responsible for notifying senior H&A management, via email and/or phone, as necessary.

   All work-related injuries, illnesses, and near misses <u>shall</u> be reported to the RHSC, regardless of severity. Thus, at a minimum, all first aid cases must be reported. It is not the responsibility of the staff manager or project manager to determine what shall be reported to the RHSC. The RHSC will work closely with the CHSM to determine report-ability and record-ability of an injury/illness on each case.

3. Accident report - After the initial response (medical attention, etc.) is completed, the accountable staff manager is responsible for initiating an investigation into the cause of the accident/incident

and for completing the H&A accident/incident report form. The H&A "Supervisor Accident/Injury/Near Miss Report" (SAIR) (Attachment D6) In the case of large projects, the Site Safety Officer may initiate this.

The staff manager is responsible for submitting the completed report to the RHSC by the close of business on the day following the event (24 hours). Again, if a serious work-related injury/incident occurs, the staff manager shall fax the report directly to the Corporate H&S Manager.

4. Report distribution - Copies of the report shall immediately be forwarded to the Corporate Human Resources (HR) Representative via fax (Laura Colombo- Fax #- 781.685.2161 and CHSM Fax# - 714.371.1866) for placement in the respective incident/injury case and workers' compensation files. This is the responsibility of the RHSC. In the event that the RHSC is not available, the staff manager will be delegated the responsibility.

   Corporate HR will ensure a "First Report of Injury or Illness" report is filed with our insurance carrier, currently Liberty Mutual. This will fulfill our obligation to meet OSHA recordkeeping requirements and begin the process to ensure medical bills are properly processed through our workers compensation carrier.

   The RHSC will contact the Corporate H&S Manager to discuss recording the injury on the OSHA 300 log and summary of occupational injuries and illnesses.

5. Corrective actions - The staff manager and RHSC (with input from the injured staff member and other staff members involved in the incident) are responsible for determining a course of action to ensure that the accident/incident does not occur again. Responses to serious work-related accidents or incidents may require the approval of the Corporate H&S Manager and senior management.

It is important that all H&A staff members understand these reporting procedures and the significance of the role of the staff member's staff manager in the process of responding to and reporting on-the-job injuries, illnesses and near misses.

4.6.11 Medical Attention

The staff member should seek emergency medical services from an institution that is convenient for the services needed, such as a clinic, hospital, etc. If the injury is not an emergency, but medical treatment is required, refer the staff member to the Concentra clinic listed in the table under Section 1.1 on page 1 of this HASP. The staff member may seek medical services from their own physician, but only if a signed notification form is on file with the Company stating that they prefer to be examined by their own physician in the event of a work-related injury.

4.6.12 Training

Personnel will not be permitted to participate in or supervise field activities until they have been trained to a level required by their job function and responsibility. Haley & Aldrich staff members, contractors, subcontractors, and consultants who have the potential to be exposed to contaminated materials or physical hazards must complete the training described in the following sections.

4.6.12.1 40-Hour Health and Safety Training

This basic course provides instruction on the nature of hazardous waste work, protective measures, proper use of personal protective equipment, recognition of signs and symptoms which might indicate exposure

to hazardous substances, and decontamination procedures. It is required for all personnel working on-site, such as equipment operators, general laborers, and supervisors, who may be potentially exposed to hazardous substances, health hazards, or safety hazards consistent with 29 CFR 1926.65 Hazardous Waste Operations and Emergency Response.

4.6.12.2 8-hour Annual Refresher Training

Haley & Aldrich personnel are required to complete the 40-hour health and safety training is subsequently required to attend an annual 8-hour refresher course to remain current in their training. All site personnel must show attendance at an 8-hour refresher training course within the past 12 months.

4.6.12.3 8-Hour Supervisor Training

On-site managers and supervisors directly responsible for, or who supervise, staff members engaged in hazardous waste operations should have eight additional hours of Supervisor training in accordance with 29 CFR 1926.65. This course includes, but is not limited to, elements appropriate to supervising hazardous waste related projects (e.g., accident reporting/investigation, regulatory compliance, work practice observations, auditing, emergency response procedures, etc.).

4.6.12.4 Competent Person Training

Personnel participating in field activities which include excavation of any kind are required to be Competent Person Trained. In accordance with Code of Massachusetts Regulations (CMR) for excavation and trench safety (520 CMR 14.00) a competent person must be present at and responsible for any excavation or trenching that occurs on Site in order to receive the necessary permits.

4.6.12.5 Additional Training for Specific Projects

Haley & Aldrich will ensure their personnel have received additional training on specific instrumentation, equipment, confined space entry, construction hazards, etc., as necessary to perform their duties. This specialized training will be provided to personnel before engaging in the specific work activities.

4.6.12.6 Documentation of Training

The Haley & Aldrich Project Manager will be responsible for maintaining and providing to the client/site manager documentation of H&A staff members' compliance with required training. The client/site manager will only allow properly trained and qualified personnel to perform work at the site.

5.0 PROTECTIVE MEASURES

This section presents the personal protective equipment requirements and the general safety equipment requirements for the Site. Work shall not commence until the necessary safety equipment, as described below, is present on-Site and being used properly.

5.1 Personal Protective Equipment Requirements

A summary of PPE requirements by task is presented in Table 5.1-1. Work shall not commence unless the required PPE is present and being used appropriately. The Site Safety Officer may require additional PPE in the event of changes to Site-specific conditions. In such an instance, a HASP Amendment Form should be completed and submitted to the Project Manager and Regional Health and Safety Coordinator.

5.2 Site Safety Equipment Requirements

The following safety equipment items are required on Site:

- First Aid Kit
- Flashlight
- Duct Tape
- Cellular Phone
- Two 30 inch diameter ring buoys, each with 90 ft of line for emergency rescue operations during work within HBHA Pond

The required equipment listed above must be on site during the task being performed. Work shall not commence unless the equipment is present.

6.0 MONITORING PLAN AND EQUIPMENT

This section presents the monitoring/screening equipment requirements for personal protection on the Site, the standard action levels and required responses for chemical exposures, and a standard air monitoring plan to be used while completing work on the Site. Given the COCs at the Site, workers may come in contact with the following volatile compounds: ammonia, benzene, 1,2-dichloroethane, TCE, naphthalene, and benzo (a) pyrene. Based on the amount of work that is centered around/on the HBHA Pond, and the primary volatile compounds of concern on the Site are ammonia and benzene. The general approach to worker health and safety regarding exposure to volatiles will be to screen for volatiles using a PID. Since benzene has the lowest PEL (1 ppm) of the listed volatiles at the Site, when air monitoring readings within the breathing zone reach any concentration above background levels, a Draeger tube will be used to identify the compound and give a concentration. Exposure Guidelines for common contaminants in air are listed in Table 4.4-1.

6.1 Monitoring/Screening Equipment Requirements

Air monitoring is required on the Site for the personal protection of workers. Air monitoring of the breathing zone will be conducted using an 11.7eV PID and is required at the commencement of intrusive activities on the Site, when first exposed to the contaminated media. Such activities include, but are not limited to drilling and soil sampling, well installation, and running tank treatability studies. Air monitoring is not required during low-exposure activities such as surface water sampling and groundwater monitoring and sampling. If unusual odors are noted during these activities, air monitoring should commence.

Work shall not commence until a PID is present on Site. If elevated concentrations of volatiles are detected by the PID in the breathing zone (greater than 1 ppm above background sustained for 5 minutes), compound specific Draeger Tubes will be used to determine the compound and concentration of the compound in the air. Requirements for PPE upgrades based on monitoring with the Draeger gas detection tubes are in Table 6.1.1.

All monitoring/screening equipment must be intrinsically safe where warranted. Instruments will be calibrated and maintained in accordance with the manufacturer's recommendations. Calibration records will be maintained in a daily field log book. Backup monitoring equipment is required to be available on Site as determined by the Site Safety Officer. Field activities will be suspended if the properly calibrated field monitoring instrumentation is not available.

6.2 Standard Air Monitoring Plan

The following is the standard air monitoring plan to be followed while conducting work on the Site. Please refer to Haley & Aldrich Operating Procedures OP1004-Operation and Calibration of PID Photoionization Detector & OP1006-Operation of Draeger Gas Detection Pump (included in Attachment D4) for additional information on the specifics of the PID and Draeger sampling methods.

The standard air monitoring plan is as follows:

- Secure necessary air monitoring equipment (PID) and compound specific Draeger Tubes.
- Prior to the beginning of work obtain background readings with the PID away from the site.
- Monitor the breathing zone (9 inch radius hemisphere centered at the nose and forward of the shoulders) with the PID when first exposed to the media.

- Monitoring should be conducted most frequently (e.g., every 15 to 30 minutes) when work first begins in a particular area. After this, and if no exceedances of exposure limits are noted (see Table 4.4-1), monitoring may be conducted less frequently (e.g., every 60 minutes).
- If any reading above background levels is detected with the PID for 5 minutes or longer, back away for a few minutes. Screen the air again after any vapors/gases have been given a chance to dissipate.
- If detection levels above background are still noted at or around 1 ppm, use a Draeger tube for benzene to try to determine if the compound setting off the PID is benzene. If so, evacuate the area and call the RHSC and PM for further guidance.
- If the Draeger tube test for benzene returns a negative result, consult the odor threshold table below for the other volatiles on site. Conduct Draeger tube tests as necessary to identify the constituent setting off the PID. Understand the PEL for that compound and continue to use the PID as a screening device. Draeger tube tests shall be taken as necessary to ensure worker safety.
- Record monitoring data and PPE upgrades in field book or on Record of Field Monitoring form and maintain with project files. Record time, location and results of monitoring and actions taken based upon the readings.

Contaminant of Concern	Odor Threshold
Ammonia	6 ppm
Arsenic	N/A
Benzene	9 ppm
Benzo[a]pyrene	N/A
1,2-Dichlorethane	11 ppm
Naphthalene	0.015 ppm
Trichlorethylene	2 ppm

6.3 Additional Monitoring

In addition to the air monitoring plan that is established for the Site using a PID and Draeger tube approach to air monitoring, multiple gas detectors will be used when necessary including, but not limited to working in enclosed spaces or buildings.

Standard action levels and required responses for constituents detected with a multiple gas detector are listed below:

Instrument	Normal	Operating levels	Action levels – required responses
Oxygen Meter	20.9%	Between 19.5-23.5%	Below 19.5 %: leave area, requires supplied air Above 23.5%: leave area, fire hazard
CGI	0%	Less than 10%	Greater than 10%: fire/explosion hazard; cease work
Hydrogen Sulfide	0%	Less than 10 ppm.	Greater than 15 ppm (or 10 ppm for 8 hrs) leave area, requires supplied air respirator
Carbon Monoxide	0%	Less than 25 ppm	Greater than 200 ppm for 1 hour (or 25 ppm for 8 hrs) leave area, requires supplied air respirator

7.0 DECONTAMINATION AND DISPOSAL METHODS

This section presents procedures and protocols for personal hygiene and decontamination of equipment. Please refer to Haley & Aldrich Operating Procedures OP3027-Decontamination Procedure & OP3028-Investigation Derived Wastes for additional information (Attachment D4).

7.1 Personal Hygiene Safeguards

The following minimum personal hygiene safeguards shall be adhered to:

- No smoking products, tobacco products, or alcoholic beverages on any HAZWOPER project
- No eating or drinking in the exclusion zone
- It is required that personnel present on site wash hands before eating, smoking, taking medication, chewing gum/tobacco, using the restroom, or applying cosmetics and before leaving the site for the day
- It is recommended that personnel present on site shower or bathe at home at the end of each day of working on the site

7.2 Standard Personal Decontamination Procedures

Outer gloves and boots should be decontaminated periodically as necessary and at the end of the day. Brush off solids with a hard brush and clean with soap and water or other appropriate cleaner whenever possible. Remove inner gloves carefully by turning them inside out during removal. Wash hands and forearms frequently. It is good practice to wear work-designated clothing while on-site which can be removed as soon as possible. Non-disposable overalls and outer work clothing should be bagged onsite prior to laundering. If gross contamination is encountered on-site contact the Project Manager and SSO or RHSC to discuss proper decontamination procedures. The steps required for decontamination will depend upon the degree and type of contamination and the type of PPE in use, but will generally follow the sequence below.

1. Remove and wipe clean hard hat
2. Rinse boots and gloves of gross contamination
3. Scrub boots and gloves clean
4. Rinse boots and gloves
5. Remove outer boots
6. Remove outer gloves
7. Remove Tyvek coverall
8. Remove respirator, wipe clean and store
9. Remove inner gloves

7.3 Location of Decontamination Station

The decontamination station will be in or near the GWTB or other suitable site location adjacent to work areas, as appropriate.

7.4 Disposal of PPE

All used PPE must be bagged (sealed) and field personnel should communicate with the Project Manager to determine proper disposal. A drum or container for containerizing investigation-derived waste will be provided.

7.5 Tools & Equipment Decontamination

All decontamination should be conducted at the site and not at the office or lab. See OP 3027: Decontamination Procedure for additional details. The following are needed for the decontamination of tools and other equipment:

- Distilled water
- Tap water
- Drums for water
- 5-gallon buckets
- Poly sheeting
- Alconox soap
- Cleaning brushes
- Paper towels

7.6 Standard Equipment Decontamination Procedures

All monitoring instrumentation and delicate instruments that are difficult to decontaminate or sensitive to water should be protected from contamination during use through the use of plastic sheeting. To the extent possible, efforts should be taken to limit the degree of contamination to hand tools and sampling equipment during use. Proper PPE must be worn while performing decontamination, including the wearing of chemical safety goggles and gloves. Standard equipment decontamination procedures are as follows. Any additional requirements are listed under Specific Equipment Decontamination Procedures below.

1. Wash using Alconox
2. Rinse with tap water
3. Rinse with de-ionized water

7.7 Specific Sampling Equipment Decontamination Procedures

All equipment that comes in contact with the physical media being sampled (i.e., Surface Water, Sediment, etc.) must be decontaminated as specified below.

Stainless steel samplers used for the collection of samples for chemical analysis will be cleaned prior to use and between each sampling point in accordance with the following procedure:

- Brush with soapy (phosphate free soap) water
- Rinse with de-ionized water (provided by the laboratory)

The peristaltic pump used for surface water purging and sampling and/or pond sediment sampling, will be decontaminated prior to use and between each location according to the following procedures:

- Spray the discharge tubing, with de-ionized water (provided by the laboratory) to rinse off particulates
- Pump soapy (phosphate free soap) water solution through the pump
- Circulate potable water through the pump and discharge tubing until all traces of soap are gone
- Pump de-ionized water (provided by the laboratory) through the pump and tubing

NOTE: If the tubing is dedicated to each monitoring location and disposed of after sampling is completed, decontamination will be not required.

7.8 Specific Monitoring Equipment Decontamination Procedures

Because monitoring equipment is difficult to decontaminate, care should be exercised to *prevent* contamination. Sensitive monitoring instruments should be protected when they are at risk of exposure to contaminants. This may include enclosing them in plastic bags allowing an opening for the sample intake. Ventilation ports should not be covered.

If contamination does occur, decontamination of the equipment will be required; however, immersion in decontamination fluids is not possible. As such, care must be taken to wipe the instruments down with detergent-wetted wipes or sponges, and wiped with deionized water-wetted wipes or sponges.

The water level indicator, YSI 650 and dissolved oxygen electrodes and cable will be cleaned prior to use and between each sampling location by the following procedure:

- Spray de-ionized water (provided by the laboratory) on the outside surfaces
- Wipe outside surface with paper towel

PID lamps will be decontaminated following the manufacturer's instructions.

7.9 Standard Disposal of Wash Solutions and Contaminated Equipment

All contaminated wash water, rinsates, solids and materials used in the decontamination process that cannot be effectively decontaminated (such as polyethylene sheeting) will be containerized and labeled with an indelible marker as to contents and date of placement in the container, and any appropriate stickers required (such as PCBs). Sampling of containerized wastes will be performed immediately upon completion of the investigations to minimize storage time on site. Storage of decontamination derived wastes on site will not exceed 90 days under any circumstances.

7.10 Standard Disposal Methods for Contaminated Materials

Contaminated materials must be segregated into liquids or solids and drummed separately for offsite disposal. Materials should be drummed and sampled for disposal as required by appropriate disposal facilities.

7.11 Disposal Methods for Contaminated Sediment

Contaminated sediment spoils must be drummed for disposal off-site unless otherwise specifically directed.

7.12 Decontamination (Personnel)

1. Equipment Drop
   a. Deposit equipment used on site (tools, sampling devices, monitoring equipment, radios, etc.) on plastic drop cloths
   b. Decontaminate or dispose of items before removal from the exclusion zone
2. Outer Boot/Glove Wash and Rinse
   a. Scrub outer boots/gloves with decontamination solution
   b. Rinse using water
3. Outer Boot/Glove Removal
   a. Remove outer boots/gloves
   b. If outer boots/gloves are disposable, deposit in container with plastic liner
   c. If outer boots/gloves are non-disposable, store in a clean, dry location

4. Outer Garment Removal
   a. Remove chemical protective outer garments and deposit in appropriate container
5. Respiratory Protection Removal
   a. Remove hard hat and face piece, and place them on a clean surface
   b. Wash and rinse face piece
   c. Wipe off and store face piece in a clean, dry location
6. Inner Glove Removal
   a. Remove inner gloves
   b. Deposit in container for disposal
7. Field Wash
   a. Thoroughly wash hands and face with soap and water
   b. Shower as soon as possible

7.13 Decontamination (Equipment)

- All drilling equipment (i.e., augers, rods, bits, sampling tubes, etc.) will be steam cleaned with pressurized steam prior to the onset of drilling activities, between boring locations, and before leaving the site.
- Steam cleaning will be conducted in a designated area on site, which will be determined by the onsite H&A representative at the site.
- All monitor well materials (casings, screens, caps, plugs, and protective casings) will be cleaned with a low-temperature, pressurized water rinse prior to installation.
- Water generated from cleaning new monitor well materials or from initial steam cleaning of pre-cleaned drilling equipment prior to its first use on the site will not be maintained.
- Sample collection equipment (split-spoon samplers, hand augers, bailers, collection utensils, etc.) will be decontaminated before initial use, between samples, and before leaving the site with a non-phosphate detergent wash and/or high-pressure steam, tap water rinse, and final triplicate deionized water rinse.
- After decontamination, sample collection equipment will not be transported to the sampling location on unclean surfaces (e.g., transport in or on new plastic).
- Monitor well development/purge pumps will be decontaminated before and after use in each well with a non-phosphate detergent water wash, tap water rinse, and final deionized water rinse. This wash and rinse sequence will be circulated through the pump system and applied to exterior surfaces that will be or have been in contact with groundwater.
- Contractors are responsible to decontaminate their own equipment.

7.14 Disposal of Contaminated Soil

Soil cuttings can be returned to the boreholes from which they came. Extra cuttings must be drummed for disposal off-site.

8.0 CONTINGENCY PLANNING

[Please refer to Haley & Aldrich Operating Procedure OP1021-Emergency Action Plan (Included in Attachment D4.)]

How H&A responds to an emergency depends on whether we are at an active facility or another other location. Many active facilities have very stringent requirements for the mitigation of emergencies. Therefore, the PM is responsible for identifying any specific requirements from the client contact.

The following are H&A's basic responses to handling Emergencies.

8.1 Fire

- Major Fires: Major fires will be mitigated by the local fire departments or by client's on-site fire/emergency response departments.
- Incipient Stage Fires: Incipient stage fires will be extinguished by on-site personnel using fire extinguishers. Only those who have received annual training may use an extinguisher.

8.2 Medical

All H&A employee injuries and illnesses will be documented using the SAIR. The SAIR Report is attached to this HASP as Attachment D6.

- First Aid: First aid will be addressed using the on-site first aid kit. H&A employees are not required or expected to administer first aid/CPR to any H&A, Contractor, or Civilian personnel at any time and it is H&A's position that those who do are doing it on their behalf and not as a function of their job.
- Trauma: Based upon the nature of the injury, the injured party may be transported to the nearest hospital or emergency clinic by on-site personnel or by ambulance. First response to a trauma incident is to call 911 or facility security. H&A staff members are expected to assist in ancillary roles only such as directing ambulances to the scene. It is the discretion of the staff member on site whether an ambulance should be procured in remote locations where ambulance services will not be effective.

8.3 Hazardous Materials Spill

- Small incidental spills: (e.g., pint of motor oil) caused by H&A employees and/or by the contractor will be mitigated by the H&A staff member and/or the contractor.
- Large spills: (e.g., large leak from heavy equipment fuel tank). The contractor is responsible for cleanup. In the event that it poses a serious human or environmental threat, the local Fire Department and/or client emergency response department will be contacted. Once emergency has been mitigated typically clean up will be provided by a vendor.

8.4 Rescue

H&A employees will not enter any confined spaces for rescue purposes. Water rescues will be performed by the appropriate emergency services.

8.5 Weather Related Emergencies

H&A employees and their subcontractors should be aware of potential health effects and/or physical hazards of working during inclement weather. If applicable, safeguards against the effects and hazards of heat stress, cold stress, frostbite, thunderstorms, and lightning, etc., should be included with the section pertaining to physical hazards in this HASP.

8.6 Evacuation Alarms

Evacuation alarms and/or emergency information will be communicated among personnel on site through verbal communication.

8.7 Emergency Services

Emergency services will be summoned via on-site or cellular phone.

8.8 Emergency Evacuation Plan

The site evacuation plan is as follows:

1. Establish a designated meeting area to conduct a head count in the event of an emergency evacuation.
2. If the work area is not near an emergency exit, exit via the closest route and meet at the designated meeting area.
3. Notify emergency response personnel (fire, police and ambulance) of the number of missing or unaccounted for employees and their suspected location.
4. Administer first aid will in the meeting area as necessary.

Under no circumstances should any personnel re-enter the site area without the approval of the Corporate H&S Manager, the RHSC, and the fire department official in charge.

9.0 HEALTH & SAFETY PLAN ACKNOWLEDGMENT FORM

Note: Only H&A employees sign this page.

I hereby acknowledge receipt and briefing on this Health & Safety Plan prior to the start of on-site work and declare that I understand and agree to follow the provisions and procedures set forth herein while working on this site.

PRINTED NAME	SIGNATURE	DATE

10.0 PRE-JOB SAFETY CHECKLIST

The following checklist is designed to help Project Managers verify that all Health & Safety requirements are satisfied for projects involving site work and to aid in the preparation of the site-specific HASP.

Please initial and date the appropriate box once each requirement has been satisfied prior to commencement of site work.

#	Project H&S Requirements	Approval by PM or RHSC (initial each box or place NA)	Date Approved
1	Project site history has been researched and summarized, current site conditions have been determined and documentation of previous investigations, risk analyses and chemical data has been assembled and summarized.	KMG	3/29/2011
2	Project work scope has been outlined and potential chemical and physical hazards associated with work tasks have been identified.	KMG	3/29/2011
3	Job Hazard Analysis has been performed and attached to the HASP.	NA	NA
4	H&A personnel to be involved with the project have been identified and are current with medical surveillance, OSHA 40 hour and 8 hour refresher training. HAZWOPER site supervisor requirements are satisfied.	KMG	3/29/2011
5	Additional training requirements have been met: e.g., nuclear density gauge, DOT, Confined Space Entry, Competent Person Training for Excavation, OSHA 10 hour certification, Railway Safety Training, etc.	NA	NA
6	H&A personnel that may be required to wear a respirator are medically qualified and have current certification of fit testing.	NA	NA
7	Client's additional H&S requirements have been met: e.g., facility safety orientations, safety documentation, meetings, and special PPE requirements.	NA	NA
8	H&A subcontractors have met H&A's minimum requirements including: current OSHA 40 hour training, medical surveillance, written HASP, insurance, MSDSs.		
9	MSDSs are on site and available for chemicals on site.		
10	Safety equipment is available: e.g., flashlight, telephone, ladders, traffic cones, barricade tape, fire extinguisher, first aid kit, PPE, respiratory protection, air and dust monitoring instrumentation (calibrated), PFD, 90' life line with ring, decontamination equipment, etc.		
11	HASP and supporting documentation is complete and signed by all members.		

TABLE 2.3-1
ARSENIC, AMMONIA, AND BENZENE CONCENTRATIONS BY COMPARTMENT
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

	Arsenic (dissolved)					Ammonia					Benzene				
Area	**Range**	**Avg**	***n***	**Standard Deviation**	**Ref**	**Range**	**Avg**	***n***	**Standard Deviation**	**Ref**	**Range**	**Avg**	***n***	**Standard Deviation**	**Ref**
Halls Brook Inlet	0.0006-0.0034	0.0013	16	0.0007	B	0.0033-0.0078	0.00558	6	0.00182	A	--	--	--	--	--
Groundwater	0.035-2.302	0.299	84	0.423	C	1.100-2.110	1.843	7	0.36128	A	0.00012-4.812	0.648	54	1.372	C
Shallow Water (Epilimnion)*	0.002-0.151	0.021	47	0.024	C	0.002-0.0688	0.0153	38	0.01596	A	0.00015-0.0081	0.0018	31	0.0019	C
Deeper Water (Hypolimnion) *	0.005-5.043	0.855	55	1.066	C	0.0023-0.597	0.06665	35	0.10518	A	0.00015-2.53	0.264	36	0.611	C
HBHA Pond Outlet	0.0012-0.0096	0.0049	16	0.00217	B	0.004-0.0172	0.00992	6	0.00537	A	--	--	--	--	--

Notes:
* To simplify data management, assumes stratification is occurring at the sample time and the boundary is as described in Notes 2 and 3, which is based on historical measurements.
1. All concentration values given in μg/L.
2. The shallow water (epilimnion) is defined as 0-199 centimeters (cm).
3. The deeper water (hypolimnion) is defined as 200 cm and deeper.
4. The data used for these values are assumed to be collected during baseflow conditions
5. Data ranges and averages collected by Tetra Tech NUS include values below the detection limit, which were expressed as half the laboratory reporting limit.
6. Groundwater data for arsenic was calculated using data from stations NML-9, NML-10, DMLS-2, and DMLS-3. Ammonia data was calculated using stations NML-9 and NML-10 (Ford, 2004, 2005b).

References:
A: Ford, 2005b.; B: Tetra Tech NUS, Inc., 2005.; C: Ford, 2004.

TABLE 3.1-1
PRE-DESIGN INVESTIGATION (PDI) TASK BREAKDOWN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Task No.	Task	Relevant Standard Operating Procedures (SOPs)	PDI-1	PDI-2	PDI-3	PDI-4A	PDI-4B	PDI-4C	PDI-5	PDI-6	PDI-9	PDI-10	PDI-11	PDI-12A	PDI-12B	PDI-15	PDI-16
1	Sediment Sampling	OP3004- Sediment Sampling OP1008- Operations Over, Near or on Water	x	x			x				x						
2	Bathymetric Survey (incl. debris)	OP1008- Operations Over, Near or on Water	x														
3	Peat Probing	OP2030- Direct Push Borings OP2000- Monitoring Field Explorations	x														
4	Accessibility Survey	OP1008- Operations Over, Near or on Water		x													
5	Wetland Peat Probing and Soil Boring	OP1008- Operations Over, Near or on Water OP2030- Direct Push Borings OP2000- Monitoring Field Explorations		x													
6	Groundwater Profiling Using DPT and Low Flow Sampling	OP3010- Groundwater Sampling OP3011- Groundwater Sampling Using Direct Push Technology OP3012- Low Stress/Low Flow Groundwater Sampling Procedure			x										x		
7	Groundwater Sampling	OP3010- Groundwater Sampling OP3012- Low Stress/Low Flow Groundwater Sampling Procedure			x						x	x			x		
8	Groundwater Sampling from barge	OP3010- Groundwater Sampling			x												
9	Drive Point Piezometer Installation	OP2021- Piezometers			x						x	x					
10	Water Level Measurement	OP3008- Manual Water Level Measurement Procedure			x						x	x			x		
11	Monitoring Well Development	OP3009- Monitoring Well Development Procedure			x						x	x			x		
13	Surface Water Sampling	OP3007- Surface Water Sampling OP3012- Low Stress/Low Flow Groundwater Sampling Procedure				x	x	x			x	x				x	x
14	Surface Water Screening with full spectrum sonde	OP3012- Low Stress/Low Flow Groundwater Sampling Procedure				x	x	x			x	x				x	x
15	Fluorescent Dye Tracer Study	OP1008- Operations Over, Near or on Water OP3007- Surface Water Sampling				x											
16	Meteorological Monitoring	OP1008- Operations Over, Near or on Water						x									
17	Tank Treatability Study	OP3007- Surface Water Sampling SOP 3023 - Air Sample Collection with Tedlar Bags							x								
18	Deep Soil Borings	OP2005- Test Borings OP 1002- Drilling Safety								x				x			
19	Soil Borings and Sampling	OP2005- Test Borings OP2030- Direct Push Borings OP 1001- Excavation and Trenching Safety OP 1002- Drilling Safety								x			x	x			
20	Monitoring Field Explorations	OP2000- Monitoring Field Explorations			x					x	x	x	x	x	x		
21	Identification and Description of Soils in the Field	OP2001- Identification and Description of Soils in the Field Using Visual-Manual Methods								x			x	x			
22	Surficial Soil Sampling	OP3003- Surficial Soil Sampling OP3003A- Addendum to Surficial Soil Sampling								x			x	x			
23	Subsurface (Pond) Sampler and Instrumentation Deployment and Collection	OP1008- Operations Over, Near or on Water	x					x								x	x

NOTES

1. Additional tasks include surveying, test pits, hand sampling, etc.

2. In some cases, PDI series are listed in place of individual subparts.

TABLE 4.3-1
CHEMICALS EXPECTED TO BE ENCOUNTERED ON SITE
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

Chemical	Media	Sediment Sampling	Bathymetric Survey (incl. debris)	Peat Probing	Accessibility Survey	Wetland Peat Probing and Soil Boring	Groundwater Profiling Using DPT and Low Flow Sampling	Groundwater Sampling	Groundwater Sampling from barge	Drive Point Piezometer Installation	Water Level Measurement	Monitoring Well Development	Surface Water Sampling	Surface Water Screening with full spectrum sonde	Fluorescent Dye Tracer Study	Meteorological Monitoring	Tank Treatability Study	Deep Soil Borings	Soil Borings and Sampling	Monitoring Field Explorations	Identification and Description of Soils in the Field	Surficial Soil Sampling	Subsurface (Pond) Sampler and Instrumentation Deployment and Collection
Nitrogen Species [Ammonia (NH_3), Nitrite, Nitrate)	GW						x	x	x	x	x	x											
	SOIL			x		x												x	x			x	
	SW												x	x	x		x						x
	SED	x																					x
Phosphorous	SW												x	x	x		x						x
Arsenic	GW						x	x	x	x	x	x											
	SED	x																					x
	SOIL			x		x												x	x			x	
	SW												x	x	x		x						x
VOCs (i.e. Benzene, 1,2-Dichloroethane, Trichloroethene)	GW						x	x	x	x	x	x											
	SED	x																					x
	SOIL			x		x												x	x			x	
	SW												x	x	x		x						x
PAHs (i.e. Benzo(a)pyrene, Naphthalene)	GW						x	x	x	x	x	x											
	SED	x																					x
	SOIL			x		x												x	x			x	
	SW												x	x	x		x						x

(Media key: GW = Groundwater; SW = Surface Water; SOIL = Soil; SED = Sediment)

TABLE 4.4-1
OCCUPATIONAL EXPOSURE LIMITS (CONCENTRATIONS IN AIR)
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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CHEMICAL	ROUTES OF EXPOSURE	IDLH	Ceiling	STEL	PEL	TLV	REL	PID (IP eV)	FID	ODOR THRESHOLD	IRRITATION THRESHOLD	ODOR DESCRIPTION
VAPORS & GASES												
Acetone	R, I, C	2500	-	750 [ACGIH]	1000	500	250	9.69	60	13	-	fragrent, mint-like
Ammonia	R, I, C	300	-	35 [NOSH, ACGIH]	50	25	25	10.18**	-	0.5-2	10	Pungent suffocating odor
Benzene	R,A,I,C	Ca [500]	-	1 [NIOSH]; 2.5 [ACGIH]	1	0.5	0.1	9.24	150	4.68	-	Solvent, aromatic
Carbon tetrachloride (Tetrachloromethane)	R,A,I,C	Ca [200]	25 [instantaneous]; 200 [5 min peak in any 4 hrs]	2 [NIOSH, 60-min]; 10 [ACGIH]	2	5	Ca	11.47**	10	50	-	Sweet, pungent, ether-like
Chlorobenzene	R,I,C	1000	-	-	75	10	-	9.07	200	0.68	-	Almond-like
Chloroform	R,I,C	Ca [500]	50 [OSHA]	2 [NIOSH, 60-min]	-	10	-	11.42**	65	50	-	Sweet, pleasant
o-Dichlorobenzene	R,A,I,C	200	50 [NIOSH, OSHA]	50 [ACGIH]	-	25	-	9.06	50	0.3	E 20-30	Pleasant, aromatic
p-Dichlorobenzene	R,A,I,C	Ca [150]	-	-	75	10	Ca	8.98	-	0.18	E 80-160	Distinct, aromatic, mothball-like
Dichlorodifluoromethane (Freon 12)	R,C	15000	-	-	1000	1000	1000	11.75**	15	-	-	Ether-like when at very high concs.
1,1-Dichloroethane	R,I,C	3000	-	-	100	100	100	11.06**	80	200	-	Distinct, chloroform-like
1,2-Dichloroethane (Ethylene dichloride)	R,I,A,C	Ca [50]	100 [OSHA]	2 ppm [NIOSH]; 200 ppm [OSHA, 5-min max peak in any 3 hrs]	50	10	1	11.05**	80	88	-	Chloroform-like
1,1-Dichloroethylene (1,1-DCE, Vinylidene chloride)	R,A,I,C	Ca [ND]	-	-	-	5	Ca	10.00**	40	190	-	Chloroform-like
1,2-Dichloroethylene	R,I,C	1000	-	-	200	200	200	9.65	50	0.85	-	Bitter, chloroform-like
Ethanol	R,I,C	3300	-	-	1000	1000	1000	10.47**	25	10	-	Weak, ether-like, wine-like
Ethylbenzene	R,I,C	800	-	125 [NIOSH; ACGIH]	100	100	100	8.76	100	2.3	E 200	Aromatic
Ethylene Glycol	R,I,C	ND	50 [OSHA]; 100 mg/m^3 [ACGIH]	-	-	-	-	-	-	-	-	Odorless
Formaldehyde	I,C	Ca [20]	0.1 [NIOSH, 15-min]; 0.3 [ACGIH]	2	0.75	-	Ca [0.016]	10.88**	-	0.83	-	Pungent, suffocating
Gasoline	R,I,A,C	Ca [ND]	-	500 [OSHA; ACGIH]	300	300	-	-	-	-	E 0.5	Petroleum-like
n-Hexane	R,I,C	1100	-	-	500	50	50	10.18	70	130	E.T 1400-1500	Gasoline-like
Hydrogen Cyanide	R,A,I,C	50	4.7 [ACGIH; Skin]	4.7 [NIOSH - skin]	10 [skin]		-	-	-	0.58	-	Bitter almond
Hydrogen peroxide	R,I,C	75	-	-	1	1	1	10.54**	-	-	-	Sharp
Methanol	R,I,A,C	6000	-	250 [NIOSH; ACGIH; skin]	200	200 [skin]	200	10.84**	12	1000	-	Pungent
Methyl Ethyl Ketone Peroxide	R,I,C	ND	0.2 [NIOSH; ACGIH]; 0.7 [OSHA]	-	-	-	-	-	-	-	-	Characteristic odor
Methyl Chloroform (1,1,1-TCA)	R,I,C	700	350 [NIOSH, 15-min]	450 [ACGIH]	350	350	Ca	11.00**	105	20-100	-	Chloroform-like
Methylene Chloride (Dichloromethane, Methylene dichloride)	R,I,A,C	Ca [2300]	-	125	25	50	Ca	11.32**	100	25-50	E 5000	Chloroform-like
Methyl Mercaptan	R,C	150	10 [OSHA]; 0.5 [NIOSH, 15-min]	-	-	0.5	-	9.44	-	-	-	Garlic, rotten cabbage
MIBK (Hexone)	R,I,C	500	-	75 [NIOSH; ACGIH]	100	50	50	9.30	-	-	-	Pleasant
Naptha (coal tar)	R,I,C	1000	-	-	100	400	100	-	-	-	-	Aromatic
Naphthalene	R,A,I,C	250	-	15 [NIOSH; ACGIH]	10	10	10	8.12	-	0.3	E 15	Mothball-like
Octane	R,I,C	1000	385 [NIOSH, 15-min]	-	500	300	75	9.82	80	48	-	Gasoline-like
Pentachlorophenol	R,A,I,C	2.5 mg/m^3	-	-	0.5 mg/m^3 [skin]	0.5 mg/m^3 [skin]	0.5 mg/m^3 [skin]	-	-	-	-	Pungent when hot, benzene-like
Phenol	R,A,I,C	250	15.6 [NIOSH, 15-min]	-	5 [skin]	5 [skin]	5 [skin]	8.50	-	0.04	E.N.T. 68	Sweet, acrid
Propane	R,C	2100	-	-	1000	1000	1000	11.07**	80	1600	-	Odorless (commonly smells foul due to additive for odor detection)
Stoddard Solvent (Mineral Sprits)	R,CI,I	20000 mg/m^3	1800 mg/m^3 [NIOSH, 15-min]	-	500	100	350 mg/m^3	-	-	1	E 400	Kerosene-like
Styrene	R,I,A,C	700	200 [OSHA]	100 [NIOSH]; 600 [OSHA, 5-min max peak in any 3 hrs]; 40 [ACGIH]	100	20	50	8.40	85	0.047	E 200-400	Sweet, floral
1,1,2,2-Tetrachloroethane	R,I,A,C	Ca [100]	-	-	5 [skin]	1 [skin]	1 [skin]	11.10**	100	1.5	-	Pungent, chloroform-like
Tetrachloroethylene (Perchloroethylene, Perc, PCE)	R,I,A,C	Ca [150]	200 [OSHA]	300 [OSHA, 5-min max peak in any 3 hrs]; 100 [ACGIH]	100	25	Ca	9.32	70	4.68	N.T513-690	Chloroform-like
Toluene	R,A,I,C	500	300 [OSHA]	150 [NIOSH]; 500 [OSHA, 10-min max peak]	200	50	100	8.82	110	2.14	E300-400	Sweet, pungent, benzene-like
Trichloroethylene (TCE)	R,I,A,C	Ca [1000]	200 [OSHA]	300 [OSHA, 5-min max peak in any 2 hrs]; 100 [ACGIH]	100	50	Ca	9.45	70	21.4	-	Chloroform-like
1,2,3-Trimethylbenzene	R,I,C	ND	-	-	-	-	25	8.48	-	-	-	Distinctive, aromatic
1,2,4-Trimethylbenzene	R,I,C	ND	-	-	-	-	25	8.27	-	-	-	Distinctive, aromatic
1,3,5-Trimethylbenzene	R,I,C	ND	-	-	-	-	25	8.39	-	-	-	Distinctive, aromatic
Turpentine	R,A,I,C	800	-	-	100	20	100	-	-	200	E.N 200	Pine-like
Vinyl Chloride	R,C	Ca [ND]	5 [OSHA, 15-min]	-	1	1	Ca	9.99	-	3000	-	Pleasant odor at high concs.
Xylenes	R,A,I,C	900	-	150 [NIOSH, ACGIH]	100	100	100	8.56 (m- and o-) 8.44 (p-)	111/116	1.1	E.N.T. 200	Aromatic

TABLE 4.4-1
OCCUPATIONAL EXPOSURE LIMITS (CONCENTRATIONS IN AIR)
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

CHEMICAL	ROUTES OF EXPOSURE	IDLH	Ceiling	STEL	PEL	TLV	REL	PID (IP eV)	FID	ODOR THRESHOLD	IRRITATION THRESHOLD	ODOR DESCRIPTION
VAPORS & GASES												
DUSTS, MISTS, FUMES, AND MISCELLANEOUS COMPOUNDS												
Asbestos	R	Ca (ND)	-	-	0.1 fiber/cc	0.1 fiber/cc	0.1 fiber/cc	-	-	-	-	-
PCBs-42% Chlorine	R,A,I,C	Ca [5 mg/m^3]	-	-	1 mg/m^3 [skin]	1 mg/m^3 [skin]	0.001 mg/m^3	-	-	-	-	Mild, hydrocarbon
PCBs-54% Chlorine	R,A,I,C	Ca [5 mg/m^3]	-	-	0.5 mg/m^3 [skin]	0.5 mg/m^3 [skin]	0.001 mg/m^3	-	-	-	-	Mild, hydrocarbon
Aluminum - metal dust	R,C	ND	-	-	15 mg/m^3 (total); 5 mg/m^3 (respirable)	10 mg/m^3	10 mg/m^3 (total); 5 mg/m^3 (respirable)	-	-	-	-	-
Aluminum - soluble salts	R,I,C	ND	-	-	2 mg/m^3	2 mg/m^3	2 mg/m^3	-	-	-	-	-
Arsenic- inorganic	R,A,I,C	Ca [5 mg/m^3]	0.002 mg/m^3 [NIOSH, 15-min]	-	0.01 mg/m^3	0.01 mg/m^3	Ca	-	-	-	-	-
Barium:soluble compounds	R,I,C	50 mg/m^3	-	-	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3	-	-	-	-	-
Beryllium	R,C	Ca [4 mg/m^3]	0.005 mg/m^3 [OSHA]; 0.025 mg/m^3 [OSHA, 30-min max peak]; 0.0005 mg/m^3 [NIOSH]	0.01 mg/m^3 [ACGIH]	0.002 mg/m^3	0.002 mg/m^3	Ca	-	-	-	-	-
Cadmium dusts	R,I	Ca [9 mg/m^3]	-	-	0.005 mg/m^3	0.01 mg/m^3	Ca	-	-	-	-	-
Chromates (Cr(VI) Compounds) & Chromic Acid	R,I,C	Ca [15 mg/m^3]	0.1 mg/m^3 [OSHA]	-	0.001 mg/m^3	0.05 mg/m^3 [water soluble]; 0.01 mg/m^3 [insoluble]	Ca	-	-	-	-	-
Chromium (III) Compounds	R,I,C	25 mg/m^3	-	-	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3	-	-	-	-	-
Chromium Metal	R,I,C	250 mg/m^3	-	-	1 mg/m^3	0.5 mg/m^3	0.5 mg/m^3	-	-	-	-	-
Copper - dust & mist	R,I,C	100 mg/m^3	-	-	1 mg/m^3	1 mg/m^3	1 mg/m^3	-	-	-	-	-
Lead	R,I,C	100 mg/m^3	-	-	0.050 mg/m^3	0.05 mg/m^3	0.050 mg/m^3	-	-	-	-	-
Manganese (compounds and fume)	R,I	500 mg/m^3	5 mg/m^3 [OSHA]	3 mg/m^3 [NIOSH]	-	0.2 mg/m^3	1 mg/m^3	-	-	-	-	-
Mercury & Inorganic Mercury Compounds	R,I,A,C	10 mg/m^3	0.1 mg/m^3 [NIOSH, Skin]; 0.1 mg/m^3 [OSHA]	-	-	0.025 mg/m^3	0.05 mg/m^3 [skin]	-	-	-	-	-
Organo-Mercury Compounds	R,A,I,C	2 mg/m^3	0.04 mg/m^3 [OSHA]	0.03 mg/m^3 [NIOSH]	0.01 mg/m^3	0.01 mg/m^3 [alkyl]; 0.1 mg/m^3 [aryl]	0.01 mg/m^3	-	-	-	-	-
Nickel (metal and compounds)	R,I,C	Ca [10 mg/m^3]	-	-	1 mg/m^3	1.5 mg/m^3 [metal]; 1 mg/m^3 [soluble inorganic compounds]; 1 mg/m^3 [insoluble inorganic compounds]	0.015 mg/m^3	-	-	-	-	-
Particulate (Not otherwise regulated)	R, C	ND	-	-	15 mg/m^3 (total); 5 mg/m^3 (respirable)	10 mg/m^3 (inhalable); 3 mg/m^3 (respirable)	-	-	-	-	-	-
Portland cement	R,I,C	5000 mg/m^3	-	-	50 mppcf	10 mg/m^3	10 mg/m^3 (total); 5 mg/m^3 (respirable)	-	-	-	-	-
Selenium compounds	R,I,C	1 mg/m^3	-	-	0.2 mg/m^3	0.2 mg/m^3	0.2 mg/m^3	-	-	-	-	-
Silica, crystalline	R, C	Ca [25 mg/m^3 (cristobalie, tridymite) ; 50 mg/m^3 (quartz, tripoli)]	-	-	Dependent on silicon dioxide content of silica (see Appendix C of the NIOSH Pocket Guide to Chemical Hazards, 2005)	Dependent on minerology [see ACGIH 2005 TLVs and BEIs Handbook]	0.05 mg/m^3	-	-	-	-	-
Silver (metal and soluble compounds)	R,I,C	10 mg/m^3	-	-	0.01 mg/m^3	0.1 mg/m^3	0.01 mg/m^3	-	-	-	-	-
Thallium, soluble	R,A,I,C	15 mg/m^3	-	-	0.1 mg/m^3 [skin]	0.1 mg/m^3 [skin]	0.1 mg/m^3 [skin]	-	-	-	-	-
Tin (metal)	R,C	100 mg/m^3	-	-	2 mg/m^3	2	2 mg/m^3	-	-	-	-	-
Tin (organic compounds)	R,A,I,C	25 mg/m^3	-	-	0.1 mg/m^3	0.1 mg/m^3 [skin]	0.1 mg/m^3 [skin]	-	-	-	-	-
Zinc oxide dust & fume	R	500 mg/m^3	15 mg/m^3 [NIOSH, dust]	10 mg/m^3 [NIOSH; ACGIH; fume]	15 mg/m^3 (total dust); 5 mg/m^3 [respirable dust]; 5 mg/m^3 [fume]	2 mg/m^3 [respirable]	5 mg/m^3 (total dust); 5 mg/m^3 [fume]	-	-	-	-	-

NOTES & ABBREVIATIONS:

All units in parts per million (ppm) unless otherwise noted.
R = Respiratory (Inhalation)
I = Ingestion
A = Skin Absorption
C = Skin and/or Eye Contact
-: Not available
ND: Not detectable.

Ca = Carcinogen
** = Use 11.7 eV lamp
IP: Ionization potential
eV: Electrovolts
IDLH: Immediately dangerous to life and health
Ceiling: Highest allowable instantaneous concentration.
STEL: Short-term exposure limit.
Exposure period is 15 minutes unless otherwise indicated

PEL: OSHA Permissible Exposure Limit (legally-enforceable)
REL: NIOSH Recommended Exposure Limit
PID: Photoionization Detector
OSHA: United States Occupational Safety and Health Administration
NIOSH: National Institute of Occupational Safety and Health
TLV: ACGIH Threshold Limit Value
ACGIH: American Conference of Governmental Industrial Hygienists

TABLE 4.5-1
PHYSICAL HAZARDS ENCOUNTERED WHILE PERFORMING TASKS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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Potential Job Hazards	Sediment Sampling	Bathymetric Survey (incl. debris)	Peat Probing	Accessibility Survey	Wetland Peat Probing and Soil Boring	Groundwater Profiling Using DPT and Low Flow Sampling	Groundwater Sampling	Groundwater Sampling from barge	Drive Point Piezometer Installation	Water Level Measurement	Monitoring Well Development	Surface Water Sampling	Surface Water Screening with full spectrum sonde	Fluorescent Dye Tracer Study	Meteorological Monitoring	Tank Treatability Study	Deep Soil Borings	Soil Borings and Sampling	Monitoring Field Explorations	Identification and Description of Soils in the Field	Surficial Soil Sampling	Subsurface (Pond) Sampler and Instrumentation Deployment and Collection
Heavy equipment	x	x	x		x	x			x								x	x	x	x	x	
Drilling hazards																	x	x	x	x	x	
Noise (above 85 dBA)																	x	x	x	x	x	x
Extreme weather conditions	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Rough terrain for drilling equipment	x		x		x	x																
Heavy lifting (more than 50 lbs)	x	x	x		x	x			x													x
Poisonous insects or plants	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Water hazards	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Use of a boat	x	x					x	x	x			x	x	x								x
Other: Work on Ice	x	x						x														x

TABLE 5.1-1
PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

DRAFT

Required PPE	Sediment Sampling	Bathymetric Survey (incl. debris)	Peat Probing	Wetland Peat Probing and Soil Boring	Groundwater Profiling Using DPT and Low Flow Sampling	Groundwater Sampling	Groundwater Sampling from barge	Drive Point Piezometer Installation	Water Level Measurement	Monitoring Well Development	Surface Water Sampling	Surface Water Screening with full spectrum sonde	Fluorescent Dye Tracer Study	Meteorological Monitoring	Tank Treatability Study	Deep Soil Borings	Soil Borings and Sampling	Monitoring Field Explorations	Identification and Description of Soils in the Field	Surficial Soil Sampling	Subsurface (Pond) Sampler and Instrumentation Deployment and Collection
Hard hat								x								x	x	x	x	x	
Safety glasses w/side shields	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Steel-toe footwear	*		*	x	x	*	*	x								x	x	x	x	x	
Hearing protection (plugs, muffs)																x	x	x	x	x	
Tyvek ™ coveralls	*		*	*	*			*								*	*	*	*	*	
Leather work gloves			*	*	*			*								*	*	*	*	*	*
Inner gloves - nitrile	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Personal Flotation Device (PFD)	**	**	**				**					**	**	**		**	**	**	**	**	**
High-Visibility Safety Vest	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Other: Waders	*	*	*	*	*	*	*				*	*	*	*		*	*	*	*	*	*
Level of protection required [C or D]: ***	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

*To be required at the discretion of the Site Safety Officer
**Work over water or ice requires a PFD. In cold water conditions (below 60° F), a survival suit (e.g. Mustang MS 2175 Class V PFD) is required.
*** In the event of respirator use, H&A staff must be medically qualified, fit tested and clean shaven with no facial hair that will interfere with the seal.

TABLE 6.1-1
MONITORING METHOD, ACTION LEVELS AND PROTECTIVE MEASURES
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

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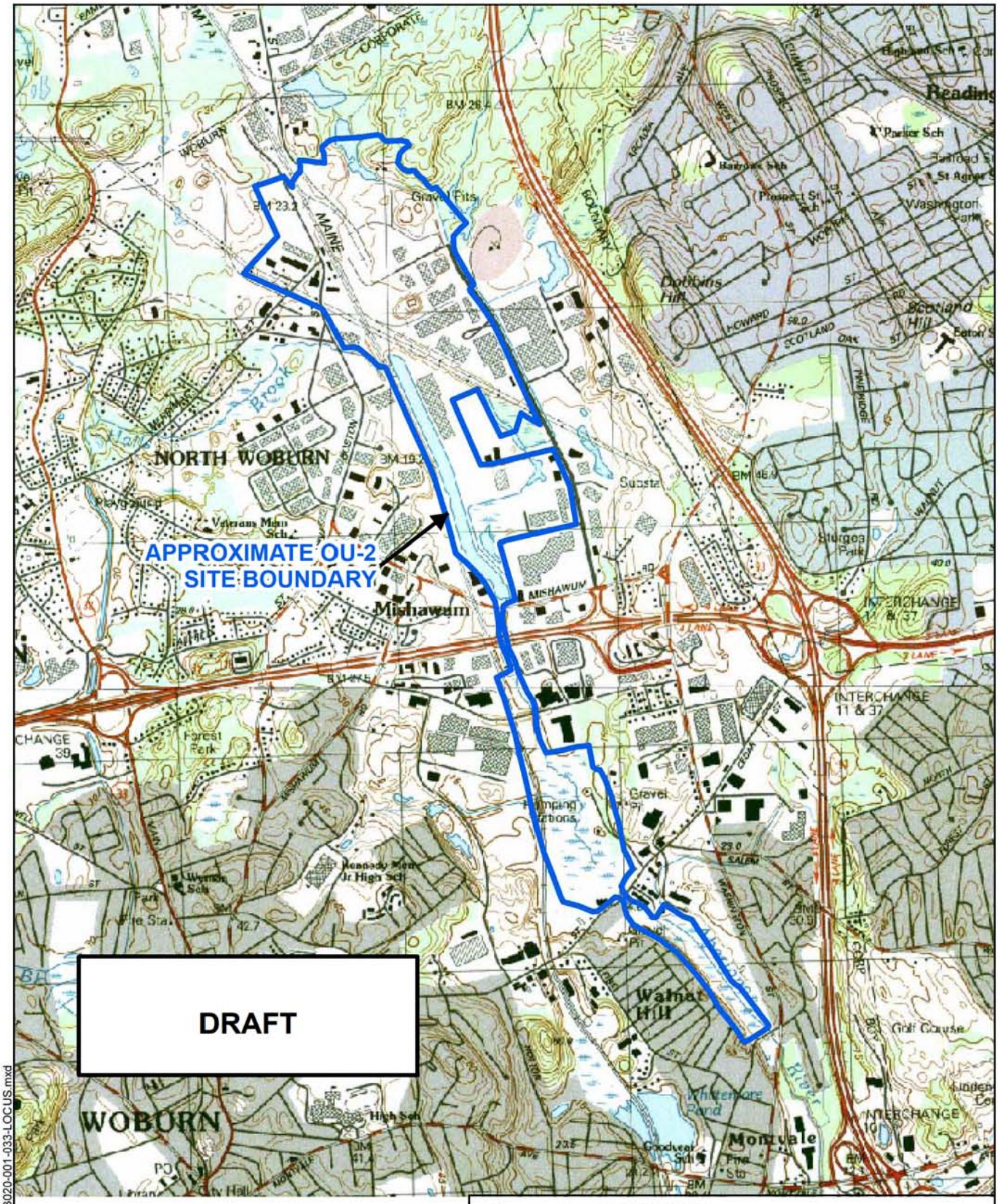
INSTRUMENT	HAZARD	ACTION LEVEL	ACTION RESPONSE
Respirable Dust Monitor	Total Particulates	> 5 mg/m^3	Upgrade to Level C Protection
OVA, HNU[2], Photovac Microtip	Total Organic Vapors	Background	Level D Protection
		10 ppm > background or lowest OSHA permissible exposure limit, whichever is lower, or as modified for this task. Sustained for >5 minutes in the breathing zone.	Upgrade to Level C - site evacuation may be necessary for specific compounds
		50 ppm over background, unless lower values required due to respirator protection factors	Cease work; upgrade to Level B[3] may be required
Explosimeter[4] (LEL)	Flammable/Explosive Atmosphere	<10% Scale Reading	Proceed with work
		10-15% Scale Reading	Monitor with extreme caution
		>15% Scale Reading	Evacuate site
0xygen Meter[5]	Oxygen-Deficient Atmosphere	19.5% - 23.5% 0_2	Normal - Continue work
		< 19.5% 0_2	Evacuate site; oxygen deficient
		> 23.5% 0_2	Evacuate site; fire hazard
Radiation Meter[6]	Ionizing Radiation	0.1 Millirem/Hour	If > 0.1, radiation sources may be present[7]
		> 1 Millirem/Hour	Evacuate site; radiation hazard
Drager Tubes	Vapors/Gases	Species Dependent > 1 ppm vinyl chloride > 1 ppm benzene > 1 ppm 1,1-DCE	Consult resources for concentration toxicity/detection data. Upgrade to Level C if concentration of compounds exceed thresholds shown at left; may need to cease work if other levels exceeded - site specific
Gas Chromatograph (GC)	Organic Vapors	3 ppm total OV > background or > lowest specific OSHA permissible exposure limit, whichever is lower	On-site monitoring or tedlar bag sample collection for off-site/laboratory analysis

Notes:
1. Monitor breathing zone.
2. Can also be used to monitor some inorganic species.
3. Positive pressure demand self contained breathing apparatus
4. Lower explosive limit (LEL) scale is 0-100%. LEL for most gasses is 15%.
5. Normal atmospheric oxygen concentration at sea level is 20%.
6. Background gamma radiation is ~0.01-0.02 millirems/hour.
7. Contact H&A Health and Safety staff immediately.



SITE COORDINATES: 42°30'21"N 71°8'12"W

U.S.G.S. QUADRANGLE: WILMINGTON, MA

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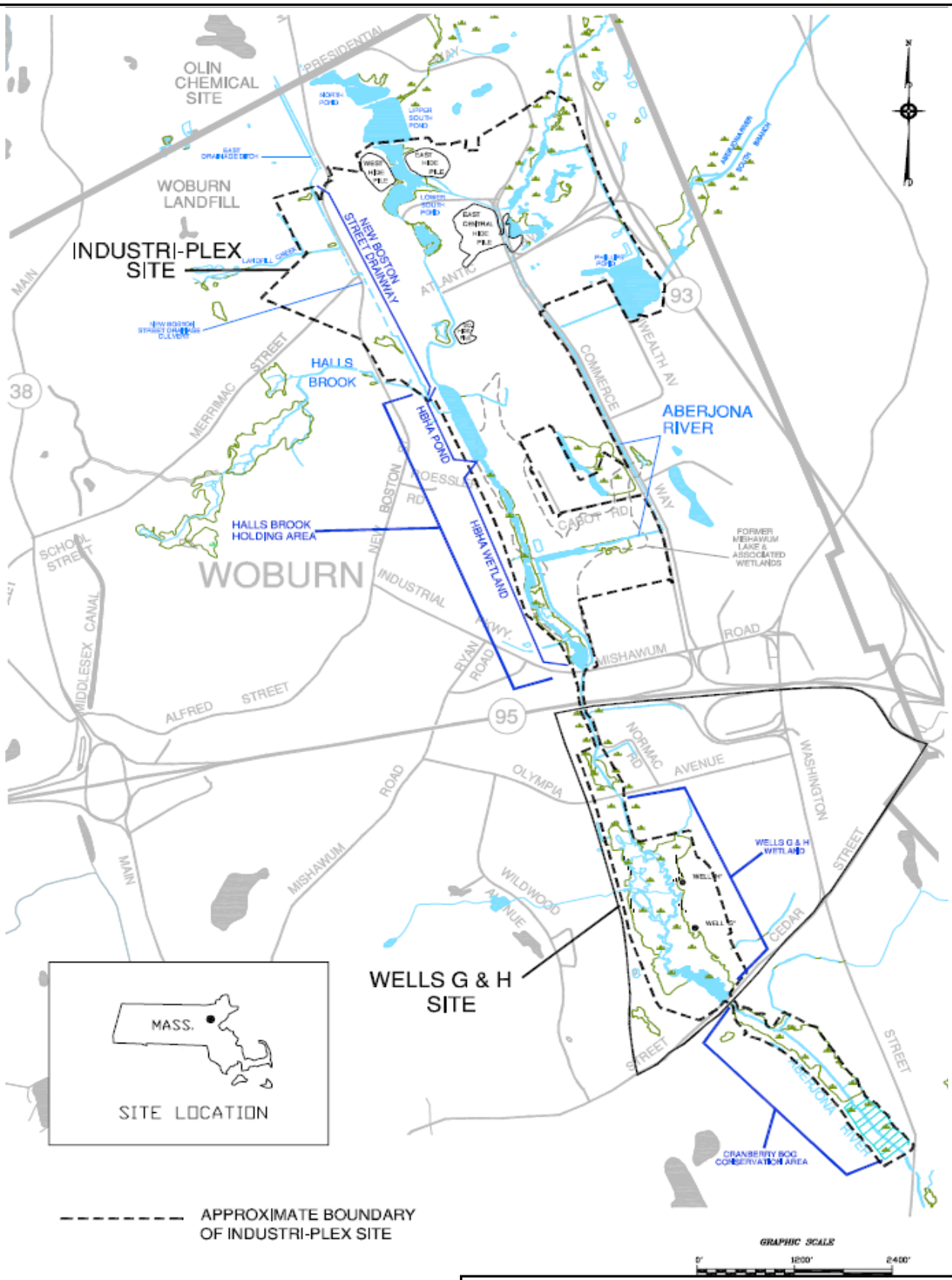
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

PROJECT LOCUS

SCALE: 1:24,000
MARCH 2011

FIGURE 1-1

G:\33020\GLOBAL\GIS\MapProjects\33020-001-033-LOCUS.mxd



Note:

1. FIGURE ADAPTED FROM "FINAL RD/RA STATEMENT OF WORK - INDUSTRI-PLEX OPERABLE UNIT 2 (INCLUDING WELL G& H AND OPERABLE UNIT 3) SUPERFUND SITE" 30 NOVEMBER 2007. FIGURE A-1.

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REMEDIAL DESIGN
INDUSTRI-PLEX OPERABLE UNIT 2
WOBURN, MASSCHUSETTS

SITE PLAN

SCALE: NONE
MARCH 2011

FIGURE 1-2

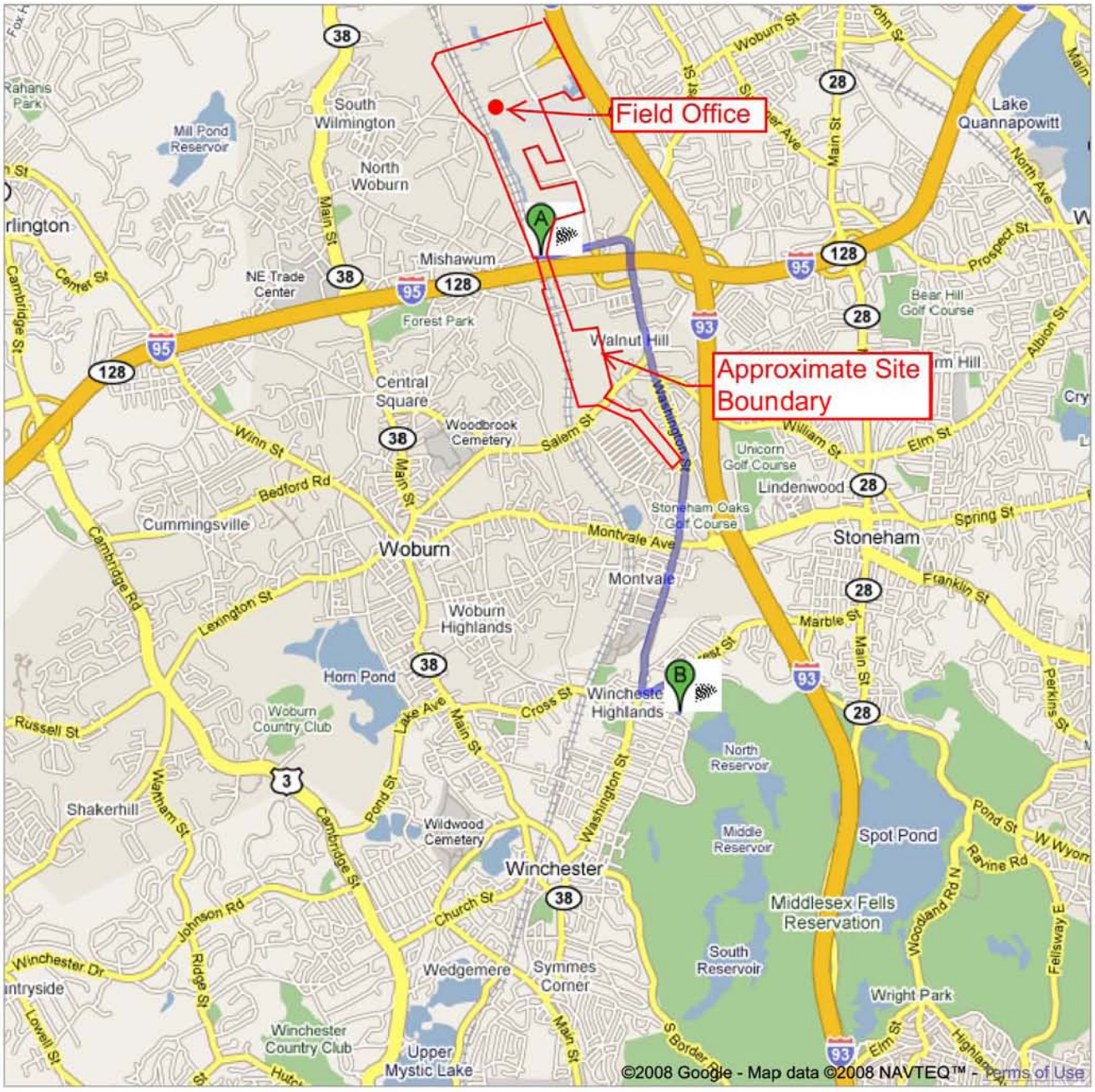
G:\33020\030\Health Safety\Revised per EPA_Feb 2010\Figures\2010-0205-HAI-Figure 1-2_SITE PLAN-F.xls

ATTACHMENT D1

Directions to the Nearest Hospital and Occupational Clinic

Start **Mishawum Station**
End **Winchester Hospital**
41 Highland Ave, Winchester, MA 01890
Travel **3.6 mi – about 11 mins**

Get Google Maps on your
Text the word "GMAPS" to 4



Mishawum Station

Drive: 3.6 mi – about 11 mins

1. Head **east** on **Mishawum Rd** toward **Commerce Way**	0.5 m 2 mins
2. Turn **right** at **Washington St**	2.7 m 7 mins
3. Turn **left** at **Forest St**	0.2 m 1 min
4. Turn **right** at **Sawmill Brook Rd**	89 ft
5. Turn **right** at **Highland Ave**	0.2 m

Winchester Hospital
41 Highland Ave, Winchester, MA 01890

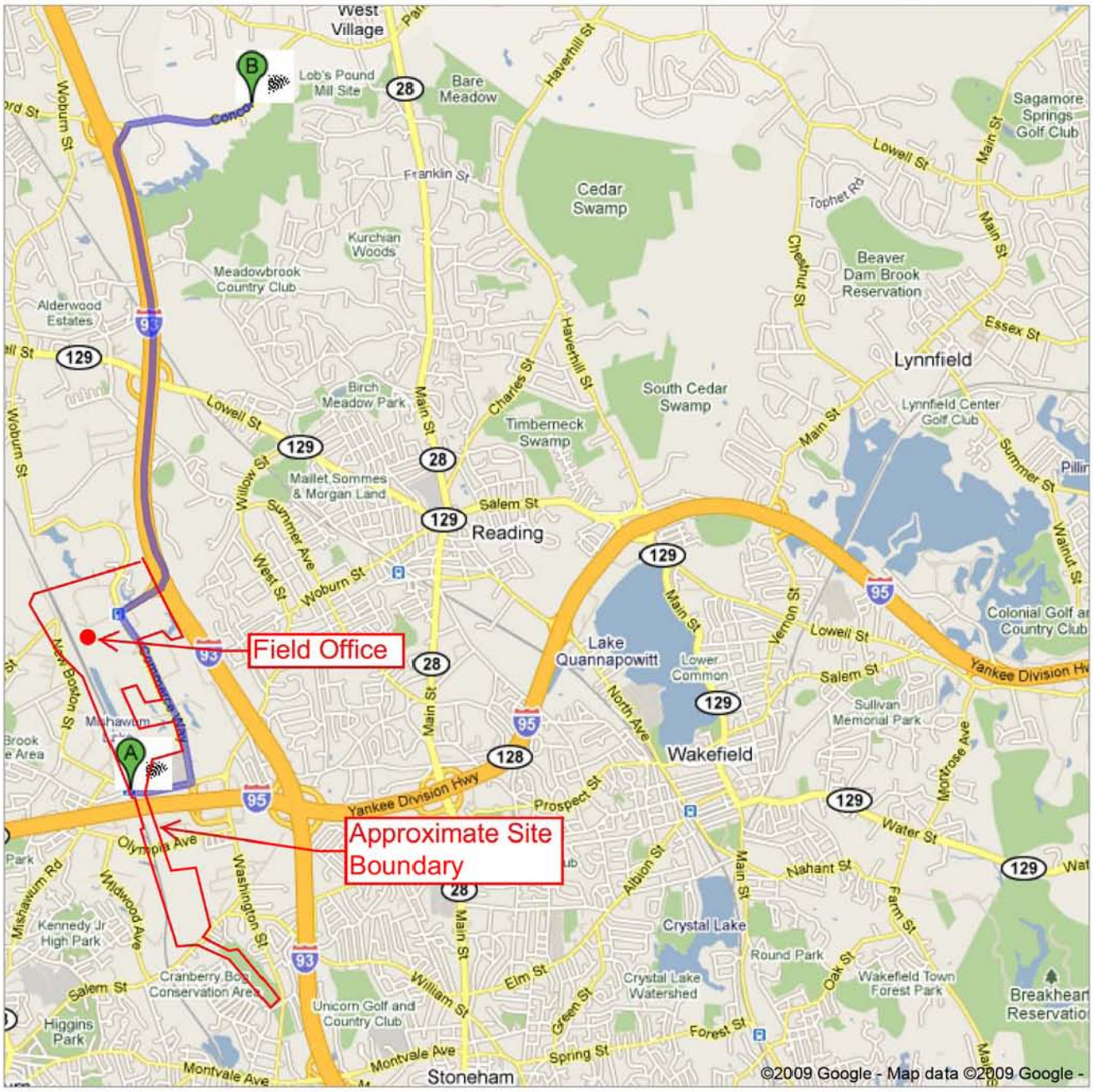
These directions are for planning purposes only. You may find that construction projects, traffic, or other events may cause road conditions to differ from the map results.

Map data ©2008 NAVTEQ™

Google maps

Directions to 66 Concord St, North Reading, MA 01864
5.1 mi – about **8 mins**

Save trees. Go green!
Download Google Maps on your phone at **google.com/gmm**



Mishawum

	1. Head **southeast** on **Mishawum Rd** About 1 min	go 0.4 mi total 0.4 mi
	2. Turn **left** at **Commerce Way** About 2 mins	go 1.1 mi total 1.4 mi
	3. Turn **right** onto the ramp to **I-93 N**	go 0.2 mi total 1.6 mi
	4. Keep **left** at the fork to continue toward **I-93 N** and merge onto **I-93 N** About 3 mins	go 2.5 mi total 4.2 mi
	5. Take exit **39** for **Concord St**	go 0.2 mi total 4.4 mi
	6. Turn **right** at **Concord St** Destination will be on the right About 1 min	go 0.7 mi total 5.1 mi

66 Concord St, North Reading, MA 01864

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

Map data ©2009 , Google

Directions weren't right? Please find your route on www.google.com and click "Report a problem" at the bottom left.

ATTACHMENT D2

HASP Amendment Form

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HASP Amendment Form

This Appendix is to be used whenever there is an immediate change in the project scope that would require an amendment to the HASP. For project scope changes associated with "add-on" tasks, the changes must be made in the body of the HASP. Before changes can be made, a review of the potential hazards must be initiated by the H&A Project Manager.

Amendment No.	
Site Name:	
Work Assignment No.:	
Date:	
Type of Amendment:	
Reason for Amendment:	
Alternate Safeguard Procedures:	
Required Changes in PPE:	

Project Manager Signature: _____ Date: _____

Regional Health and Safety Coordinator: _____ Date: _____

This original form must remain on site with the original HASP. If additional HASPs are in the field, it is the Project Manager's responsibility to forward a signed copy of this amendment to those who have copies.

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ATTACHMENT D3

Issuance and Compliance
and
Site Safety Officer Role and Responsibilities

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Issuance and Compliance
Site Safety Officer Role and Responsibilities

This Health & Safety Plan (HASP) has been prepared in accordance with the requirements of Title 29 the Code of Federal Regulations (CFR) Section 1910.120/1926.65 to provide guidance for the protection of onsite personnel from physical harm and chemical exposure while working at the subject site.

The specific requirements of this HASP include precautions for hazards that exist during this project and may be revised as new information is received or as site conditions change.

- This HASP must be signed by all Haley & Aldrich (H&A) staff members who will work on the project, including H&A visitors. By signing the Health and Safety Plan Acknowledgement Form personnel are acknowledging that they are aware of the specific hazards of the site and agree to follow the provisions and procedures required to safeguard themselves and others from those hazards.
- This HASP or a current signed copy must be retained at the site at all times when H&A staff members are present.
- Deviations from this HASP are not permitted without prior approval from the above signed. Unauthorized deviations may constitute a violation of H&A company procedures/policies and may result in disciplinary action.
- Revisions to this HASP must be outlined within the contents of the HASP. If immediate or minor changes are necessary, the RHSC and H&A Project Manager may use Attachment D2 (HASP Amendment Form), located in the back of this HASP. Any revision to the HASP requires personnel to be informed of the changes and that they understand the requirements of the change.
- This HASP is not for H&A Subcontractor use. Each subcontractor engaged is responsible for all matters relating to the health and safety of their personnel and the safe operation of their equipment. This HASP will be made available as a reference so that subcontractors are informed of the potential hazards associated with the site to the extent we are aware. Subcontractors must develop their own HASP which must be, at a minimum, at least as protective as this HASP.
- This Site Specific HASP provides only site-specific descriptions and work procedures. General safety and health compliance programs in support of this HASP (e.g., injury reporting, medical surveillance, Personal Protective Equipment (PPE) selection, etc. are described in detail in the H&A Corporate Health and Safety Program Manual and within Standard Operating Procedures (OPs). Both the manual and OPs can be located on the Company Intranet. When appropriate, users of this HASP should always refer to these resources and incorporate to the extent possible. The manual and OPs are available to clients and regulators per request.

Site Safety Officer

The site safety officer (SSO) is defined as the individual responsible to the employer with the authority and knowledge necessary to implement the HASP and verify compliance with applicable health and safety requirements.

The H&A Project Manager may designate any person as the site safety officer (SSO) and determines the order of authority on site. Usually the highest ranking person on site is the SSO. A site safety

officer must be on site at all times. When none of the designated SSOs are present on site, the senior person for H&A on site will default to the SSO. This project has identified the following hierarchy for SSO.

1. Steve Provencal/John Bode
2. Katie O'Connor
3. Kenneth Alepidis

Site Safety Officer Roles and Responsibilities

The SSO is responsible for field implementation of this HASP and enforcement of safety rules and regulations. SSO functions include:

- Act as H&A's liaison for health and safety issues with client, staff, subcontractors, and agencies.
- Verify that utility clearance has been performed by H&A subcontractors.
- Oversee day-to-day implementation of the HASP by H&A employees on site.
- Interact with subcontractor project personnel on health and safety matters.
- Verify use of required PPE as outlined in the HASP.
- Inspect and maintain H&A safety equipment, including calibration of air monitoring instrumentation used by H&A.
- Perform changes to HASP and document in Attachment D2 of the HASP as needed and notify appropriate persons of changes.
- Investigate and report on-site accidents and incidents involving H&A and its subcontractors.
- Verify that site personnel are familiar with site safety requirements (e.g., the hospital route and emergency contact numbers).
- Report accidents, injuries, and near misses to the H&A PM and RHSC as needed.

The SSO will conduct initial site safety orientations with site personnel (including subcontractors) and conduct toolbox and safety meetings thereafter with H&A employees and H&A subcontractors at regular intervals and in accordance with H&A policy and contractual obligations. The SSO will track the attendance of site personnel at H&A orientations, toolbox talks, and safety meetings. Subcontractors will document training and provide training rosters to the H&A SSO.

The SSO will report accidents such as injury, overexposure, or property damage to the Regional Health and Safety Coordinator, to the Project Manager, and to the safety managers of other on-site consultants and contractors. The SSO will consult with the safety managers of other on-site consultants and subcontractors on specific health and safety issues arising over the course of the project, as needed.

ATTACHMENT D4

Relevant Health and Safety Operating Procedures

- **OP1001 - Excavation and Trenching Safety**
- **OP1002 – Drilling Safety**
- **OP1003 – Cold Stress**
- **OP1004 – Operation and Calibration of PID**
- **OP1006 – Operation of Draeger Gas Detector Pump**
- **OP1008 – Operations Over, Near or On Water**
- **OP1010 – Health and Safety Plans**
- **OP1014 – Hazard Communication**
- **OP1015 – Heat Stress**
- **OP1016 – Recordkeeping and Reporting**
- **OP1020 – Work Near Utilities**
- **OP1021 – Emergency Action plan**
- **OP1031 – Hearing Conservation**
- **OP1033 – Tailgate Safety Meetings**
- **OP3027 – Decontamination Procedure**
- **OP3028 – Investigation Derived Wastes**

OPERATING PROCEDURE: OP1001

EXCAVATION AND TRENCHING SAFETY

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PREPARATION AND APPROVALS

VERSION	AUTHORED /DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.0	CLM/ May 2002	DBK/Jan 2003	CSO/Feb 2003	DBK/May 2003	
		TWN/Sep 2003	JPD/Sep 2003	NER/Oct 2003	SRK/Oct 2003

Total Pages: 21

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OPERATING PROCEDURE: OP1001

EXCAVATION AND TRENCHING SAFETY

1. PURPOSE

There are multiple hazards associated with working in and around excavations and trenches including cave-ins, potential running soils, dislodged excavated soils, lack of proper access and egress, and additional concerns associated with the performance of work in confined spaces. Nonfatal, and even fatal, injuries occur in association with excavation and trenching activities with a greater frequency than one might expect. Causes of bodily injury, illness, or death include asphyxiation, internal injuries due to physical crushing, and toxic exposures.

The purpose of this procedure is to provide Haley & Aldrich, Inc. staff engaged in excavation or trenching activities with an understanding of the hazards associated with these activities and to provide methods to control personal exposure to the hazards. This procedure is designed to comply with applicable Occupational Safety and Health Administration (OSHA) regulations (29 CFR 1926.650, Subpart P - Excavations).

2. EQUIPMENT

See equipment lists for related procedures, as pertinent, listed in Appendix B.

3. PROCEDURE

3.1 Brief Description of the Contractor's Responsibilities

The General Contractor or Construction Manager at a given site is typically responsible for general site safety, while individual companies are responsible for the safety of their own staff members.

3.1.1 Heavy Equipment Operation

Only experienced equipment operators will be allowed to operate heavy equipment such as backhoes, front-end loaders, etc. Where certification or licensing requirements exist, such personnel shall possess appropriate certification and/or licensing for operating specified heavy equipment. While operating heavy equipment in the work area, the equipment operator shall maintain communication with a designated signalman through direct voice contact or approved standard hand signals. In addition, all site personnel in the immediate work area shall be made aware of the equipment operations. All equipment and materials, such as pipe, rebar, etc., should be kept out of traffic lanes and access ways. At no time should the maximum load capacity of a piece of heavy equipment be exceeded, nor should any equipment be used for a function it was not designed for. Equipment should be stored so as not to endanger personnel at any time. At no time should the maximum load capacity of a piece of heavy equipment be exceeded.

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3.1.2 Stability of Adjacent Structures

Where the stability of adjoining buildings, walls, or other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of staff members. These types of projects require that a Registered Professional Engineer with knowledge of excavation safety review the scope of work for safety.

Excavation below the level of the base or footing of any foundation or retaining wall that could be reasonably expected to pose a hazard to staff members shall not be permitted except when:

- A support system, such as underpinning, is provided to ensure the safety of staff members and the stability of the structure; or
- The excavation is in stable rock; or
- A registered professional engineer has approved the determination that the structure is a sufficient distance from the excavation so as to be unaffected by the excavation activity; or a registered professional engineer has approved the determination that such excavation will not pose a hazard to staff members. In addition, sidewalks, pavements, and appurtenant structures shall not be undermined unless a support system or another method of protection is provided to protect staff members from the possible collapse of such structures.

3.1.3 Warning System for Mobile Equipment

When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system should be utilized, such as barricades, hand or mechanical signals, or stop logs.

3.1.4 Inspections

The Contractor's representative competent person shall make daily inspections of excavations, adjacent areas, and protective systems for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. The competent person should conduct an inspection prior to the start of work and as needed throughout the shift. Inspections shall also be made after every rain event or other hazard-increasing occurrence. These inspections are only required when staff member exposure can be reasonably anticipated. Where the competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed staff members should be removed from the hazardous area until the necessary precautions have been taken to ensure their safety.

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3.1.5 Fall Protection

Where staff members or equipment are required or permitted to cross over excavations, walkways or bridges with standard guardrails shall be provided. Adequate barrier physical protection shall be provided at all remotely located excavations where monitoring is absent. All wells, pits, shafts, etc., shall be barricaded or covered. Upon completion of exploration and similar operations, temporary wells, pits, shafts, etc., shall be backfilled.

Excavations and trenches should not be left unattended when the threat of a fall into the excavation is possible. The excavation should be properly barricaded with barricade tape and in some instances secured with a fence to eliminate accidental entry.

3.2 Haley & Aldrich, Inc. Safety Practices

All H&A staff engaged in activities in a construction zone must wear a hard hat, OHSA-approved work boots, long pants, and a shirt. Frequently safety eyewear is also required. Hearing protection is highly recommended. Orange safety vests are required on an increasing number of sites when visibility to construction equipment operators or vehicular traffic is a concern.

Because of the inherent dangers, entry into trenches and excavations should be avoided if there are means, other than entry, to perform the work. Where entry into trenches and excavations is necessary, strict adherence to the procedures specified in this OP is extremely important. Whenever there are questions regarding the safety of trench or excavation entry, contact the Local Health and Safety Coordinator immediately.

3.2.1 Pre-Excavation Requirements

3.2.1.1 Health and Safety Plan

All activities which will involve entry by H&A staff into excavations or trenches greater than 5 feet in depth will require that a written, site-specific Health and Safety Plan (HASP) be developed prior to the start of work and implemented once work begins. The HASP must be developed by the Project Manager and approved by the Local Health and Safety Coordinator. A possible exception to this rule may be made for large scale engineered excavations.

3.2.1.2 Competent Person

A competent person must be present during all work, which involves entry, by any personnel, into trenches or excavations greater than 5 feet in depth. For the purpose of this OP, a competent person is defined as an individual, who by education or experience, is capable of evaluating the hazards associated with trench or excavation collapse and is capable of classifying soils in accordance with the criteria specified in Attachment A of this

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OP. A competent person will have the authority to take corrective actions as needed or stop work if he/she determines that a safety hazard exists.

H&A will not assume the role of the competent person on any excavation project. The contractor who operates the heavy equipment typically performs this function.

3.2.2 Working Around Heavy Equipment

When working around heavy equipment, it is good practice to maintain visual contact with the operator if it is necessary to be within the area where the machine is working. Be aware that many large machines have blind spots where the operator can not see if there is a person present. Never assume that the operator knows where every person on a site is. Be aware of the surroundings at all times.

H&A staff should not operate the Contractor's equipment.

3.2.3 Work in Trenches and Excavations

It is H&A's policy to avoid entry into excavations and trenches when possible. However, it is apparent that staff members may have to enter excavations or trenches during the course of the many work activities H&A performs. Examples of excavations or trenches that may require H&A staff members to enter include (but are not limited to):

- Test pit excavations
- Tank removals
- Miscellaneous sampling events
- Site remediation excavations
- Foundation construction
- Caisson installation
- Utility installation

Each staff member in an excavation shall be protected from cave-ins and trench collapse by an adequate protective system <u>except</u> when:

- Excavations are made entirely in stable rock.

- Excavations are less than 5 feet in depth and an examination of the excavation by a competent person reveals no indication of a potential cave-in. The depth of the excavation is to be measured at its greatest vertical dimension. Be aware that crouching or kneeling in a trench, which is greater than three feet in depth, may still pose significant hazard for the staff member involved.

Protective systems may include sloping the excavation walls, shoring the excavation walls, or utilizing a shielding system. The protective system chosen must have the capacity to resist, without failure, all

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loads to be applied to the system. Protective systems in excavations greater than 20 feet deep must be designed by a professional engineer.

3.2.4 Sloping as a Means Of Protection

Sloping the walls of the trench or excavation is the preferred, and typically simplest, means of protecting staff members who must enter trenches or excavations which are greater than 5 feet in depth or where there is danger of collapse.

To assure the safety of the staff members in the excavation and to comply with the requirements specified in 29 CFR 1926.652, excavations may be sloped according to the following guidelines:

- The trench or excavation walls may be sloped back so that the ratio of the horizontal distance to the vertical rise (H:V ratio) of the sloped wall is at least 1½:1 (i.e., equivalent to an angle with the horizontal of 33 degrees or less);
- Alternatively, the maximum allowable slope of excavation walls may be determined by classifying the soil in accordance with Appendix E of this OP and determining the slope in accordance with Appendix F.

In many cases, determining the maximum allowable slope may allow the use of a steeper slope, which will result in a narrower excavation. However, determination of soil classification is complicated and requires that the competent person be familiar with the OSHA Excavation Standard.

3.2.5 Shoring or Shielding as a Means of Protection

Where sloping the walls of the trench or excavation is unfeasible (e.g., when there are dimensional constraints due to adjacent structures or property lines), the use of shoring or shielding systems may be necessary. Shoring systems may consist of soldier piles and lagging, sheet piles, slurry walls or soil nails and shotcrete. Shielding systems typically involves using a trench box.

Specific procedures for the construction and use of these systems should be provided by the Contractor.

3.2.6 Access and Egress

A stairway, ladder, ramp, or other safe means of egress shall be located in excavations or trenches that are 4 feet or more in depth so as to require no more than 25 feet of lateral travel for staff members.

Ramps and runways constructed of two or more structural members should have the structural members connected together to prevent displacement. Structural members used for ramps and runways should be of uniform thickness. Cleats or other appropriate means used to connect runway structural members should be attached to the bottom of the runway or should be attached in a manner to prevent tripping. Structural ramps used in lieu of steps should be provided with cleats or other surface treatments on the top surface to prevent slipping.

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3.2.7 Protection from Loose Rock Or Soil

Adequate protection should be provided to protect staff members from loose rock or soil that could pose a hazard by falling or rolling from an excavation face. Such protection should consist of scaling to remove loose material; installation of protective barricades at intervals as necessary on the face to stop and contain falling material; or other means that provide equivalent protection such as sloping or benching. Protection should be provided by placing and keeping such materials or equipment at least 2 feet from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

3.2.8 Protection from Hazards Associated With Water Accumulation

Staff members should not work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect staff members against the hazards posed by water accumulation. The precautions necessary to protect staff members vary with each situation, but could include special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline. If water is controlled or prevented from accumulating by the use of water removal equipment, the water removal equipment and operations should be monitored regularly to ensure proper operation. If excavation work interrupts the natural drainage of surface water (such as streams), diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering the excavation and to provide adequate drainage of the area adjacent to the excavation. Excavations subject to runoff from heavy rains should be inspected by a competent person after every storm event.

3.2.9 Hazardous Atmospheres

Confined space entry (CSE) rules apply for entry into trenches and excavations greater than 5 feet in depth in which a hazardous atmosphere exists, or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby. H&A employees must not perform CSE without specific authorization by the Corporate Health and Safety Manager, the Project Manager and without prior training and strict adherence to CSE rules. See OP1027.

- Adequate precautions, such as mechanical ventilation, shall be taken prior to entry into trenches and excavations in which the oxygen concentration is less than 19.5 percent or the concentration of flammable gases or vapors is in excess of 10 percent of the lower explosive limit (LEL).

- When controls are used that are intended to reduce the level of atmospheric contaminants to acceptable levels, testing shall be conducted as often as necessary to ensure that the atmosphere remains safe.

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- Appropriate respiratory protection must be donned prior to entry into any trench or excavation in which airborne levels of toxic substances are present at concentrations in excess of their Threshold Limit Value (TLV) or Permissible Exposure Limit (PEL).

3.2.10 Emergency Rescue Equipment

Emergency rescue equipment, such as breathing apparatuses, safety harnesses and lines, or basket stretchers, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.

3.2.11 Exposure to Falling Loads

Staff members should avoid being underneath loads handled by lifting or digging equipment. Staff members should stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials. Staff members should stay clear of the opposite edge of a roll-off box or dump truck when they are being loaded. Soils that miss the container pose a great threat to bystanders.

3.3 Summary of Haley & Aldrich Staff Responsibilities

3.3.1 Local Health and Safety Coordinator /Corporate Health and Safety Manager

- Will assist Project Managers with compliance with the procedure.
- Will develop, or at a minimum approve, all HASPs for activities involving entry into trenches and excavations greater than 5 feet in depth.
- Will perform field audits to help determine compliance status.

3.3.2 Project Managers

- Will ensure that projects under their direct control or authority, which involve excavation or trenching, are conducted in a safe and efficient manner and in accordance with the requirements of this OP.
- Will ensure that projects under their direct control or authority, which involve excavation or trenching, have a written HASP prepared for the activity.

3.3.3 Staff members

- Will not enter trenches or excavations greater than 5 feet in depth unless the requirements in this OP have been met.
- Will exercise caution when working around construction equipment as discussed in this OP.

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- When a perceived unsafe excavation is observed, will bring to the immediate attention of the Contractor's competent person that you recommend they review the situation and notify the project manager.

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APPENDIX A
REFERENCES

- OSHA Regulations (Standards - 29 CFR), 1926 Subpart P - Excavations (1926.650 to 1926.652)
- OSHA Handbook 2226 Excavations 2002 (Revised)

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1002 Drilling Safety
- OP2026 Exploratory Test Pits
- All 4000 series procedures

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APPENDIX C
FORMS

- See the Health and Safety Home Page (H&A Intranet) for a copy of the HASP.

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APPENDIX D
GLOSSARY

The following definitions are provided for terms used throughout this OP (as defined in 29 CFR 1926.650 and 1926.651). Other definitions can be found in Attachments E and F of this OP.

Benching (Benching system) - method of protecting staff members from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Cave-in (collapse) - the separation of a mass of soil or rock material from the side of an excavation or the loss of soil from under a trench shield or support system and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Competent person - A person who, by way of training or experience, is capable of classifying soils in accordance with 29 CFR 1910.120 Subpart P, Appendix A, who is capable of identifying existing and predictable hazards in excavations with working conditions which are unsanitary, hazardous, or dangerous to staff members, and who has the authority to take prompt corrective measures to eliminate them.

Excavation - any man-made cut, cavity, trench, or depression in an earth surface formed by earth removal.

Faces (or sides) - the vertical or inclined surfaces formed as a result of excavation work.

Failure - the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Hazardous atmosphere - an atmosphere that may cause death, illness, or injury due to being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful.

Protective system - a method of protecting staff members from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Ramp - an inclined walking or working surface that is used to gain access to one point from another and is constructed from earth or from structural materials such as steel or wood.

Registered Professional Engineer - a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of the OSHA standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

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Shield (Shield system) - a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect staff members within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either pre-manufactured or job-built. Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Shoring (Shoring system) - a structure such as a metal hydraulic, mechanical, or timber shoring system that supports the sides of an excavation and is designed to prevent cave-ins.

Sides - See "Faces."

Sloping (Sloping system) - a method of protecting staff members from cave-ins by excavating the sides of an excavation in a reverse incline. The angle of incline required to prevent a cave-in varies with such factors as soil type, environmental conditions of exposure, and application of surcharge loads.

Stable rock - natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against cave-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

Support system - a structure such as underpinning, bracing, or shoring that provides support to an adjacent structure, underground installation, or the sides of an excavation.

Trench (Trench excavation) - an open narrow excavation made below the surface of the ground. In general, the depth is greater than the width, but the width (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered a trench.

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APPENDIX E
ADDITIONAL DEFINITIONS AND SOIL CLASSIFICATION

SCOPE AND APPLICATION

This attachment describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits. The attachment contains definitions, sets forth requirements, and describes acceptable visual and manual tests for use in classifying soils.

DEFINITIONS

The definitions and examples given below are based on, in whole or in part, the following:
American Society for Testing Materials (ASTM) Standards D653-85 and D2488; The Unified Soils Classification System, The U.S. Department of Agriculture (USDA) Textural Classification Scheme; and The National Bureau of Standards Report BSS-121.

Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with critical side slopes and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.

Dry soil means soil that does not exhibit visible signs of moisture content.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Layered system means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Moist soil means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into a small diameter threads before crumbling. Moisture granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

Plastic means a property of soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

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Saturated soil means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.

Soil classification system means, for the purpose of this subpart, a method categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the environmental conditions of exposure.

Stable rock means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Submerged soil means soil which is underwater.

Type A soil means:

- Cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sand clay loam. Cemented soils such as caliche and hardpan are also considered Type A.

However, no soil is Type A if:

- The soil is fissured; or
- The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
- The soil has been previously disturbed; or
- The soil is part of a sloped, layered system when the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or
- The material is subject to other factors and would require it to be classified as a less stable material.

Type B soils means:

- Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48k Pa) but less than 1.5 tsf (144 kPa); or
- Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam, and in some cases, silty clay loam and sand clay loam.
- Previously disturbed soils except those that would otherwise be classed as Type C soil.

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- Soil that meets the unconfined compressive strength of cementation requirements for Type A, but is fissured or subject to vibration; or
- Dry rock that is not stable; or
- Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C soil means:

- Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less;or
- Granular soils including gravel, sand, and loamy sand; or
- Submerged soil or soil from which water is freely seeping; or
- Submerged rock that is not stable, or
- Material in a sloped, layered system where the layers dip into the excavation or a slope or four horizontal to one vertical (4H:1V) or steeper.

Unconfined compressive strength means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Wet soil means soil that contains significantly more moisture than moist soil, but in such a range of values that cohesive materials will slump or begin to flow when vibrated. Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

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APPENDIX F
DETERMINATION OF MAXIMUM ALLOWABLE SLOPE

SCOPE AND APPLICATION

This attachment contains specifications for sloping when used as methods of protecting staff members working in excavations from cave-ins. The requirements of this attachment apply when the design of sloping and benching protective systems is to be performed.

DEFINITIONS

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; cracking above the crest of the cut; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most unfavorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short-term exposure means a period of time less than or equal to 24 hours that an excavation is open.

REQUIREMENTS

Soil Classifications

Soil Classifications shall be determined by the methods that are outlined in Attachment E of this OP by the competent person.

Maximum Allowable Slope

The maximum allowable slope for a soil or rock deposit shall be determined from the following table.

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TABLE 1
MAXIMUM ALLOWABLE SLOPES FOR SOIL OR ROCK DEPOSITS

Soil or Rock Type	Maximum allowable Slopes (H:V) [1] for excavations less than 20 Feet Deep [3]
Stable Rock	Vertical (90°)
Type A [2]	¾:1 (54°)
Type B	1:1 (45°)
Type C	1½:1 (33°)

Notes:
1. H:V is the ratio of horizontal distance to vertical rise of the excavation side. Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.
2. A short-term maximum allowable slope of ½H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth. Short-term maximum allowable slopes for excavations greater than 12 feet (3.67 m) in depth shall be ¾H:1V (54°) for Type A soil.
3. A registered professional engineer shall design sloping or benching for excavations greater than 20 feet deep.

Actual Slope

The actual slope shall not be steeper than the maximum allowable slope.

The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least ½ horizontal to 1 vertical (½H:1V) less steep than the maximum allowable slope.

When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved.

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OPERATING PROCEDURE: 1002

DRILLING SAFETY

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PREPARATIONS AND APPROVALS

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1. PURPOSE

This OP defines the responsibilities of Haley & Aldrich staff members and drilling subcontractors with regard to safety during execution of drilling programs as required by governing regulations and standard contractual agreements. In addition, this document provides an outline of safety-related issues and guidance toward safe operations during site investigations with drilling equipment in common practice.

1.1 Discussion

Familiarity with basic drilling safety is an essential component of all drilling projects. Potential hazards related to drilling operations include, but are not limited to encountering underground or overhead utilities, traffic and heavy equipment, hoisting heavy tools, steel impacts, open rotation entanglement, and the use or unexpected encountering of toxic or hazardous substances. While staff members do not operate drilling equipment, they may work in close proximity to operating drilling equipment and may be exposed to many of the same hazards as the drilling subcontractor.

Haley & Aldrich may be held responsible by regulatory agencies and others for personal injuries or property damage as a result of drilling related accidents. It is the responsibility of the staff members to be knowledgeable of, and in conformance with Federal (OSHA) regulations applicable to worker safety and to adhere to company health and safety policies and procedures. Deviation from applicable safety regulations and established guidelines by staff members and subcontractors is not permitted. Failure to adhere to these regulations, policies and procedures is grounds for disciplinary action or termination.

1.2 Application

The following procedures apply to all Haley & Aldrich projects that include mechanical drilling activities where drilling rigs are used for soil and rock drilling, boring advancement, subsurface sample collection, groundwater monitoring well or instrumentation installation, and in-situ testing.

1.3 Equipment and Supplies

A project or site specific Health & Safety Plan (HASP) may be developed to address the particular concerns of a given project. The HASP must always be referred to prior to assembling safety and monitoring equipment in preparation for fieldwork. In the absence of a HASP, field staff must consult with the Project Manager (PM) and the Regional Health & Safety Coordinator (RHSC) for guidance. Refer to form *Subsurface Activity Pre-Field Checklist* on the Health & Safety Homepage for more information.

1.3.1 Standard Required Personnel Protective Equipment (PPE)

- Hard Hat
- Safety Glasses
- Sound Dampeners
- Steel Toe Boots

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- Protective Gloves
- Work Clothing (Denim Blue Jeans or Equivalent, Short or Long Sleeve Shirt)
- Rain Gear
- Reflective Safety Vest
- First Aid Kit/Eye Wash Kit

1.3.2 Additional Personnel Protective Equipment (PPE) as Required

- Tyvek or Saranex Coveralls/Sleeves/Apron
- Latex/Nitrile Inner Gloves/Boot Covers
- Air-Purifying Respirator & Spare Cartridges (Type Varies with Contaminants commonly Type GMC or Type H)
- Personnel Flotation Device (PFD)
- Safety Harness

NOTE: Use of the equipment outlined in Section 1.3.2 requires special training and, in the case of respiratory protective equipment, medical surveillance.

1.3.3 Required Site Safety Equipment

- Fire Extinguishers
- First Aid Kit/Eye Wash Kit
- Traffic Controls (Safety Cones, Lighting & Signs)
- Site Control – Barricades, Caution Tape (Flagging for Exclusion Zones)

NOTE: The Project Manager should coordinate site safety equipment requirements with the drilling contractor to ensure that the proper equipment is available for on-site use.

1.3.4 Required Air Quality Monitoring Equipment

Most environmental fieldwork will have extensive equipment requirements specifically related to the project needs. The following list is a representative list of air quality monitoring equipment that may be used in order to comply with requirements set forth in the HASP or project contract documents. A comprehensive list of environmental equipment and PPE must be developed for each project in coordination with the PM and RHSC prior to the start of the field program.

1.3.4.1 Air Quality Monitoring Equipment

- Photo-Ionization Detector (PID)
- Flame Ionization Detector (FID)
- Organic Vapor Analyzer (OVA)
- Combustible Gas Meter-LEL/O2
- Dust Monitor

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- Multigas Meter
- Gas Pointer
- Draeger Tube Sampling Kit
- Radiation Survey Meter
- Industrial Hygiene Personal Sampling Equipment

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2. PROCEDURE

2.1 Underground Hazards

Haley & Aldrich staff members must ensure that permission has been gained from the property owner to access the property prior to site entry and before marking proposed exploration or drilling locations. On public property the estimated location of utility installations, such as gas, electric, water, sewer, telephone, fuel, or any other underground installation that may be expected to be encountered during drilling work, will be identified by the appropriate authority. Appropriate authorities include client representatives, utility companies, nonprofit organizations (e.g. "Dig-Safe"), and others. A list of all state "utility locators" is posted on the Health and Safety Homepage under "Guidance Documents". Refer to OP 1020 *Work Near Utilities* for specific guidance on clearing underground utilities.

2.2 Overhead Utilities

The masts of exploratory equipment used on-site must be maintained a safe distance from overhead utilities. Typically, these are overhead power lines. The proper, safe distance is dependent upon the voltage carried by the line. Refer to OP 1020 *Work Near Utilities* for the requirements of working near overhead power lines. Other overhead utilities may also be present. Consult the Corporate Health & Safety Manager (CHSM) for additional information related to other overhead utility hazards.

In general, the subcontractor shall note the location of overhead power lines and other overhead electrical sources. Drilling must not occur near these areas unless precautions are taken to prevent contact. Under no circumstances is the drilling rig to be moved with the mast raised. The drilling rig mast must maintain at least 35 feet of clearance from all energized power lines. Power lines can be de-energized or shielded and the drill rig may be grounded when working within the 35-foot clearance distance. Contact the utility company to find out their requirements when working within the 35-foot clearance minimum.

2.3 Subcontractor Safety Requirements

All subcontractors must conform to applicable OSHA regulations governing worker safety including the wearing of hard hats, eye protection, sound protection, suitable work clothing, gloves, steel toe boots and additional PPE such as air-purifying respirators and Tyvek suits as necessary.

All equipment must be designed for the purpose for which it is to be used, maintained in good condition and have current licenses and inspection certificates.

Drillers must be qualified to operate the equipment and experienced in the activities conducted. Certificates of training or applicable licensure must be available upon request. Personnel will conduct themselves in a professional manner and be safety conscious at all times.

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2.4 Setting up and Blocking the Drilling Rig

It is the drilling rig operator's responsibility to ensure that the rig is properly set up. The stability of the drilling rig is critical to assure safe drilling operations. Whenever possible, the operator shall choose a dry, level and reasonably smooth drilling site. The operator shall make sure the rigs emergency brake is engaged and that the wheels which will remain on the ground are chocked. Blocking the rig will help to provide a more stable drilling structure by distributing the weight of the rig evenly. If the rig is equipped with jacks or outriggers, they will be extended from the rig to the ground, raising the rig partially or entirely off the ground. Proper blocking of the rig will prevent differential settling which could result in the rig toppling sideways. Blocks should be placed between the jack swivel and the ground to provide more support area under the pad.

2.5 Operation of the Drilling Rig

Staff members must never operate any of the subcontractor's vehicles or equipment. The drilling subcontractors are solely responsible for the safe operation of the drilling rig and for handling the equipment associated with the drilling. Drillers and staff members must be aware of the location and operation of the drill rig's emergency shut off (kill switch) which cuts the power to the rig in the event of an entanglement. The kill switch must be maintained in working order at all times.

The driller should never leave the controls of the drilling rig while the tools are rotating.

2.6 Precautions Against Entanglement

All staff members who will work in the vicinity of the drilling rig should secure all loose clothing to prevent them from becoming caught in the drilling mechanism. Only employees necessary to run the rig are allowed in close proximity, except during essential sampling and other activities. Personnel will not reach into or near the borehole or the rotating equipment, unless the drilling rig has been shut down. For the same reasons, a long handled shovel or other similar device should be used to clear the drill cuttings away from the borehole and from rotating tools. Hands and/or feet should not be used to clear cuttings.

2.7 Work on the Mast

Drill rig operators shall not climb the mast to conduct repairs if the mast can be lowered. If the mast cannot be lowered to conduct repairs, workers may utilize a ladder or may climb the mast if fall protection, such as a harness and attached lanyard, is available. Fall protection devices, in the form of a harness and lanyard, will be used where workers must climb to 6 feet or greater in height. No one should climb the mast to conduct repairs while the drilling rig is operating.

Workings at heights requirements, as described in the *Operating Procedure Fall Protection (OP1022)*, are applicable during all drilling operations. In the exceptional circumstance that there is a need to climb a drill rig mast, the driller, SSO shall prepare a task RA of the work activity.

The client project manager or the RHSC shall be consulted and the risk evaluated before

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work on the mast may proceed. If the planned activity is agreed to proceed, the rig shall be shut down, locked out and the *Working at Heights Permit* developed. The work at elevation may then proceed.

2.8 Hoisting Safety

Worn or misused cables and rope are potentially the most dangerous pieces of equipment on the drilling rig. When a steel cable or fiber rope breaks under significant tension it has a tendency to snap like a rubber band. Be constantly aware of the condition of all cables and rope being used to hoist drill pipe or other heavy objects. Any cable or rope used for such purposes which has begun to fray, stretch or unravel, or which has a number of breaks in the same strand must be replaced. Use of thumb clips or clevis pins on hoisting hooks is required (see Section 2.8 below). If you do not need to be near the rig during its operation, stay a safe distance away.

2.9 Hot Work

Ignitable vapors from natural sources or from contamination may be encountered during soil borings.

The Primary Source of Ignition (PSI) hot work is not allowed within 35' (10.67m) of an open borehole unless a *Hot Work Permit* is prepared in accordance with the *Hot Work Defined Practice* and:

- Data history shows the borehole is free of flammable vapors.
- The borehole is capped to prevent the entry of sparks.
- Where a borehole is under construction, an approved procedure is used to inert the borehole vapor space.

When there is no data history or ignitable vapors are expected to be present, the boring shall be treated as a Class 1 area, and *Hot Work Permit* requirements shall apply. The Class 1 area shall be a cylinder that is centered on the well, extending 10' (3.05m) in radius and 3' (.9144 m) in height. Drilling and ancillary activity in the Class 1 area shall meet the secondary source of ignition hot work definition. (Refer to the *Hot Work Defined Practice*.)

When ignitable vapors are not expected based on data history, boreholes under construction shall be verified by taking continuous Lower Explosive Level (LEL) readings at the top of the borehole. LEL readings should also be taken from soil cuttings and produced fluids. Readings shall remain below 5 percent of LEL, or mitigations shall be implemented.

Where neither naturally occurring sources of flammable vapor nor flammable vapors from contaminants are present, the boring is not considered a Class 1 area as defined in the *Hot Work Defined Practice*.

Mechanical drilling, when conducted in a Class 1 area, requires a *Hot Work Permit* before any drilling or other ancillary hot work can proceed. (Refer to *Hot Work Defined Practice*.)

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2.10 Equipment Safety Inspections

Drill rig operators are responsible for ensuring rigs are properly inspected. All drilling rigs and related support equipment and vehicles shall be scheduled for a periodic safety inspection. The inspections shall be the responsibility of the owner/operator of the equipment. The inspections shall include, but are not limited to, all hydraulic lines and fittings for wear and damage, all cable systems and pull ropes for damage and proper installation, exhaust systems, brake systems, drill controls, etc. The kill switches must be operable from various locations on the rig and should be tested for proper operation daily before work begins. Certification of inspection may be required from the driller upon request.

The driller in charge shall inspect the rig on a regular basis covering all major systems. If potentially hazardous deficiencies are found during the inspections, the rig may be shut down until the deficiencies are corrected and potential hazards are addressed or repaired. If staff members believe that equipment is unsafe or believe that an imminent hazard exists, staff members should exercise their stop work authority (see OP 1035 *Stop Work Authority*), notify the PM and SSO until the owner/operator can confirm that the rig is safe to operate.

Air compressors and ancillary equipment represent a significant source of energy and hazard.

All components of a compressed air system shall be inspected regularly by qualified and trained members of the workforce. The compressor owner shall check with regulatory agencies or regulations to determine if regulatory-driven inspection of this equipment is required. Operators shall be aware of and utilize the following general safety requirements for compressed air.

Air Receivers

The requirements for air receivers are:

- The maximum allowable working pressures of air receivers shall never be exceeded, except when being tested. Only hydrostatically tested and approved tanks shall be used as air receivers.

- Each air receiver shall be equipped with at least one pressure gauge and an American Society of Mechanical Engineers or equivalent certifying organization safety valve of the proper design.

- A safety (spring-loaded) release valve shall be installed to prevent the receiver from exceeding the maximum allowable working pressure.

Air Distribution Lines

The requirements for air distribution lines are:

- Air lines shall be made of high-quality materials and fitted with secure connections.

- Hoses shall be checked to make sure they are properly connected to pipe outlets before

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use.

- Air lines shall be inspected frequently for defects. Any defective equipment should be repaired or replaced immediately.
- Compressed air lines shall be identified as to maximum working pressures (in psi) by tagging or marking pipeline outlets.
- Whip checks or safety tethers shall be used on both ends of the air line.
- Air lines shall be protected from damage from other equipment.
- Air lines shall not be placed where they will create tripping hazards.

Pressure Regulation Devices

The requirements for pressure regulation devices are:

- Valves, gauges and other regulating devices shall be installed on compressor equipment in such a way that they cannot be made inoperative.
- Air tank safety valves shall be set no less than 15 psi or 10 percent (whichever is greater) above the operating pressure of the compressor. They shall never be set higher than the maximum allowable working pressure of the air receiver.
- Blowoff valves shall be located on the equipment and shall be shielded so that sudden blowoffs will not result in injury or equipment damage.

Air Compressor Operation

The requirements for air compressor operation are:

- Air compressor equipment shall be operated only by authorized and trained personnel.
- The air intake shall come from a clean, outside, fresh air source. Screens or filters can be used to clean the air.
- Air compressors shall never be operated at speeds faster than the manufacturer's recommendations.
- Moving parts that could be hazardous, such as compressor flywheels, pulleys and belts shall be effectively guarded.
- Compressed air shall not be used to clean a member of the workforce.

2.11 General Housekeeping

The work area around the drill area must be kept clean and orderly at all times. Items such as hand tools, rakes, shovels, etc. shall not be left lying on the ground to pose a trip hazard.

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Excess pipe, augers, connections, etc., should be stored in a rack or on the rig and not left lying around the rig. Remove and dispose of empty bags or other containers which have held drilling mud, cement or other dust producing materials.

Preventive measures must be in place to contain all drill fluids and cuttings. Spray, spills and run-off of drilling fluid must be arrested and recovered immediately in order to prevent the escape of potentially contaminated fluids into the environment or to avoid exposing passersby to a potential slipping hazard. During freezing weather salt or sand must be scattered on the ground surface within the work zone and the surrounding area to provide traction against slipping hazards.

2.12 Lightning

Because of the high potential for lightning strike on the mast of a drilling rig, drilling must cease when thunder and lightning storms approach and workers should take shelter away from the rig. If possible, the mast should be lowered prior to the onset of lightning storms. This decision should be a joint decision between staff members and the subcontractor. Typically work should be suspended if lightning is visible in two directions or is estimated to be less than 2 miles away.

2.13 Lighting

Lighting around a drilling operation should be sufficient to provide illumination at all times of at least:

- An average of 5-foot candle (fc) power in the immediate drilling area, with no less than 3-fc power at any point.
- A minimum of 3 fc power on all other walking and working surfaces.

Work shall be suspended until additional lighting is provided should either H&A or the Subcontractor personnel feel that work site lighting is inadequate.

NOTE: The above are minimum OSHA requirements. Under certain circumstances higher lighting values may be warranted.

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3. STAFF MEMBER SAFETY REQUIREMENTS

All staff members must conform to applicable OSHA regulations governing worker safety including the wearing of hard hats, eye protection, sound protection, suitable work clothing, gloves, steel toe boots and additional PPE such as air-purifying respirators and Tyvek suits as necessary.

A fundamental approach to minimizing one's personal risk of exposure to a variety of potential hazards is to plan ahead of the execution of activities and to set up a work space outside the immediate area of drilling or other traffic. The added distance from the drilling activities serves to provide a safety zone from vehicular traffic, falling objects, bursting hoses, vapors and fumes.

Many activities require staff members to enter into close proximity to the drill rig during operation. At such moments one should never become preoccupied or distracted from the drilling operation. Make certain of the drillers next move at all times and be aware of the hazards of hoisted objects falling and open rotation entanglement. Close to the drill rig there is a greater potential for eye damage from hammering steel splintering, bursting hydraulic lines and other solids or fluids associated with either the rotating drill stem or the borehole. Dangerous sound levels are common as well.

There are many visual and audible cues to an imminent hazard around the drill rig and any number of unsafe drilling practices to be aware of such as excessive stacking of drill rods, excessive rotation speeds, lifting overweight objects, and loose ropes, cables or chains near the rotation.

Take care against disrupting the driller's concentration or approaching him when he's hoisting or adjusting feed. Do not allow the drillers to rush their activities and suggest they take a break if frustration is an issue.

Whenever possible, exercise engineering controls to minimize low level exposure to engine or borehole vapors by working up-wind. Exhaust pipe extensions and fans may be necessary to provide adequate ventilation when working in an interior or confined area. Near continuous air quality monitoring in the breathing zone may be required on both environmental and non-environmental projects. Consult with the Project Manager and the RHSC for compound-specific guidelines for detection and the proper response actions according to company policy.

Use latex gloves in order to minimize low level exposure to soils. Use disposable boot covers to prevent small amounts of soil from boots from contaminating your personal vehicle and potentially exposing those you interact with, including your children, to harmful doses of lead or other contaminants.

Setting up exclusion zones around the work area may be necessary to ensure public safety. In some cases this may be done using caution tape and reflective cones or steel drums. Depending upon the hazard it may be necessary to install a temporary chain-link fence around the work area. OP 1046 *Site Control* provides guidance in this area.

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Setting up a decontamination area is a common practice to effectively recover contaminated wash water and materials while decontaminating equipment and PPE. Health and safety protocols are most easily followed when field decontamination practices are properly executed.

For environmental projects, the practical implications of having on hand and utilizing all of the required PPE, decontamination, sampling and monitoring equipment require use of a rented or company-owned vehicle of sufficient capacity and design to adequately transport and effectively access the equipment at the work site. In addition to the above, it may be necessary to have the applicable Material Safety Data Sheets (MSDS) for the various decontamination chemicals and environmental preservatives.

General field safety calls for attention to a variety of factors including physical stress due to extreme heat and cold as well as potential exposure to any number of hazards. Night drilling in urban neighborhoods may present security risks sufficient to warrant a police escort (Refer to OP 1046 *Site Control* for site security assessments). Drilling over water or near water poses special hazards addressed in OP 1008 *Operations Over, Near or On Water* necessitating use of personal flotation devices (PFD) and other safety requirements. Highway projects and large-scale construction sites typically involve working around vehicular traffic (OP 1043 *Site Vehicle Control*) and heavy equipment where high visibility reflective safety vests are necessary. Railway and airport projects may involve a number of special protocols including the use of defined communications and the completion of a specialized training program. Working in and around quarries, deep excavations and tunnels may require use of safety harnesses to guard against falls. Rural and undeveloped areas may present risks from poison ivy, ticks or snakes and limited access to medical attention in the event of an accident.

3.1 Basic Personal Protective Equipment (PPE)

Certain personal protective equipment (PPE) must be worn because of the physical hazards posed by the drilling operation. As a minimum on Haley & Aldrich field projects, hard hats, steel-toed work shoes, and safety eyewear (EPA Level D) must be worn at all times within the vicinity of the mast of the drilling rig. Hearing protection devices, such as ear plugs and ear muffs, shall be worn as required when the noise exposure is 85 dB (A) or greater over an 8-hour workday. Although noise levels vary with the type of drilling equipment utilized, potentially hazardous noise levels are likely to be generated during split spoon sampling and air drilling. Typically, speech at normal conversational levels becomes difficult at 2 to 3 feet when noise levels are in excess of 85 dB (A). Be aware of any additional personal protective equipment that may be required by the client. Though Haley & Aldrich is not responsible for issuing subcontractor PPE or the use of it, we must be diligent of our client's requirements and work closely with our drillers to ensure conformance with the site requirements. All protective equipment shall be provided by respective employer(s).

3.2 Special Precautions for Drilling in Landfills

In addition to the usual physical hazards of drilling, staff members drilling in landfills may experience an increased hazard from methane gas and other decomposition products. Decomposition products of organic materials typically produce very flammable and/or hazardous gases and vapors, which may accumulate in the borehole or in the general work area. To help reduce the hazards due to the presence of these products while drilling in landfills, the following procedures shall be implemented:

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- Smoking, open flames or spark-producing equipment are not permitted within 75 feet of drilling rigs open wells, gasoline-driven pumps, or fuel storage areas.
- Flammable liquids (includes empty/full cans) shall not be stored or left within 50 feet of drilling rigs, pumps, or other related machinery.
- A fire extinguisher shall be located on, or within 10 feet, of any operating drilling rig.
- Equipment engines shall be shut off during fueling.
- Containers used for fuel shall be bonded and grounded during dispensing to prevent the discharge of static electricity.
- Safety fuel cans shall be returned to a designated safe storage area after fueling is completed.
- The drilling rig must be diesel powered and equipped with a spark-arresting muffler.
- Explosive gas concentrations shall be monitored as frequently as possible using a Combustible Gas Indicator (CGI). The frequency of monitoring must be established in the HASP. The meter should be kept near the rig. Results of the monitoring data should be entered on the field log.
- Haley & Aldrich policy requires that all work stop if explosive gases are detected at 10% or greater of the lower explosive limit (LEL) in the hole being drilled or in the work area surrounding the hole. Under such circumstances it may become necessary to inert, ventilate, or flood the borehole with water during drilling to reduce the risk of downhole explosions.

3.3 Special Precautions for Drilling in Contaminated Soils

A HASP must be developed for all drilling operations when environmental contamination is reasonably expected. Follow the requirements of the HASP to safely manage exposure to contaminated soils. In the event environmental contamination is encountered unexpectedly, work must be suspended until the PM and RHSC can be contacted to develop a Site Specific HASP.

All contaminated equipment shall be properly decontaminated prior to leaving the general location of the drilling activities. Improperly decontaminated equipment returned to the Haley & Aldrich storerooms is not permitted. Subcontractors are expected to ensure that there will be no cross-contamination of the property and offsite locations as a result of the sampling event.

3.4 Training

Staff members working in the proximity of an operating drilling rig and the support equipment required should be thoroughly familiar with the operational hazards involved and the applicable work safety regulations. For environmental projects, staff members must have undergone the 40-hour OSHA (HAZWOPER) training and shall read, sign and comply with the provisions of

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the site-specific HASP drafted for the project. For other projects, standard regulations and health and safety precautions must be followed.

In the scope of this procedure a qualified equipment operator (QEO) is an individual who, through experience or training, and with the endorsement of his or her employer, is competent to operate equipment used during drilling operations. The PM shall verify that the QEO is identified in the HASP (or on the client-specific permit) prior to beginning work activity. The PM shall certify that all equipment operators have QEO credentials. Drilling subcontractors shall have a similar level of training to staff members and a HASP when required. Heavy equipment operators in most states must be certified or licensed. If at any time there may be a question about competency in regards to safe operations, the PM should request training records.

3.5 Personal Hygiene Requirements

To help limit the potential for ingestion of contaminants, eating, drinking, chewing, applying cosmetics or smoking is not allowed when working in the immediate vicinity of the drilling rig or in any restricted work areas (i.e., exclusion and decontamination zones). A break area outside the restricted work areas shall be established with a hand and face washing facility. Before eating, drinking, or smoking, all staff members shall thoroughly wash their hands and face.

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4. ROLES & RESPONSIBILITIES

Project Manager (PM)

The PM, or designee shall have specific training and knowledge of the applicable regulations regarding the activities he or she is leading as well as the necessary requirements for protective systems. The PM shall also be knowledgeable, experienced and/or trained and have the ability to identify existing or predictable hazards and has the authority to initiate prompt corrective action. The PM shall be responsible for:

- Ensuring that utility clearance has been properly conducted.
- Assuring that provisions specified in this OP are followed by staff members and the drilling subcontractor.
- Assuring that a HASP is developed for the project if it involves drilling in anticipated or unexpectedly encountered contaminated soils or significant safety hazards.
- Assuring that Haley & Aldrich staff members do not operate or handle the drilling subcontractor's equipment and that they remain clear of the drilling rig when their presence is not necessary.
- Assuring that all required personal protective equipment, for example hard hats, steel-toed shoes, and/or safety glasses are worn within the restricted work areas during the drilling operation. Hearing protection may be required in some instances.

Drilling Subcontractor

The drilling subcontractor is responsible for:

- Provide trained, qualified and competent personnel to operate drilling rigs or comparable equipment. Subcontractors shall provide trained drillers and driller's helpers who meet Haley & Aldrich requirements for drilling. The training shall include a mechanism of verifying employee and Contractor's comprehension of the work process and associated equipment via written test, observation and evaluation by a competent trainer.
  - Refresher training shall be required on a periodic basis. Refresher training in relevant topics shall be required when an individual has been observed to operate machinery in an unsafe manner or involved in an accident or near-miss incident.
- Identifying any overhead and underground utilities/hazards prior to the start of drilling activities and, if necessary, arranging to have electrical lines de-energized prior to the start of drilling. In California, this might be a contractual/work scope responsibility for H&A.
- Making the final decision as to where they feel they can safely drill all borings.

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- Safely operating the drilling rig and handling all equipment associated with the drilling operation.
- Maintaining the drilling rig and equipment in accordance with standard industry practices and safety standards.
- Containing generated material and preventing contamination from being spread as a result of drilling activities.
- Responding to staff members to correct deficiencies related to unsafe conditions or practices.

Staff Members

On-site staff members are responsible for:

- Complying with the provisions of this OP.
- Working in a safe manner.
- Notifying subcontractors/contractors of potentially unsafe conditions and utilizing stop work authority as necessary.
- Notifying the PM or RHSC of any unsafe acts or conditions in the workplace.
- Notifying the PM of any work-related injuries or illnesses that incur during work at the site.
- Conforming with the provisions outlined in applicable site-specific HASPs.

Corporate Health & Safety Manager (CHSM)

The CHSM is responsible for the development, implementation and monitoring of the procedure.

Regional Health & Safety Coordinators (RHSCs)

The RHSCs are responsible for implementing the requirements of the OP and providing support to the PMs and field staff during its implementation.

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5. REFERENCES

OSHA standard, 29 CFR 1910.134, "Respiratory Protection"

OSHA Hazardous Waste Operations and Emergency Response (Hazwoper) standard (i.e., 29 CFR 1910.120)

"Occupational Safety & Health Guidance Manual for Hazardous Waste Site Activities" published by NIOSH/OSHA/USCG/EPA, October 1985

Occupational Health and Safety Regulations (OSHA) and United States Coast Guard (USCG) 29 CFR 1926 Subpart C, General Safety and Health Provisions; 29 CFR 1926 Subpart E, Personal Protective Equipment; 29 CFR 1926.106, Working Over or Near Water; 33 CFR Part 151, Vessels Carrying Oil, Noxious Liquid Substances, Garbage, Municipal or Commercial Waste, and Ballast Water; 46 CFR Parts 25 and 26, Uninspected Vessels

U.S. Environmental Protection Agency Environmental Response Team, Response Engineering and Analytical Contract, Standard Operating Procedure Number 9, Drilling and Monitoring Well Installation at Hazardous Waste Sites, adopted from SOP 2150

BP International, Ltd., Remediation Defined Practice; Ground Disturbance, Appendix D Probing Guideline

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APPENDIX A - RELATED HALEY & ALDRICH PROCEDURES

OP1004	Operation/Calibration of PID Photoionization Detector
OP1005	Operation/Calibration of FID Flame Ionization Detector
OP1006	Operation of Draeger Gas Detector Pump
OP1007	Field Monitoring for Volatile Organics (breathing space-work zone)
OP1008	Operations Over, Near, or On Water
OP1009	Medical Surveillance Program
OP1010	Health and Safety Plans
OP1015	Heat and Cold Stress
OP1016	Recordkeeping and Reporting
OP1020	Work Near Utilities
OP1022	Health and Safety
OP2000	Monitoring Field Explorations

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APPENDIX B - FORMS

Subsurface Activity Pre-Field Checklist

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APPENDIX C - GLOSSARY

Air Drilling
A method of rotary drilling that uses compressed air as its circulation medium to remove cuttings from the borehole.

Bit
The cutting or boring element used in drilling wells. Most bits used in rotary drilling are roller-cone bits. The bit consists of the cutting elements and the circulating element. The circulating element permits the passage of drilling fluid and utilizes the hydraulic force of the fluid stream to improve drilling rates.

Borehole
The hole drilled by the bit. A borehole may have casing in it or may be open (i.e., uncased), or a portion of it may be cased and a portion of it may be open.

Casing
Steel or PVC pipe placed in a well during the drilling process to prevent the wall of the hole from caving in during drilling and after installation.

Cuttings
The fragments of rock and soil dislodged by the bit and brought to the surface in the drilling mud.

Drill Stem
All members in the assembly used for drilling by the rotary method from the swivel to the bit, including the Kelly bar, drill pipe and tool joints, drill collars, stabilizers, and various subsequent items.

Driller
The individual of the drilling company directly in charge of a drilling rig and crew. His/her main duty is operation of the drilling rig and hoisting equipment, but he/she is also responsible for the downhole condition of the well, operation of downhole tools, and pipe measurements.

Drilling Fluid
Circulating fluid, one function of which is to force cuttings out of the borehole and to the surface. While a mixture of clay, water, and other chemical additives is the most common drilling fluid, boreholes can also be drilled using air, gas, or water as the drilling fluid.

Grouting
To fill the annulus between the casing and borehole with liquid slurry of grout (cement or bentonite) and water to support the casing and prevent fluid migration between permeable zones.

Mast
A portable derrick capable of being erected as a unit, as distinguished from a standard derrick, which cannot be raised to a working position as a unit.

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Mud
A liquid fluid that may be used to circulate through the borehole during rotary drilling and work over operations. It functions to bring cuttings to the surface, to cool and lubricate the bit and drill stem, to protect against blowouts by holding back subsurface pressures and to deposit a mud cake on the wall of the borehole to prevent loss of fluids to the formation. The mud used in modern drilling operations is a complex, three-phase mixture of liquids, reactive solids, and inert solids. The liquid phase may be freshwater, diesel, oil, or crude oil and may contain one or more conditioners.

Rig
The mast, drawworks, and attendant surface equipment of a drilling unit.

Rotary Drilling
A drilling method in which a hole is drilled by a rotating bit to which a downward force is applied. The bit is fastened to and rotated by the drill stem, which also provides a passageway through which the drilling fluid is circulated. Additional joints of drill pipe and added as drilling progresses.

Well Head
The equipment installed at the surface of the borehole when a well is installed in the borehole. A well head may include such equipment as the casing head and tubing head.

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APPENDIX D - PROBING GUIDELINE

Overview:

This guidance establishes minimum probing requirements for all personnel involved with ground disturbance activities as defined in this procedure. Staff members and contractors may deem it necessary to have more stringent requirements in place for specific tasks, based on past work experience and hazard assessments.

Definitions:

PPE – Personal Protective Equipment

Poly pipe – plastic pipe (polybutylene)

PVC – Poly Vinyl Chloride (plastic pipe)

General Requirements:

BEFORE conducting probing operations, all personnel shall be familiar with the general requirements for prevention of subsurface facility strikes. All ground disturbance work shall only be conducted upon receipt of a completed Subsurface Clearance Review, which is signed by the designated competent person. In addition, the terms and requirements of the Review MUST be discussed with all involved with the task prior to initiating work.

Procedure/Process:

1. Use caution probing for the following:
   - Probe for steel or polypipe carefully. Probe may penetrate line if excessive force is used.
   - Probe for PVC and fiberglass pipelines with extreme caution. Be aware that some clients may not allow the use a probe for these types of lines.
   - Do not probe electrical lines or fiber optic lines and cables.
2. Probe should be positioned and used directly above the center line of the pipeline.
3. After probing pipeline, note depth then probe to each side of pipeline to insure that the initial probe was an accurate indication of the pipeline.
4. Probe pipeline 25 feet, on each side of dig site and at dig site.

NOTE: If not sure of pipeline material (*i.e.: PVC, poly pipe, fiberglass, and special coated pipelines*) seek additional information before continuing work.

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APPENDIX E - DRILLING METHODS

Drilling Methods

The most commonly used drilling methods are:

- Hollow-stem auger
- Solid-stem auger
- Bucket auger
- Direct- mud rotary
- Reverse-air rotary
- Cable tool

The type of equipment used depends upon the site geology, hydrology, equipment available, and monitoring design. Control of cuttings and other potentially contaminated materials at the drill site may influence drilling method selection. Depending upon equipment availability and site geology, more than one method may be combined to complete a particular monitoring well installation.

Hollow-Stem auger

Hollow-stem auger drilling uses large diameter (up to 14-inch outside diameter [OD]) continuous- flight augers which mechanically excavate drilled materials from the hole. These augers are built with a large (up to 10.25- inch inside diameter [ID]) axial opening to allow access to the bottom of the hole without withdrawing the auger string. The augers act as temporary casing during and at the completion of drilling to facilitate the sampling of sediment and water and the installation of monitoring wells.

Some advantages of hollow-stem auger drilling often make it the preferred method of installing monitoring wells. Hollow-stem auger drilling is relatively rapid, especially in shallow applications in poorly lithified to unlithified sediments. Little or no outside fluid is required in the drilling process. Though a relatively large volume of cuttings are generated, they are normally easily contained. The volume of effluent, resulting from well-development efforts and requiring disposal, is normally lower than with some methods, notably mud rotary. Hollow-stem auger drilling readily supports thin-wall and split-tube sampling in poorly lithified sediments.

Most hollow-stem rigs also support other drilling methods such as mud rotary, solid-stem auger, and coring. Hollow-stem rigs are relatively simple, with few lubricated parts at positions likely to contaminate the test hole or monitoring well.

There are some disadvantages and limitations to the use of the hollow-stem auger method in the construction of monitoring wells. It is limited to drilling in poorly lithified to unlithified sediments and to a maximum depth of about 150 feet. Shallow bedrock or other hard-to-drill materials may reduce this depth significantly. Hollow-stem augers are prone to cross contamination of fluids within the bore hole along the large annular space around the auger tubing. High hydrostatic pressures in the bore hole can cause problems with sand heaving up into the augers during sampling and well- installation procedures. Wide variations in bore-hole

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size, common to auger drilling in poorly cohesive sediments, may complicate effective sealing of the annular space during monitoring-well installation. The design of hollow-stem augers produce an approximately 1- inch thick rind of smeared cuttings which may effectively seal the bore-hole walls in clayey sediments. This rind may interfere with the flow of fluids to the monitoring well.

U.S. Environmental Protection Agency guidelines (U.S. Environmental Protection Agency, 1986, 1987) recommend that hollow-stem auger inside diameters be 3 to 5 inches greater than the outer diameter of well casings to allow effective placement of filter and sealing materials. Ideally, 2-inch diameter monitoring wells should therefore be installed within 5.5 inch ID or larger hollow-stem augers.

Hollow-stem auger drilling is usually appropriate in the more poorly lithified sediments. The method is well suited to drilling in glacial drift. These sediments, however, are composed primarily of sticky bentonitic clays that require a rig which can supply high drill head torque to complete deeper holes. Cretaceous shale, chalk, and sandstone provide for difficult hollow-stem auger drilling but may often be penetrated with larger, more powerful rigs equipped with heavy-duty augers. Sediments containing abundant large boulders may be penetrated only with great difficulty by hollow-stem methods. Other well lithified bedrock units such as well-cemented sediments, igneous and metamorphic rocks preclude hollow-stem drilling.

Solid-Stem auger

Solid-stem auger drilling uses continuous- flight augers which mechanically cut and continuously transport cuttings to the land surface. Augers are available in diameters of 3 to 14 inches.

Augers used for monitoring-well construction must be of sufficient diameter (about 3 to 5 inches larger in diameter than the monitoring well OD) to allow effective placement of well filter and sealing materials.

Solid-stem augering has a number of advantages. It produces a moderate amount of easily contained cuttings; little or no fluid is required in the drilling process. The entire surface area of the augers is easily accessible, facilitating complete and simplified decontamination. Thin wall and split barrel soil sampling operations are supported. Smaller rigs than used in hollow-stem auger drilling may be used, simplifying decontamination, site maneuvering and often incurring lower costs. These rigs drill relatively rapidly, especially in shallow applications. Solid-stem rigs are relatively simple, with few lubricated parts at positions likely to contaminate the test hole or monitoring well. Rigs capable of supporting this method are available throughout the U.S.

Solid-stem auger drilling has some disadvantages. It is prone to cross contamination of fluids in the bore hole along the large annular space around the auger. Like hollow-stem augers, the design of these augers produce an approximately 1-inch thick rind of smeared cuttings which may effectively seal the bore-hole walls in clayey sediments. This rind may interfere with the flow of fluids to the monitoring well. Solid-stem augers must be removed from the hole before any soil sampling or well installation can commence. The method is, therefore, generally limited to stable earth materials which will not collapse when the augers are removed from the hole.

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Saturated silts, sands and gravels, and materials below those sediment types are not suited to monitoring-well construction by this drilling method. Soil sampling during solid-stem auger drilling is labor intensive, especially in deeper holes because the augers must be removed from the hole during each sampling procedure. Workers are also more likely to contact contaminated materials and equipment during this repeated large scale handling of down-hole equipment.

Solid-stem auger drilling is generally restricted to the more cohesive, yet poorly lithified sediments. The method is well suited to drilling in glacial tills. These sediments are composed primarily of sticky-bentonitic clays that require high rotary head torque to cut and transport cuttings from deeper holes. Cretaceous shale, chalk, and sandstone provide for difficult auger drilling but may often be penetrated with larger, more powerful auger rigs and heavy-duty augers. Sediments containing abundant large boulders may be penetrated only with great difficulty by solid-stem auger methods. Other well lithified bedrock units preclude solid-stem auger drilling.

Bucket auger

Bucket auger drilling uses a rotating cylindrical bucket with cutting blades mounted on a hinged bottom to repeatedly cut and lift sediments from the hole, much like the operation of a common post hole auger. Bucket-auger rigs may be equipped to drill holes from 10 to 60 inches in diameter. Bore holes for monitoring wells drilled are commonly 12 inches in diameter. Bucket-auger rigs are capable of drilling to about 100 feet in depth.

Bucket augering requires little or no fluid in the drilling process. The entire surface of the drilling tools is easily accessible, allowing complete and simplified decontamination. Though normal soil sampling tools are not usually supported, samples from the drilling process are adequate for most purposes and easily located as to position within stratigraphy of the hole. A variation of bucket-auger drilling available fashioned after the California Stovepipe method, advances casing during the drilling process. This variation greatly limits the potential for cross contamination of fluids within the bore hole. Bucket-auger rigs are relatively simple, with few lubricated parts at positions likely to contaminate the test hole or monitoring well.

They are capable of quite rapid drilling rates. Bucket-auger rigs are available at throughout the U.S.

Disadvantages of bucket augering include the production of a large volume of cuttings and fluids (when operating within the saturated zone). When water-tight casing is not advanced concurrent with drilling, cross contamination of fluid-bearing intervals is likely. Bucket augering is generally limited to poorly lithified but cohesive sediments, but may continue even into sand and gravel if the hole is cased concurrent with the drilling process, or the hole is kept full of water.

Even moderately lithified sediments usually are too resistant for bucket-auger rigs to penetrate. Bucket augering is generally restricted to the more cohesive, yet unlithified sediments. The method is well suited to drilling in glacial tills. Cretaceous shale, chalk, and sandstone are difficult to impossible to drill using the bucket-auger method. Sediments containing abundant large boulders preclude bucket-auger drilling.

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Direct-Mud Rotary

In the direct- mud rotary method, the borehole is advanced by rapid rotation of a drill bit mounted upon the end of drill rods. The bit cuts and breaks the material at the bottom of the hole into small pieces (cuttings). The cuttings are removed by pumping drilling fluid (water, or water mixed with bentonite or other fluid enhancers) down through the drill rods and bit and up the annulus between the bore hole and the drill rods. The drilling fluid also serves to cool the drill bit and stabilize the borehole walls, to prevent the flow of fluids between the borehole and surrounding earth materials, and to reduce cross contamination between aquifers.

Direct- mud rotary drilling offers a number of advantages. It is a very fast and efficient means of drilling. Efficient rigs can produce several hundred feet of hole per day. The direct-mud rotary method can reach to several thousand feet in depth and create hole diameters to greater than 48 inches. The method is adaptable to a wide range of geologic conditions. Only exceptionally large, poorly stabilized boulders or karst (cavernous) conditions are unsuited for direct-mud rotary drilling. Direct- mud rotary rigs are widely available throughout the U.S. Sediment sampling is broadly supported in direct- mud rotary drilling: standard split-barrel and thin-wall sampling are available in poorly lithified materials while a broad range of coring apparatus are supported for consolidated rock. Hydrologic conditions have little effect upon direct- mud rotary drilling; operations are usually unhindered by the presence of ground water. Direct- mud rotary drilling readily supports the telescoping of casings to successively smaller sizes to isolate drilled intervals and to protect lower geologic units from contamination by previously drilled, contaminated upper sediments.

Direct- mud rotary drilling has some inherent disadvantages for monitoring-well installation. If the drilling mud is not carefully engineered, drill fluids may invade permeable zones, compromising the validity of subsequent monitoring well samples from those intervals. The mud cake necessary for hole stability will usually interfere to some unknown extent by ionic exchange with the analysis of monitoring well water samples (U.S. Environmental Protection Agency, 1991). Organic compounds that are commonly added to drilling fluids may also interfere with chemical and physical tests on sediment samples. Poorly engineered drill fluids may produce difficult-to-remove mud cakes that inhibit the flow of fluids to the well. Relatively large volumes of cuttings and drilling fluids may provide containment problems and must be disposed of properly. At sites being monitored for hydrocarbons, inherently complex rotary rigs may introduce grease and oil to the monitoring system. Mud pumps, water swivels, rotary drives, rod connections, and drill- fluid components all may contribute hydrocarbons inadvertently to the system, despite the best decontamination/degreasing efforts. When water or other materials are introduced to the drill hole, those materials must be sampled and analyzed as control samples.

Despite these problems, direct- mud rotary drilling may sometimes be the best available alternative, especially for deep wells or wells completed into well lithified rocks. When direct-mud rotary methods are used, hole diameters should be 3 to 5 inches larger than the outer diameter of the well casings to allow effective placement of filter and sealing materials. Two inch diameter monitoring wells should therefore be installed within 5.5- inch diameter or larger holes.

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Direct- mud rotary drilling is well suited to most geologic conditions. Only areas prone to lost circulation such as karstic limestones and boulder formations such as found along high- gradient stream valleys are beyond the capabilities of direct-mud rotary drilling.

Reverse-Air Rotary

The reverse-air rotary method operates by the same general principles as direct- mud rotary except that compressed air is pumped down the drill rods and returns with the drill cuttings up through the annulus. The reverse-air rotary method is best suited to drilling in relatively stable to consolidated formations. Casing is sometimes used to prevent caving in poorly consolidated formations.

Reverse-air rotary drilling is a very fast and efficient means of drilling. Rigs that are properly equipped and staffed can drill several hundred feet of hole per day. The reverse-air rotary method can reach to several thousand feet in depth and create hole diameters up to approximately 17 inches. Reverse-air rotary rigs are unrestrained by karst (cavernous) terrain.

Sediment sampling is supported both in poorly lithified materials (by split-barrel samplers) and in consolidated rock (by coring). Reverse-air rotary drilling supports the telescoping of casings to successively smaller sizes to isolate drilled intervals and protect lower geologic units from contamination by previously drilled contaminated upper sediments. Reverse-air rotary rigs are sometimes fitted with a casing driver to overcome bore hole instability problems in unconsolidated sediments. When so equipped, reverse-air rotary rigs minimize the potential for interaquifer contamination. Reverse-air rotary rigs are available throughout the U.S.

Reverse-air rotary drilling presents some disadvantages. In contaminated formations, the use of high-pressure air may pose a significant hazard to the drill crew due to rapid transport of contaminated material up the bore hole during drilling. Large volumes of hazardous gases may be discharged at the surface, posing an immediate hazard to the drill crew and others in the vicinity. Introduction of air to ground water could interfere with chemical analyses primarily by oxidation and by vigorous agitation and mixing. Concentrations of volatile contaminants are very likely to be reduced in ground water adjacent to holes drilled using the reverse-air rotary method. The air discharged from air compressors normally contains finely atomized lubricating oil. To help prevent this oil from contaminating monitoring well drill holes, compressor discharge filters must be installed (and maintained during regular intervals) on rigs used to drill monitoring wells. Air-discharge samples should be collected as reference samples for future comparison where hydrocarbon contamination is being studied. These samples are a necessity in applications where lubrication of down-the-hole hammers or other tools is essential. The use of foam additives to aid cuttings removal can also introduce organic contaminants into the monitoring system. These should be avoided, but where necessary, samples of the foaming agent must be taken as reference samples.

Cuttings above the water table are usually very fine and hard to interpret. Also, the drying effect of the air in the annulus may reduce or eliminate any natural moisture in the cuttings, thereby masking low yield water producing zones. Conversely, when high- yield aquifers are encountered, large volumes of water may be produced during drilling, a definite disadvantage if the water is contaminated and requires special handling and disposal.

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When reverse-air rotary methods are used, hole diameters should be 3 to 5 inches larger than the outer diameter of the well casings to allow effective placement of filter and sealing materials. Two- inch diameter monitoring wells should therefore be installed within 5.5- inch diameter or larger holes.

Cable Tool

Cable-tool drilling involves chipping and cutting earth materials by lifting and dropping a heavy, solid chisel-shaped bit, suspended on a steel cable from a truck- mounted rig. Steel casing is often used to keep the hole open during drilling in unstable materials. Casing is also used to isolate potentially contaminated strata.

In the context of monitoring-well drilling, the cable-tool method is unrestricted as to depth, diameters, and ability to penetrate geologic materials. The method is well suited to drilling both below and above the water table. Small volumes of easily contained cuttings are produced. Little or no outside drilling fluids are normally needed, and fluids which are used are primarily to facilitate cuttings removal by a bailer or sand pump.

Detection and isolation of thin fluid bearing intervals and ease of well development is unsurpassed by any other drilling technique. Excellent sediment samples are obtainable. Successively smaller casing may be easily telescoped within previously installed casing to avoid carrying shallow contaminated materials into lower stratigraphic units. Sampling of soil and water during drilling and the installation of monitoring equipment is easily accomplished during cable-tool drilling. Cable-tool rigs are extremely simple with few lubricated parts at positions likely to contaminate the test hole or monitoring well. Some cable-tool rigs are dual purpose, also supporting rotary-drilling techniques. The primary disadvantage of cable-tool drilling is its relatively slow rate of penetration. Cable tool drilling rates range from as low as 10 feet per day to rarely over 100 feet per day in glacial drift. Cable-tool rigs are becoming relatively rare. Only a few may be found.

Sufficient annular space should be maintained between drilling casing and monitoring-well casing to allow effective placement of filter and sealing materials. Test holes or steel casing around the well casings should be 3 to 5 inches greater in diameter than the monitoring-well casings. Two-inch diameter monitoring wells should therefore be installed within a 5.5-inch diameter or larger test hole or drilling casing.

Cable-tool drilling is applicable throughout the U.S. in all geologic and hydrologic conditions.

Direct Push

Direct push technology includes several types of drilling rigs and drilling equipment which advances a drill string by pushing or hammering without rotating the drill string. While this does not meet the proper definition of drilling, it does achieve the same result — a borehole. Direct push rigs include both cone penetration testing (CPT) rigs and direct push sampling rigs such as a PowerProbe or Geoprobe. Direct push rigs typically are limited to drilling in unconsolidated soil materials and very soft rock.

CPT rigs advance specialized testing equipment (such as electronic cones), and soil samplers using large hydraulic rams. Most CPT rigs are heavily ballasted (20 metric tons is typical) as a

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counter force against the pushing force of the hydraulic rams which are often rated up to 20 kN. Alternatively, small, light CPT rigs and offshore CPT rigs will use anchors such as screwed-in ground anchors to create the reactive force. In ideal conditions, CPT rigs can achieve production rates of up to 250–300 meters per day.

Direct push drilling rigs use hydraulic cylinders and a hydraulic hammer in advancing a hollow core sampler to gather soil and groundwater samples. The speed and depth of penetration is largely dependent on the soil type, the size of the sampler, and the weight and power the rig. Direct push techniques are generally limited to shallow soil sample recovery in unconsolidated soil materials. The advantage of direct push technology is that in the right soil type it can produce a large number of high quality samples quickly and cheaply, generally from 50 to 75 meters per day. Rather than hammering, direct push can also be combined with sonic (vibratory) methods to increase drill efficiency.

Sonic (Vibratory) Drilling

A sonic drill head works by sending high frequency resonant vibrations down the drill string to the drill bit, while the operator controls these frequencies to suit the specific conditions of the soil/rock geology. Vibrations may also be generated within the drill head. The frequency is generally between 50 and 120 hertz (cycles per second) and can be varied by the operator.

Resonance magnifies the amplitude of the drill bit, which fluidizes the soil particles at the bit face, allowing for fast and easy penetration through most geological formations. An internal spring system isolates these vibrational forces from the rest of the drill rig.

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OPERATING PROCEDURE: OP1003

COLD STRESS

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP1003

COLD STRESS

1. PURPOSE

This OP is designed to prevent injuries due to cold temperatures, wind chill, or emersion. Injuries from these types of exposures include hypothermia and frost bite, as defined below.

2. DISCUSSION

Cold stress is the term used to describe the effects of low temperatures on the body. Hypothermia and frostbite are the primary concerns. Persons working outdoors or indoors in low temperatures, especially at or below freezing, are subject to potential cold stress. Also, persons briefly immersed in cold water, or even in moderately cold water for extended periods, may suffer from hypothermia. Exposure to extreme cold for a short period of time can cause severe injury to the surface of the body, or can result in profound generalized cooling (hypothermia), possibly causing death. Signs of hypothermia may include sluggishness and inattention. Areas of the body which have high surface area-to-volume ratios, such as fingers, toes, and ears, are the most susceptible to frostbite. Exposed areas, such as the face, may also be rapidly affected. Frostbite may appear as a white patch on the nose, ears, or appendages.

3. APPLICATION

This SOP should be followed when H&A Staff members working in the field are potentially exposed to cold weather, especially at or below freezing. It also applies to H&A Staff members working in refrigerated or other artificially cooled environments, and to H&A Staff members working over large bodies of water. It is designed to aid in the prevention or minimization of cold stress injuries.

4. DEFINITIONS

4.1 Cold Stress

The production of physiological effects due to cold temperatures and\or wind chill.

4.2 Frostbite

Freezing of tissue, often resulting in tissue death.

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4.3 Hypothermia

Condition of reduced body temperature resulting in loss of dexterity, loss of mental alertness, collapse, and possible death.

4.4 Wind Chill

The effect of air movement on apparent temperature in a cold environment.

5. PROCEDURE

5.1 Cold Stress Awareness

Employees shall be made aware of the factors, which influence the development of cold injury: ambient temperature, the velocity of the wind, and moisture. They shall be made aware of proper protective measures and equipment.

5.1.1 Low Temperatures

Low temperatures can be a threat in both outdoor and indoor environments. In either case, lack of precautions and improper clothing can contribute to injuries. H&A Staff members should use the following chart as a guide. However, employees must reduce exposures if experiencing subjective cold stress problems, even at temperatures above those listed in the chart.

5.1.2 Wind Chill

"Wind chill" describes the chilling effect of moving air in combination with cold temperatures. Even low velocity winds increase the cold stress on the body. A new "wind chill" chart is presented below (Figure 1) and should be used in gauging apparent (equivalent) temperatures for the exposure times above. Employees should make use of wind breaks, buildings, or other structures to reduce wind chill effects. Note: This is the new wind chill temperature index.

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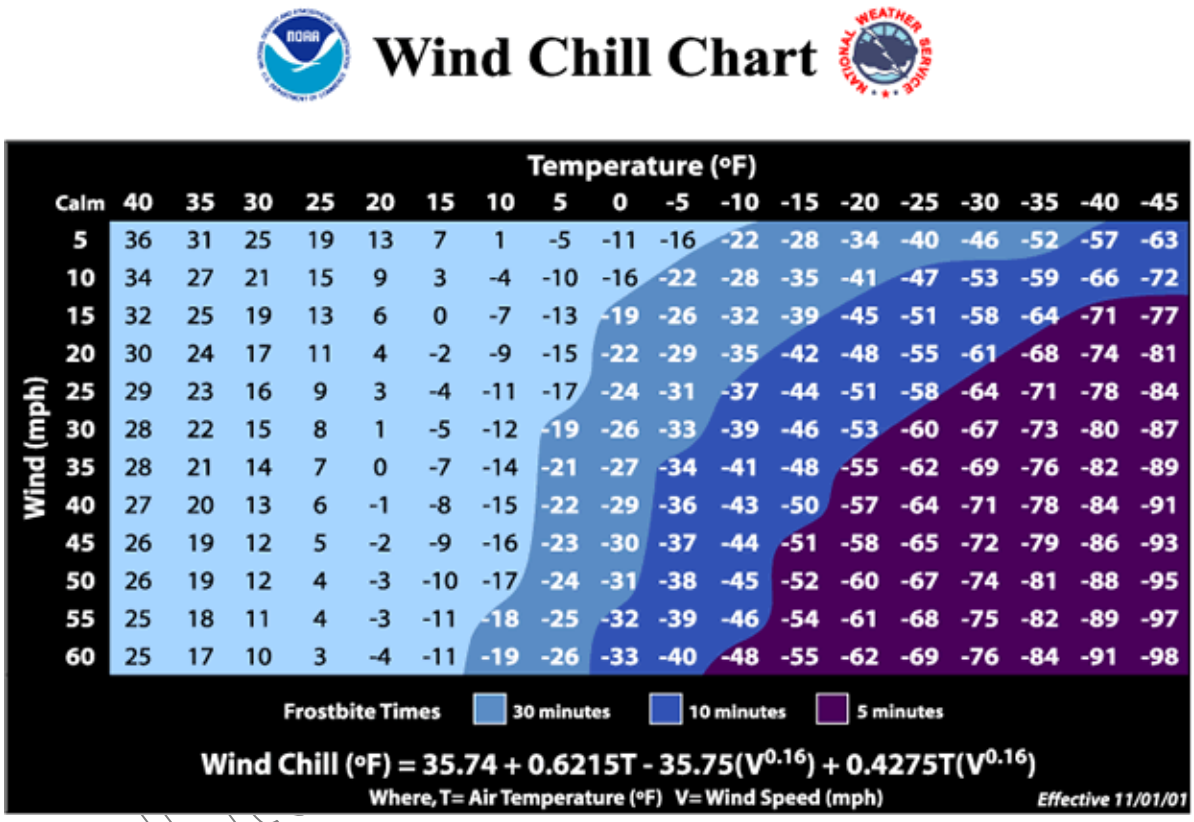
Figure 1 – Wind Chill Chart



Wind Chill Chart

Wind (mph)	Temperature (°F)																	
Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

5.1.3 Moisture

Moisture is also important, as it conducts heat away from the body. It is very important to keep dry in a cold environment. Protective clothing must keep out environmental moisture while preventing the build-up of sweat. Any employee becoming wet in a cold area should be immediately removed to a warm area to prevent hypothermia.

5.2 Personal Equipment

The essence of staying warm in the winter is having the proper clothing layers and knowing how to use them effectively.

5.2.1 Heat Loss

The body basically acts as a furnace, producing heat through chemical reactions and activity. This heat is lost through conduction, convection, evaporation, radiation, and respiration. As physical activity increases so does heat production and conversely as activity decreases so does heat production. The key to keeping warm is to add insulation to the body.

5.2.2 Insulation

The thermal insulation of clothing is proportional to the thickness of the dead air space enclosed. Dead air is defined as any enclosed unit of air that is small enough that natural convection currents would not arise in it. Such currents have been detected in units as small as 2 millimeters in diameter. The dead air next to the skin is heated up by the body and provides a layer of warmth around the body. The clothing is not what is keeping you warm it is the dead air. This is because the denser a material the faster it can transfer heat through conduction, the density of air is obviously minuscule compared to a piece of a fabric.

5.2.3 The Layering Principle

The key to providing this dead air space is through having a number of layers of clothing. Each layer provides a certain amount of additional dead air space. This allows you to add or shed layers to increase or decrease your accumulated dead air space as the temperature changes and/or as your activity level changes. Remember, your body is the heat source, the clothing layers only serve to trap the heat and slow down your heat loss to the cold environment. You need to find the proper heat balance between the number and types of layers and your activity level.

Why not just have lots of layers on and sweat? Heat loss from a wet surface can be up to 25 times greater than a dry surface (due to the higher density of water). If you sweat and get soaked, you will lose heat much more quickly through evaporation of the water. Also you are loosing an incredible amount of water through sweating since the air is so dry. Too much water loss leads to dehydration which significantly increases the risk of hypothermia. So you want to control your layers so as to be warm at the activity level you are in but not sweating profusely.

Thus, working in the cold is a *constant* process of adjusting your layers to keep comfortable. This means having a number of layers you can add or subtract and allowing for versatility within layers. Convection may account for the greatest amount of heat loss under most conditions. In order to properly insulate, you need to have an outer layer that is windproof.

Another convective factor is the “bellows action” of clothing. As you move a bellows action occurs which tends to pump your accumulated warm air out through openings in your clothing and sucks the cooler air in. In some conditions this action can reduce your body’s personal insulation by 50% or more. Thus, it is important that *all* layers have effective methods of being “sealed” (i.e. buttons, zippers etc.) Openings in layers allow you to ventilate, to open the “chimney damper” if you are beginning to overheat, without having to actually remove a layer. So opening and closing zippers on a jacket, or armpit zips will allow you to either ventilate if you are getting too hot or seal up if you are getting chilly, all without having to add or take off a layer. With clothes that are too loose, the bellows action pumps warm air out through the openings. You need to have clothes that fit properly but not tightly. Too tight, and the clothes compress and actually reduce dead air space in layers below as well as restricting body movement.

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5.3 Precautionary Measures

All employees working in low temperatures, especially at or below freezing, are to follow specific precautionary measures to prevent cold stress, which include:

- Take a spare set of clothing with you in case your work clothes are not warm enough or become wet.
- Dress in layers. If you are cold, add a layer. If you begin to sweat, remove a layer. Maintain a clothing level that keeps you warm but dry (not sweating).
- Recognize the environmental and workplace conditions that may be dangerous;
- Learn the signs and symptoms of cold-induced illnesses and injuries and what to do to help workers;
- Avoid exhaustion or fatigue because energy is needed to keep muscles warm;
- When the air temperature is below 41 F, staff should be aware that cold stress is now considered a potential hazard;
- Wearing thermal clothing, including gloves and footwear, beneath chemical resistant clothing where necessary;
- When clothing becomes wet and temperatures are below 36 F, clothing must be replaced immediately;
- Drink warm, palatable drinks to replace liquids. Dehydration is important;
- Never going into the field alone when cold stress could occur;
- Observing fellow employees for signs of cold stress and administering first aid, as necessary;
- Taking periodic breaks to allow recovery from cold stress; and
- Employees working near water in which they may become immersed must wear floatation suits offering thermal protection. Brief emersion in water below 60 or prolonged emersion at even 70 can produce hypothermia.

5.4 First Aid Procedures

During periods in which the temperature falls below freezing, workers should observe each other for signs of hypothermia or frostbite. If exposed skin begins to sting or tingle, rub the exposed area to stimulate circulation. However, if the exposed area is numb, do not rub it. Do not use snow; this will only make the injury more serious. Promptly seek a protected or indoor environment. Warm the affected parts in warm water (104 - 133 °F) or by other suitable means. Workers experiencing signs or symptoms of hypothermia should immediately be taken to a warmer environment. Heating devices should be used to provide relief from cold. Care must be exercised, however, with electrical devices in conductive or moist environments. Combustion devices, such as catalytic heaters, may be used where there is adequate ventilation. They must not be used in tightly closed spaces where accumulation of carbon monoxide can occur.

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5.5 Personal Protective Equipment

Thermal protective clothing is available from various vendors, and selection assistance is available from your location's administrative assistants or LHSC. Those who qualify are offered an Allowance", details can be located on Human Resource Policy 11-6 "Clothing, Prescription Safety Eyeglasses, & Safety Footwear Allowance". This policy is located in the employee handbook. Generally, the following guidelines should be followed:

If there is a need for chemical resistant protective clothing, chemical resistant protective clothing generally does not provide protection against cold stress, and in some instances it can increase susceptibility. For this reason, thermal clothing, gloves, and footwear should be worn beneath chemical resistant personal protective equipment in cold weather. Most extreme weather wear now provides weather temperature ratings on tags or the garment. Observe tags for appropriate temperature protection.

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Table 1 – PPE Clothing Recommendations

Clothing Materials

Some of the different types of materials for winter clothing and insulation are discussed below.

1. Wool - derives its insulating quality from the elastic, three-dimensional wavy crimp in the fiber that traps air between fibers. Depending on the texture and thickness of the fabric, as much as 60-80% of wool cloth can be air. Wool can absorb a fair amount of moisture without imparting a damp feeling because the water "disappears" into the fiber spaces. Even with water in the fabric wool still retains dead air space and will still insulate you. The disadvantage to wool is that it can absorb so much water (maximum absorption can be as much as 1/3 third the garment weight) making wet wool clothing very heavy. Wool releases moisture slowly, with minimum chilling effect. Wool can be woven in very tight weaves that are quite wind resistant. An advantage to wool is that it is relatively inexpensive (if purchased at surplus stores). However, it can be itchy against the skin and some people are allergic to it.

2. Pile or Fleece fabrics - is a synthetic material often made of a plastic (polyester, polyolefin, polypropylene, etc.). This material has a similar insulative capacity as wool. Its advantages are that it holds less water (than wool) and dries more quickly. Pile is manufactured in a variety of different weights (thicknesses) offering different amounts of loft and insulation. This allows for numerous layering possibilities. The disadvantage of pile is that it has very poor wind resistance and hence a wind shell on top is almost always required. Versions of pile are available that have a middle windproof layer.

3. Polypropylene and other Hydrophobic fabrics - polypropylene is a synthetic, plastic fiber which offers dead air space and a fiber which cannot absorb water. The fiber is hydrophobic so it moves the water vapor away from the source (the body). Polypropylene layers are extremely effective worn directly against the skin as a way of keeping the skin from being wet and reducing evaporative heat loss. As the water moves away from the body it will evaporate, but each additional millimeter of distance between your skin and the point of evaporation decreases the amount of body heat lost in the evaporative process. Some fabrics rely on the chemical nature of the fiber to be hydrophobic. Others fabrics use a molecular coating t0 achieve the same end.

4. Polarguard™, Hollofil™, Quallofil™ and others - these are synthetic fibers which are primarily used in heavy outer garments like parkas. The fibers are fairly efficient at providing dead air space (though not nearly as efficient as down). Their advantages are that they do not absorb water and dry fairly quickly. Polarguard™ is made in large sheets. Hollofil™ is a fiber similar to Polarguard but hollow. This increases the dead air space and makes the fiber more thermally efficient. Quallofil™ took Hollofil™ one step further by creating four "holes" running through the fiber.

5. "Superthin" fibers - Primaloft™, Microloft™, Thinsulate™ and others - the principal behind these synthetic fibers is that by making the fiber thinner you can increase the amount of dead air space. For example, take an enclosed space 5 inches wide and place 2 dividers into that space, each 1 inch thick. You have an effective air layer of 3 inches. If you take the same 5 inch space and divide it with 4 dividers, each 1/4 inch thick you now have an effective air layer of 4 inches. You have gained one

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inch. Under laboratory conditions a given thickness of Thinsulate™ is almost twice as warm as the same thickness of down, however, the Thinsulate™ is 40% heavier. Thinsulate™ is made in sheets and therefore tends to be used primarily for outer layers, parkas and pants. New materials such as Primaloft™ and Microloft™ are superthin fibers that are close to the weight of down for an equivalent fiber volume. They are now being used in parkas as an alternative to down. They have similar warmth to weight ratios as down without the worries about getting wet.

6. Down - feathers are a very efficient insulator. They provide excellent dead air space for very little weight. The major problem with down (and it can be a major problem) in the winter is that down absorbs water. Once the feathers get wet they tend to clump, and lose dead air space. Using down items in the winter takes special care to prevent them from getting wet. Some people are allergic to down.

7. Cotton - Note: Cotton is basically useless in winter time. It wicks water, but unlike polypropylene, cotton absorbs this moisture and the water occupies the space previously occupied by dead air. This means a loss in dead air space, high evaporative cooling, and a garment that is almost impossible to dry out.

The Body and Clothing

1. Head - because the head has a very high surface to volume ratio and the head is heavily vascularized, you can lose a great deal of heat (up to 70%) from the head. Therefore, hats are essential in winter camping. The adage - if your toes are cold, put on a hat - is true. A balaclava is particularly effective and versatile. A facemask may be required if there are high wind conditions due to the susceptibility of the face to frostbite.

2. Hands - mittens are warmer that gloves. It is useful to have an inner mitten with an outer shell to give you layering capabilities. However, gloves are always essential as well in winter because of the need for dexterity in various operations.

3. Feet - finding the right footgear depends a great deal on the activity you are involved in as well as temperature and environment. Regular boots are *not* sufficient. They simply do not provide the necessary dead air space. The options for boots include:

> **Insulated Boots** - such as Sorels™ or "Mickey Mouse" boots. These are rubber or leather and rubber boots that use a layer of wool felt to provide dead air space. The Mouse boots can be Army surplus or modern copies (avoid the copies since they are often poorly made). With the true Army boots, the black boots are rated to -20 degrees and the white ones to -40 degrees.
>
> **Socks** - one of the best systems for keeping feet warm is using multiple layers. Start with a hin polypropylene liner sock next to the skin to wick moisture away followed by 1 - 2 pairs of wool or wool/nylon blend socks. Make sure the outer socks are big enough that they can fit comfortably over the inner layers. If they are too tight, they will constrict circulation and increase the chances of frostbite. Keeping your feet dry is essential to keeping your feet warm you may need to change your socks during the day.

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Gaiters - are essential if you are working in the snow. They keep snow from getting into your boots and keep your socks and pants legs free from snow.

4. Outer Layer - it is essential to have an outer layer that is windproof and at least water resistant. In some cases it may be best to have the garment waterproof. It also needs to be able to be ventilated. There is a big trade off between waterproof and ability to ventilate. A completely waterproof item will keep the water that is moving through your other layers trapped, adding to weight and causing some heat loss. However, in wet snow conditions, if the garment is not waterproof it can get wet and freeze. Gore-Tex™ and other similar fabrics provide one solution. These fabrics have a thin polymer coating which has pores that are large enough to allow water vapor to pass through but too small to allow water droplets through. Nothing is perfect, however, and although Gore-Tex ™ does breathe, it doesn't breathe as well as straight cotton/nylon blends. If you opt for a straight wind garment, 65/35 blends of cotton and nylon work well. The other approach is to have a waterproof garment with sufficient ventilation openings to allow water vapor to escape. This provides the ability to work in wet snow without worrying about getting the garment soaked. Part of the basis for making the decision is the area and you are traveling in. If you are in the dry snow of the Rockies you needn't worry so much about waterproof. If you are in the northeastern mountains where freezing rain is a possibility or very wet snow, you need to be prepared to be wet.

5. Zippers - are wonderful accessories for winter clothing. Having underarm zippers on jackets can greatly increase your ability to ventilate. Having side zippers on pants can allow you to ventilate and to add or subtract a layer without taking off your boots.

Apparel	**Recommendation**
Socks	Stretch socks are not advisable, since they restrict circulation. Wool has superior insulating qualities.
Trousers	Wool, thermal, or quilted. Suspenders or coverall-types are recommended, as belts restrict circulation.
Boots	Felt-lined or insulated, rubber bottomed, leather topped.
Shirt	Wool shirt or sweater, over cotton or synthetic wicking material provides best protection.
Headcover	Wool knit hat or hood. Use a liner with hardhats. Use snorkel hoods in extreme environments.
Gloves	Mittens offer better protection, but restrict dexterity. Layers of differing materials may be appropriate for different work. Gortex outer shells are recommended to reduce dampness.
Face mask	In extreme cold, facial protection is important to prevent frostbite. A ski mask or a snorkel hood may be appropriate.
Coat	An anorak, parka, or hooded coat, as appropriate. Down provides good insulation. Synthetics such as thinsulate may be satisfactory. Gortex outer shells are recommended to reduce dampness.
Under garments	In moderate exposures, cotton may be adequate, however polypropylene and other materials, which "wick" moisture away from the skin, may be superior for heavy work.

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APPENDIX A
REFERENCES

- National Weather Services- Office of Climate, Water, and Weather Services
- OSHA Trade News Release, December 2003
- Fundamentals of Industrial Hygiene, National Safety Council, 5th edition

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1000 Site Safety – Construction Sites
- OP1001 Excavation and Trenching
- OP1002 Drilling Safety
- OP1008 Operations Over, Near, or On Water
- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP1014 Hazard Communication
- OP1015 Heat Stress
- OP1020 PPE Use, Purchase and Selection
- OP1022 Health and Safety
- OP1026 Policy on Confined Space Entry

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APPENDIX C
FORMS

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APPENDIX D
GLOSSARY

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OPERATING PROCEDURE: OP1004

OPERATION/CALIBRATION OF PID PHOTOIONIZATION DETECTOR

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP1004

OPERATION/CALIBRATION OF PID PHOTOIONIZATION DETECTOR

1. PURPOSE

This procedure describes the operation and calibration techniques for the Model PI 101 Photoionization Detector, manufactured by HNU Systems, Inc. The instrument will measure organic vapor levels. There are three direct reading ranges: 0-20 ppm, 0-200 ppm and 0-2,000 ppm at a minimum gain (all specifications are benzene referred). The detection limit is 0.1 ppm. The linear range is 0.1-600 ppm. The response time is less than 3 seconds to 90% of full scale. The instrument will have an 11.7 eV UV lamp.

2. EQUIPMENT & SUPPLIES

2.1 Supporting Materials

- HNU PI 101 instrument with 10.2 or 11.7 eV UV lamp
- Span gas cylinders: 100 ppm isobutylene in air
- Calibration "Tee" with rotometer

3. PROCEDURE

3.1 Responsibilities

The Site Technician will be responsible for the calibration, operation and maintenance of the photoionization detector (PID).

The Safety Officer will be responsible for insuring that the work is performed and that the required data is collected.

3.2 Operation

The location and extent of use of the PID will be determined by the Safety Officer.

The following procedures will be performed daily, prior to initiation of air monitoring activities and after an instrument warm-up period. The following are general operating instructions for the instrument; more detailed instructions are provided in the manufacturer's operation manual.

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1. Instrument zero: Turn the function switch to the stand-by position. If the meter does not read zero, rotate the zero potentiometer until a zero reading is obtained. Wait 15-20 seconds to ensure that the reading is stable. If not, readjust andre-check.

2. Calibration: Turn the function switch to the measurement range to be used for sampling. Attach the 8" probe extension to the calibration "Tee", then attach the calibration gas cylinder and rotometer to the remaining connections on the "Tee". Open the cylinder until a slight flow is detected on the rotometer. The HNU unit draws the volume of sample for detection and the excess is indicated on the rotometer. Adjust the span potentiometer so that the instrument reading is the exact value of the calibration gas. Close and remove the span gas. If the instrument span setting is changed, the instrument zero step will be repeated.

3. All calibration checks will be documented in the Site Log Book.

4. Operation: Verify that the function switch is at the measurement range in use during normal sampling. Note the instrument readings during the site visit.

3.3 Repair and Maintenance

If the instrument fails to function as per manufacturer's specifications, it will be replaced with a spare. The defective unit should be sent to the manufacturer for diagnostic treatment and correction.

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APPENDIX A
RELATED HALEY & ALDRICH PROCEDURES

- OP1005 Operation/Calibration of FID Flame Ionization Detector
- OP1006 Operation of Draeger Gas Detector Pump
- OP1007 Field Monitoring for Volatile Organics (breathing space-work zone)
- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans

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APPENDIX B
GLOSSARY

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OPERATING PROCEDURE: OP1006

OPERATION OF DRAEGER GAS DETECTOR PUMP

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OPERATING PROCEDURE: OP1006

OPERATION OF DRAEGER GAS DETECTOR PUMP

1. PURPOSE

This procedure describes the operation techniques for the Model 21131 Draeger Gas Detector Pump. The pump is designed to operate as a grab sampler to gather real time air quality data. The basic unit consists of a bellows type hand pump and compound specific glass detector tubes. The instrument can measure a broad range of organic and inorganic vapors at detection levels ranging as low as 0.01 part per million (ppm). The Draeger pump should be utilized in support of continuous air quality monitoring devices such as the HNU detector or OVA

2. EQUIPMENT & SUPPLIES

2.1 Supporting Materials

- Draeger Bellows Pump
- Compound specific Draeger tubes and pre tube filters as required
- Draeger tube instruction sheets with compound reactivity data

3. PROCEDURE

1. Inspect the bellows pump for cracks or holes in the pump mechanism. Compress the pump 4 to 5 times to void any air from previous sampling events. Compress the pump and place your thumb over the inlet hole while releasing the bellows. Check to see that the bellows remains fully compressed until you release your thumb from the inlet hole. Movement of the bellows towards the pre-compression status is indicative of a leak in the bellows.

2. Read the instruction of the compound specified sampling tubes to determine the compound(s) the tubes were designed to detect, detection range(s) number of pump compressions required, nature of the tube reaction, necessity of a pre-tube filter and compounds which may cause a false positive reaction.

3. Insert the applicable tube into the pump and compress the pump to re-check the integrity of the pump bellows. The pump should remain compressed. Remove the tube from the pump and break the ends of the glass tubes off utilizing eye protection. Re-insert the tube, with pre-filter as required, into the pump noting the flow direction arrow on the tube. The arrow should point toward the pump.

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4. Operate the pump by fully compressing the bellows and allowing full recovery for the number of pump cycles indicated in the compound specific tube instructions.

5. Inspect the tube for the color reaction noted in the tube instruction data. Tubes in which a reaction has taken place should be preserved by capping the tube ends with the supplied rubber end caps and refrigeration. Tubes in which no reaction has taken place can be re-used by capping both ends, storage under refrigeration and subsequent re-use as noted above.

6. Tubes should be stored under refrigeration between sampling events. Spent tubes should be properly disposed of as a site-generated hazardous waste.

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APPENDIX A
RELATED HALEY & ALDRICH PROCEDURES

- OP1004 Operation/Calibration of PID Photoionization Detector
- OP1005 Operation/Calibration of FID Flame Ionization Detector
- OP1006 Operation of Draeger Gas Detector Pump
- OP1007 Field Monitoring for Volatile Organics (breathing space-work zone)
- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans

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APPENDIX B
GLOSSARY

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OPERATING PROCEDURE: OP1008

OPERATIONS OVER, NEAR, OR ON WATER

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OPERATING PROCEDURE: OP1008

OPERATIONS OVER, NEAR, OR ON WATER

1. PURPOSE

To ensure that Haley & Aldrich, Inc. staff members are aware of safe operations when working over, near, or on water bodies that are applicable to worker safety and pollution prevention rules and regulations.

In addition, this procedure provides guidance on methods and techniques for work scope items that are performed over water such as: 1) installation of CTD (conductivity, temperature, depth) pilot test, 2) sediment trap sampling, 3) installation of AquaTornado™, 4) installation of SolarBee™, and 5) installation of cofferdam simulation barrier.

1.1 Background

Haley & Aldrich conducts work activities that require staff members to work on vessels or land-based activities over, near, or on water. Worker safety, equipment approval, and pollution prevention regulations for these operations must conform to a variety of Federal and State regulations depending on the water body, equipment used, and nature of the operation. This Haley & Aldrich procedure has been developed in accordance with certain Occupational Safety and Health Administration (OSHA) and United States Coast Guard (USCG) rules.

Projects involving fieldwork near bodies of water must be evaluated by the Project Manager (PM), Local Health and Safety Coordinator (LHSC), and/or the Corporate Health and Safety Manager (CHSM) for potential hazards to employees.

1.2 Application

This procedure applies to Haley & Aldrich, Inc. (H&A) projects and activities while working over, near or on water. The information and requirements within this procedure apply to navigable and non-navigable waterways. The actual determination of whether or not a given project or activity will fall within the requirement of this procedure will be made by the Project Manager with the Local Health and Safety Coordinator providing assistance. If there is a question about applicability, the Corporate Health and Safety Manager will determine applicability.

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2. EQUIPMENT & SUPPLIES

- Head protection
- Hearing protection
- Eye and face protection
- Chemical Resistant Clothing
- Respiratory protection
- Safety harness, lifelines and lanyards
- USCG approved lifejacket, personal flotation device (PFD) or buoyant work vest
- A 30 – inch diameter ring buoy with 90 feet of line for emergency rescue operations.
- At least one lifesaving skiff or boat immediately available for rescues.
- For activities where personnel must board a vessel, an appropriate ramp, gangway, ladder or Jacobs ladder must be available.
- Appropriate illumination for activities that will occur at night or in reduced visibility. OSHA requires a minimum of five foot-candles measured in the working area.
- A first aid kit shall be available on site or on the vessel.
- No hazardous material in bulk (> 55 U.S. gallons) shall be carried on board a vessel unless the vessel has been inspected and certified for that purpose by the USCG.
- Appropriate fire fighting equipment shall be provided on any vessel. Work areas shall be marked with safety signs as required.
- No plastics or other garbage shall be discharged overboard from any vessel. Any garbage that accumulates shall undergo proper disposal.

Equipment must be kept in good working condition and worn properly at all times.

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3. PROCEDURE

3.1 Project Evaluation

Project Managers are responsible for insuring that his/her projects with activities over, near, or on water meets the minimum requirements discussed in this procedure. It is the responsibility of the PM to enlist the assistance of the LSHC if the contractor providing appropriate field services is not familiar with USCG or OSHA worker safety, equipment requirements, or pollution prevention responsibilities related to water safety.

3.2 General Requirements

Haley & Aldrich projects that require staff members to work near or over bodies of water (over 3 ft. deep) must develop a site-specific health and safety plan (HASP), regardless of the type of work that is being performed. This includes geotechnical and environmental related work activities and, in particular, includes drilling and sampling work from boats, barges, and jack-up rigs. Health and Safety Plan templates can be obtained from the Health and Safety Homepage on the Company Intranet.

When working on a vessel, such as a barge, Haley & Aldrich Staff Members must conduct a visual inspection of the vessel to determine whether the items listed below are present. In the event that an item listed is not present, contact the Project Manager and inform him/her that one is not available on the vessel. Project Managers are expected to communicate OSHA requirements to the responsible party and to ensure that our subcontractors, such as drillers, have a health and safety plan for their staff on the site.

Staff Members shall never work alone when working on a vessel. One or more additional Haley & Aldrich staff member(s) or one or more contractor representative(s) shall be present at all times.

It is the responsibility of the staff members on the site in consultation with the PM to determine whether the water and weather conditions are safe for work activities. Consideration shall be made based on water velocity, water temperature, degree of recreational and commercial use, adverse weather (wind, heavy rain, fog, snow, etc.), and unknown structures and hazards below the water.

Vessels shall have the appropriate navigational equipment, emergency lights, and running lights.

3.3 Reporting of an Oil or Chemical Spill

In the event of an oil or chemical spill into U.S. waters, the entity that owns or operates the vessel shall make a report immediately to the National Response Center (1-800-424-8802). The Incident Report Number shall be entered in the daily field log to forestall any subsequent questions about a failure to notify.

In the event of a spill, immediate steps shall be taken to stop the source of the discharge and to clean up and mitigate environmental damages. Major spills are not in the scope of H&A work activities. Staff members must have advanced training and certification to respond to spills on the water.

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The PM shall be notified of spill or release incidents. In the event of any significant pollution incident, the PM shall notify the, LHSC, CHSM, and the Operational Leader from their business unit.

3.4 Uninspected Vessel Operations

If an uninspected vessel is used, the PM shall ensure that the vessel is suitable for its intended service prior to commencing field activities. The vessel shall be examined and made structurally sound by the contractor before commencing any work. If there are any questions regarding the vessels condition, a marine surveyor should be used identify deficiencies. In the event a H&A staff member believes that the vessel is unsafe for use, he/she shall contact the PM immediately to discuss the situation and their concerns.

3.5 Inspected Vessel Operations

In a large number of cases, the type of work H&A performs will not require the use of an inspected vessel. If an inspected vessel is used for the field activities, the contractor providing the vessel shall be responsible for ensuring that the vessel has and maintains the appropriate vessel inspection certification. The contractor shall ensure that personnel operating the vessel have the appropriate licenses and certificates. The contractor shall provide the PM with an appropriate Oil Spill Prevention Certificate of Financial Responsibility prior to the commencement of field activities.

3.6 Field Procedures

The following field procedures will be performed over water following the requirements listed in Section 3.2 General Requirements. For purposes of this operating procedure, the steps listed below for the installation of CTD array, sediment trap, and SolarBee™ assume that H&A staff are aboard a vessel.

3.6.1 Installation of CTD (Conductivity, Temperature, Depth) Array

Deployment of the CTD array will be conducted by two staff from the project pontoon boat.

1. Measure the depth of the pond at the RM2 location and collect parameters at 50 cm intervals using the multi-parameter probe.

2. Program the CTD probes – Solinst Model 3001 LTC Levelogger Junior F30/M10 or equivalent with project information and set to record conductivity, temperature and depth data at 10 minute intervals.

3. Attach an anchor to the main CTD array line to the appropriate depth.

4. Attach the main line to a surface marker buoy, with enough slack on the line to prevent the buoy from completely “drowning”, but not as much to have the line free floating (as our existing mooring are constructed).

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3.6.2 Installation of Sediment Trap

Deployment of the sediment trap(s) will be conducted by two staff from the project pontoon boat.

1. Measure the depth of the pond at desired location.
2. Lower concrete anchoring weight to bottom of pond and attach submerged buoy.
3. Attach surface marker buoy to submerged buoy.
4. Attach the sediment trap to the main line between the submerged buoy and surface buoy.
5. Pull the trap line out of the water to retrieve the sediment trap.

3.6.3 Installation of AquaTornado™

Deployment of the sediment trap(s) will be conducted by two staff from the project pontoon boat.

1. At desired location, lower concrete anchoring weight to bottom of pond.
2. Attach AquaTornado™ main line attached to anchoring weight.
3. Release AquaTornado™ to the water surface.

3.6.4 Installation of SolarBee™

The SolarBee™ will be installed by a subcontractor according to manufacturer installation guidelines. See Appendix E for SolarBee™ guidelines.

3.6.5 Installation of Cofferdam Simulation Barrier

The Cofferdam Simulation Barrier (Turbidity Barrier)will be installed by a subcontractor according to manufacturer installation guidelines. See Appendix E for Cofferdam Simulation Barrier (Turbidity Barrier) guidelines.

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APPENDIX A
REFERENCES

- Occupational Health and Safety Regulations (OSHA) and United States Coast Guard (USCG) 29 CFR 1926 Subpart C, General Safety and Health Provisions; 29 CFR 1926 Subpart E, Personal Protective Equipment; 29 CFR 1926.106, Working Over or Near Water; 33 CFR Part 151, Vessels Carrying Oil, Noxious Liquid Substances, Garbage, Municipal or Commercial Waste, and Ballast Water; 46 CFR Parts 25 and 26, Uninspected Vessels

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP2000 Monitoring Field Explorations

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APPENDIX C
FORMS

None required

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APPENDIX D
GLOSSARY

- **Inspected Vessels.** The US Coast Guard determines whether a vessel operating in the U.S. must be inspected by an evaluation of its intended service, the vessels length and the intended area of operation (ocean; lakes, bays or sounds; rivers, etc.). If the contractor providing the vessel is unsure of the inspection status, the owner/operator of the vessel shall refer to 46 Code of Federal Regulations Table 24.05-1(a). Questions should be directed to the local USCG Marine Safety Office.

- **Barge.** Any water transportable vessel not equipped with means of self-propulsion.

- **Uninspected Vessels.** All vessels indicated in Column 6 of 46 CFR Table 24.05-1(a).

- **Garbage Discharge -** 33 CFR 151.67 prohibits the discharge of plastic or garbage mixed with plastic into the sea or the navigable waters of the United States. "Plastic" and "garbage" are defined in 33 CFR 151.05.

- **National Response Center -** The U.S. National Response System is the federal government's mechanism for emergency response to discharges of oil and releases of chemicals. The National Response Center is the communications hub of the National Response System. Its 24-hour phone number is (1-800-424-8802)

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APPENDIX E
MANUFACTURER INSTALLATION PROCEDURES

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Main Office and Service Center
SolarBee Division of Pump Systems, Inc.
530 25th Ave E, PO Box 1930, Dickinson, ND 58602
(866) 437-8076 (701) 225-4495 Fax (701) 225-0002

INSTALLATION PROCEDURE

1. PRIOR TO ARRIVAL:

A.) Confirm Install date set by Home Office and Client
B.) Contact Client 1 day prior to arrival
  a.) Set up a meet location and time
  b.) Obtain driving directions to site

2. AT ARRIVAL:

A.) Conduct visual inspection of site
  a.) Locate an assembly site
  b.) Locate a launch site
B.) Determine preliminary location of SolarBee(s)
  a.) Ascertain inflow and outflow locations
  b.) Discuss SolarBee(SB) location with operator. Consider:
    * Primary objectives of this application
    * Short circuiting
    * Pond, lake or tank operating depth
    * Obstructions such as aerators, lines, baffles, etc.

3. SB ASSEMBLY:

A.) Unload machine and parts at assembly site
  a.) Organize hardware needed
  b.) Organize tools to be used
B.) Assemble SB
  a.) Check fluid intake connections
  b.) Check impeller clearance
  c.) Insert fuse and check operation of drive assembly
  d.) Attach chain(s) for anchoring
  e.) Lock down float arms
C.) Conduct SB orientation and safety procedures
  a.) All parts and their function
  b.) Machine operation and maintenance
  c.) Review applicable safety procedures for SB application
    * Working on water
    * Working in boat
    * Working over water
    * Confined space entry
    * Fall protection
  d.) Issue SB Manual to operator
  e.) Leave extra brushes and brush caps for machines with gearmotors
  f.) Fill out installation information sheet

4. INSTALL SB:

A.) Move assembled SB machine to launch site
  a.) Use gin pole apparatus if necessary
B.) Unload boat and launch in pond
  a.) Check fuel, throttle and steering operation
  b.) PFD's- MUST BE WORN AT ALL TIMES WHILE IN BOAT
  c.) BOAT CAN ONLY BE OPERATED BY A 2-MAN CREW
C.) Load anchors in boat *(If Shore Power Kit iused, install SS mooring cqble in pond)
D.) Tow SB machine to predetermined location in pond or lake
  a.) Attach anchor chain to anchors, drop anchors
  b.) Release float arms

5. TESTING AND FINAL ADJUSTMENT:

A.) Test pond
  a.) Test sludge or bottom sediment levels using the peristaltic pump. Determine:
    * Sludge and slurry or bottom sediment levels
    * Total pond depth
  b.) Test pond using YSI submersible sonde. Determine:
    * Temperature, conductivity, dissolved oxygen and pH at one (1) foot intervals from water surface to top of slurry or sediment or total depth
B.) Final adjustments at SB machine
  a.) Set fluid intake depth according to (1) pond or lake depth or (2) sludge or bottom sediment test results
  b.) Set distribution dish depth

6. CLEAN-UP AND RELOAD:

A.) Reload
  a.) Reload boat, any and all spare parts
  b.) Reload all tools and hardware
B.) Clean-up
  a.) Police entire area for tools, parts, or garbage

7. REPORT:

A.) Report on install completion to sales personel involved

TURBIDITY BARRIER OPERATIONS MANUAL

THE MANUFACTURER OF THE TURBIDITY BARRIERS OFFERS THIS MANUAL AS GENERAL OPERATIONAL GUIDELINES ONLY. ANY INSTALLATION OF CONTAINMENT PRODUCTS SHOULD BE IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS.

DEPLOYMENT:

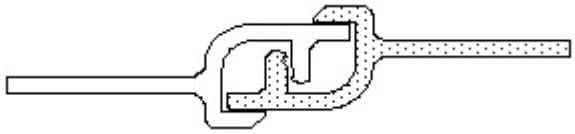
TURBIDITY BARRIERS can be deployed from either land or from a work boat. When considering the placement of any boom, allow for enough distance between the boom and the operating equipment to avoid damage to the barrier.

STEP 1:

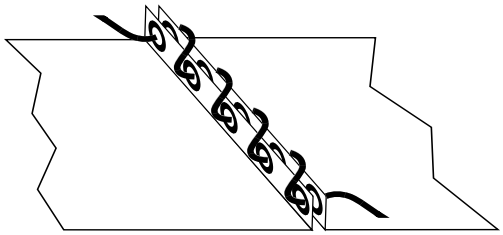
Each barrier is shipped with the skirt section furled and tied to the floatation section. These packaging ties should be left in place to protect the barrier and make maneuvering of the barriers easier in the water. Remove the first couple of packaging ties from the end of the barrier to expose the end connectors. A second boom end is now brought over to meet the first with the top and bottom aligned.

STEP 2:

If the boom is equipped with aluminum slide connectors, slide one connector into the other and secure with the toggle pin provided.



Aluminum Universal Connection



Lacing with continuous line

For all other end types, simply tie the two sections together between the mating grommet holes with short lengths of sturdy line (5/16" or better), a single continuous length (See Figure) or heavy duty cable ties (100 + lb break strength). At the bottom of the boom be sure to connect the shackles provided together to make sure the ballast/load line is continuous.

Re-furl the skirt section to the float, using the packaging ties or light line.

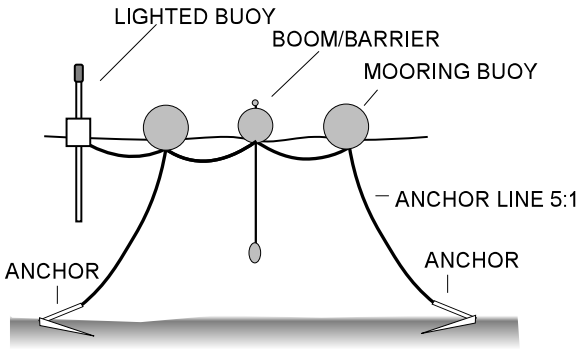
STEP 3:

The boom can now be dropped into the water, leaving the last boom section on the shore or deploying vessel. The next boom section is attached as in STEPS 1 and 2. Continue to pay-out the barriers until all of the end connections are made up.

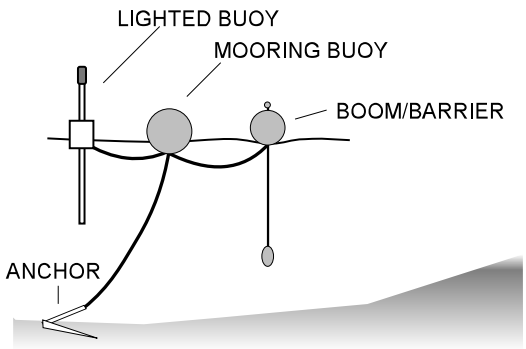
STEP 4:

The boom may require anchor systems to maintain it's position in a desired area. In applications where anchor systems are used it is vital that the anchor line be attached to a buoy, and a tether line attached from the buoy to the boom. This will prevent the anchor from pulling the boom under the water during tidal or adverse conditions. (See anchoring diagram below)

TIDAL ANCHORING



NEAR SHORE ANCHORING



STEP 5:

Once all of the sections are joined the boom can be maneuvered into position in the water. When deploying the barriers in a current situation, it is best to begin the deployment from the upstream side, allowing the current to carry the barriers downstream. The boom should be anchored as necessary to achieve the desired configuration. Shore ends can be tied off to any suitable dead man on shore including; steel posts, concrete block, sheet pile or sturdy trees.

The packaging ties can now be removed and the skirt allowed to drop. (The ties can be removed prior to this step if there is no danger of damaging the boom on objects under water during maneuvering.)

For barriers supplied with optional skirt reefing lines;
Pull the draw cord up vertically from the top of the floatation using the hand hold loop. Tie off the draw cord against the washer and grommet at the desired elevation. Generally the barrier's ballast chain should be one to two feet off of the bottom at high water, when permitted, to prevent scour and entrenchment of the ballast in the mud line.

RETRIEVAL of the boom is a simple matter of reversing the steps for deployment. When supplied with skirt reefing lines, draw the reefing line up as far as possible before moving the barriers. It is recommended that the skirt be re-tied to the floatation element and that the barrier folded accordion style to ease handling and re-use.

Turbidity barriers should be stored out of direct sunlight, indoors or under cover to prevent UV degradation.

OPERATING PROCEDURE: OP1010

HEALTH AND SAFETY PLANS

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OPERATING PROCEDURE: OP1010

HEALTH AND SAFETY PLANS

1. PURPOSE

To ensure that site-specific health and safety plans (HASP) are developed and implemented for:

- all projects for which HASPs are required by state and federal law; and
- all other projects involving activities which pose the reasonable possibility of exposure to health hazards and/or physical hazards.

1.1 Background

The Occupational Safety and Health Administration standard, "Hazardous Waste Operations and Emergency Response" (29 CFR 1910.120) requires that a site-specific HASP be written for the following operations:

- cleanup operations and initial investigations required by a governmental body (whether Federal, state, local or other) involving hazardous substances that are conducted at uncontrolled hazardous waste sites;
- corrective actions involving cleanup operations at sites covered by the Resource Conservation and Recovery Act; and
- voluntary cleanup operations at sites recognized by Federal, state, local or other governmental bodies as uncontrolled hazardous waste sites.

The nature of Haley & Aldrich's business is such that some field operations and activities, outside of those specified above, may also expose employees to a variety of chemical and/or physical hazards. No single set of rules or protective measures is appropriate for each field operation. Thus, geotechnical and construction projects are subject to the development of HASPs.

Therefore, all projects involving field work must be evaluated by the Project Manager, Local Health and Safety Coordinator, and/or the Corporate Health and Safety Manager for potential hazards to employees. When it is determined that the project activities may result in employee exposure, a site-specific HASP will be required.

1.2 Application

This policy applies to all Haley & Aldrich, Inc. (H&A) and Haley & Aldrich Design and Construction (HADC) projects and activities. The actual determination of whether or not a given project or activity will

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pose the reasonable possibility of exposure to health hazards and/or physical hazards, and therefore, whether or not a HASP will be required, will be made by both the LSHC and PM at the time of project evaluation. Sections 5.2 and 5.3 of this OP list activities for which HASPs are likely to be required.

2. PROCEDURE

2.1 Project Evaluation

Each project manager is responsible to ensure that each of their projects meeting the criteria described in Section 5.2 and 5.3 is evaluated to determine whether or not a HASP will be required for the project. It is the responsibility of the PM to enlist the assistance of the LSHC if the need for a HASP is not immediately clear.

- To assist the PM and the LSHC in performing the project evaluation, a Project Evaluation Checklist is provided in Attachment A.

Another purpose of the review/checklist is to identify those projects whose activities appear to meet the criteria in Sections 5.2 and 5.3 below but which have not yet been evaluated by a representative of the H&S group.

Once the checklist has been completed, it must be signed by the PM and placed in the project file.

2.2 Activities for Which HASPs Are Required

All operations and activities specified below must have a written site-specific HASP prepared prior to the start of field operations if it is related to hazardous waste operations:

- Cleanup operations and initial investigations involving hazardous substances that are required by a governmental authority, whether Federal, state, local, or other, at uncontrolled hazardous waste sites
- Corrective actions involving cleanup operations at sites covered by RCRA
- Voluntary clean-up operations at sites recognized by Federal, state, local, or other governmental bodies as uncontrolled hazardous waste sites
- All other Haley & Aldrich "hazardous waste" related field operations including investigative and remedial activities as defined by OSHA
- Subsurface sampling operations such as drilling, test pitting related to Hazwoper
- Any project that requires the use of an air purifying respirator
- Operations involving confined space entry
- Underground storage tank removals

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- Operations involving buried drums, drum sampling, or drum handling of hazardous chemicals
- Operations involving potential exposure to ionizing radiation
- Operations involving potential exposure to highly toxic substances
- Surface water sampling operations including lagoon sampling and working on barges
- Operations involving working near or over water greater than 3' deep
- Any project in which one must enter an excavation or trench greater than 5' in depth and/or a known hazard (atmospheric, standing water, engulfment, etc.) may be present in the excavation/trench including Construction Monitoring projects that are on Hazwoper sites

2.3 Activities For Which HASPs May Be Required

Other operations that will generally require HASPs, depending upon the degree of hazard involved, include the following activities:

- Groundwater monitoring
- Bulk sampling of potentially hazardous materials (lead, asbestos)
- Process/waste stream sampling at industrial facilities
- Plant decommissioning activities
- Construction, operations, and maintenance of remediation systems
- Air monitoring activities, including stack sampling and fugitive emissions monitoring

2.4 Site Walk-through

When preparing to do an initial job walk-through at a site that has (or may have) chemical contamination, it is usually not necessary to prepare a HASP for the job walk-through activity. However, if the site has surface contamination or other hazards that may pose risks to the individual performing the site walk-through, then evaluation and planning must take place (and be documented) prior to site entry so that steps to avoid hazards will be taken and that the proper PPE will be worn by the H&A employee(s).

2.5 Cost

Cost of developing a project HASP should be a consideration during the proposal development stage. Since the cost of the HASP will be charged to the project, the Project Manager must initiate the project evaluation process at the time of proposal preparation so that these costs can be added to the project budget. Larger projects may require an entire day to develop and this development time must be charged to the project.

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2.6 Preparation

Unless otherwise arranged, all HASPs will be written by PMs and reviewed by the LHSC.

Prior to initiating a new HASP, the PM should consider whether a HASP has already been developed for a current phase of the project. H&A's HASPs are modular in nature and can often be modified from a plan prepared for previous project work at the same location. (This may only applicable if new tasks are being added and all other conditions are the same.)

If a HASP will be required, the PM is responsible for ensuring the HASP is completed and implemented. The PM may personally develop the HASP or defer the responsibility to another person on the project team who is knowledgeable of the project. In some instances, the CHSM should be consulted when complex and hazardous work activities and conditions are anticipated.

An example short form template is posted on the Health and Safety Home Page (H&A Intranet) and can be saved as a MicroSoft ®Word document. The template is designed to be expandable to meet individual project needs. A "user's guide" for the HASP is also available in the same section on the Intranet.

2.7 Format and Content

To maintain consistency throughout the company, a standardized format will be utilized for all HASPs. The amount of detail provided in each HASP will vary with complexity of the project, degree of hazard involved, etc. As a minimum, each HASP must address the following topics, where appropriate:

H&A HASP Section	Content
1.0	**Project Information**
	Organization and Responsibilities
	Training, Initial and Site Specific
2.0	**Site Description**
	Site Description
	Site Background
3.0	**Project Task Breakdown**
	Scope of Work
4.0	**Hazard Assessment**
	Potential Hazards and Hazard Assessment for Each Task & Operation
5.0	**Protective Measures**
	Respiratory Protection
	Personnel Protective Clothing and Equipment for Each Task
	Action Levels for Upgrades/Downgrades of PPE
	Site Control and Decontamination
6.0	**Monitoring Plan**
	Ambient Air Monitoring and Personal Monitoring
	Noise, Heat/Cold, Radiological, etc. Stress Monitoring
7.0	**Decontamination**

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Personnel Hygiene and Decontamination Facilities & Procedures
Special Protective Measures

8.0 Contingency

Site Specific Medical Surveillance Parameters
Emergency Response Plan and Contingency Procedures
Emergency References
Hospital Location Map
On-site First Aid and Emergency Equipment
Accident Reporting, Investigation, and Recordkeeping

All elements of the HASP must conform to Haley & Aldrich policies and procedures.

2.8 Approvals

In all cases, the HASP must be approved and signed by the LHSC and the PM before it is implemented in the field. Complicated and higher risk projects will require CHSM review and approval prior to use and distribution. A copy of each completed HASP must be maintained on file by the PM. A common electronic file on the local office network will be set up for retention of all final HASPs.

2.9 Issuance and Acceptance

Upon completion and approval of the HASP, the PM must provide a copy of the HASP to all H&A personnel who will be performing activities covered by the HASP. All such personnel, , are required to read the HASP and sign on the "Pre-work and Health and Safety Briefing" page. Copies of all HASP "Signoff" sheets must be maintained in the project file by the PM.

2.10 Modifications

Once field operations begin, it may be necessary to alter HASP content, should it be determined that the hazards have changed, or that personal protective equipment, protective procedures, or emergency information, may not be adequate. In addition, when the scope of work or tasks have been changed, the HASP must be modified to address the health and safety requirements for those new tasks. Should this occur, all proposed modifications to the HASP shall be reviewed and approved by the PM before such changes are implemented. The re-issued HASP will incorporate any changes.

An addendum page may be added to the HASP rather than make changes to the original HASP text. The addendum must be attached to the HASP and must be included with the HASP copies used at the field jobsite.

2.11 Implementation

The responsibility for implementing the requirements of the HASP rests with the Project Manager. The PM must ensure that all personnel who cannot or will not comply with the requirements of the HASP are excluded from activities covered by the HASP. In addition to the HASP requirement determination, the PM, along with assistance from the LHSC, will make other health and safety determinations at the time of initial project

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evaluation. These will include, but not be limited to, the need for on-site health and safety audits during the project, personal air monitoring, and the need for full- or part-time on-site health and safety personnel during the field operations.

2.12 HASP requirements for Subcontractors

Subcontractors and Contractors do not sign H&A's HASP. Health and Safety Plans for our direct subcontractors is a very important issue, especially since OSHA can cite both the subcontractor and the prime contractor at a worksite for an OSHA violation. Under the "multi-employer worksite doctrine", any of three employers can be liable for an OSHA citation:

- the controlling employer,
- the employer who creates the hazard, and
- the employer whose employees are exposed to the hazard.

H&A policy regarding HASPs for subcontractors is outlined in Section 3.04 of Level I H&S Manual. It states that "subcontractors supporting remedial investigations will be expected to submit an appropriate HASP to the PM for review before being permitted to conduct work onsite". H&A does not approve these plans but merely acknowledges that to the best of our knowledge it contains the expected contents for the operations the subcontractor will perform. There should be no exceptions to this requirement whenever a HASP is required under the OSHA standard (1910.120) by the nature of the worksite hazards and activities. We shall not hand our HASP to a subcontractor and allow them to sign our HASP in an understanding that we will "oversee" the safety of their employees.

Each subcontractor that Haley & Aldrich hires must be responsible for their own safety program, site-specific planning, and compliance with all applicable regulations. It's Haley & Aldrich's responsibility to hire only competent and qualified subcontractors and make sure they are fully prepared to do the work we ask of them and are fully compliant while they are on-site.

Project Managers should provide subcontractors with sufficient information prior to the start of work so they can formulate their own plans. Project Managers should review the subcontractor's plan before the start of work to make sure it's acceptable.

2.13 Responsibilities

2.13.1 Staff Members

- Will read, understand, and abide by the requirements of the HASP
- Will sign the "Pre-work Health and Safety Briefing" before the commencement of any work related to the HASP.

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2.13.2 Project Managers

- Will implement the project evaluation process for all projects described in sections 5.2 and 5.3 in this OP by contacting a representative of the H&S department at the time of project proposal;
- Will read and approve the HASP prior to distribution;
- Will distribute a copy of the HASP to the field contact
- Will ensure that all employees working in the field at site that requires a HASP sign the "Pre-work Health and Safety Briefing" before the commencement of any work related to the HASP;
- Will maintain a file of all HASPs developed for their projects;
- Will ensure the implementation of the requirements of the HASP.

2.13.3 Local Health and Safety Coordinator

- Will assist in the project evaluation process to determine the need for a HASP;
- Will provide technical support to PMs in determination of HASP development;
- Will typically work as the Location H&S Liaison and with the CHSM for HASP support

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APPENDIX A
REFERENCES

- The Occupational Safety and Health Administration standard, "Hazardous Waste Operations and Emergency Response" (29 CFR 1910.120)

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1009 Medical Surveillance Program
- OP1013 Radiation Safety Program
- OP1014 Hazard Communication

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APPENDIX C
FORMS

- See the Health and Safety Home Page (H&A Intranet) for a copy of the HASP.

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APPENDIX D
GLOSSARY

- **Health and Safety Plan (HASP)** - A document written for a particular site or operation which is designed to provide employee protection by describing the nature of the anticipated hazards, the potential effects of exposure to these hazards, the protective measures and equipment to be utilized to minimize exposure, and the appropriate actions to be taken in the event of an emergency.

- **Cleanup Operation** - An activity in which hazardous substances are handled, removed, contained, incinerated, neutralized, stabilized, cleaned-up, or in any other manner processed or handled with the goal of making the site safer for people or the environment

- **Uncontrolled Hazardous Waste Site -** An area in which an accumulation of hazardous waste creates a threat to the health and safety of individuals, or the environment, or both

- **Hazardous Waste -** A waste or combination of wastes as defined in 40 CFR 261.3 or 49 CFR 171.8

- **Hazardous Substance -** Any hazardous waste or any substance listed under section 101(14) of CERCLA, any biological or disease causing agent listed under 101(33) of CERCLA, or any substance listed by the DOT as a hazardous material under 49 CFR 172.101

- **Highly Toxic Substance -** Any substance which has a listed oral (rat) LD_{50} of 50 mg/kg or less; which is listed as a Confirmed Human Carcinogen (i.e., designation A1) by the American Conference of Governmental Industrial Hygienists (ACGIH); or which has an ACGIH Threshold Limit Value, Time-Weighted Average (TLV-TWA) of 1 ppm or less.

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OPERATING PROCEDURE: OP1014

HAZARD COMMUNICATION

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
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OPERATING PROCEDURE: OP1014

HAZARD COMMUNICATION

1. PURPOSE

The purpose of the Haley & Aldrich "Hazard Communication Program" is to be an effective tool in creating and maintaining a safe working environment where chemical hazards are involved. Through the training required by this program, Haley & Aldrich staff members are informed, not only of the hazardous properties of these substances, but also of safe work practices and protective measures that will minimize their exposure to those hazards.

This program also defines the responsibilities of both Haley & Aldrich management and staff members in jointly implementing its provisions so that the end result is a safe working environment for all company personnel.

1.1 Discussion

The OSHA Hazard Communication Standard requires every employer to provide information to their staff members about the hazardous substances to which they may be exposed, by means of a hazard communication program, labels and other forms of warning, material safety data sheets, and information and training. Haley & Aldrich routinely use chemicals either in the office, field, or our labratories that require we comply with this standard.

This "Hazard Communication Program" establishes the policies and procedures necessary to adequately and appropriately inform Haley & Aldrich staff members, contractors, and vendors of the potentially hazardous substances to which they may be exposed during the course of their work activities.

The hazard communication standard is also frequently called the "worker right-to-know" regulation.

1.2 Application

This program applies to any hazardous substance that is known to be present in the workplace in such a manner that staff members may be exposed (via any route of exposure) during normal conditions of use or in a reasonably foreseeable emergency resulting from workplace operations. Such hazardous substances are generally chemicals that may create a health or safety risk when an staff member is exposed.

Specific hazardous substances included in this program and used by Haley & Aldrich staff members are listed in Attachment A, "Hazardous Chemical Inventory List." This program does not apply to: 1) hazardous wastes, 2) wood or wood products, 3) articles that may have hazardous substances as part of their make-up, but would not present risks of exposure during normal use, or 4) consumer products that are packaged for

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distribution to, and use by, the general public, provided that staff member exposure to the product is not significantly greater than the consumer exposure during the principal consumer use of the product. Due to the nature of our work, contaminants that are identified in our environmental work is not covered under the scope of this OP.

This program also does not apply to any food, drug, tobacco product, or cosmetic item brought into the workplace by a Haley & Aldrich staff member, contractors, and vendors.

Haley & Aldrich facilities with environmental laboratories are required to have a Chemical Hygeine Plan. These documents are not intended to be duplications of one another. Elements of each document can be used to satisfy the regulatory requirements for OSHA.

2. EQUIPMENT & SUPPLIES

- Material Safety Data Sheets
- Labels

3. PROCEDURE

3.1 Hazard Determination

Haley & Aldrich does not manufacture or import hazardous substances for subsequent sale or distribution. Haley & Aldrich relies on the evaluations performed by the manufacturers of the hazardous substances it purchases to determine whether those substances or products are hazardous as defined by the OSHA standard.

Appropriate hazard warnings are communicated to staff members during training sessions and included in the company's labeling procedures.

3.2 Inventory of Hazardous Substances

A Chemical Inventory containing the names of hazardous substances (and products which contain hazardous substances) which are present at each H & A location, or are used by Haley & Aldrich staff members in the course of their work, has been prepared and is included in Attachment A to this program. The inventory is also available in the front of each locations MSDS manual. The materials are listed alphabetically.

The inventory is reviewed and updated semi-annually and maintained as part of the written hazard communication program. Managers are responsible for compiling information on the hazardous substances maintained in their operating area(s) and forwarding that information to the LHSC on a routine basis. These MSDSs will be used to develop the locations master copy of MSDSs.

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3.3 Non-routine Tasks

Occasionally, Haley & Aldrich staff members are required to perform tasks that are outside the scope of their normal operations. If that task involves the use of a hazardous substance with which the staff member is not familiar, or if the use of the substance is significantly different from that experienced in the past by the staff member, a brief training session will be conducted, before the work task begins, to inform the staff member of the new hazards posed by the substance. It will be the discretion of the manager to determine whether a formal training session is needed. If this is the practice, staff members will be required to read the MSDS at a minimum. The manager documents the training session with the staff member(s) by indicating the staff member's name, the date, and a brief description of the information covered. This documentation is then placed in the staff member's health and safety training file, which is maintained by the LHSC.

3.4 Labels and other Forms of Warning

3.4.1 Purchased Products

The hazard communication standard requires manufacturers, importers and distributors to label, tag, or mark each container of a hazardous substance that leaves their workplace with the following information:

- Identity of the hazardous substance(s),
- Appropriate hazard warnings, and
- Name and address of the manufacturer, importer, or other responsible party.

Containers received at Haley & Aldrich facilities or purchased in the field by Haley & Aldrich staff members should be checked upon receipt to ensure that each container is labeled with this information. If any container is not labeled, it should be rejected for use by Haley & Aldrich staff members until a MSDS is present. The manufacturer or distributor of the substance is then contacted promptly and the shipment returned to its origin or secured and not used until a MSDS is present.

Haley & Aldrich staff members or its subcontractors shall not deface or in any way obscure the information contained on these container labels. If a label becomes soiled, weathered, or worn such that it is no longer readable, a manager should be contacted so that the container may be appropriately re-labeled with the required information.

3.4.2 Secondary Containers

When hazardous substances are transferred from their original container into secondary containers (such as safety cans, one-gallon jugs, or hand-held squeeze bottles), the secondary container is labeled with the same information that appears on the label on the original container, except for the manufacturer's name and address. Thus, every container of a hazardous substance in the workplace must at least: 1) identify the name of the hazardous substance(s) contained inside, and 2) provide an appropriate hazard warning for the user.

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3.4.3 Stationary Containers

Though Haley & Aldrich does not have stationary containers such as tanks and other vessels that contain hazardous substances, they must be labeled, marked or tagged with the same information that is required on portable containers. However, Haley & Aldrich has the option to use signs, placards, operating procedures, or other such written materials in lieu of affixing labels to stationary process containers, as long as the alternative method identifies the containers to which it is applicable and conveys the information required to be on a label to all affected staff members.

3.5 Material Safety Data Sheets

3.5.1 Acquiring and Compiling MSDSs/ Chemical Approval

Chemical manufacturers of hazardous substances are required to develop a MSDS for each hazardous substance they produce. They must then provide a MSDS with each initial shipment of a hazardous substance to purchasers.

Haley & Aldrich does not allow a "new" known or suspect hazardous substance to be purchased until it has received the review and approval of Management. Any chemical that is purchased for use must be reviewed by the manager and given clearance for entry into the facility or into the field. The manager must read the MSDS prior to the use of the chemical. If chemical hazards are associated with the chemical, the Managers must be informed of the potential hazard. Contractors that bring chemicals in must also get approval from their H&A company representative. If further review of the material is required, the LHSC will forward the MSDS and relevant information to the CHSM for a final determination. Thus, the particular manager requesting the material is required to work together with the LHSC and CHSM to obtain the necessary MSDS for approval prior to purchase.

If shipment of a hazardous substance arrives at Haley & Aldrich without a MSDS and one is not already on file, the Haley & Aldrich Manager, within 7 days of noting the missing information, sends a written inquiry to the manufacturer or distributor to request the information. An example MSDS request letter is shown in Attachment B.

The use of the Internet and specific websites is another option to procure a MSDS. A website that is free and useful is located on the Haley & Aldrich Intranet Site on the Health and Safetyy Homepage under Links. This may expedite the process and eliminate letters and excessive phone calls.

All new MSDSs received, must be immediately forwarded to the LHSC.

3.5.2 Maintenance of MSDSs and Availability to Staff members

Haley & Aldrich will maintain a master compilation of MSDSs for all hazardous substances present on site, in the office, or laboratories. This compilation contains the most current available version of the MSDS for each substance indicated on the locations master list of hazardous substances. The MSDSs are arranged alphabetically, by material name, in the same manner as the substances are listed on the locations master list of hazardous substances.

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MSDSs will be maintained in a manual that is available to all H&A staff members at all times and our subcontractors upon request. Electronic copies of MSDSs are not an acceptable format for the primary retention of MSDSs. Hard copies must be maintained.

3.6 Information and Training Program

Haley & Aldrich Staff Managers are responsible that hazard communication training is provided to their new staff members and that continuing training, as may be required for new substances and hazards, is provided to existing staff members. Haley & Aldrich provides staff members access to information on any hazardous chemicals in their individual work area(s). Staff members are informed of job activities which may involve contact with, or use of, hazardous substances. LHSCs will assist managers to ensure training is completed.

Training provided to Haley & Aldrich staff members includes instruction on the following topics:

- The presence and accessibility of the written hazard communication program with its list of hazardous substances and MSDS.
- Physical and health hazards that may be associated with the staff member's job tasks and the safe work procedures that have been established for those activities.
- How to use and access the types of information presented on MSDSs. Staff members are also informed of the type of information available on the label of the hazardous materials used in the workplace.
- The general types of hazards expected on the job (e.g., flammable, corrosive materials) and the equipment and procedures to be implemented to avoid exposure to the hazards (e.g., gloves, ventilation).
- Emergency procedures when working in environmental laboratories.

The training of new staff members should be scheduled prior to their assignment to job activities that involved hazardous substances. Retraining or updates for existing staff members are provided on an as-needed basis depending on the introduction of new materials or hazards to the workplace. Each staff member acknowledges in writing that he/she has attended this training by signing the attendance sheet.

3.7 Recordkeeping

The LHSC is responsible for maintaining the following program records:

- Copy of the current written hazard communication program.
- Up-to-date (semi-annual) list of the hazardous substances used. (Chemical Inventory)
- Most current copy of the MSDS for each hazardous substance used at the facility or in the field.

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- Documentation of training for all staff members whose job assignments include possible exposure to hazardous substances.
- Documentation of retraining or update training as may be required.
- Log of all information and training programs provided to staff members.

3.8 Contractor Policy

3.8.1 Potential Exposure at Haley & Aldrich Work Sites

When employees of a contractor engaged by Haley & Aldrich to perform activities where they may be exposed to hazardous substances in the Haley & Aldrich work area(s) during the course of their contract work, the Haley & Aldrich Manager responsible for retaining the contractor is responsible for ensuring that the contractor and its staff members are informed of the hazardous substances, as well as any suggestions for appropriate protective measures. The responsible Haley & Aldrich Manager (or designee) must also inform the Haley & Aldrich subcontractor of:

- the means by which contractor staff members will have access to the MSDS for each substance to which the staff members may be exposed,
- recommended precautionary measures that need to be taken to protect contractor staff members during the workplace's normal operations and in foreseeable emergencies, and
- the labeling system used by Haley & Aldrich to label stationary and/or secondary containers of hazardous substances, where such containers are present in the contractor work area.

A one-page summary of the Haley & Aldrich Hazard Communication Program requirements pertaining to contractors is provided in Attachment C. Space is provided at the bottom of the page for the contractor to sign and acknowledge that he has been informed of the Haley & Aldrich obligations.

3.8.2 Contractor Materials

If a contractor brings hazardous substances to any Haley & Aldrich owned or leased work location for use in their contract work activities, the contractor must provide an MSDS for each of those materials to the Haley & Aldrich Manager in charge of their work upon request.

If the contractor introduces a new hazard to the work site that may affect Haley & Aldrich staff members, that contractor is responsible for informing Haley & Aldrich management and the affected staff members of the hazard. The contractors H&A project representative has full authority to refuse the use of any chemical at a Haley & Aldrich worksite or facility. Many chemicals, unfortunately, cannot be replaced or substituted. If this is the case, specific safety procedures must be initiated.

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3.9 Responsibilities

The following descriptions of duties comprise the collective responsibilities of Haley & Aldrich management, Local Health and Safety Coordinator, and staff members in implementing this hazard communication program for the company.

3.9.1 Corporate Health and Safety Manager

- Establishing the company's commitment to implement and maintain an effective hazard communication program for its staff members.
- Authorizing the necessary resources to successfully implement the program.
- Ensuring that supervisors and other managers enforce compliance with the provisions of the program within their staff groups or on their projects.
- Developing this written hazard communication program, which contains the procedures to be followed in preparing a list of hazardous substances, obtaining and maintaining material safety data sheets (MSDS), labeling containers of hazardous substances, and providing information and training to Haley & Aldrich staff members and contractors.
- Overall management of the company's hazard communication program.
- Providing assistance to management in implementing the provisions of the program.
- Conducting periodic assessments of the program implementation to ensure compliance with the OSHA standard.
- Reviewing and updating the written program as necessary to ensure that it is current.

3.9.2 Managers

- Obtaining an MSDS for any new hazardous substance that is requested to be purchased for use in the workplace and forwarding the MSDS to the LHSC to be inventoried in the master MSDS manual.
- Ensuring that their staff members have received training on the requirements of the hazard communication standard. Training will be conducted by use of an outside vendor or a qualified internal person. The specific requirements of the training program are detailed in Section 11 of this program. Staff members shall also receive training when staff members undertake new job tasks or jobs that represent new possible exposure hazards.
- Ensuring, to the extent possible, that all hazardous materials handled by staff members remain in their originally labeled containers, or if transferred to smaller containers, are labeled in a

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manner that identifies the contained substance and its hazards to the staff member using the substance.

- Coordinating supplemental training for staff members who may be exposed to a new substance that presents physical or health hazards that have not been previously addressed in staff member training sessions.

- Work with contractors to ensure that there is a mutual understanding of the chemical hazards present at the work site and that MSDSs are present for all relevant parties to review.

3.9.3 Local Health and Safety Coordinator

- Maintaining a master list of the hazardous substances present in company facilities or used by staff members in normal job tasks (see Attachment A). The master list will be maintained from individual lists forwarded by supervisors of the various departments.

- Maintaining a master copy of the MSDSs provided by the manufacturer or distributor for each hazardous substance on the list. The master compilation will be assembled from the individual compilations of MSDSs forwarded by the supervisors of the operating groups.

- Reviewing and approving new hazardous substances prior to purchase.

- Maintaining copies of the most recent written hazard communication program in a location that is accessible to staff members. All staff members must be informed of the location and availability of this program.

3.9.4 Staff members

- Understanding the basic provisions of this hazard communication program regarding the regulatory requirements, labeling of containers, and use of MSDSs.

- Understanding where hazardous substances are present in their work area(s) and operations, and knowing the physical and health hazards of those substances.

- Following the procedures outlined in this program for labeling secondary containers when transferring hazardous substances from their primary containers for use.

- Understanding the methods and observations that may be used to detect the presence or release of a hazardous substance in the work area.

- Understanding and utilizing the measures that can be taken to protect themselves from chemical hazards, such as appropriate work practices and personal protective equipment.

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APPENDIX A
REFERENCES

- Hazard Communication Standard- OSHA 29 CFR1910.1200

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APPENDIX B
GLOSSARY

- **Annual or Annually** - Measured by a 12-month period of time.

- **Article** - means a manufactured item which: 1) is formed to a specific shape or design during manufacture, 2) has end use function(s) dependent in whole or in part upon its shape or design during end use, and 3) does not release, or otherwise result in exposure to, a hazardous substance under normal conditions of use or in a reasonably foreseeable emergency resulting from workplace operations.

- **Combustible liquid** - means any liquid having a flash point at or above 100 ºF, but below200 ºF.

- **Common Name** - means any designation or identification such as code name, code number, trade name, brand name or generic name used to identify any chemical other than by its chemical name.

- **Container** - Any bag, barrel, bottle, box, can, cylinder, drum, reaction vessel, storage tank, tank truck, or the like that contains a hazardous substance. Pipes or piping systems are not considered to be containers.

- **Emergency -** means any potential occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment, which may or does result in a release of a hazardous substance into the workplace.

- **Exposure or Exposed** - means that an staff member is subjected, in the course of employment, to a chemical that is a physical or health hazard. Subjected to a health hazard means by any route of entry, including inhalation, ingestion, skin contact or absorption.

- **Flammable Liquid** - means any liquid having a flashpoint below 100 ºF.

- **Flashpoint** - means the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested according to specific methods.

- **Gas** - An aeriform fluid which is in the gaseous state at standard temperature and pressure.

- **Hazard Warning** - means any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning which convey the specific physical and health hazards including target organ effects of the chemical in the container.

- **Health Hazard** - means any chemical for which there is statistically significant evidence that acute or chronic health effects may occur in exposed staff members. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants,

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corrosives, sensitizers, neurotoxins, and agents which damage the lungs, skin, eyes, or mucous membranes.

- **Immediate use** - means the hazardous substance will be under the control of, and used only by, the person who transfers it from a labeled container, and only within the work shift in which it is transferred.

- **Immediately Dangerous to Life or Health (IDLH)** - Any atmosphere that poses an immediate hazard to life or produces immediate irreversible debilitating effects on health.

- **Label** - means any written, printed, or graphic material displayed on or affixed to containers of hazardous chemicals.

- **Material Safety Data Sheet** - means written or printed material concerning a hazardous chemical which is prepared in accordance with the hazard communication standard.

- **Mixture** - means any solution or intimate admixture of two or more substances, at least one of which is present as a hazardous substance, which do not react with each other.

- **Odor Threshold Limit -** the lowest concentration of a contaminant in air that can be detected by the olfactory sense (smell).

- **Physical Hazard** - means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, an organic peroxide, an oxidizer, or is explosive, flammable, pyrophoric, unstable or water reactive.

- **Produce** - means to manufacture, process, formulate, repackage, or re-label.

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OPERATING PROCEDURE: OP1015

HEAT STRESS

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP1015

HEAT

1. PURPOSE

To establish a hot environments program and to assure that staff members know and recognize symptoms of heat stress and are prepared to take appropriate remedial and corrective action.

2. DISCUSSION

Heat stress is a disruption of normal body functions that occurs when high heat and humidity are coupled with hard work or use of equipment that interferes with the body's normal temperature regulating system. The human body normally controls heat buildup by the evaporation of perspiration and reduced activity. The use of personal protective equipment (principally impermeable and semipermeable work clothes) and job performance requirements can impair the body's ability to dissipate heat buildup. This increase in internal core temperatures can continue until it reaches a level that involuntarily shuts down the body's ability to function properly. These conditions range from heat cramps to more serious and potentially fatal, heat stroke.

There are no Federal Occupational Safety and Health Administration (OSHA) standards regulating exposure to hot environments. However, the American Conference of Governmental Industrial Hygienists (ACGIH) has developed recommended heat stress threshold limit values (TLVs). These recommended TLVs have been used in the development of this SOP. Additional information about heat stress can be located at the following OSHA technical website:

http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html

3. APPLICATION

This OP should be followed when H&A Staff members working in the field are potentially exposed to hot working conditions. It also applies to H&A Staff members working in facilities and such where there is radiant heat sources such as furnaces, boilers, etc. It is designed to aid in the prevention or minimization of heat stress illnesses.

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4. DEFINITIONS

4.1 Acclimatization

Acclimatization is a physiological adjustment to work under hot conditions. A gradual conditioning to improve a person's ability to withstand heat stress conditions and enhance the ability to perform work under those conditions.

4.2 Heat Stress

Heat stress is a basic term used to describe the illness which may be suffered by the body as a result of overexposure to heat. These illnesses include heat cramps, heat exhaustion, and heat stroke.

4.3 Heat Cramps

Heat cramps, or painful spasms of the muscles, are caused when staff members drink large quantities of water but fail to replace their bodies' salt loss. Tired muscles -- those used for performing the work -- are usually the ones most susceptible to cramps. Cramps may occur during or after working hours and may be relieved by taking liquids by mouth or saline solutions intravenously for quicker relief, if medically determined to be required.

4.4 Heat Exhaustion

Heat exhaustion results from loss of fluid through sweating when a staff member has failed to drink enough fluids or take in enough salt or both. The staff member with heat exhaustion still sweats but experiences extreme weakness or fatigue, giddiness, nausea, or headache. The skin is clammy and moist, the complexion pale or flushed, and the body temperature normal or slightly higher. Treatment is usually simple: the victim should rest in a cool place and drink an electrolyte solution (a beverage used by athletes to quickly restore potassium, calcium, and magnesium salts). Severe cases involving victims who vomit or lose consciousness may require longer treatment under medical supervision.

4.5 Heat Rash

Also known as prickly heat, heat rash may occur in hot and humid environments where sweat is not easily removed from the surface of the skin by evaporation. When extensive or complicated by infection, heat rash can be so uncomfortable that it inhibits sleep and impedes a staff member's performance or even results in temporary total disability. It can be prevented by resting in a cool place and allowing the skin to dry.

4.6 Heat Stroke

Heat stroke is the most serious health problem for staff members in hot environments. It is caused by the failure of the body's internal mechanism to regulate its core temperature. Sweating stops and the body can no longer rid itself of excess heat. Signs include (1) mental confusion, delirium, loss of consciousness, convulsions or coma; (2) a body temperature of 106 degrees F or higher; and (3) hot dry

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skin which may be red, mottled, or bluish. Victims of heat stroke will die unless treated promptly. While awaiting medical help, the victim must be removed to a cool area and his or her clothing soaked with cool water. He or she should be fanned vigorously to increase cooling. Prompt first aid can prevent permanent injury to the brain and other vital organs.

4.7 Metabolic Heat

Metabolic heat is generated by the metabolic functions of the body.

4.8 Radiant Heat

Radiant heat is produced by the absorption of electromagnetic energy such as sunlight. Only the object absorbing the radiation is heated. The air through which the radiation passes is not effected.

4.9 Relative Humidity

Relative humidity is the ratio of the actual partial pressure of the water vapor in air to the saturation pressure of pure water at the same temperature.

5. PROCEDURE

5.1 Recognition of Heat Stress Conditions

5.1.1 Environmental Conditions

Ambient temperature, relative humidity, air movement, and radiant heat play major roles in heat stress. Obviously, higher temperatures enhance the likelihood of producing discomfort and heat stress. The higher the relative humidity the less evaporation of perspiration takes place and thus evaporative cooling is reduced.

Air movement (fans or natural breezes) aids in evaporative and corrective cooling. The greater the air movement, the greater the cooling effect except at temperatures higher than body temperature. When the air temperature is greater than 95 degrees F, the process of moving air across the body actually creates a greater risk than a cooling effect. Direct radiant heat can add significantly to heat stress as evidence of working in the sun. Shade is a valuable deterrent to heat stress.

5.1.2 Personal Conditions

Physical conditions play a major role in determining a person's ability to withstand heat stress. Age is a major factor. Generally speaking, younger persons are more resistant to heat stress. Those in poor physical condition, overweight, not used to physical exertion, or involved with excessive alcohol are more subject to heat stress. Ones geographical background also plays a

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significant role in the tolerance of working in hot work conditions such as Tucson and Southern California.

5.1.3 Working Conditions

Working conditions are just an important factor to heat stress as those mentioned above. The use of personal protective equipment can interfere with normal cooling mechanisms and greatly enhance the possibility of heat stress. Working long hours can produce fatigue that makes heat stress more likely. Working during the hottest part of the day, particularly in bright sunlight, also promotes the onset of heat stress.

5.2 Precautionary Measures

Heat stress can be minimized by following one or all of the following:

5.2.1 Engineering Controls

Engineering controls including general ventilation and spot cooling by local exhaust ventilation at points of high heat production may be helpful. Shielding is required as protection from radiant heat sources. Evaporative cooling and mechanical refrigeration are other ways to reduce heat. Cooling fans can also reduce heat in hot conditions. Equipment modifications, the use of power tools to reduce manual labor and personal cooling devices or protective clothing are other ways to reduce the hazards of heat exposure for staff members.

5.2.2 Work Practices

Work practices such as providing plenty of drinking water -- as much as a quart per staff member per hour -- at the workplace can help reduce the risk of heat disorders. Training first aid staff members to recognize and treat heat stress disorders and making the names of trained staff known to all staff members is essential. Locations should also consider an individual staff member's physical condition when determining his or her fitness for working in hot environments. Older staff members, obese staff members and those on some types of medication are at greater risk. These conditions should be discussed with the company doctor at some time during your medical exam.

5.2.3 Work and Rest

Work and rest periods with longer rest periods in a cool area can help staff members avoid heat stress. If possible, heavy work should be scheduled during the cooler parts of the day and appropriate protective clothing provided. Supervisors should be trained to detect early signs of heat stress and should permit staff members to interrupt their work if they are extremely uncomfortable. The American Conference of Governmental Industrial Hygienists (ACGIH) has developed recommended heat stress threshold limit values (TLVs). These may be found in their annual handbook.

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5.2.4 Acclimatization

Acclimatization to the heat through short exposures followed by longer periods of work in the hot environment can reduce heat stress. New staff members and staff members returning from an absence of two weeks or more should have 5-day period of acclimatization. This period should begin with 50 percent of the normal workload and time exposure the first day and gradually building up to 100 percent on the fifth day.

5.2.5 Staff Member Education

Staff member education is vital so that staff members are aware of the need to replace fluids and salt lost through sweat and can recognize dehydration, exhaustion, fainting, heat cramps, salt deficiency, heat exhaustion, and heat stroke as heat disorders. Staff members should also be informed of the importance of daily weighing before and after extremely heavy work activity days to avoid and recognize dehydration.

5.2.6 Measurement

Though rare, portable heat stress meters or monitors are used to measure heat conditions. These instruments can calculate both the indoor and outdoor Wet Bulb Globe Test (WBGT) index according to established ACGIH Threshold Limit Value equations. With this information and information on the type of work being performed, heat stress meters can determine how long a person can safely work or remain in a particular hot environment.

5.3 Recognition of Heat Illnesses (See Section 4)

5.3.1 Heat Cramps

- muscle spasms of large muscle groups
- pain in the leg muscles, back muscles, and abdomen

5.3.2 Heat Exhaustion

- pale, cool, moist skin
- heavy sweating
- dizziness
- nausea
- fainting

5.3.3 Heat Stroke

- red, hot, skin looks sunburn or dry pale skin with no sweating
- nausea
- irritable
- dizziness and confusion
- strong rapid pulse

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- possible seizure
- possible coma

5.4 First Aid for Heat Stress

5.4.1 Heat Cramps

- Move victim to a cool place.
- Administer drinks of cool water.
- Apply manual pressure to cramped muscles.
- Seek medical attention if symptoms are not alleviated or if more serious problems are indicated.

5.4.2 Heat Exhaustion

- Respond quickly, this could turn into heat stroke.
- Move the victim to a cool and shaded place.
- Remove as much clothing as possible.
- Apply a wet cloth over body.
- If dizzy, lay on back and raise legs 6”-8”
- Administer drinks of cool water.
- Seek medical attention.

5.4.3 Heat Stroke

- Treat as a true medical emergency. Seek medical help immediately.
- Reduce body temperature quickly.
- Douse with water.
- If possible, have drink cool water every 15 minutes.
- Wrap in wet cloth.
- If available, use cold packs under arms, neck, and ankles.
- Protect from injury during convulsion.
- Assure an open airway for breathing.
- Transfer to a medical facility.

5.5 Considerations and Prevention

- Prior to entering hot work environments, provide training regarding the hazards, precautions, and first-aid for heat stress.
- Include appropriate guidance in Health and Safety Plans.
- Wear light weight and colored clothing.
- Ensure that an ample supply of suitable fluids is available.
- Ensure that a proper rest area is available.
- Take adequate breaks.
- Conduct labor intensive work during cooler part of the day.

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- Ensure that staff members remain alert for symptoms of heat stress and practice good avoidance techniques.
- Ensure that observation for appearance of heat stress symptoms is maintained.
- Ensure that first-aid measures are employed rapidly when symptoms appear.
- Observe each other for the early symptoms of heat stress.
- Try to eliminate excessive amounts of alcohol from non-workhour activites.

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APPENDIX A
REFERENCES

- OSHA Technical Manual (TED 1—0.15A) - Chapter 4 "Heat Stress"
- OSHA Trade News Release, December 2003
- Fundamentals of Industrial Hygiene, National Safety Council, 5th edition

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1001 Excavation and Trenching
- OP1002 Drilling Safety
- OP1003 Cold Stress
- OP1008 Operations Over, Near, or On Water
- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP1014 Hazard Communication

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APPENDIX C
FORMS

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APPENDIX D
GLOSSARY

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OPERATING PROCEDURE: OP1016

RECORDKEEPING AND REPORTING

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PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP1016

RECORDKEEPING AND REPORTING

1. PURPOSE

Haley & Aldrich has developed this procedure to:

1. ensure compliance with federal and state requirements for the recording and reporting of occupational injuries and illnesses, and

2. provide procedures required for the investigation of accidents and near miss incidents resulting in an injury/illness or damage to individuals and to property.

1.1 Discussion

The OSHA standard requires that work-related accidents be reported to the employer and serious injuries and illnesses be reported to the administering federal and/or state agencies. The Occupational Safety and Health Administration (OSHA) standard, "Reporting Occupational Injuries and Illnesses" (29 CFR 1904) requires that employers prepare and maintain records of recordable, work-related injuries and illnesses incurred by their staff members. The Bureau of Labor Statistics of the U.S. Department of Labor is responsible for administering the recordkeeping system established by the standard.

The following states have their own OSHA-approved job safety and health programs for workers. States with approved programs must have a standard that is identical to, or at least as effective as, the federal standard. A review of these states websites indicates that the recordkeeping requirements and forms used by Federal OSHA will satisfy our needs for these states recordkeeping requirements. In addition, the “First Report of Injury” form filled out by Human Resources (HR) to our insurance carrier (Liberty Mutual) satisfies all mandatory OSHA initial incident reporting for all states.

Michigan	Michigan Occupational Health and Safety Admin.
Arizona	Industrial Commission of Arizona
California	California Div. of OSHA
Virginia	Virginia Department of Labor

Every state requires some type of injury and illness notification. These requirements usually involve the completion and submission of that state’s "employers’ first report of injury" form for occupational injuries and illnesses, which meet that state’s "reportable" criteria. The report filed with Liberty Mutual, by HR, satisfies this requirement. This procedure has been developed, in part, to assure compliance with these federal and state requirements. Finally, injury and illness data is tracked and utilized by the CHSM to identify problem areas and reduce recurrence of such injuries and illnesses.

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1.2 Application

This policy applies to all H&A staff members.

2. PROCEDURE

2.1 Accident Reporting

Staff members must report all work-related accidents, near miss incidents, and incidents resulting in property damage or injury to their staff managers immediately after the occurrence. Staff Managers must report all work-related accidents (other than those resulting in only minor injuries) and all near miss incidents to their Local Health and Safety Coordinator (LHSC). The notification of the LHSC by the staff manager must be made verbally, as soon as possible after the occurrence. Prior to filling out any documentation, management must ensure that the emergency is over and the injured staff member has received the proper medical attention immediately following the incident.

2.2 Supervisor Accident Injury Report (SAIR – SAF 004 Form)

All injuries and accidents must be reported to the LHSC or the Corporate Health and Safety Manager (CHSM) as soon as possible and prior to conducting any type of accident investigation. The summary of the accident or incident investigation must be recorded on the Supervisors Accident Injury Report (see Company Intranet or Appendix C for copy). The completed SAIR must be submitted to the LHSC **within 24 hours of the occurrence** of the accident or incident. The SAIR must be forwarded by the LHSC to the CHSM and the Human Resources Department in Boston as soon as possible. The report is used by HR as the basis to initiate a worker's compensation claim with our insurance carrier.

2.3 Instructions for Completing the Supervisor Accident Injury Report (SAF 004)

If more than one staff member is injured, complete a report for each staff member. It is important that applicable details are included on the form. The staff member must be involved in filling out the SAIR to ensure accuracy and concurrence of events. Below are the entries required to successfully filling out the SAIR.

1. Name of injured staff member

2. Haley & Aldrich ID #

3. Staff member's home office and department

4. Accident date, day of week, and time of day

5. Name of project and project manager

6. Project number

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7. Description of the specific location of the accident, including the facility name and location, and the specific location within the facility where the accident occurred.

8. Description of the specific activity the staff member was engaged in when the accident occurred. Describe in detail how the accident occurred, using all factors that may have contributed to it. Answer all the "W Questions": who, what, when, where, why, and how.

9. Names of any witnesses

10. Equipment and materials involved in incident

11. Description of the injury in detail, e.g., "injured lower back while lifting a ream of paper in the office."

12. Description of first aid or medical treatment provided

13. Name and address of medical provider if known

14. Statement whether any lost time will be incurred, approximately how much lost time will be involved, and the date that the lost time began

15. Staff member's specific job title (e.g., geologist, project manager, equipment operator, etc.).

16. Description of the preliminary determination of cause of incident.

17. Description of the action(s) necessary to prevent recurrence. Describe the action(s) taken thus far to prevent recurrence.

18. Person(s) who are responsible for corrective actions

The staff manager preparing the report should then sign it and submit it to their LHSC for review and signature. After review by the LHSC and signature, the report should be submitted to the CHSM and HR.

2.4 Timeliness of Reporting

To assure that matters related to internal recordkeeping, state reporting requirements and Worker's Compensation are addressed in a timely fashion and that prompt and appropriate medical attention is provided to the ill or injured staff member, it is imperative that:

- Staff members report all work-related injuries and illnesses incurred, regardless of their severity, to their staff manager immediately after their occurrence. All injuries must be reported to the appropriate staff manager **within 24 hours**. If an injury occurs on a Friday, staff members are required to leave a message on their staff manager's voice mail during the weekend or talk to them prior to returning back to work on Monday.

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- Staff members notify their staff manager as soon as they become aware that a work related injury or illness **is likely to result in a day away from work.**

- Staff members notify their LHSC or staff manager if they **become aware that a first aid case has increased in severity** and may result in the need for additional medical attention. (Example, cut that becomes infected.)

- Staff managers notify their LHSC as soon as they become aware that an staff member has incurred a work-related injury or illnesses (other than a minor injury) or that an injury or illness is likely to result in a day away from work.

Our insurance carrier reserves the right to refuse any claim that is not reported in a timely manner. It is essential that staff members communicate their injury status to the LHSC and staff manager as soon as possible to avoid refusal of payment of medical bills.

2.5 Reporting Serious Accidents

Within eight (8) hours after the death of any staff member from a work-related incident or the in-patient hospitalization of three or more staff members as a result of a work-related incident, we must orally report the fatality/multiple hospitalization by telephone or in person to the Area Office of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, that is nearest to the site of the incident. The CHSM will use the OSHA toll-free central telephone number, 1-800-321-OSHA (1-800-321-6742). If the incident occurs in a state-approved program, the CHSM, or designee, will call the applicable state agency.

If the incident involves a motor vehicle accident and occurs on a public street or highway, and does not occur in a construction work zone, we do not have to report the incident to OSHA. However, these injuries must be recorded on the office's OSHA injury and illness records.

To assure that these requirements are met:

- All serious accidents, must be reported to the CHSM and/or the LHSC of the office in which the accident occurred.
- If the serious accident is reported to the LHSC first, he/she must immediately report it to the CHSM. The CHSM, or his designee, will then report the accident to H&A management, OSHA and other appropriate agencies.

2.6 Accident Investigation

The objective of the accident investigation is to provide factual documentation of root cause and contributing factors and to determine strategies to prevent recurrence. The accident investigation is a learning tool (fact-finding) to be used to improve operations and is not a device used to assess blame (fault-finding). On some occasions H&A may be required to conduct a formal accident investigation and provide supporting documentation to our clients.

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It should be assumed that an incident that may result in legal action will require an investigation. If we anticipate that legal action may result from the incident, most likely the project manager of the project will be asked by H&A legal counsel to facilitate an investigation.

2.6.1 Investigation Procedure

In general, the project manager should perform the accident investigation. In cases where the staff member's project manager is not present or available, a representative from the business unit will conduct the accident investigation. Haley & Aldrich does not have a standard investigation protocol or a standard document format at this time. CHSM and corporate counsel will assist in determining the required protocol and document format for each case. The investigator should be familiar with the staff member's job function, the equipment used, and activity at the time of the accident. The investigation should begin as soon as possible after the occurrence of the accident, and after any injured staff member's welfare has been initially addressed.

2.7 Injury and Illness Recordkeeping

OSHA 29 CFR 1904, or state equivalent rule, requires that each employment facility prepare and maintain records of recordable, work-related injuries and illnesses incurred by their staff members. Specific requirements of this standard include the recording of each recordable injury and illness on:

- A separate supplementary record of occupational injuries and illnesses form (i.e., OSHA No. 301 Form) or an equivalent state "Employer's First Report of Injury" form (Accomplished by HR when reporting incidents to Liberty Mutual) and on
- A regularly updated, cumulative log of injuries and illnesses (i.e., the OSHA No. 300 Log), and on
- An Annual Summary of Work Related injuries and Illnesses (i.e., the OSHA No 300A Form)

Offices in Michigan, Arizona, California, and Virginia may use the federal forms to satisfy this recordkeeping requirement. These forms and this log must be available in each facility for inspection at all times and the OSHA 300A Form must be posted in the workplace each year during the month of February for three consecutive months.

2.8 OSHA 300 Log

Recordable injuries and illnesses must be entered on the facility's OSHA 300 Log by the LHSC within **six work days** after receiving information of the injury or illness. The log must be maintained and each entry onto the log made in strict accordance with OSHA rules. The instructions to fill out the log can be retained from the H&A Safety Homepage. The information on the Homepage is the Bureau of Labor Statistics publication "Recordkeeping Guidelines for Occupational Injuries an Illnesses" and should be used by the LHSC for guidance. The CHSM will be involved in all cases to determine recordability.
Blank copies of the Log of Work-Related injuries and Illnesses (OSHA 300 Log) can be found on the Safety Homepage under "forms- OSHA 300log.xls". To successfully utilize this form, it must be downloaded from the Intranet and altered from "protected" by following the prompt on the screen.

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The determination of recordability of all injuries and illnesses will be made by the CHSM.

At the completion of the calendar year, the log must be finalized and totaled, reviewed by the CHSM, reviewed by the LHSC, and properly filed at the office. In addition a Supplementary Form (OSHA 300A) will be filled out at the end of the year by the LHSC, reviewed and signed by the CHSM and posted in each facility during the month of February through April. Original OSHA 300 Logs and OSHA 300A Forms must be maintained by the LHSC in each facility for 5 years following the year for which they pertain.

2.9 Supplementary Record of Occupational Injuries and Illnesses (OSHA 301 Form)

For each recordable injury or illness reported, a Supplementary Record of Occupational Injuries and Illnesses, OSHA 301 Form, or its equivalent must be filled out. This is accomplished by HR. H&As insurance carrier satisfies this requirement on H&As behalf when a report of the incident is filled out with our insurance carrier. The particular state's "Employer's First Report of Injury" form, a form which generally contains all the information required by the OSHA 301 Form, is utilized by the insurance carrier to determine compensability. Note that each state requires that its "Employer's First Report of Injury" form be completed and submitted only if an injury or illness meets its "reportability" criteria. We rely solely on our insurance carrier to satisfy the reporting of this form(s) for each state. This report is generated by the information provided by the staff manager in the Form SAF004- SAIR. Thus, it is imperative that the information is accurate and thorough on the SAIR.

2.10 Worker's Compensation Claims

Any occupational illness or injury, which results in a worker's compensation claim that was not initially reported, must be reported to the HR representative in Boston so that a state "Employer's First Report of Injury" form can be completed. Questions regarding the filing and processing of Worker's Compensation claims should be directed to the LHSC or CHSM.

2.11 Responsibilities

2.11.1 Staff Members

- Report all real or potential work-related injuries and illnesses, regardless of their severity, to their staff managers and LHSC after their occurrence;
- Report all changes in the status of their injury or illness to their staff manager and LHSC as soon as possible; and
- Report all near miss incidents and property damage to their staff manager and LHSC after their occurrence.

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2.11.2 Staff Managers

- Report all work-related illnesses and injuries, other than minor injuries, which their staff members incur, to their LHSC within one day of their occurrence;
- Report serious accidents to the CHSM or their LHSC after their occurrence;
- Participate or conduct a formal accident investigation of the incident based on the severity, when instructed by their LHSC; and
- Complete and submit an SAIR to the LHSC, when instructed by their LHSC.

2.11.3 Corporate Health and Safety Manager

- Determines the recordability of all injuries and illnesses for the company;
- Works with HR and the LHSCs to ensure that the proper recordkeeping has been initiated, filed, and retained as required by the authorities;
- Obtains and maintains sufficient original blank copies of all required forms and logs on the Health & Safety Homepage on the company intranet;
- Participates in accident investigations as needed;
- Evaluates OSHA 300 logs to determine trends and make recommendations to management to reduce the occurrences of injuries or illnesses; and
- Forwards copies of the updated, totaled, and signed OSHA 300 Log and Summary (300A) for the previous year to their LHSC by the 2nd Monday of each January.

2.11.4 Local Health and Safety Coordinators

- Perform all the injury/illness recordkeeping requirements specified in this OP at the local level;
- Provide completed copies of SAIRs to HR as soon as possible as to assist the HR Representative in the completion of the "Employer's First Report of Injury" form and other worker's compensation documentation;
- Maintain a proper account of all injuries and illnesses for their office, including first aid cases;
- Post OSHA 300A Summary Form in their respective offices from February 1 through April 30;

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- Responsive to any possibility that a staff member may be injured and ensure that the proper process is implemented; and

- Track injuries and illnesses within their offices by maintaining a 300 log of all injuries and illnesses reported to them by staff managers within their office.

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APPENDIX A
REFERENCES

- Occupational Safety and Health Administration (OSHA) standard, "Reporting Occupational Injuries and Illnesses" (29 CFR 1904).

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APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP1013 Radiation Safety Program
- OP1014 Hazard Communication
- OP1017 Chemical Hygiene Plan

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APPENDIX C
FORMS

- Supervisor Accident Injury Report (SAF 004) – please see the Health and Safety page on the intranet to retrieve this form.

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APPENDIX D
GLOSSARY

- **Days Away From Work-** When an injury or illness involves one or more days away from work, we must record the injury or illness on the OSHA 300 Log with a check mark in the space for cases involving days away and an entry of the number of calendar days away from work in the number of days column. If the staff member is out for an extended period of time, you must enter an estimate of the days that the staff member will be away, and update the day count when the actual number of days is known. Weekend days, holidays, vacation days or other days off are included in the total number of days recorded if the staff member would not have been able to work on those days because of a work-related injury or illness.

- **Facility** - A single physical location where business is conducted or where services or industrial operations are performed. Distinctly separate activities performed at a single location are each treated as a separate facility for recordkeeping purposes. Therefore, each H&A office is considered a separate facility and recordkeeping is required to be maintained at each office.

- **First Aid** - Any one-time treatment, and any follow-up visit for the purpose of observation of minor scratches, cuts, burns, splinters, and so forth, which do not ordinarily require medical care. This treatment is considered first aid even though it is provided by a physician or registered professional personnel.

- **Medical Treatment** - Treatment administered by a physician or by registered professional personnel under the standing orders of a physician. For purposes of the OSHA recordkeeping requirement, "medical treatment" does not include first-aid treatment even though provided by a physician or a registered medical professional. "Medical treatment" means the management and care of a patient to combat disease or disorder.

- **Near-miss Incident** - Any abnormal work occurrence, that could have resulted in a serious injury or significant property damage, but, for a matter of chance does not result in either. Such occurrences indicate a potential problem as surely as do accidents resulting in injury or property damage.

- **Property Damage** – Significant damage or loss to equipment, facilities, or other property.

- **Recordable Occupational Injuries or Illnesses** - Any work-related illness, or a work-related injury that results in any of the following:

  - Death
  - Days away from work
  - Hospitalization or medical treatment (other than first aid)
  - Restricted work or transfer to another job
  - Loss of consciousness
  - Diagnosis of significant injury or illness
  - Significant aggravation of pre-existing condition

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- **Restriction of Work** - Occurs when an staff member, because of a work-related injury or illness:
  - Is kept from performing one or more of the routine functions of his or her job, or from working the full workday that he or she would otherwise have been scheduled to work; or
  - Is recommended by a physician or other licensed health care professional that the staff member not perform one or more of the routine functions of his or her job, or not work the full workday that he or she would otherwise have been scheduled to work.
- **Serious Accident** - Any work-related accident that results in:
  - A death
  - Hospitalization of three or more staff members
- **Work Related** - You must consider an injury or illness to be work-related if an event or exposure in the work environment either caused or contributed to the resulting condition or significantly aggravated a pre-existing injury or illness.

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OPERATING PROCEDURE: 1020

WORK NEAR UTILITIES

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PREPARATION AND APPROVALS

VERSION	AUTHORED/ DATE	REVIEWED/ DATE	REVIEWED/ DATE	REVIEWED/ DATE	APPROVED/ DATE
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1. PURPOSE

This procedure describes the minimum requirements for work near underground and overhead utility hazards and guy wires.

Ground disturbance activities such as excavating or drilling have the potential to contact underground utilities and may be considered a hazardous activity and a permit to work may be required.

Work near overhead hazards and guy wires may be considered a hazardous activity, and a permit to work may be required.

This procedure defines under which conditions a permit is required and identifies the specific requirements for the permit to work.

For details on the permit to work process, refer to the *Permit Management Program* Operating Procedure (OP1038).

1.1 Discussion

Buried and overhead utilities must be identified and located prior to beginning invasive field work. A several step process is used to accomplish a good understanding of utilities in an area. This process is intended to be iterative and overlapping, and is then supplemented later by additional safety precautions to prevent the hitting of utilities. The process includes a pre-work identification of utilities, a notification to local utilities and a technical investigation of potential utilities, followed by field truth testing. This process is discussed in more detail below.

At the beginning of a project, a review will be made of any available property maps, blue line drawings, or as-built plans prior to site activities. This exercise often will result in an incomplete picture and should always be supplemented whenever possible with additional information. However, examining as-built maps and plans, if available, always enhances an understanding of utility locations in the area of investigation.

During the project site walk, discrepancies or new information regarding utility locations should be added to project maps. The site walk is a good time to review and confirm overhead utility lines.

After the above actions have occurred, the next action, and one that should always be taken even when on private land, is notification of potential subsurface activity to the local utility locator Services (e.g. Dig-Safe, One-Call, etc.).

1.2 Underground Utilities

This procedure provides a description of methods that are applied to establishing and clearing locations for subsurface investigations by locating utilities. Most often, other parties with experience in locating subsurface utilities conduct this activity. However, site field personnel oversee such operations and clearly have a responsible role in understanding when the job has been completed. These other parties are discussed further below.

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1.3 Overhead Utilities

Prior to conducting work near overhead utilities, overhead hazards shall be identified by type. When working under or near utility lines, distances from those lines shall be taken into consideration. These distances shall be documented in the applicable section of the Overhead Utilities Permit.

There are four types of hazards associated with work on or near energized electrical equipment:

- Upset or shutdown of an operating area.
- Shock and burn due to contact or flashover.
- Electrical flash burn from electrical arcs.
- Blast injuries from electrical arcs.

An electrically hazardous task shall be analyzed by considering two primary hazards: flash and shock. These hazards are identified by using boundaries based on energy levels (i.e., the amount of energy carried by the electrical lines). Performing work inside these boundaries requires training, planning, procedures and personal protective equipment. Project specific activities involving work with or inside the minimal radial clearance distances defined below shall be conducted by a qualified subcontractor and only with the approval of the Corporate Health & Safety Manager (CHSM).

1.4 Application

This program applies to all places where Haley & Aldrich staff members work.

1.5 Documentation

Projects with underground or overhead utilities on-site should include a discussion of the hazards associated with those utilities in the HASP. When the utilities are in an area where they may be impacted by site activities, a Risk Assessment (RA) shall be conducted and documented. Each RA shall be "tailgated" to on-site personnel. Tailgate Safety Meetings shall be documented on the Health & Safety Tailgate Meeting form which is available on the Health & Safety Home Page of Haley & Aldrich Intranet. A permit shall be required if the RA conducted classifies the residual risk as 'substantial' risk level or higher. (Refer to the *Work Risk Assessment* Operating Procedure (OP1011).

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2. PROCEDURE

2.1 Approvals and Agreements

The following requirements apply before work is to begin:

- Approvals and agreements (as applicable) either verbal or written have been obtained.
- Notification to underground facility operator/owner(s) that may not be associated with any known public notification systems such as the One-Call program in North America regarding intent to cause ground disturbance within the search zone.

NOTE: Some private utilities such as sewage and water may not be part of a notification system. It is expected that private locators will communicate the location of these types of UGF's.

- Notifications of landowners and/or tenant, where deemed reasonable and practicable.
- Proximity and Common Right of Way Agreements shall be checked, if the line locator information is inconclusive.

2.2 Underground Utility Clearance

Haley & Aldrich staff members must ensure that permission has been gained from the property owner to access the property prior to site entry and before marking proposed exploration or drilling locations. On public property the estimated location of utility installations, such as gas, electric, water, sewer, telephone, fuel, or any other underground installation that may be expected to be encountered during drilling work, will be identified by the appropriate authority. Appropriate authorities include client representatives, utility companies, nonprofit organizations (e.g. "Dig-Safe"), and others. A list of all state "utility locators" is posted on the Health and Safety Homepage under "Guidance Documents".

NOTE: It is important to note that not all utilities participate in the "one-call" agency or process. As such, inquiries must be made with the "one-call" agency to determine which entities do not participate, so they can be contacted independently.

Also, most stake-outs or markings have a limited time period for which they remain valid, typically 2 to 3 weeks. It is critical that this time period be taken into account to prevent expiration of clearance prior to completion of the invasive activities. If the utility clearance period expires before completion, the clearance process must be repeated.

The Project Manager shall verify that the proposed dig or drill zones are adequately marked or staked prior to the locators site visit, and that the appropriate Line Location Organization/ Contractor has been notified (a minimum of 72 business hours in advance) of planned ground disturbance activities and a request for line location has been registered with the applicable One-Call or Dial Before You Dig organization when applicable. The Project Manager shall affirm that responses have been received from all known underground facility operators/owners.

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When in doubt, the Project Manager shall verify additional investigations and research regarding the possibility of underground lines and contact appropriate parties as needed for verification. At a minimum, notifications to any appropriate party or concern that the excavation is still in progress, shall be made once every ten days, or when re-marking and/or flagging of lines that are no longer visible is needed. Utility companies or owners of underground installations shall be contacted within established or customary local response times, advised of the proposed work, and asked to establish the location of the utility underground installations prior to the start of drilling.

NOTE: Unless required by law, it is H&A policy to have the subcontractor call in to utility owners and any required authority or utility locating service. In California, it is the responsibility of staff members to call in to utility owners and any required authority or utility locating service.

Completion of the utility clearance is not a guarantee that underground facilities will not be encountered in the boreholes. Utility locators and owners of underground installations do not accept the liability for damage or losses if a utility is encountered or an accident occurs. In addition, utility owners and utility locating service firms do not typically conduct clearances on private properties. Accordingly, Haley & Aldrich Field Staff are required to review all available utility plans and conduct a thorough site walkover with the contractors to view proposed work locations prior to the start of subsurface activity. Field Staff and subcontractors must walk along utility alignments to identify gate boxes and manholes, open manholes and identify utility depths and alignment, sight along alignments, use existing plans and measure existing features (manholes etc.) to determine accuracy of plans with as-built maps or plans. Using information that can be obtained, the site should be viewed in detail for physical evidence of buried lines or structures. Evidence of surface elements of buried utilities should be documented, such as manholes, gas or water valves, catch basins, patched pavement cuts, etc. If on private property, onsite facilities personnel must be contacted to obtain utility plans.

2.2.1 Line Location

Available records shall be referenced and contacts made to determine the existence and location of underground facilities/pipelines and utilities in the vicinity of the work area. It is the Project Manager's responsibility to confirm that known available sources of information have been obtained and cross-referenced to verify, as far as is reasonable and practicable, the existence of known facilities/pipelines and underground utilities is understood. Sources of information, including but not limited to, the following shall be referenced when applicable to the job:

2.2.2 Consult Local Operations Personnel

Plot plans, pipeline or facilities maps or lease drawings (as available) shall be obtained and discussed with area operations personnel. Business units or other operator personnel familiar with area operations may have knowledge of facilities/pipelines and abandoned lines not otherwise documented.

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2.2.3 Line Location Documentation

Line location documentation (or appropriate regional agency or company) provides a listing of companies who registered buried facilities in the proposed work area. Some public utilities and private companies are not members of a type of registry (i.e., One Call System [North America], dial Before You Dig [Australia] or equivalent in other regions). In order to give line operators sufficient time to respond to a request to locate, a minimum of a 72 business-hour waiting period is required prior to beginning work.

Some areas require written permission or notification from the UGF owner prior to initiation or work and emergency situations (interruption of essential public service has occurred) may require less waiting time. Local laws should be researched and incorporated in local practices.

2.2.4 Visible Company Markers

Check the work area for facilities/pipelines or utility markers and verify the company named has been contacted to supply any additional information regarding underground facilities.

NOTE: Never rely solely on company markers for location purposes. Markers may have been knocked down or removed at some point in the past and may have been repositioned inaccurately.

2.2.5 Visible Indicators

Visible indicators are evidence of utilities or underground facilities (previously disturbed soils, nearby lines, service pits, propane tanks, gas meters, electric service risers, buildings with no visible evidence of service, etc.) within the proposed work area, including the search zone.

This may include facilities/pipelines, power lines, natural gas providers, utility cables, new clearings, spoil piles, road construction, pipeline signs, settlement, vegetation color changes or growth. If there are visual signs of activity that are not reflected on the plot plan, the plan shall be updated.

Additional considerations should be made to determine the possibility of underground facilities installed horizontally in the past that may not have the visible normal surface indicators.

2.2.6 Landowner Conversations

Landowner and/or tenant may also have additional knowledge of buried utilities not documented elsewhere and should be contacted when reasonable and practical. All conversations should include a discussion on the possibility of previous horizontally installed underground facilities in the area.

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2.2.7 Plot Plan

NOTE: A plot plan, pipeline or facilities map or lease drawing indicating the location of known underground and overhead facilities and utilities within the search zone identified shall be available for reference at the work site.

Ground disturbance activities shall not proceed without an updated plot plan or drawing clearly indicating the number of facilities/pipelines or utilities, line sizes, locations and alignments. Available plot plans or drawings shall be reviewed and cross-referenced with other sources of information to verify that they are accurate and complete. Plot plans shall be retained with any required permits. Plot plans shall be updated to reflect "as built" underground facilities and maintained for future reference.

If a plot plan or drawing is not available, a hand drawn map shall be made during the preplanning phase prior to field activities and shall reflect all available information as accurately as possible.

It is expected that caution will be exercised while drilling in the uppermost 5 feet below the ground surface in the event the clearance has failed to identify an existing utility. Hand-excavation, vacuum pre-excavation or probing may be necessary to confirm the location of shallow utilities when utility companies or owners cannot respond to a request to locate underground utilities or cannot establish the exact location of these installations. Geophysical techniques, such as ground penetrating radar and magnetometry can also be utilized to locate potential underground hazards.

2.2.8 Markings

No subsurface investigation activities will be allowed until efforts described above have been made to have utilities properly located and marked.

Proposed subsurface investigation locations can be marked using spray paint on the ground, stakes, or other similar method. Markings of proposed locations shall be made in white, in accordance with the generally accepted universal color code for facilities identification (AWMA 4/99).

White:	Proposed excavation or drilling location
Pink:	Temporary Survey Markings
Red:	Electrical, Power Lines, Cables, Conduit, and Lightning Cables.
Yellow:	Gas, Oil, Steam, Petroleum, and Gaseous Materials.
Orange:	Communications, Alarm, or Signal Lines, Cables, and Conduits.
Blue:	Potable Water.
Purple:	Reclaimed Water, Irrigation, and Slurry Lines.
Green:	Sewers and Drain Lines.

The public and private utility entities generally only mark the locations of their respective underground facilities within public rights-of-way. Determination of utility locations on private property is the responsibility of the property owner. It is incumbent

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on Haley & Aldrich and the drilling subcontractor to exercise caution and use good judgment when faced with uncertainty.

The search area shall be electronically swept using sweep search techniques to verify maximum detection capabilities. If the sweep shows no indications of underground utilities, the work may proceed after completion of permit requirements. If the sweep detects an unknown underground utility, the work may continue only after ensuring that the utility is not within the dig zone. This may require safe exposure methods and using other information sources.

The initial lines shall be clearly identified and marked within the search zone. Initially all lines should be marked at 15' (4.5m) intervals or less as required for clarity of locate. Minimum expectations or requirements should include but are not limited to:

- Competent personnel with a minimum of five years experience in cable location should be used at all times. Project Manager and/or Business Unit General Manager approval should be obtained when this requirement cannot be met.
- For off-site services, cable locator SHALL liaise with local asset owners to gain their knowledge/experience of the area. This includes checking for new services or those installed by directional drilling.
- Dial Before You Dig/One Call or site plans shall be reviewed with the project manager/site supervisor and locations of any nearby services confirmed and marked on the ground.
- All identified/marked services to be documented on site plans (with dimensions were possible) before cable locator leaves the site.
- Possible electrical sources within the vicinity to be energized/turned on (i.e., light poles, signs, etc.) at the time of locating. This increases the chance of picking up underground electrical services.
- Direct connection (clamping on) to possible nearby underground services should be undertaken wherever possible using qualified or competent personnel. This increases success rate/reliability in locating underground service.
- If anticipated services are not identified or located, no drilling or ground disturbance is to occur until the service is visually identified.
- Dig zone to be marked as ‘clear’ only when the above criteria is met.

2.2.9 Tailgate Safety Meetings

A pre-job safety meeting including a robust Job Hazard Analysis (JHA) that utilizes a formal hazard recognition process, completion, reviews and acceptance of the relevant permit (*Ground Disturbance Permit*, *Hot Work Permit*, etc., as required in the local permit system) and a review of the HASP with Emergency Response Plan shall be held. Refer to OP 1028 for Job Hazard Analysis protocols.

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Appropriate documentation of such meeting shall be kept with the permit and/or the HASP.

The following topics (as a minimum) have been discussed and the meeting recorded (with signed attendance list).

- Review of potential hazards, safe work practice, permitting requirements, etc.
- Agreement that mechanical ground disturbance does not occur unless a competent person in charge is present at the job site. A competent person shall determine if there is a need to be present during ground disturbance activities if there are no underground facilities/pipelines in the search or drill/dig zones, or when manual potholing is being done (shovels or vacuum excavator).
- With the exception of a pre-risk assessed removal of an empty or de-energized UGF such as a decommissioned Underground Storage Tank (UST), pipeline or flowline, mechanical excavation equipment shall not be used to dig or drill within 2 feet (60cm) of an underground facility.
- An equipment spotter shall be in place for all excavation within a 10 foot (3m) proximity of an underground utility. If the attention of the spotter is diverted elsewhere or they leave the site, the excavation operation **SHALL STOP** until his or her return. The spotter shall remain in a safe and designated location, be in constant communication and in the direct vision of the equipment operator during excavation.
- Dig zones shall be adequately marked.
- When excavating, proper cutback and shoring shall be done in accordance with local, state and federal regulations and this document, as well as the OP 1008 *Working Over, Near or On Water*, when applicable.
- Pick axes (or similar tools) can only be used following evaluation and approval by the Project manager.
- Agree that all staff members have the right and responsibility to 'Stop Work' when they suspect work practices or conditions might be unsafe. (Refer to the OP 1035 *Stop Work Authority*.)
- Personal protective equipment requirements, including the need for use of fire retardant clothing, shall be discussed and adhered to. (Refer to the OP 1024 *Personal Protective Equipment*.)
- Accidents, injuries, first aids and near miss incidents shall be reported immediately and in accordance with OP 1016 *Recordkeeping and Reporting*.

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2.2.10 Verifying and Exposing Underground Facilities

Underground facilities within the dig zone or a drill zone shall be hand exposed or vacuum excavated (non-destructive digging) to sufficiently verify location, line size, and alignment.

NOTE: When digging in proximity to energized underground facilities, every effort shall be made to limit people in the immediate dig vicinity to spotter and operator only. This serves to minimize the number of people that could be in the line-of-fire, were an incident to occur.

2.2.11 Exposing Flagged or Suspected Underground Facilities within the Dig or Drill Zones

Use vacuum excavation or hand dig to expose (pothole). The pothole(s) shall be made large enough and suitably spaced to accurately determine location, depth, orientation and line size.

If exposing for the purpose of crossing or repair, the pothole(s) shall extend a minimum of 2 feet (60cm) parallel from the line.

When constructing a new pipeline/flowline that runs parallel to an existing line within 5 feet (1.5m), the existing line shall be initially potholed to confirm size, depth and location, and then at appropriate intervals, to confirm alignment. Intervals shall be determined by the Project Manager and be documented on the relevant permit (Ground Disturbance Permit, Hot Work Permit, etc., as required in local permit system).

UGF's within 2 feet (60cm) or at a distance dictated by the local asset owner of a drill or dig zone shall be hand cleared and positively identified.

2.3 Overhead Utilities

When work is undertaken near electrical lines, the distance maintained from those lines shall also meet the minimum distances for electrical hazards as defined in Table 1: Minimum Radial Clearance Distances below.

NOTE: This procedure primarily focuses on electrical overhead utilities; however, other hazards shall be taken into consideration when performing work.

Table 1 Minimal Radial Clearance Distances *

Normal System Voltage Kilovolts (kV)	Required Minimal Radial Clearance Distance (feet/meters)
0 – 50	10/3.05
51 – 100	12/3.66
101 – 200	15/4.57
201 – 300	10/6.1
301 – 500	25/7.62

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501 – 750	**35/10.67**
750 - 1000	**45/13.72**

* For those locations where the utility has specified more stringent safe distances, those distances shall be observed.

2.3.1 Local Utility Requirements

The Project Manager (PM) shall research and determine if the local, responsible utility has more restrictive requirements than those stated in Table 1 above.

2.3.2 Guy Wires

To prevent damage, guy wires shall be visibly marked and work barriers or spotters provided in those areas where work is being conducted. Additionally, when working around guy wires, the minimum radial clearance distances for electrical power shall be observed.

2.3.3 Safe Work Conditions

When working around overhead utilities and guy wires, one or more of the following four conditions shall be met:

- The utility company shall confirm, preferably in writing, that power is de-energized.
- Minimum radial clearance distances shall be established and maintained according to Table 1 unless a change is authorized through the exceptions process. (Refer to Section 5.5 Exceptions Process and the *Management of Change* Operating Procedure (OP1037).
- Where utilities voltages cannot be verified, use Figure 1: Example Voltages of this section as guidance. However, voltages can be higher than those depicted in Figure 1.
- If insulating blankets are used to isolate a power line, they shall be placed by a utility company or qualified contractor. The utility company/contractor shall also determine the minimum safe operating distance and provide the information in writing.

2.3.4 Safe Work Practices

When working around overhead utilities and guy wires, the following safe work practices shall be observed:

Before work starts:

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- A RA shall be conducted to identify hazards and controls. (Refer to the *Work Risk Assessment* Operating Procedure (OP1011). If the risk is classified as a 'substantial' risk level or higher, a permit shall be required.

- A daily tailgate safety meeting shall be completed with the involvement of all staff and contractors at the location of the overhead hazard or guy wire. (Refer to the *Tailgate Safety Meeting* Operating Procedure (OP1033).

- The power or utility authority shall be notified of the work, and the utility shall give permission, where required. Permissions shall be as required by local regulations.

- Even if the lines have been de-energized, controls shall be maintained to prevent damage to lines.

- Operators and personnel handling tag lines or attaching or disconnecting loads shall wear rubber footwear and tested lineman's gloves of adequate voltage rating with protectors. Operators shall also have a rubber blanket or equivalent protection to use.

- Operators shall be instructed to stay on equipment when there is contact with any electrical line.

- As applicable, spotters, physical barriers or markings shall be used to maintain the appropriate minimal radial clearance distances from overhead utilities.

- A spotter is required where work is conducted directly outside of the minimal radial clearance distance and it is difficult for the operator to maintain the required clearances by visual means or physical barriers. If a spotter is utilized, the spotter's sole function shall be to verify that the minimum clearance distance is maintained and to give timely warning to the operator if that distance is violated.

- The work area shall be free of nonessential personnel and equipment.

- All equipment used in the vicinity of utilities shall be equipped with grounding chains.

- No equipment shall be transported with the boom or dump-bed up. Equipment shall be positioned so that it is parallel to the direction of travel.

- To minimize the possibility of the box of the truck traveling into power lines, a truck shall only off-load material if the truck is facing away from the power lines or parallel to those lines.

- Cranes or other equipment shall not be parked directly under any high voltage lines during suspension of work, overnight or over a weekend.

- Equipment shall not be serviced or refueled under overhead utilities.

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- Tag lines shall be of a nonconductive type when used near energized lines

2.3.5 Overhead Utilities Permit

A permit shall be required if the RA conducted classifies the residual risk as 'substantial' risk level or higher. (Refer to the *Permit Management Program* Operating Procedure (OP1038).

At a minimum, the *Overhead Utilities Permit* shall:

- Indicate preliminary planning work has been completed that describes, in part, overhead utility hazards and guy wires.
- Link the work to other permits, appropriate activities and SIMOPS. (Refer to the Simultaneous Operations [SIMOPS] Operating Procedures (OP1039).
- Address hazards identified in the RA.
- Be developed and communicated at the location of the work to potentially affected workforce immediately prior to implementing the work.
- Contain the proper signatures and signoffs. (Refer to the *Permit Management Program* Operating Procedure (OP1038).

The PM shall authorize and the contractor(s) doing the work shall accept and sign the *Overhead Utilities Permit*. The PM and contractor shall also sign to indicate that the job RA, the Task Safety and Environmental Analysis (TSAA), the *Overhead Utilities Permit* and the Tailgate Safety meeting have been carried out and risk controls are in place prior to starting work.

2.3.6 Utility Company Notification

The PM shall verify that the appropriate utility companies have been notified of planned work activities around overhead utilities, hazards and guy wires. The PM or contractor shall contact the local owning power utility to determine the power line voltages and obtain all applicable utility permits.

2.3.7 Tailgate Safety Meeting

Personnel performing work in proximity to overhead hazards shall conduct a tailgate safety meeting to review the overhead hazards, the RA and the job they are about to perform. The tailgate safety meeting shall be completed and reviewed with staff members immediately prior to beginning work around overhead utilities and guy wires at the location of the overhead hazard. The tailgate safety meeting shall be documented on the Health & Safety Tailgate Meeting form found on the Health & Safety Home Page under "Forms".

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2.4 Exceptions Process

If circumstances necessitate a variance from requirements contained in the *Overhead Utilities Permit,* an additional action as dictated in the *Management of Change (MoC)* Operating Procedure (OP1037), including a RA and an action plan, is necessary.

The following items, at a minimum, shall be considered as part of the MoC RA:

- Regulatory or legal requirements.
- Voltages.
- Proximity and impact to personnel, public dwellings and other developed areas such as buildings, roadways or parks.

Unless explicitly addressed in the MoC, all other provisions and requirements in this procedure shall apply.

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3. RESPONSIBILITIES

Project Managers (PM)

- Identify utility hazards by type, product, pressure, temperature or voltage and who owns them.
- Direct the completion of the RA, HASP, Utility Clearance, Overhead Utilities Permit and MoC, as applicable and necessary.
- Verify the credentials of the Utility Clearance Company.
- Establish the clear expectation to exercise 'Stop Work.'
- Obtain, in writing, authorizations and assurances from the local utility.
- Verify the assessment of non-traceable lines

Site Safety Officers (SSO)

- Participate in the Tailgate Safety Meeting whenever the scope of work requires a permit to work.
- Verify in the meeting that site personnel involved in a work activity are competent and correctly prepared for the work they will perform, and verify that workers have a clear understanding of the scope of work, hazards, controls and mitigations.
- Confirming that 'Stop Work' requirements and obligations are understood thoroughly by the workforce.
- Documenting the Tailgate Safety Meeting.
- Complete the RA, HASP, Overhead Utilities Permit and MoC, as applicable and necessary.
- Establish the clear expectation to exercise 'Stop Work.'
- Coordinate SIMOPS as applicable.

Staff Members

- Understanding their authority and obligations under the scope of work described in the Tailgate Safety Meeting.
- Signing the appropriate documentation that they attended the meeting.
- Understanding the requirements of 'Stop Work Authority'.

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Corporate Health and Safety Manager (CHSM)

- Responsible for monitoring compliance with the requirements of this program.
- Maintain associated documents, processes and training materials.
- Communicate lessons learned.

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APEPNDIX A - FORMS

Subsurface Clearance Review

Subsurface Clearance Log

Overhead Utilities Permit

Risk Assessment Tool

Tailgate Safety Meeting Form

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APPENDIX B - REFERENCES

OP1011 - Work Risk Assessment

OP1033 - Tailgate Safety Meeting

OP1037 - Management of Change (MoC)

OP1038 - Permit Management Program

OP1039 - Simultaneous Operations [SIMOPS]

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OPERATING PROCEDURE: 1021

EMERGENCY ACTION PLAN

PREPARATION AND APPROVALS

VERSION	AUTHORED/ DATE	REVIEWED / DATE	REVIEWED/ DATE	REVIEWED/ DATE	APPROVED/ DATE
Ver. 0	N.Reardon/Aug2003	CSO/Sept2003	JAK/Sept2003	MPD/Oct2003	JAK/ Oct2003
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1. PURPOSE

Haley & Aldrich staff members must be prepared to respond to many types of emergency situations that may occur on company property or facilities, project sites or during travel. It is imperative that the safety of staff members, subcontractors, guests, visitors and bystanders be a priority during any emergency.

All staff members of Haley & Aldrich shall use the policies and procedures contained in this Plan as a guide for emergencies. This Plan is designed to provide staff members and other responders such as the police or fire department with an overview of their duties and responsibilities during an emergency.

Conveying the information contained in this document to Haley & Aldrich staff members through training is a critical aspect of this Emergency Action Plan (EAP).

In general, emergency action plans shall incorporate the following hierarchy of protection:

1. **People:** Staff members, on-site personnel, visitors and the public;
2. **Environment:** Environmental resources which may be affected by the emergency;
3. **Property & Equipment:** Personal property and owned or rented equipment.

1.1 Mission Statement

The Emergency Action Plan will provide a framework for the communication network and actions to be implemented in the event of a crisis at a Haley & Aldrich office or worksite. The plan will (1) outline the decision making process to evaluate the degree of severity of the crisis situation, (2) evaluate the potential impact of the situation on the safety and security of Haley & Aldrich personnel, subcontractors and visitors, and (3) develop and implement the appropriate course of action in response to the crisis situation.

1.2 General Overview of the Plan

Response to an emergency affecting Haley & Aldrich is a cooperative effort between on-site personnel and local government agencies such as police, emergency medical personnel, and the fire department. This cooperative effort is intended to allow for strong lines of communication. The Plan is designed to ensure that all Haley & Aldrich staff members understand their role and responsibilities during emergencies.

A Health & Safety Plan shall be prepared for all Haley & Aldrich field operations, refer to OP1010 *Health & Safety Plans*. The current HASP template is located at HANK\Client Delivery\Health & Safety\Health & Safety Plan Templates\HASP Template Revision 5

Section 1.0 of the HASP is reserved for critical emergency information, including:

- Primary emergency contacts, including names, work and mobile telephone numbers for company personnel, suppliers and client contacts.

- Other useful contact numbers, such as those for police, medical emergency and

ambulance services, fire department, regulatory agencies, utilities and site representatives or owners.

- Map and route to medical facilities.
- Names of preferred occupation health professionals.

Section 8 of the HASP is reserved for contingency plans and contains information such as:

- Names of first aid-trained personnel.
- Locations of first aid kits, fire extinguishers and spill kits.
- Evacuation procedure, including but not limited to: muster areas, personnel count process, and communication plans.
- Shelter-in-place procedure

1.3 Emergency Response Plan

An Emergency Response Plan should be in place at each site location. Appendix B – Emergency Response Plan Template gives an outline of the information to include in an Emergency Response Plan.

1.4 Emergency Preparedness

With the exception of very small incidents, Haley & Aldrich typically does not participate in emergency response activities. In this regard the typical Haley & Aldrich response is to follow the direction of our client contact and shelter-in-place or evacuate as required by site conditions. Haley & Aldrich staff members will attempt to mitigate incipient stage emergencies with equipment on-site only after notification of the emergency has been transmitted to site personnel, emergency equipment is readily available at the site of the emergency and staff members have been trained in the use of the emergency equipment. Should a more robust response to on-site emergencies be required, and Haley & Aldrich is responsible for providing those services, Haley & Aldrich will contract those services to a third party.

The equipment necessary for response to emergencies shall be readily available to Haley & Aldrich staff members. The staff members shall be trained on how to use emergency equipment and to identify and anticipate emergencies specific to a particular site and the activities being conducted therein.

Preparedness for emergencies shall include the following:

- Procedures and training in place to verify appropriate reporting and response.
- Communication capability and backups for adverse emergency conditions, including weather and vapor releases from site operations or neighboring sites.
- Emergency signals from neighboring facilities that could impact the work site.

- Signage and labeling of on-site facilities and materials, which shall comply with the OP 1014 *Hazard Communication* and legal and regulatory requirements to provide adequate warning to emergency responders (e.g., the National Fire Protection Association 704 diamonds). Material Safety Data Sheet (MSDS) information shall be made available onsite per regulatory requirements.

- Meetings with local fire, police, ambulance and other emergency service providers to familiarize them with the nature and associated hazards of the facility.

- Evacuation and muster plans (in alignment with the operating site), where applicable.

- First aid kits

- Food, drinking water, clothes and blankets and climate protection gear, as necessary.

- Fire protection equipment, such as fire extinguishers.

- Vapor detectors to monitor on-site or off-site exposures.

- Spill response materials, such as absorbent pads, disposal drums, shovels and wetvacs.

- Other items as identified in permits or risk assessments associated with the specific site work.

Agreements should be made with client operations, where the site is controlled by our clients, to obtain needed supplies. Agreements shall be made with stakeholders (e.g. whether Haley & Aldrich and its contractors will be self-sufficient for emergencies or to what degree the operating site resources will assist with emergencies).

1.4.1 Emergency Action Alert

An Emergency Action Alert is defined as any condition which exists (or is likely to exist) that endangers the safety of people or could cause property damage. Examples of situations that qualify as Emergency Action Alerts are medical emergencies, fires, severe weather, and/or bomb threats. These situations require the activation of the site-specific Emergency Action Plan. However, hazardous material spills, mass disasters, civil disturbances and other emergency conditions may arise that could also require the use of these emergency procedures. Should a staff member receive information regarding any type of crisis that may require the activation of the Emergency Action Plan and/or the partial/total evacuation of the facility, the Regional Health and Safety Coordinator (RHSC) will be notified via telephone.

NOTE: Emergency action may be initiated using any one of the following communication methods: telephones (including mass text messages), public address systems, word-of-mouth, or horns or alarms or manual pull box alarms that may be located throughout the facility. Wherever stationed, all staff members should familiarize themselves with the site-specific notification procedures, the use of emergency notification equipment, and identify the closest location of any

emergency notification equipment.

1.5 Haley & Aldrich Emergency Action Response

Each Haley & Aldrich office has a senior staff member, RSHC or, in the case of field activities, identified staff member, who will be responsible for coordinating emergency response activities for that site. In general, these individuals will act as the "Incident Commander" in emergency situations. Should these individuals not be available at the time of the emergency, these duties will fall to the next ranking individual at the site.

2. PROCEDURE

Incidents require prompt reporting, investigation and documentation as specified in OP 1016 *Recordkeeping and Reporting*.

Response plans to emergencies shall be site-specific and may include, but are not limited to:

- Natural Disasters
- Utility Strikes or Failures Facility Failures
- Equipment Failures
- Fires
- Chemical Releases Explosions Accidents
- Medical Emergencies
- Security violations
- Off-site Impacts
- Third Party Media

The HASP for each site shall have a Contingency Plan. This section shall address the response to all emergencies based on the risk assessment

Examples include:

- Confined space rescue
- Drilling or excavation near live utilities.
- High-angle rescue
- Rescue from excavation
- Unexpected toxic gas or material exposure.
- Water Rescue
- Working alone.

Once it is determined that an incident has occurred or is about to occur, a systematic approach to the emergency will be established to respond to the incident.

2.1 Fire Emergencies

This section of the EAP will be implemented in the event of (1) A fire alarm activation OR (2) A fire is discovered by a facility occupant OR 3) A bomb threat is received.

Because of the inherent risk of fire in the building, it is necessary to address appropriate response actions to fires.

2.1.1 Alarm Activation & General Evacuation Procedures

Any staff member or visitor that becomes aware of a fire shall immediately activate the facility fire alarm system or initiate notification procedures as detailed in the site-specific HASP. For office locations or sites with fire monitoring systems, the fire alarm system will in turn notify all facility occupants that a fire emergency exists. This is accomplished by pulling a lever on a manual pull station, which in turn will sound an

audible alarm.

All staff members and visitors will regard any activation of a fire alarm as a true fire emergency unless there has been previous notification of the alarm system being tested. The office administrator or Site Safety Officer (SSO) shall secure the office sign-in log to determine who was in the office at the time of the alarm. Visitors shall be escorted from the site by the staff member they were meeting.

When an alarm is activated, all occupants will immediately leave the site using the escape routes posted at each site. Building evacuation procedures are outlined in more detail in Section 2.9 of this EAP.

Once out of the building, all staff members and visitors shall congregate in the designated assembly area(s) to determine if someone is missing. This headcount shall be performed to the extent possible as personal safety, time and capabilities permit. No staff member or visitor shall leave the assembly area, either to re-enter the facility or leave the property, until all known staff members and guests are accounted for and until advised to do so by the RHSC or other designee (e.g., Business Unit General Manager, client contact, fire department, etc).

The local responsible staff member will provide information as necessary and/or requested to the fire department. This information may include, but is not limited to:

- Location of the fire;
- Status of the evacuation, including personnel missing that may still be in the facility (to the extent that this information is available); and
- Special hazards associated with the facility that may impede firefighting efforts.

2.1.2 Extinguishing Fires

Those staff members trained in the use of fire extinguishers and that have been given the authority to operate a fire extinguisher may extinguish incipient stage fires (see definition below). This is only acceptable when there are no hazards beyond the normal duty of extinguishing a normal incipient stage fire.

Incipient stage fires are defined as:

A fire which is in the initial or beginning stage and which can be controlled or extinguished by portable fire extinguishers, Class II standpipe, or small hose systems without the need for protective clothing or breathing apparatus.

Staff members are not qualified to fight interior structural fires.
Interior structural fires are defined as:
Interior structural fire fighting is the process of fire suppression and/or rescue inside of buildings or enclosed structures which are involved in a fire situation beyond the incipient stage. This definition is met if the structural elements of the building catch fire.

2.1.3 Return to Work

No staff member is to return to the area of the fire until it is safe to do so. The fire department and building/facility personnel will assess the area for damage and safety hazards once a fire, which has caused minor to major building damage, has been extinguished. Fires that have caused considerable damage may require an extensive assessment by qualified professionals. Through the collaborative efforts of the fire department, building engineers, and maintenance personnel, a thorough assessment of the area will be conducted to determine the safety and integrity of the structure. Once the fire department and/or other qualified individuals have determined that the structure is safe, an "all-clear" will be signaled and staff members may return to their work areas. It is possible that an "all clear" is signaled but staff members will not be able to return to their work areas based on the assessment. These staff members may be sent home or to another, safe area of the building to continue their work.

In the event excessive damage has occurred, the area will be barricaded and signs posted to inform staff members and other occupants of the requirements of not entering the structure. The appropriate authorities, company personnel and insurance company(s) will conduct proper investigations and inspections to assess the damage.

2.1.4 Post Emergency Action

All damaged fire protection equipment will be promptly identified, repaired, or removed from service. Any extinguishing equipment that has been dispensed must be immediately removed from service and may not be placed back into service until the extinguishing agent has been replaced. In addition, all fire extinguishers that have lost the acceptable amount of pressure must be removed from service until the extinguishers' pressure has been replenished. Work may not resume until adequate fire protection has been restored to the work site.

In the case of a possible re-ignition of the fire, a staff member properly trained in extinguishing fires will stand by with fire equipment, such as a fire extinguisher or water hose line, until the possibility of re-ignition has been eliminated.

If conditions are such that the area must be barricaded and unauthorized individuals are not permitted to enter the area, security personnel or a designee will be posted at the designated area to prevent unauthorized entry.

Any staff member or visitor that has suffered any type of injury as a result of the fire (e.g., smoke inhalation, burns) must receive the necessary medical attention and fill out an injury incident report as detailed in OP 1016 *Recordkeeping and Reporting*. An injury report can be filled out by a witness to the injury if the individual who sustained the injury or injuries is unable to complete the form. Injury forms are available from the RHSC and should be returned to the RHSC upon completion.

The RHSC must promptly complete an incident report describing the fire. The detail of the report will vary based on the size, extent, & severity of the fire. The final incident report describing the fire must be submitted to the CHSM upon completion. Outside

professional resources should be considered if arson is suspected in any investigation.

2.2 Bomb Threats

Bomb threats may be received via telephone, e-mail, word-of-mouth, or written notice. Additionally, suspicious packages may be received via mail. Procedures for bomb threats received by telephone are outlined in the "Telephone Bomb Threat" section below. Procedures for bomb threats received by e-mail, word-of-mouth, or written notice are outlined in the "E-mail, Word-of-Mouth, or Written Notice Bomb Threat" section below. Procedures for handling suspicious packages are outlined in the "Suspicious Packages" section below.

2.2.1 Telephone Bomb Threat Procedures

BE CALM, BE COURTEOUS, AND LISTEN. DO NOT INTERRUPT THE CALLER.

1. All personnel that handle incoming calls should acquaint themselves with the bomb threat telephone log (see Appendix A). This log should be completed in all cases when a threatening call is received.

2. When the call is received, activate the call recording feature at the main switchboard (if possible) and try to keep the caller talking as long as feasible by following the bomb threat telephone log.

3. Try to ascertain the following information if the bomb threat telephone log is not available:
   a. Where is the bomb located? Facility area?
   b. When is the bomb going to explode?
   c. What kind of bomb is it?
   d. What kind of package is the bomb contained in??
   e. Why was the bomb placed?
   f. Who is speaking?
   g. How does the speaker know so much about the bomb?

4. After the phone conversation has ended, complete the basic requirements below to help respond to the incident:

   a. Write out as much of the message as possible in its entirety and any other comments on a separate sheet of paper and attach it to the bomb threat telephone log or other sheet of paper that you kept notes about the conversation on. DO THIS RIGHT AWAY. YOU WILL FORGET IMPORTANT DETAILS AS TIME PASSES.

   b. The staff member shall then notify the senior site manager as soon as possible by telephone or in-person and inform them of the situation. If the senior site manager not available, the staff member shall notify his or her supervisor by telephone or in-person. If the supervisor is not available, the Business Unit General Manager or CEO will be notified. The supervisor, Business Unit General Manager, or CEO (as

applicable) will then take on the role of the senior site manager.

c. The senior site manager will decide to the extent possible if the threat is viable and thus, if building security and the local police and/or fire department should be notified. In general, however, ALL BOMB THREATS SHOULD BE TAKEN SERIOUSLY.

d. The senior site manager will then decide to the extent possible if a facility evacuation is warranted (in general, evacuation will be necessary). If it is warranted, evacuation shall take place as outlined in the Fire Emergencies section. Evacuation may be initiated by the senior site manager by tripping the building's fire alarm. Again, all bomb threats should be taken seriously and the building should be evacuated when a threat is received.

e. Staff members shall be informed to not touch any suspicious or unfamiliar objects.

f. The senior site manager will assist in coordinating the building's security staff and informing them of the situation to the extent possible as personal safety, time and capabilities permit.

g. The senior site manager will relinquish all authority of the emergency when the legal authorities arrive on site. All staff members are expected to fully cooperate with authorities.

h. The senior site manager will participate in any post-incident evaluation regarding the emergency. Other staff members who are asked to participate in a post-incident evaluation are expected to cooperate fully.

2.2.2 E-mail, Word-of-Mouth, or Written Notice Bomb Threats

Upon receipt of a bomb threat by e-mail, word-of-mouth, or written notice, the staff member who initially receives the threat shall immediately notify the senior site manager by telephone or in person. If the senior site manager is not available, the employee should notify his or her supervisor by telephone or in-person immediately. If the supervisor is not available, the Business Unit General Manager or CEO should be notified. The supervisor, Business Unit General Manager, or CEO (as applicable) will then take on the role of senior site manager.

After the senior site manager has been notified, he or she will follow the following procedures:

1. The senior site manager will decide to the extent possible if the threat is viable and, thus, if building security and the local police and/or fire department should be notified. In general, however, ALL BOMB THREATS SHOULD BE TAKEN SERIOUSLY.

2. The senior site manager will then decide to the extent possible if a facility

evacuation is warranted (generally, evacuation will be necessary). If it is warranted, evacuation shall take place as outlined in the Fire Emergencies section. Again, all bomb threats should be taken seriously and the building should be evacuated when a threat is received.

3. Staff members shall be informed to not touch any suspicious or unfamiliar objects.

4. The senior site manager will assist in coordinating the building's security staff and informing them of the situation to the extent possible as personal safety, time and capabilities permit.

5. The senior site manager will relinquish all authority of the emergency when the legal authorities arrive on site. All staff members are expected to fully cooperate with authorities.

6. The senior site manager will participate in any post-incident evaluation regarding the emergency. Other staff members who are asked to participate in a post-incident evaluation are expected to cooperate fully.

2.2.3 Suspicious Packages

Once a package has been identified as potentially dangerous, the staff member who initially received or encountered the packaged and identified it as suspicious shall clear the immediate area without causing any unnecessary alarm or panic to guests or other staff members. Additional staff members may assist with clearing the area.

The staff member who initially received or encountered the package shall then notify the senior site manager by telephone or in-person. If the senior site manager is not available, the staff member should notify his or her supervisor by telephone or in-person immediately. If the supervisor is not available, the Business Unit General Manager or CEO should be notified. The supervisor, Business Unit General Manager, or CEO (as applicable) will then take on the role of senior site manager.

The senior site manager will follow the following procedures after being informed of a suspicious package:

1. The senior site manager will decide to the extent possible if the threat is viable and, thus, if building security and the local police and/or fire department should be notified.

2. The senior site manager will then decide to the extent possible if a facility evacuation is warranted. If it is warranted, evacuation shall take place as outlined in the Fire Emergencies section of this document.

3. Staff members shall be informed to not touch any suspicious or unfamiliar objects.

4. The senior site manager will assist in coordinating the building's security staff

and informing them of the situation to the extent possible as personal safety, time and capabilities permit.

5. The senior site manager will relinquish all authority of the emergency when the legal authorities arrive on site. All staff members are expected to fully cooperate with authorities.

6. The senior site manager will participate in any post-incident evaluation regarding the emergency. Other staff members who are asked to participate in a post-incident evaluation are expected to cooperate fully.

2.2.4 Bomb Searches

Staff members familiar with the facility and its contents will assist in conducting the bomb search when requested by legal authorities. All search activities will be conducted by an outside, trained agency (e.g., State or Local Police Bomb Squad). Staff members will generally NOT participate in any bomb searches.

2.3 Medical Emergencies

Staff members should be aware of the various types of medical emergencies that may take place at the offices or on job sites. Examples of injuries or illnesses that may occur at Haley & Aldrich include but are not limited to:

Lacerations (i.e., cuts); Seizures; Back injuries; Heart problems; Burns; Choking; Sprains; Slips, trips, and falls; and/or Chemical irritation; Intoxication Asphyxiation (i.e., suffocation);

2.3.1 First Aid Emergencies

First aid medical emergencies are situations that require only on-site first aid to treat the injury or illness. Outside medical professionals or other emergency responders are not notified in these situations.

Staff members that have been trained in Cardiopulmonary Resuscitation (CPR), use of a defibrillator, and/or basic First Aid may assist in medical emergencies that occur within or near the Building. These staff members are not expected to provide medical assistance that they do not feel comfortable or qualified to perform.

Basic staff member responsibilities during first aid emergencies include:

All staff members must know where the nearest first aid kit is located prior to the commencement of any type of physical work. The kit must be easily accessible and have the materials listed below;

Supplies for First Aid	***Type of Supply Required by Number of Staff Members***			
	1-5	6-15	16-200	over 200
Dressings in adequate quantities consisting of:				
1. Adhesive dressings	X	X	X	X
2. Adhesive tape rolls, 1-inch wide	X	X	X	X
3. Eye dressing packet	X	X	X	X
4. 1-inch gauze bandage roll or compress		X	X	X
5. 2-inch gauze bandage roll or compress	X	X	X	X
6. 4-inch gauze bandage roll or compress		X	X	X
7. Sterile gauze pads, 2-inch square	X	X	X	X
8. Sterile gauze pads, 4-inch square	X	X	X	X
9. Sterile surgical pads suitable for				
pressure dressings			X	X
10. Triangular bandages	X	X	X	X
11. Safety pins	X	X	X	X
12. Tweezers and scissors	X	X	X	X
* Additional equipment in adequate quantities consisting of:				
13. Cotton-tipped applicators			X	X
14. Forceps			X	X
15. Emesis basin			X	X
16. Flashlight			X	X
17. Magnifying glass			X	X
18. Portable oxygen and its breathing equipment				X
19. Tongue depressors				X
20. Appropriate record forms	X	X	X	X
21. Up-to-date `standard' or `advanced'				

*To be readily available but not necessarily within the first-aid kit.

Each kit must be inspected monthly and supplies replenished, as needed, to ensure that the materials are available;

Kits must be kept in an orderly arrangement and clean from dust, debris and chemical exposure. All fluids and materials that have expiration dates must be checked three times per year and replaced when needed;

Prior to staff members being designated to perform first aid services they must receive approval from the CHSM and receive adequate first aid training. This training shall address the basic concepts of first aid, cardiopulmonary resuscitation, blood borne pathogens, and special requirements dealing with the hazards that might be encountered at the facility which may include:

- Electrocution

- Chemical burns
- Crushing and pinching injuries
- Dehydration
- Fall related injuries
- Seizures;
- If the injury appears that it will require more sophisticated medical services, immediately have someone, such as a bystander, contact emergency medical services (i.e., dial 911);

2.3.2 First Responder to a Medical Emergency

Never jeopardize your own safety to provide medical attention to a co-worker. Assess the area to determine the possible cause of the injury (e.g., chemical spill, electrocution) prior to entering an area in order to prevent your own injury.

Never enter a fire-engulfed area in an attempt to rescue or assist a trapped and/or injured person.

Dial 911 and provide the dispatcher with the following information:

- Type of emergency;
- Specific location of the victim;
- Condition of the victim;
- Any dangerous conditions that may impede medical personnel from getting to the victim;
- If the injury or emergency involves a chemical, provide the name of the chemical and have Material Safety Data Sheet (MSDS) available. MSDS's are available through the RHSC for each office.
- Comfort the victim if possible and try not to move him or her until emergency medical services have arrived.
- Attempt to provide the level of first aid that you feel comfortable with in helping suppress any symptoms, bleeding, etc. DO NOT ATTEMPT TO PROVIDE ANY TYPE OF FIRST AID THAT YOU ARE NOT FAMILIAR WITH OR HAVE NOT BEEN TRAINED IN.
- Send someone outside the facility at the nearest gate or building entrance, if possible, to "flag down" the emergency medical service when they reach the

vicinity of the facility.

- Do not touch any spilled body fluids. Contact appropriate contractors post-incident to facilitate this type of clean-up. Barricade any areas where body fluids have been spilled until these medical waste clean-up contractors have arrived.

- Once the victim has been cared for and is transported, witnesses to the injury should report to the RHSC to fill out an official Accident Report.

2.4 Civil Disturbances

Civil disturbances include all of the following: bomb threats, arson, violence, vandalism, labor strikes, and riots. In general, staff members are not trained to handle these types of emergencies. It is the responsibility of law enforcement agencies to respond to these types of disturbances.

Bomb threats are specifically discussed in Section 2.2 of this document.

It is possible that staff members may inadvertently become involved with such disturbances. Staff members are expected to respond logically and with common sense in such an event. Do not take an active role in defusing or mitigating the disturbance.

In general, all civil disturbances shall be responded to in the following manner:

1. Notify the senior manager on-site.

2. The senior manager on-site will immediately contact the local police department and/or other emergency response agencies as needed.

3. Staff members will be evacuated if needed, or be alerted to any potential dangers. NO staff members will attempt to mitigate any civil disturbance.

4. If the civil disturbance is a bomb threat, follow the procedures outlined in Section 2.2 of this plan.

2.5 Hazardous Materials Spills

2.5.1 General Overview of Response to Hazardous Chemicals

Haley & Aldrich does not respond to major chemical spills or releases. It is the policy of the company to respond to spills that Haley & Aldrich has the resources and ability to mitigate. Any clean up of a chemical spill that requires the use of any type of respiratory protection is strictly prohibited.

This section is a guide to assist staff members in evaluating spills and provides technical assistance for responding to spills and releases that the senior site manager or designee has determined are within the scope of Haley & Aldrich's capabilities.

2.5.2 First Responder Responsibilities

1. The staff member discovering the spill shall immediately notify the senior site manager.

2. Initiate the emergency notification system if the release warrants an evacuation.

3. The senior site manager will determine if the area should be immediately evacuated and barricaded. Barricade the area only if it can be done safely.

4. The senior site manager will also determine if the spill can or cannot be handled in-house, has entered the municipal or local sewer system, or has left the premises under Haley & Aldrich's control.

5. If the spill can be handled in-house, the senior site manager will determine the procedures necessary to conduct proper clean-up. If the spill cannot be handled in-house, the senior site manager will contact an independent Hazardous Waste Clean-up contractor to conduct the clean-up.

6. If the spill or release has left property under Haley & Aldrich's control, or entered the sewer system, the local client contact or fire department shall be contacted immediately.

First Responder Operations requires 8 hours of training. Hazardous Material Technician level requires a minimum of 24 hours of training. At this time, Haley & Aldrich has only a few staff members trained at this level. Therefore, spills that are determined by the senior site manager to not be manageable in-house must be cleaned-up by a qualified contractor.

2.6 Natural Disasters

2.6.1 Winter Storms

Winter storms can create several problems that may challenge Haley & Aldrich in its attempt to protect the well-being of its personnel and prevent damage to property. These problems may include but are not limited to:

- Hazardous walking conditions;
- Inaccessibility to valves, hydrants, fire hoses, and fire pumps; Roof collapse due to excessive accumulation of ice and/or snow; Evacuation difficulties;
- Driving conditions that impede emergency vehicles from accessing the property; and
- Stranded guests at the building (possibly many guests)

Once it has been determined that an emergency condition exists, the senior site manager will coordinate such tasks as monitoring of snow removal procedures, such as:

- cleaning snow and ice from exits, entrances, and fire hydrants;
- removing snow from roofs in areas subject to drifting; and
- inspecting and clearing roof drains
- monitoring weather reports from the National Weather Service

After the storm has ended:

An immediate damage assessment will be made by the senior site manager and temporary repairs will be undertaken as soon as possible by the facility owner.

If damage to the building or site due to the severe weather presents a danger to staff members, the area or building will be evacuated as necessary until required repairs have been made and the area is deemed safe for occupancy; and

Any remaining snow will be removed, with priority given to valves, hydrants, pump houses, and fire department access routes.

2.6.2 Tornadoes

It is customary for the National Weather Service to alert citizens of impending tornadoes by stating that there is a "WATCH" or "WARNING."

A tornado WATCH implies that a tornado is expected to develop.

A tornado WARNING means that a tornado has been sighted and residents in the immediate area should take cover.

Any staff member who learns that the National Weather Service has issued a tornado “WATCH” for the area where the work site is located should alert the senior site manager. After the senior site manager has been alerted, he or she may elect to send “spotters” to various locations of the site or building, depending on the direction of the storm or weather hazard, to watch for any approaching tornadoes. The senior site manager will keep updated on developments from the National Weather Service.

Immediately upon receiving a report that a tornado “warning” has been issued in the area, the senior site manager will alert all staff members of the approaching tornado by using the Public Announcement System within the office or alert notification system at jobsites.

Staff members and guests will be required to move to the lowest level of the building or other designated site safe area and will be instructed to follow the directions of the senior staff member present.

After the tornado has passed, search and rescue operations will begin immediately, if appropriate. In addition, the following actions will occur if needed:

1. The facility owner will be contacted and will take action to protect personnel and property from further harm (e.g. temporary repair or covering of openings

in the buildings and clearing debris and water from roofs to prevent the roof from collapsing).

2. If damage due to the tornado presents a danger to staff members, the building or area will be evacuated as necessary until repairs have been made and the area/building is deemed safe for occupancy;

3. The senior site manager will ensure that the fire protection system is intact and will be on alert for possible fires or flooding.

4. Salvage operations will be initiated only upon determination that any threats to human life have been eliminated.

2.6.3 Severe Weather Emergency Action Communications

Severe weather can include, but is not limited to heavy rains, tornadoes, hail, snow, ice, frequent lightning, high winds, severe thunderstorms and hurricanes. Notification of severe weather will be received through local television or radio stations or through verified word-of-mouth from Haley & Aldrich staff.

2.6.4 General Response for Adverse Weather Conditions

2.6.4.1 Severe thunderstorm, winter storm or tornado WATCH:

When a severe thunderstorm warning, winter storm warning, or tornado watch is issued, the senior site manager will monitor the weather conditions and may dispatch a weather spotter to an appropriate area of the building, if necessary.

2.6.4.2 Severe thunderstorm, winter storm or tornado WARNING:

When a severe thunderstorm warning is issued, actions to be taken by the senior site manager include:

- If staff members need to be informed of the situation, provide a briefing on known information;
- Inform staff members of any actions that will be taken; and
- If necessary, instruct staff members to move to a safe area of the building.

2.7 Training

Once the Emergency Action Plan is finalized, a training plan will be developed to acquaint all staff members with its procedures. Staff members shall receive adequate basic training in the procedures outlined in this document. During new staff member orientation, the RHSC will review the EAP with the new staff member. A copy of the plan shall be provided to the staff member at that time.

The EAP must be located on a bulletin board in a conspicuous area at all times so that all staff members have an opportunity to review it.

2.8 Communications

2.8.1 Communicating with the Media

Staff members shall refrain from giving information regarding emergency situations to the media or other various emergency organizations when at work or away from their job, and shall direct all inquiries to Haley & Aldrich Business Unit General Managers. Information conveyed to the media must be accurate and factual. This requires ample time to investigate the emergency, including speaking with involved individuals and the authorities. If needed, and only after consulting with Haley & Aldrich senior management, Haley & Aldrich will establish a press release and it shall be reviewed for accuracy by the senior site manager or other individual who served as Incident Commander during the emergency.

2.8.2 Communicating with Emergency Organizations (Police, Fire, City, Hospital)

All staff members are expected to cooperate fully with authorities. It is crucial to maintain a complete and straight line of communication with Emergency Organizations during an incident. If possible, the senior site manager will act as a liaison between staff members and the responding emergency organization.

2.8.3 Communicating with Families

Haley & Aldrich's Human Potential Manager will maintain accurate records of staff member, addresses and phone numbers so that family members can be contacted if necessary.

Staff members should refrain from contacting family members of co-workers who may have been injured in an emergency. Such contacts should be made only by the Human Potential Manager or their designee due to the emotional impact such information may have on family members and the need to ensure that accurate and correct information is communicated.

2.9 Evacuation Procedures

Staff members should familiarize themselves with this section prior to the commencement of work by physically walking the different evacuation routes as if an actual emergency were taking place. Staff members should examine posted evacuation plans to familiarize themselves with escape routes. Periodically, Haley & Aldrich may conduct drills to assure that all staff members are familiar with the evacuation procedure. During building evacuation, staff members should proceed out of the building calmly.

After leaving the building, staff members will assemble in one of the designated assembly areas during an emergency. Because of the nature of our work and the unique egress patterns, there is no primary rally area for any one person or work function. However, it is imperative that ALL staff members remain in a rally area until an "All Clear" has been announced. Outdoor

areas where staff members should assemble during an emergency vary among each office location. Each office must designate a specific outdoor assembly area or areas at least 200 feet away from the building and must communicate the location of this area(s) to all staff members.

3. RESPONSIBILITIES

Corporate Health and Safety Manger (CHSM) / Regional Health and Safety Coordinator (RHSC)

The CHSM, through the RHSC's is responsible for ensuring that all work sites adequately address emergency actions for their particular work sites through Emergency Action Plans or HASPs and maintaining this OP.

Senior Site Managers & Project Managers (PM)

Senior site managers and project managers are responsible for assuming control over site related emergencies and ensuring the safety of staff members and site assets during emergency situations.

HASP Writer

The Health and Safety Plan (HASP) writer is an individual who has knowledge of all work activities being performed on the work location at each phase of the project. The HASP writer shall:

- Evaluate the project scope of work and determine applicable OPs.
- Verify that the applicable OPs and regulatory requirements from the Contractor program are included in the site-specific HASP.
- Update the HASP as needed.

Staff Members

Staff members are responsible for identifying and notifying senior site managers of abnormal conditions which may result in an emergency and following direction on responding to those emergencies as appropriate and within their skill set.

4. REFERENCES

Occupational Health and Safety Regulations (OSHA), 29 CFR 1910.38, Employee Emergency Plans

5. RELATED HALEY & ALDRICH PROCEDURES

OP1010 - Health & Safety Plans

OP1011 - Work Risk Assessments

OP1014 - Hazard Communication

OP1016 - Recordkeeping & Reporting

OP1028 - Job Hazard Analyses

APPENDIX A – BOMB THREAT TELEPHONE LOG

BOMB THREAT TELEPHONE LOG

*****STAY CALM. CREATE AUDIO RECORDING OF CALL IF POSSIBLE*****

Date:	
Time call received:	
Time call ended:	

QUESTIONS TO ASK

1. When is the bomb going to explode?

2. Where in the building is the bomb located right now?

3. What kind of bomb is it?

4. What does it look like?

5. Why did you place the bomb?

6. Who is speaking?

7. How do you know about the bomb?

DESCRIPTION OF CALLER'S VOICE & TONE OF VOICE:

MALE	FEMALE	YOUNG	MIDDLE-AGED	OLDER
ANGRY	CALM	PLEASANT	NERVOUS	

Any distinguishing features of caller's voice (e.g., accents, etc.)?

Any background noise? What is it?

Is the voice familiar to you? If so, who do you think it sounds like?

OTHER NOTES

APPENDIX B - EMERGENCY ACTION PLAN TEMPLATE

This template should be used for Haley & Aldrich offices. The Contingency Plan format should be used for HASPs.

Emergency Response Plan Template

I. Purpose & Scope of plan

II. Notification guidelines to management and to agencies

III. Maps --- facility, community, plot plans, sensitive areas, etc.

IV. External Contacts / Emergency Information ---- business name, contact names and numbers

- Fire, Police, Regulatory Agencies, Hospitals, EMS, HAZMAT Contractors, Media -- Newspapers, TV Stations, Radio Stations, etc.

V. Local Resources -- company names, contact name, phone numbers, description of resources

- Oil Spill Response Contractors, Rental Equipment, Hotels, Banks, Food suppliers, Communications, Office Supply suppliers, mail service numbers, weather information numbers, IT Services, etc.

VI. Evacuation Procedures

VII. Incident Management Team org chart / description --- including Unified Command (ICS)

VIII. Incident Management Team descriptions -- and how to activate the team

- Checklists
- Roles & Responsibilities

IX. Emergency Operations Center (or Command Post) requirements, designation and backup location

X. Linked Plans

- Other emergency plans (hurricane, etc)
- Area Contingency Plans (agencies) etc.

XI. Plan Maintenance

- Schedule --- how often will it be updated
- Contact name --- who is responsible for maintenance
- Configuration Management; amendments documentation (what was changed, when, approval)

XII. Training & Exercising

- When, how, who, scope, etc.

XIII. Nonregulatory Reporting Guidelines (Incident & Near Miss Notification and Reporting Guidance Manual

XIV. Distribution list

- who receives copies

XV. Appendices:

- Forms --- notification forms, Threat Assessment Worksheet, Injury/Illness/Near-Miss.
- Glossary of terms
- Definition

OPERATING PROCEDURE: 1031

HEARING CONSERVATION

Haley & Aldrich

PREPARATION AND APPROVALS

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HEARING CONSERVATION PROGRAM

1. PURPOSE

The purpose of this procedure is to establish an Occupational Hearing Conservation Program as defined in the Occupational Noise Exposure standard (29 CFR 1910.95) for all Haley & Aldrich employees exposed at or above 85 dBA as an 8-hour time weighted-average (TWA). This program contains the following elements:

- An assessment of occupational noise exposures
- Annual audiometric tests of potentially exposed workers
- Maintenance of noise and hearing data records
- Noise abatement and/or administrative controls
- Availability of hearing protectors
- Employee training and education

An ongoing noise exposure evaluation program is required under the OSHA Standard for Occupational Noise Exposure (29 CFR 1910.95) when information indicates that any employee's exposure may equal or exceed an 8 hour Time-Weighted Average of 85 dBA. Monitoring shall be repeated whenever a change in production, process, equipment or control increases noise exposure to the extent that:

- Additional employees may be exposed at or above the action level or
- The attenuation provided by the hearing protectors being used by the employees may be rendered inadequate."

If after determining the noise level is at or above 85 dBA TWA, then it is required that Haley & Aldrich provide its exposed employees the following:

- Annual audiometric test
- Annual hearing conservation training
- Hearing protection
- Monitoring of employee occupational exposures
- Notification of monitoring results for representative exposures

1.1 Discussion

This procedure exceeds the minimum requirements for a hearing conservation program.

If the Noise level exceeds 90 dBA, the OSHA Occupational Noise Exposure standard requires that engineering and administrative control measures must be investigated, evaluated and where feasible, utilized to reduce employee exposures. It is important that any measure investigated, utilized, or evaluated to reduce the noise levels be documented.

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1.2 Application

This program applies to all places of employment where Haley & Aldrich employees work.

2. PROCEDURE

2.1 Managing the Hearing Conservation Program

All employees at Haley & Aldrich County who are exposed to a noise level of 85 dBA or above will be in the hearing conservation program and have their hearing checked annually by a licensed health care facility. All results of the hearing tests will be kept in Human Resources. Employees will be scheduled for testing one year from the date of the baseline testing and yearly thereafter.

If the Noise level exceeds 90 dBA, the OSHA Noise Standard requires that engineering and administrative control measures must be investigated, evaluated and where feasible, utilized to reduce employee exposures. It is important that any measure investigated, utilized, or evaluated to reduce the noise levels be documented. Suggested engineering measures to reduce noise:

- Contact the manufacturer for noise abatement suggestions
- The purchase of quieter equipment or routine maintenance to reduce noise levels
- Reduction of noise level at the source
- Substitution of materials (i.e., plastic for metal)
- Dampening or reducing surface vibration
- Increasing the distance between the employee and the noise source
- Enclosures or sound insulation material
- Relocation of job tasks which may be completed out of high noise areas
- Administrative Measures to Reduce Noise: When engineering measures alone reduce the noise below 90 dBA, administrative methods may be used to minimize employee exposure such as worker rotation from high noise levels to quiet areas.

2.2 Audiometric Testing

The two types of audiometric tests are annual and baseline tests. Annual audiometric testing is required for employees with an 85 dBA TWA or higher noise exposures and is conducted as part of the Haley & Aldrich Medical Surveillance Program. Testing can be done anytime during the day. Baseline audiometric testing is conducted when an employee is initially hired. The baseline is extremely important because it is the reference against which future audiograms are compared to determine the extent to which an employee's hearing is deteriorating. OSHA indicates that a baseline should be conducted within 6 months of hiring.

It is required that the baseline audiogram be preceded by at least 14 hours without exposure to workplace noise. Time that hearing protection is worn may be included as part of the 14 hours without exposure to noise. The medical surveillance provider shall also notify the employee that they need to avoid non-occupational noise exposure during the 14 hours prior the audiometric test. Documentation of this notification is strongly recommended.

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A retest audiogram can be conducted to verify or confirm a hearing threshold result. A retest is required under the following circumstances:

- If an employee has suffered a Standard Threshold Shift, the employer may obtain a retest within 30 days and use the results of the retest as the annual audiogram. A Standard Threshold Shift is a change in hearing threshold relative to the baseline audiogram of an average of 10 or more dBA at 2000, 3000, and 4000 Hz. If a Standard Threshold Shift has occurred, the employee must be informed in writing within 21 days of the determination. Employees will be trained in using hearing protectors, and in care of the hearing protectors. If the employee is already using hearing protectors, they will have to be retrained and refitted. If necessary, hearing protectors can be changed to a different type.
- The Audiologist or Physician can request a retest to confirm test results.
- When problems are suspected by the test administrator.

3. TRAINING AND AUTHORIZATION

Hearing Conservation Training is required annually for all employees with noise exposures of 85 dBA TWA or greater. The goal of the training is to orient employees to the purpose of hearing protection, the use of hearing protection and plant policy regarding the hearing conservation program.

The following topics will be included in the employee training of the hearing conservation program:

- The effects of noise on hearing: It can take many years to occur, and the employee may not realize the gradual hearing loss. The loss occurs without any pain and cannot be corrected by any known medical or surgical treatment. A good rule of thumb to remember is that if you have to raise your voice at a distance of three feet, you are in an area with a possible hazardous noise level. Repeated unprotected noise exposure will cause a permanent hearing loss. The hearing conservation program at Alexander County has been established to ensure that if you ever have a standard threshold shift, your noise exposure can be lessened by using engineering or administrative controls or more effective hearing protection. Thus, the problem can be controlled.
- The purpose of the annual hearing test and an explanation of the test procedures to monitor your hearing. Periodic audiometric testing provides an “early warning” of hearing disability. Factors such as noisy hobbies, ear infections, diseases of the ear as well as general illness may also cause hearing loss. All employees’ hearing will be checked upon employment and once a year thereafter. You will be notified of any changes in your hearing. You cannot “fail” the test and you will not lose your job due to the results of the test.
- The purpose of hearing protectors, instructions on selection, the advantages, disadvantages, fitting use and care. The proper use of hearing protection will prevent many types of hearing loss. You must wear the required hearing protection properly and regularly to reap the benefits of the protection. You should have already been fitted by human resources or trainer for your size and type of earplug. If you have any problems with the fit of your hearing protectors, contact the Corporate Health & Safety Manager (CHSM).

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4. RECORDKEEPING

Records are an important part of any effective hearing conservation program. The information contained in these records reflects the quality and effectiveness of the hearing conservation program.

A number of documents are required to be maintained under the OSHA Noise Standard once the "Action Level" had been initiated. Some of these records must be retained for specified periods as shown in the following table. It is also required that these records be provided, upon request, to employees, former employees, representatives designated by the individual employee and the Assistant Secretary of Labor.

The Following Records/Documentation is required by this procedure:

- Sound Survey (retain at least two years)
- Employee notification on the results of the sound survey
- Audiometric Tests (retain for at least the duration of employment)
  - Baseline
  - Annual
  - Audiogram Evaluation Requirements
  - Standard Threshold Shift Requirements
  - Audiologist Review
- Hearing Protection Used
- Hearing Conservation Training
- Audiometer Records
  - acoustic calibration check
  - exhaustive calibration check
  - biological calibration check
  - self-listening check
  - Recording hearing loss on the OSHA 300 log

5. RESPONSIBILITIES

5.1 Project Managers and Supervisors

- Read and understand instructional documents provided by the hearing protector manufacturer.
- Monitor the noise levels in their work areas.
- Provide additional on-the-job training if the employee is not thoroughly familiar with the equipment and/or written procedures.
- Maintain inventory inspection records of work area inspections.

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5.2 Employees

- Read and understand instructional documents provided by the manufacturer for the equipment used.
- Recognize the conditions that may lead to excessive noise exposure.

5.3 CHSM

- Understand the general reasons for this procedure.
- Coordinate medical surveillance for affected employees.
- Select hearing protectors for distribution to employees.

6. REFERENCES

OSHA Standard 29 CFR Part 1910.95, Occupational Noise Exposure, Department of Labor, Occupational Health and Safety Administration

U.S. Environmental Protection Agency Code of Federal Regulations 40 CFR 211 Subpart B

ISO 4869-1 (1990). *Acoustics—Hearing Protectors Part 1: Subjective* method for the measurement of sound attenuation, *International Organization for Standardization, Geneva.*

ISO 4869-2 (1994). *Acoustics—Hearing Protectors Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn,* International Organization for Standardization, Geneva.

ANSI S12.6-1997 [R2002] (2002) American National Standard for the Measuring Real-Ear Attenuation of Hearing Protectors, American National Standards Institute, New York.

Gauger, D., and Berger, E. H. (2004). *A new hearing protector rating: The* noise reduction statistic for use with A-weighting (NRSA), *Technical Report No. E-A-R 04-01/HP, American National Standards Institute, New York. This report can be found online at the following URL web URL* http://www.e-a-r.com/pdf/hearingcons/TO4_01EPA.pdf.

NSI S12.68 (2007). American National Standard Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors, are Worn, American National Standards Institute, New York.

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National Institute for Occupational Safety and Health, June 1998, Criteria for a Recommended Standard: Occupational Noise Exposure, NIOSH Publication, No. 98-126

EPA Standard, Title 20, Part 211

Occupational Health and Safety Administration, January, 1999. The OSHA Technical Manual, OSHA Publication, Section IV, Appendix IV: C.

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APPENDIX A - HOW TO PROPERLY WEAR HEARING PROTECTORS

It is an OSHA requirement that Haley & Aldrich ensure the proper initial fitting and that the employer provides training in the use and care of all hearing provided to employees. Employee hearing protection training is required:

- Annually during HAZWOPER Training
- Each time an employee shows a Standard Threshold Shift change in hearing.

To prevent a hearing loss, hearing protectors must be worn correctly and taken care of. Keep your ear plugs clean by washing them in warm soapy water and make sure they are completely dry before inserting them in your ears. Inspect your hearing protection regularly. If they become damaged, hard, worn out, then Haley & Aldrich will replace them with a new pair.
Everyone has different size ear canals, so each person will be fitted to ensure they receive the right size hearing protector. Each employee will be instructed on how to put their personal hearing protectors in and also be given the chance to practice inserting the hearing protectors into the ear canal. Two different types of hearing protectors will be provided employees. If there is a problem with the fit comfort of your hearing protectors, contact the CHSM and you will be given a different type of protection.

Life span of hearing protection

Sponge plugs: 1 or 2 days

Custom plugs: 18-24 months

Insert plugs: 4-6 months

Muffs: Replace when worn out

The life of the hearing protector is dependent upon the care it is given. A sponge type hearing protector is disposable. But, as long as it is clean, it may be used until it no longer expands. How long the hearing protection lasts is unique to each employee depending on the chemical make-up of their body.

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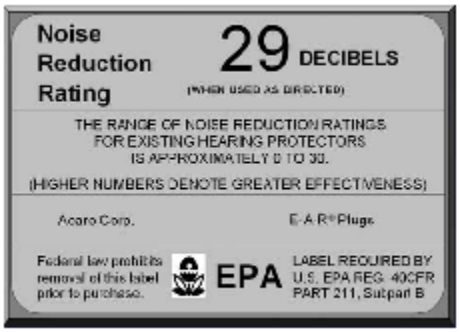
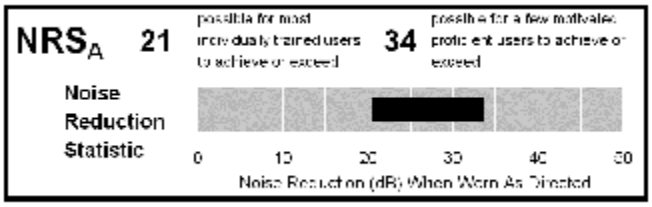
APPENDIX B - NOISE REDUCTION RATINGS

Noise Reduction Ratings

Hearing protectors sold in the U.S. are required by the U.S. Environmental Protection Agency (EPA) to have a noise reduction rating (NRR), which is an estimate of the reduction of noise at the ear when protectors are worn properly. However, due to the discrepancy between how protectors are fit in the testing laboratory and how users wear protectors in the real world, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have developed derating formulas to reduce the effective NRR.





While the NRR and the SNR (Single Number Rating) are designed to be used with C-weighted noise, which means that the lower frequencies are not de-emphasized, other ratings (NRR(SF) and NRSA) are determined for use with A-weighted noise levels, which have lower frequencies de-emphasized. The National Institute for Occupational Safety and Health recommended and the U.S. EPA mandated that 7-dB compensation between C and A weighting be applied when the NRR is used with A-weighted noise levels.

OSHA has defined in their training manual for inspectors that the adequacy of hearing protection for use in a hazardous noise environment should be derated to account for how workers typically wear protection relative to how manufacturers test the protector's attenuation in the laboratory.[11] For all types of hearing protection, OSHA's derating factor is 50%. If used with C-weighted noise, the derated NRR will become NRR/2. If used with A-weighted noise, OSHA applies the 7-dB adjustment for C-A weighting first then derates the remainder. For example, a protector with 33-dB attenuation would have this derating:

- Derated NRR = (33 – 7)/2

NIOSH has proposed a different scheme for derating based upon the type of protector. For earmuffs, the NRR should be derated by 25%, for slow-recovery foam earplugs the derating is 50% for all other protection, the derating is 70%. NIOSH applies the C-A spectral compensation differently than OSHA. Where OSHA subtracts the 7-dB factor first and derates the result, NIOSH derates the NRR first and then compensates for the C-A difference. For example, a slow recovery foam earplug with a 33-dB NRR would have this NIOSH derating:

- Derated NRR = (33/2) – 7

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NIOSH also has different derating percentages for various types of hearing protection. Currently, the derating factor is 70% for premolded plugs, 50% for fast expansion foam plugs (formable plugs) and for muffs is 25%.[1] For example, to find the derated NRR for an earmuff by using the NIOSH derating system, the procedure would go as follows:

- Derated NRR = (Original NRR x (1-.25)) – 7

Expected Updates in Noise Reduction Ratings

In 2007, the American National Standards Institute published a new standard for noise reduction ratings for hearing protectors, ANSI S12.68-2007. Using the real ear attenuation at threshold data collected by a laboratory test prescribed in ANSI S12.6-2008, the noise reduction statistic for A-weighted noise (NRSA) is computed using a set of 100 noises listed in the standard. The noise reduction rating, rather than be computed for a single noise spectrum the NRSA incorporates variability of both subject and spectral effects. ANSI S12.68 also defines a method to estimate the performance of a protector in an atypical noise environment. Building upon work from the U.S. Air Force and the ISO 4869-2 standard, the protector's attenuation as a function of the difference in C and A-weighted noise level is used to predict typical performance in that noise environment. The derating may be quite severe (10 to 15 decibels) for protectors that have significant differences between low and high frequency attenuation. For "flat" attenuation protectors, the effect of C-A is less. This new system eliminates the need for calculators, relies on graphs and databases of empirical data, and is believed to be a more accurate system for determining NRRs.

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OPERATING PROCEDURE: 1033

TAILGATE SAFETY MEETINGS

Haley & Aldrich

PREPARATION AND APPROVALS

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OPERATING PROCEDURE: OP1033

TAILGATE SAFETY MEETINGS

1. PURPOSE

This procedure provides guidance on the delivery of tailgate safety meetings.

2. DISCUSSION

During fieldwork, site-specific operational and safety topics must be communicated to all staff members on site. Inasmuch as site conditions may be dynamic during active site work, Project Managers (PMs) shall ensure that up to date information is provided to staff members. The mechanism for communicating this information is the tailgate safety meeting.

It is important to note that the frequency of the meetings will vary based upon site activities, site conditions, and client requirements (i.e. if the client requires daily meetings and/or meeting prior to each field task, meetings will be held at that frequency).

At a minimum, meetings shall be held with field staff every 5 working days.

2.1 Application

This program applies to all places of fieldwork where Haley & Aldrich staff members work.

2.2 Documentation

Each Tailgate Safety Meeting shall be documented on the Health & Safety Tailgate Meeting form which can be found on the Health & Safety Home Page of Haley & Aldrich Intranet.

3. PROCEDURE

Tailgate Safety Meetings shall be held at the start of each project. The meetings shall be specific to site activities and conditions, discuss and resolve the risks and mitigations, discuss health, safety, security and environmental concerns and raise the safety consciousness of each worker before they start work.

These meetings shall include, but are not limited to:

- A review of relevant Health and Safety Plan (HASP) elements to be performed at an appropriate frequency. A review shall be done whenever the HASP is updated and should also be done regularly to remind staff members of relevant elements.
- A Hazard Communication (HAZCOM) review.
- Address the risks of issues arising from the site walk and the location of on-site equipment and materials.
- Complete the Tailgate Safety Meeting forms.

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- A review of applicable permits.
- A review of the right and obligation to 'Stop Work.'
- Completion and review of job hazard analyses (JHA) for the tasks to be completed. This is a site-specific risk assessment; therefore, the focus should be on how to complete activities on a given site during that activity. The JHA hazard analysis discussion should include identification of 'Stop Work' triggers, and these shall be documented on the JHA form.
- Implement the controls set forth in the HASP and JHA's. Verify that all parties on site have a complete understanding of the work plan and controls that are in place.
- Allocate resources and complete permits.

Meetings are usually conducted by the PM or SSO, or both.

3.1 Stop Work Authority and Management of Change

The PM or SSO shall identify and communicate additional hazards throughout the project and utilize 'Stop Work' and Management of Change when necessary. Competent persons responsible for monitoring the work shall communicate changes in conditions to the PM or SSO.

Before work starts, the delegation of authority shall be communicated for coordination of the 'Stop Work' activities, and mitigation actions following a 'Stop Work' intervention (see OP 1035).

Changes to scope of work shall be documented in the HASP, followed by a Tailgate Safety Meeting to communicate the changes to the staff members.

3.2 Documenting the Tailgate Safety Meeting

The Tailgate Safety Meeting form is located on the Haley & Aldrich Intranet on the Forms & Templates Page under Health & Safety. The Tailgate Safety Meeting form shall be used to document the following:

- During the meeting, prior to starting work:
  - Record of meeting discussion.
  - Other site activities which may impinge on operational safety.
  - Planned activities.
  - Communicating and documenting changes in scope of work.
  - Muster point locations.
  - Hazards and controls as detailed in the HASP.
  - Site-safety discussion topics.
  - Emergency information.
  - Authorizations, duties and responsibilities.
  - Permits.
  - Sign-in times and workforce signatures. By signing, individuals confirm their fitness for duty; an understanding of the hazards and controls associated with their assigned tasks and their obligation to 'Stop Work.'

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- After the completion of work:
  - Best practices observed during work.
  - Lessons learned, including incidents, near-miss reports and any other concerns or observations.
  - Post-job review.
  - All 'Stop Work' interventions.
  - Sign-out times and workforce signatures. By signing, individuals confirm that they have left uninjured, unless they have been affected by an incident or received first aid, which should be documented as part of the post-job review.

3.3 Communication of Site Specific Topics

The PM or SSO shall prepare for the meeting from the following site-specific topics:

- Job Hazard Analyses.
- HASP.
- Scope of Work.
- Client's Requirements.

The PM and SSO shall inform site staff members of the presence of subcontractors and their activities.

3.4 Tailgate Meeting Locations

Tailgate safety Meetings shall be held in a location which is safe for staff members, has a minimum of background noise, is large enough to safely and comfortably accommodate the workforce and is undercover during inclement weather. Generally, meetings will be held within the Support Zone.

4. TRAINING

The authority to stop work will be communicated to all field staff annually during their HAZWOPER update training.

5. RESPONSIBILITIES

5.1 Project Managers

- Verify or delegate the responsibility to verify that the Tailgate Safety Meeting is carried out according to the requirements set by this procedure.
- Establish the clear expectation to exercise 'Stop Work.'

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5.2 Site Safety Officers

- Participate in the Tailgate Safety Meeting whenever the scope of work requires a permit to work.
- Verify in the meeting that all site personnel involved in a work activity are competent and correctly prepared for the work they will perform, and verify that workers have a clear understanding of the scope of work, hazards, controls and mitigations.
- Confirming that 'Stop Work' requirements and obligations are understood thoroughly by the workforce.
- Documenting the Tailgate Safety Meeting

5.3 Staff Members

- Understanding their authority and obligations under the scope of work described in the Tailgate Safety Meeting.
- Signing the appropriate documentation that they attended the meeting.

5.4 Corporate Health and Safety Manager

- Responsible for monitoring compliance with the requirements of this program.
- Maintain associated documents, processes and training materials.
- Communicate lessons learned.

6. REFERENCES

Title 8, California Code of Regulations, Construction Safety Orders, Section 1509 (e)

Tailgate Safety Meeting Form http://intranet/Forms-and-Templates/Health-and-Safety.aspx

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OPERATING PROCEDURE: (OP3027)

DECONTAMINATION PROCEDURE

LEVEL II (Interim)

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.1	R. Selover: 04/05/08	DMC 04/06/08	JBB 04/07/08		

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OPERATING PROCEDURE: OP3027

DECONTAMINATION PROCEDURE

1. PURPOSE

This procedure describes decontamination of field equipment potentially exposed to contaminants. Proper decontamination is required to minimize the potential for cross-contamination that would compromise sample quality. The degree of decontamination required will be dependent on the nature of the activity, equipment used and on the amount of exposure to contaminants.

2. EQUIPMENT & SUPPLIES

Decontamination equipment and solutions are generally selected based on ease of decontamination and disposability.

- Polyethylene sheeting;
- Metal racks to hold deconned equipment;
- Soft-bristle scrub brushes or long-handle brushes for removing gross contamination and scrubbing with wash solutions;
- Large galvanized wash tubs, stock tanks, or wading pools for wash and rinse solutions;
- Plastic buckets or garden sprayers for rinse solutions;
- Large plastic garbage cans or other similar containers lined with plastic bags can be used to store contaminated clothing;

Contaminated liquids and solids should be segregated and containerized in DOT-approved plastic or metal drums, appropriate for offsite shipping/disposal if necessary.

3. PROCEDURE

Decontamination activities must be performed in a controlled contaminant reduction area outside any exclusion zones established on the site. Care must be taken to minimize the potential for transfer of contaminated materials to the ground or onto other materials. Regardless of the size or nature of the equipment being decontaminated, the process will utilize a series of steps that involve removal of gross material (dirt, grease, oil etc.), washing with a detergent, and multiple rinsing steps. In lieu of a series of washes and rinse steps, steam cleaning with low-volume, high-pressure equipment (i.e. steam cleaner) is acceptable.

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Drill rigs, backhoes and other exploration equipment must be decontaminated prior to initiating site activities, in-between exploration locations to minimize cross- contamination potential, and prior to mobilizing off site after completion of site work. Heavy equipment is generally decontaminated with a combination of steam-cleaning equipment and manual scrubbing. Particular attention should be paid to parts in direct contact with contaminants, e.g. shovels, tires, augers, drilling decks, etc.

A decontamination pad must be constructed that is appropriate for the size and type of equipment being decontaminated for control and containerization of all decontamination fluids.

At a minimum, the decontamination pad will have the following elements:

- an impermeable barrier capable of containing decontamination fluids;
- a low point where fluids will collect and can be pumped into appropriate containers;
- durability to withstand equipment such as vehicle and foot traffic;
- appropriate ancillary equipment such as racks to place decontaminated equipment to drain without further exposure to contaminated fluids;
- Labels to alert personnel as to the potential presence of contaminated materials.

3.1 Decontamination of Sampling Equipment

All equipment that comes in contact with the sampling media (i.e. Surface Water, Sediment, etc.) must be decontaminated as specified below. An alternative approach is to have multiple pieces of equipment, and a centralized decontamination location where the procedures below can be reproduced in a grouped setting.

Stainless steel samplers used for the collection of samples for chemical analysis will be cleaned prior to use and between each sampling point in accordance with the following procedure:

- brush with soapy (phosphate-free soap) water; and
- rinse with de-ionized water provided by the laboratory.

The peristaltic pump used for surface water purging and sampling and/or pond sediment sampling will be decontaminated prior to use and between each location according to the following procedures:

- spray the discharge tubing, with de-ionized water (provided by the laboratory) to rinse off particulates;
- pump soapy (phosphate-free soap) water solution through the pump and;
- circulate potable water through the pump and discharge tubing until all traces of soap are gone; and
- pump de-ionized water (provided by the laboratory) through the pump and tubing.

NOTE: If the tubing is dedicated to each monitoring location and disposed of after sampling is completed, decontamination will be not required.

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3.2 Decontamination of Monitoring Equipment

Because monitoring equipment is difficult to decontaminate, care should be exercised to *prevent* contamination. Sensitive monitoring instruments should be protected when they are at risk of exposure to contaminants. This may include enclosing them in plastic bags allowing an opening for the sample intake. Ventilation ports should not be covered.

If decontamination is required, wipe the instruments down with detergent-wetted wipes or sponges, and wiped with de-ionized water-wetted wipes or sponges.

3.3 Disposal of Wash Solutions and Contaminated Equipment

All decontamination fluids such as wash water, rinsates, solids and materials used that cannot be effectively decontaminated (such as polyethylene sheeting) will be containerized and labeled with an indelible marker as to contents and date of placement in the container, and any appropriate stickers required. Storage of decontamination wastes on site will not exceed 90 days under any circumstances. Characterization of wastes for proper disposal will be performed immediately upon completion of the investigation to minimize storage time on site.

Please refer to Haley & Aldrich Operating Procedure OP3028-Investigation Derived Wastes for a complete discussion of handling and disposal of these materials.

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APPENDIX A
REFERENCES

ASTM D5088 - Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites

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OPERATING PROCEDURE: OP3028

INVESTIGATION DERIVED WASTES

LEVEL II (Interim)

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PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
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OPERATING PROCEDURE: OP3028

INVESTIGATION DERIVED WASTES

1. PURPOSE

This procedure applies to the management and characterization of investigation soils and/or groundwater as required in accordance with the Remedial Design Work Plan. In some areas and/or sections within the Site it is permitted to return soil cuttings/test pit soils and groundwater to the source area. In other areas it may not be practical to return cutting/soils to their origin, and they are better handled by this characterization/disposal procedure. These practices are consistent with USEPA procedure for IDW at RCRA facilities and CERCLA sites (reference 1, 2, 3). Typically, investigative derived wastes are dealt with following "Best Management Practices"; and are not handled under RCRA regulations until proven to be listed and/or identified as characteristically hazardous waste (reference 1). Investigative soils and groundwater often cannot be considered a listed waste due to the lack of generator knowledge concerning chemical source, chemical origin, and timing of chemical introduction to the subsurface. Consequently, waste sampling and characterization is performed to determine if the wastes exhibit a characterization of hazardous waste. Once the IDW characterization is complete, RCRA regulations apply if determined hazardous; if determined to be non-hazardous solid wastes, best management /solid waste handling practices apply. The disposal of soil cuttings, test pit soils and/or purged groundwater must be reviewed on a case by case basis prior to initiation of field activities. Two scenarios typically exist:

1. No Disposal/No Containerization Required - When sufficient Site information exists that allows investigative soils, cuttings, and/or purged groundwater to be placed back into the borehole or spread on the ground surface. This may be employed when it is believed that the area of concern will require a final remedy involving in-situ treatment, or an off-Site disposal removal effort is likely required, or no chemical impact is evident; and the material replacement does not pose a health threat or contaminate new areas.

   Alternatively, no information may be available in the area of activity or investigation, and impacted media/soils are identified. Activities such as new construction and /or maintenance works below grade may encounter environmental conditions that were unknown. Again it is logistically practical to complete the activity, employ health and safety measures appropriate to the conditions identified, and evaluate the extent and magnitude of the impact. Timely notification to the client would be required to formulate a course of action, and collect chemical samples from the area of concern (if warranted). Investigative works maybe conducted in areas where it is not known if impacted soils/groundwater exist, and the presence of hazardous constituents is not known. Again RCRA guidance permits Best Management Practices of keeping media on-Site (reference 2).

2. Disposal Required/Containerization Required – When sufficient facility and/or Site information regarding the investigative Site conditions warrant that all materials handled will be contained and disposed of.

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Investigation results may dictate that all IDW be recovered and contained. This approach may be performed to facilitate quick closure/allow access quickly back into the investigative area regardless of environmental impact or not.

If a known listed hazardous and/or characteristically hazardous waste/contaminated environmental media is being handled, then handling must be performed in accordance with RCRA Subtitle C (reference 2).

The following procedure describes the techniques for characterization of investigation derived waste (IDW) for disposal purposes. IDW may consist of soil cuttings (augering, boring, well installation soils, test pit soils), rock core or rock flour (from coring, reaming operations), groundwater (from well development, purging and sampling activities), personal protective equipment (PPE), and disposal equipment (DE).

2. EQUIPMENT & SUPPLIES

- Sample spoons, trowel, auger.
- Sample mixing bowl.
- Sampling bailer, or pump.
- Sample glassware.
- Ratchet to open drums.

3. PROCEDURE

The procedures for handling and characterization of field activity generated wastes are:

1. Soil/Rock Cuttings - Soils removed from boring activities and well construction tasks (including rock flour from bedrock coring) will be contained within an approved container, suitable for transportation and disposal.

2. Once placed into the approved container, any free liquids (i.e., groundwater) will be poured off for disposal as waste fluids. No free liquid as determined by the "paint filter test" (reference 5) shall be present.

3. Contained soils will be screened for the presence of Volatile Organic Compounds VOCs), using a Flame-ionization detector (FID); this data will be logged for future reference.

4. Once screened, full and closed; the container will be labeled in accordance with the Project Specific label and placed into the temporary container storage area. At a minimum, the following information will be shown on each container label: date and time of filling/generation, Site name, source of soils

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(i.e., borehole or well), and Site contact information. If necessary, the exterior of the container will be cleaned to remove any lose soil/cuttings.

5. Prior to container closure, representative samples from the containers will be collected for waste characterization purposes and submitted to the project laboratory.

6. Alternatively, it maybe practical to collect waste characterization samples as the containers are filled. The waste characterization sampling scheme will be dictated by the Remedial Design Work Plan and establish the volume of soils required for analysis (depending on parameters required), the number of containers considered representative, the homogenization procedure, volatile analysis collection procedure (if required), and preparation handling requirements. Typically at a location where an undetermined site specific parameter group exists, sampling and analysis may consist of the full RCRA Waste Characterization (ignitability, corrosivity, reactivity, toxicity), or a subset of the above based upon data collected, historical information, and generator knowledge.

7. Groundwater from well construction development, purging, and sampling requires disposal and shall be contained.

   Containment may be performed in 55-gallon drums, tanks suitable for temporary storage (i.e., nalgene) or if large volumes of groundwater are anticipated, tanker trailers (5,000 to 10,000 gallons ±), or drilling "Frac" tanks may be utilized
   (20,000 gallons ±). In all cases the container/tank used for groundwater storage must be clean before use such that cross-contamination does not occur.

8. Decontamination Water/Fluids - Decon water and/or fluids will be segregated, contained, and disposed accordingly.

   Decontamination waters may be disposed of with the contained groundwater once analytical results have been acquired. Depending on the analytical results, it may be appropriate to discharge the decontamination water to the Publicly Owned Treatment Works (POTW); or discharge to an On-Site treatment system; or off-Site for treatment.

9. Personal Protective Equipment (PPE) – A number of disposal options exists for spent PPE generated from investigation tasks. The options typically employed are:

   a. Immediately disposed of within on-site dumpster/municipal trash; or
   b. If known to be contaminated with RCRA hazardous waste, dispose off-Site at a RCRA-Subtitle C facility; or alternatively decontaminate PPE/DE and dispose on-site within dumpster/municipal trash.

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3.1 Waste Characterization Procedure

The Remedial Design Work Plan will identify the appropriate sampling strategy and analytes required to determine the IDW characteristics and disposal requirements. USEPA SW-846 (reference 4) describes the rationale for sampling plan development and sampling procedures. Generally random sampling and preparation of a composite sample of the media is employed for most investigative programs. Often a minimum of 4 representative samples is required to gain valid waste characteristic data to determine the disposal option applicable (if statistics are employed). Sampling procedures for IDW are:

Solid Wastes –Grab sampling using pre-cleaned sample spoons from bulk piles, lugger boxes, or as drums are being filled. In some instances when sufficient media mixing is evident, drum sampling from a random number of drums by accessing only the top solids may be permitted. In other instances where stratification is evident, a sample trowel/hand auger or device to collect from the entire vertical profile is required. Typically, a composite sample(s) from representative areas of the container(s) is homogenized and submitted for analysis. If VOCs are being evaluated, compositing and homogenization is not permitted. Individual grab samples are typically required.

- Waste Waters – Grab sampling techniques using pre-cleaned bailers or sampling pumps are typically employed. Waters in bulk are typically sampled once using a bailer or pump. The Remdial Design Work Plan will outline the appropriate sample frequency and analytes necessary to adequately characterize the contained waters. Facility sewer discharge permit parameters will be evaluated when disposal to the POTW is being considered.

- PPE – Depending on presence of contamination with RCRA hazardous waste, use D) above.

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APPENDIX A
REFERENCES

1. USEPA RCRA - Guidance and Policies: Management of Remediation Waste Under RCRA (October 1998).

2. USEPA RCRA - Management of Contaminated Media (October 1998).

3. USEPA CERCLA Guidance (Options Relevant to RCRA Facilities): Guide to Management of Investigation - Derived Wastes (January 1992).

4. USEPA Office of Solid Waste- SW846 Chapter 9 Sampling Plan, Chapter 10 Sampling Methods (September 1986).

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APPENDIX B
FORMS

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DRUM WASTE RECORD

Page of

PROJECT		H&A FILE NO.	
LOCATION		PROJECT MGR.	
CLIENT		FIELD REP	
CONTRACTOR		DATE	

Drum Number	Boring Identification	Drill Cuttings/Wash Water		Date Generated	Comments
		Solid	Liquid		

Location of Drums:

* Please attach a site plan showing the drum locations

Notes:

APPENDIX C
GLOSSARY

DE – Disposal Equipment
IDW – Investigation Derived Wastes
PPE – Personal Protective Equipment
POTW – Publicly Owned Treatment Works
USEPA – United States Environmental Protection Agency
RCRA – Resource Conservation and Recovery Act
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

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DRAFT

ATTACHMENT D5

CCREL Ice Sheet Safety Information

Ice Jams & Ice Jam Flooding

Advance Measures & Technical Assistance

Safety on Floating Ice Sheets

Contact Us

- Home
- Ice Jam Database, Bulletins & Surveys
- Flood Conditions, Outlooks, and Water Data Reports
- Ice and Snow Maps
- Related Links
- Technical Resources

For many of us in northern climates, working or playing on the frozen surface of a river or lake is part of winter. Knowing how to do so safely can be a matter of life or death. This handout presents general, common-sense precautionary measures that should be followed when you plan to be on a floating freshwater ice cover. Since it cannot cover every ice condition you may encounter, your judgement is critical. Remember: *Only you are responsible for your own safety!*

PREPARATION

There are four things to focus on when planning an outing on the ice: your **physical condition**, your **clothing**, your **equipment**, and your **procedures**.

Physical Condition
Anyone who goes out on the ice should be in reasonably good condition and be able to sustain periods of intense exertion if an emergency arises—either falling through the ice themselves or rescuing someone who does. Being able to swim, or at least being comfortable staying afloat, is important in an emergency and can reduce the chances for panic.

Clothing
Naturally you should choose clothing that provides protection from low air temperatures, wind, and precipitation while at the same time allowing you mobility. But in addition, when you select clothing, keep in mind the possibility of falling through the ice. Clothing that would severely restrict your ability to swim or to stay afloat is not a good choice. Hip boots or waders should never be worn, as they can fill with water and restrict movement while adding weight. A personal flotation device (PFD) should be worn. This can be a vest or jacket, either inflatable or aturally buoyant.

Equipment
Include items for testing and measuring the ice thickness, as well as items for rescue or self-rescue. In the first category are a heavy ice chisel, an ice drill or auger (manual or powered), a measuring tape or stick that can be hooked under the bottom edge of the ice in an auger hole, and possibly a perforated ladle for cleaning ice out of the auger holes. In addition to the PFD, bring a rope or rescue throw bag containing a rope that floats. Ice rescue picks sold for ice fishermen are an excellent idea. They thread through your jacket sleeves like children's mittens and are immediately available in an emergency for pulling yourself out of the water onto the ice.

Procedures

- Never go out on an ice cover alone, and never go out on the ice if there is any question of its safety.
- While you are planning the outing, obtain the record of air temperature for the past several days and continue observing air temperatures while the ice will be used to support loads.
- Always let someone know of your plans and when you will return.
- When you arrive at the water's edge, visually survey the ice. Look for open water areas, and look for signs of recent changes in water levels: ice sloping down from the bank because the water dropped, or wet areas on the ice because the water rose and flooded areas of the ice that couldn't float because it was frozen to the bottom or the banks. (If the ice is snow-covered, look for wet areas in the snow.)
- Listen for loud cracks or booms coming from the ice. In a river this can mean the ice is about to break up or move; on a lake larger than several acres such noises may be harmless responses to thermal expansion and contraction.
- Look for an easy point of access to the ice, free of cracks or piled, broken ice.
- If you are taking a vehicle or other equipment on the ice, go out on foot first. Vigorously probe ahead of yourself with the ice chisel. If the chisel ever goes through, carefully turn around and retrace your steps back to shore, and try again some other day.
- Near shore, listen for hollow sounds while probing. Ice sloping down from the bank may have air space underneath. This is *not* safe; ice must be floating on the water to support loads.

- After getting on the ice, others in the group should follow in the leader's steps, but stay at least 10 feet apart.
- Only after you have learned the characteristics of the ice cover should any vehicle be taken on the ice.

WHAT YOU NEED TO KNOW ABOUT THE ICE

Once on the ice, it is time to begin more systematic observations of the ice sheet you want to use to support a load. There may be many variations in the structure, thickness, temperature, and strength of a floating freshwater ice sheet.

How Thick Is the Ice?
This is determined by drilling holes with the drill or ice auger. The technique is to drill a hole and check the ice thickness every 150 feet or so along the intended path. This should be done more frequently if the ice thickness is quite variable. Note whether the ice in each hole is clear (sometimes called black ice) or white (due to air bubbles—sometimes called snow ice). Measure the thickness of both kinds.

On rivers the ice thickness and quality can change a lot in a short distance; be particularly alert to variations in ice thickness due to bends, riffles or shallows, junctions with tributaries, etc. For both rivers and lakes, warm inflows from springs can create areas of thinner ice. The ice near shores can either be thinner (due to warm groundwater inflow or the insulating effect of drifted snow) or thicker (due to the candle-dipping effect of variable water levels).

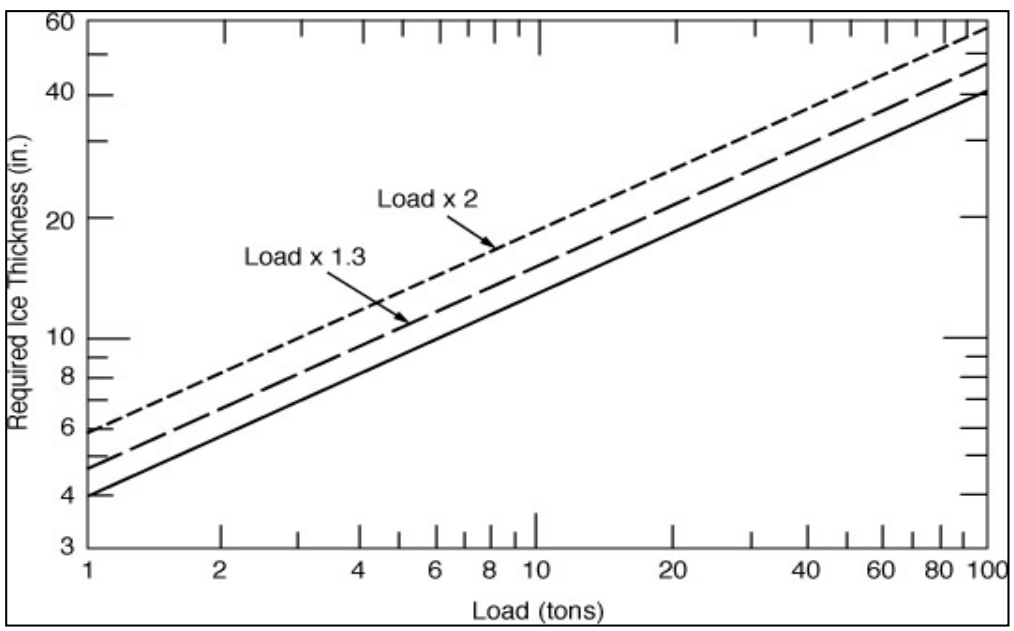
Measure the snow cover thickness on the ice cover; significant variations in thickness may mean highly variable ice thicknesses.

How Thick Does It Need to Be?
A simple formula to estimate the minimum ice thickness required to support a load is

$$h = 4\sqrt{P}$$

where ***h*** is the ice thickness in inches and ***P*** is the load, or gross weight, in tons. You can also use the graph or table to determine the minimum thickness.

Remember that the load is the *total* load in tons (not a vehicle's load capacity).



Load (tons)	Required Ice Thickness (inches)	Distance Between Loads (feet)
0.1	2	17

1	4	34
2	6	48
3	7	58
4	8	67
5	9	75
10	13	106
20	18	149
30	22	183
40	26	211

The equation, graph, and table are valid when the load (such as a person on foot, or a wheeled or tracked vehicle) is distributed over a reasonable area of a continuous ice sheet. The larger the load, the greater the area it should cover for the calculation to remain valid. Neither large loads that are concentrated in relatively smaller areas, nor loads that are at or near the edge of a large opening in the ice, are safely described by the equation, graph, or table.In such cases, seek more advice.

The equation, graph and table assume clear, sound ice. If white, bubble-filled ice makes up part or all of the ice thickness, count it as only half as much clear ice.

Any recent large snowstorm creates a new load on the ice. If the new snow is heavy enough, the ice sheet will sag and its top surface will be submerged below the water level. Then water will flood the top of the ice sheet through cracks, saturating the lower layers of the snow. Until this slush is completely frozen, stay offthe ice sheet. When the saturated snow becomes frozen, it is an added thickness of white ice.

Contrary to what you would expect, a rapid, large air temperature drop makes an ice sheet brittle, and the ice may not be safe to use for 24 hours or more.

If the air temperature has been abovefreezing for at least 6 of the past 24 hours, multiply the load by 1.3 before you use the equation (or use the lower dashed line on the graph), obtaining a larger minimum ice thickness to account for any possible weakening. If the air temperature stays above freezing for 24 hours or more, the ice starts losing strength, and the equation, figure, and table no longer represent safe conditions. Stay off the ice!

You are likely to encounter cracks in the ice. Cracks are either wet or dry. If they are dry, they do not penetrate the ice sheet and are not a concern. If they are wet, multiply the load by 2, as shown on the graph, before you use the equation to obtain the required minimum ice thickness.

If you plan to leave a load on the ice for extended periods, usually more than two hours, multiply the load by 2 (as shown by the upper dashed line in the graph) before you use the equation to find the required minimum ice thickness.

SAFE OPERATIONS ON THE ICE COVER

If using an enclosed vehicle, alwaysdrive with the windows or a door open for quick escape.

If you drive across wet cracks, your path should be as close to perpendicular to them as possible, instead of parallel to them.

A load deflects the ice slightly into a bowl shape. When you drive on floating ice, this moving bowl generates waves in the water. If the speed of the waves equals the vehicle speed, the ice-sheet deflection is increased and the ice is much more likely to break. The problem is more serious for thin ice and shallow water. In general you avoid this danger by driving below 15 mph.

When there are two loads on the ice, the safe distance between them is about 100 times the ice thickness at the required minimum thickness. This is shown in the third column of the table. When the two loads are different, choose the spacing shown for the larger load. At ice thicknesses greater than the required minimum, this spacing can be reduced.

A loaded ice sheet will creep, or deform, over a long period of time, without any additional load. If an ice

sheet has to be loaded for a long period, drill a hole near the load. If the water begins to flood the ice through the hole, move the load immediately. Remember this if your vehicle ever becomes disabled: if left for a few days, it may break through the ice as a result of long-term creep.

IN CONCLUSION...

Be sure you understand this information. Don't hesitate to seek the advice of others whose experience you trust. Be safe out on the ice!

Funding for Site provided by USACE Headquarters Civil Works Directorate, Civil Emergency Management Branch.

Ice Engineering Research Group

Cold Regions Research and Engineering Laboratory
72 Lyme Road,
Hanover, New Hampshire, USA 03755-1290

Pagemaster: Jane Mason
E-mail: jane.g.mason@usace.army.mil
Phone: (603) 646-4669
Page last updated: 5 March 2008 (jgm)

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Security and Privacy Notice

Haley & Aldrich, Inc.
465 Medford St.
Suite 2200
Boston, MA 02129-1400

Tel: 617.886.7400
Fax: 617.886.7600
HaleyAldrich.com

HALEY & ALDRICH

MEMORANDUM

9 January 2009
File No. 33020-045

TO: de maximis, inc.
Mr. Bruce Thompson

FROM: Haley & Aldrich, Inc.
Russell Schuck/Thomas Holden/Kenneth Alepidis

SUBJECT: Operating Procedures and Contingency Plan for Sampling at HBHA Pond over Ice
Industri-Plex OU2
Woburn, MA

This memorandum provides a plan outlining health and safety related topics associated with the surface water sampling conducted at the HBHA Pond at the Industri-Plex OU2 site, during winter conditions when HBHA Pond is either fully or partially frozen and work will performed by individuals on foot from the ice surface. Haley & Aldrich field staff will be required to take various precautions during the over-ice sampling events. See below for brief discussion of the over-ice safety protocols, sampling equipment and procedures.

ICE THICKNESS MEASUREMENTS

As noted in the Haley & Aldrich Site-Specific Health and Safety Plan, a minimum of four inches of ice cover will be required for work over ice. Sampling will not be conducted if the minimum ice thickness requirement is not present in the vicinity of the proposed sampling, including the access corridor from shore. In order to determine thickness of ice prior to the sampling event, the following will be conducted:

- Observations – Air temperature will be monitored over several days prior to the day of the sampling event. Staff will visually survey pond ice for open water areas, noting changes in pond water levels, shifting ice, the quality of ice (clear, cloudy, bubble filled, etc.), and the presence and nature of cracks in the ice (dry or wet). Staff will also listen for loud cracks and booms, or hollow sounds in the ice near shore. The observations as noted above will be used to determine the quality of the ice and the potential for unsafe over-ice conditions.

- Ice Drilling – An ice drill, ice chisel, or ice auger (manual powered) will be used to make holes in ice to measure for ice thickness and for sampling. The ice will be probed at regular intervals as to safely determine thickness of ice

between shore and sampling location, and around the actual sampling location. The staff performing ice thickness testing will be tethered to shore until ice thickness has been determined to be safe (see further clarification below). Distance between test probes to assess the consistency of ice thickness will be determined in the field, and will be varied based on the ice thicknesses observed. For example, the test probes will be closely spaced (e.g., every 15 feet) if initial ice thicknesses are closer to the minimum ice thickness requirement of four inches, and will be spaced at greater intervals (e.g., every 50 feet) if the ice thickness is significantly greater than the minimum requirement.

If, while probing, it is determined the thickness of the ice on the way to the sampling location or at the actual sampling location is less than the required four inches, the field staff will immediately cease work and exit the pond. However, if it appears that a small localized area along the initial proposed access corridor (not at the sample location itself) is less than the required minimum thickness, and a minor modification to the corridor can be defined with acceptable ice thickness, the work may continue. If, in this process of probing the ice thickness for an acceptable corridor, the measured thickness is found to be less than the minimum allowable at additional location(s) and a safe corridor cannot be readily established (i.e., the ice is inconsistent and below the minimum allowable thickness) the field staff will immediately cease work and exit the pond.

If presence of ice-free open water is observed or changes in ice conditions is present near a pond sampling or monitoring location (RM1, RM2, MP-1), the sampling plan and schedule may be altered to adjust for the inaccessible location(s). Field staff will avoid walking on ice in known areas of the pond where ice conditions are anticipated to be unsafe, such as; pond inlets/outlets, areas of increased flow, higher water temperatures, or increased surface water agitation or movement.

Once a corridor from shore to sample location of acceptable ice quality and thickness is established, the corridor will be marked out on the ice and the field staff will use such corridor for foot traffic. The length of the corridor will be minimized to reduce excess travel over the ice.

SAFETY EQUIPMENT AND USAGE

The following safety-related equipment will be used onsite during over-ice sampling events:

- Safety Rope - During over-ice sampling, a safety rope will be affixed to a stable structure on shore (tree, utility pole, etc.) and extend across the ice to the sampling location. A ring buoy will be attached to the end of the rope, at the sampling location. If ice thickness is measured to be less than six inches at the sampling location, safety ropes will be attached from the shore to each individual staff working on the ice, and the ring buoy will be placed on shore. In addition, the staff performing ice thickness testing will be tethered to shore until ice thickness has been determined to be safe.

- Cold Water Immersion Suit/Personal Flotation Device (PFD) - Cold water immersion suit/PFD (Class III or greater) will be worn by staff at all times while working over ice. The immersion suits have ratings for the allowable immersion time under different water temperatures and conditions. The cold water immersion suits used by staff have CLO (Clothing Insulation Values) ranging from 0.185-0.420. This is a measure of the ability of the suit to insulate a submerged person. Higher values of this number offer greater insulation in a submerged condition, and could potentially prolong cold water survival times. Safe exposure times for aforementioned suits 1.25-2.25 hours respectively in 0°C water.

- Ice Rescue Picks – Each individual working over ice will have two ice rescue picks affixed to there clothing. In the event of falling through ice, the ice picks can be used to pull ones self out of the water and onto the ice.

- Ice Traction – Ice traction devices will be used on field staff footwear to increase stability and footing on ice.

- Safety Boat – A small boat will be placed on shore adjacent to the sampling location while working over ice, and tied to a stable structure on shore. In the event of an emergency, the boat can be employed to provide flotation or access to an individual who has fallen through ice.

- Safety Vehicle – A safety vehicle will be parked on shore adjacent to the sampling location. In the event of an emergency, the vehicle will be available for an individual who has fallen through ice.

- Extra Clothing – Sets of dry clothing and blankets will be stored in the safety vehicle or at the Remediation Building for each individual working over ice.

ICE-SPECIFIC FIELD SAMPLING EQUIPMENT

The following sampling-related equipment will be used onsite during over-ice sampling events:

- Ice Drilling – An ice drill, ice chisel, or ice auger (manual powered) will be used to make holes in ice to measure for ice thickness and to provide access for water sampling.

- Ice Ladle – An ice ladle will be used to clear holes in ice used for water sampling.

- Measuring Device – A measuring device will be used to measure ice thickness.

RESPONSE ACTIONS

A shore-based staff person (likely a third person, assuming two are involved in the sampling on the ice) will be present on shore during over-ice work activities to monitor

ongoing work. The shore-based staff person shall be present at all times when someone is on the ice.

In the event a field staff breaks through ice and is submerged in water to waist depth or deeper, the accompanying field staff or third person present on shore will immediately contact local authorities (such as 911 and fire department). The City of Woburn Fire Department has been contacted previously regarding this project and is capable of water rescues.

After contacting the local authorities, the second or third field staff may attempt to aid the submerged person by throwing the ring buoy, pulling the safety rope if the person is holding on, or by pushing the safety boat onto the ice towards the ice break location and pulling the boat and person(s) onto shore, provided it can be done safely from the shore or near shore if the ice is sufficiently thick near shore.

If the submerged person is able to come ashore prior to the local authorities' arrival, the safety vehicle (with accompanying clothing and blankets) will be used to warm and dry the person, or to drive the submerged person to the Thermal Oxidation Unit (TOU) building where heat, and dry clothing and blankets will be provided. If the submerged person could not exit the pond prior to the arrival of the local authorities, the authorities will conduct a rescue.

In the event a field staff breaks through ice and is submerged to a depth shallower than waist high, field staff onsite will attempt to aid the person (as discussed above), but may not immediately contact local authorities. If it is evident the submerged person is not able to easily exit the pond or is in danger of cold-related stress, hypothermia, or frost bite resulting from breaking through the ice, the local authorities will be contacted.

COMMUNICATION PLAN

In the event of an ice-related emergency, field staff will also follow precautions, contingency planning, and emergency communications as described in the Site Specific Health and Safety Plan, as well as the provided in the following Haley & Aldrich operating procedures: Hazard Communication, Cold Stress, Emergency Action Plan. These operating procedures have been provided in the Site Specific Health and Safety Plan.

Signature Page:

Staff (print)	Signature	Date

G:\33020\045\2009-0107-HAI-IPLEX Ice Memo-F.doc

ATTACHMENT D6

Supervisor's Accident/Injury/Near Miss Report (SAIR)

HALEY & ALDRICH

Supervisor's Accident / Injury / Near Miss Report (SAIR)

Safety Form 004

- **Staff Manager is responsible for completing this form. LHSC and/or Field Supervisor will complete form only as a backup.**
- **Staff Manager forwards completed copy to LHSC; LHSC reviews, signs and faxes to CHSM & BOS HR within 24 hours.**

1. **Name of injured:** _____ 2. **Employee ID #:** _____
3. **Office of injured:** _____ 4. **Date and time of incident:** _____
5. **Project Name:** _____ 6. **Project No.:** _____
7. **Location of incident (be specific):** _____
8. **Brief explanation of incident (attach separate sheet if necessary):** _____
9. **List witnesses (if not H&A, give company & phone no.):** _____
10. **Equipment/materials involved in incident:** _____
11. **Describe injury or illness symptoms in detail:** _____
12. **Describe first aid/medical treatment received:** _____
13. **Name and address of medical treatment provider:** _____
14. **Lost time from work?** ☐ Yes ☐ No 15. **Actual or estimate of lost days:** _____
16. **Preliminary determination of the cause of the incident:** _____
17. **Recommended corrective action/comments:** _____
18. **Person(s) responsible for corrective actions:** _____

Date Corrected: (Verified by LHSC) **LHSC Signature:**

Staff Member: _____ **Date:** _____

Staff Manager: _____ **Date:** _____

Local H&S Coordinator: _____ **Date:** _____

Corporate H&S Manager _____ **Date:** _____

ATTACHMENT D7

Material Safety Data Sheets (MSDSs)

MSDS

H&A Field Representative Package, Table of Content

Alconox Soap (Decon Kit)
Distilled Water (Decon Kit, Trip blanks)
Methanol (Decon Kit and soils High VOC, VPH)
Hexane (Decon Kit)

Samples preservatives
Hydrochloric Acid
Nitric Acid
Sulfuric Acid
Sodium Bisulfate (Low soils VOC)
Sodium Hydroxide

Isobutylene Gas (PID calibration)

Spray Paint (all colors)

Unleaded Gasoline (generators, pumps)

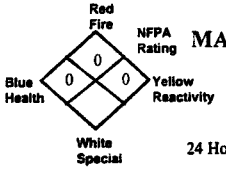
Portland Cement (concrete, grout)

Silica Sand (sand Cones, Wells)

Loctite 410 (Adhesive)
Loctite 712 (Accelerator)

Magnalube

Alconox ®



MATERIAL SAFETY DATA SHEET

Alconox, Inc.
30 Glenn Street
White Plains, NY 10603

24 Hour Emergency Number – Chem-Tel (800) 255-3924

I. IDENTIFICATION

Product Name (as appears on label)	ALCONOX
CAS Registry Number:	Not Applicable
Effective Date:	January 1, 2001
Chemical Family:	Anionic Powdered Detergent
Manufacturer Catalog Numbers for sizes	1104, 1125, 1150, 1101, 1103 and 1112

II. HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

There are no hazardous ingredients in ALCONOX as defined by the OSHA Standard and Hazardous Substance List 29 CFR 1910 Subpart Z.

III. PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point (F):	Not Applicable
Vapor Pressure (mm Hg):	Not Applicable
Vapor Density (AIR=1):	Not Applicable
Specific Gravity (Water=1):	Not Applicable
Melting Point:	Not Applicable
Evaporation Rate (Butyl Acetate=1):	Not Applicable
Solubility in Water:	Appreciable-Soluble to 10% at ambient conditions
Appearance:	White powder interspersed with cream colored flakes.
pH:	9.5 (1%)

IV. FIRE AND EXPLOSION DATA

Flash Point (Method Used):	None
Flammable Limits:	LEL: No Data UEL: No Data
Extinguishing Media:	Water, dry chemical, CO_2, foam
Special Fire fighting Procedures:	Self-contained positive pressure breathing apparatus and protective clothing should be worn when fighting fires involving chemicals.
Unusual Fire and Explosion Hazards:	None

V. REACTIVITY DATA

Stability:	Stable
Hazardous Polymerization:	Will not occur
Incompatibility (Materials to Avoid):	None
Hazardous Decomposition or Byproducts:	May release CO_2 on burning

ALCONOX MSDS - ALCONOX MSDS - ALCONOX MSDS - ALCONOX MSDS - ALCONOX MSDS

VI. HEALTH HAZARD DATA

Route(s) of Entry:	Inhalation? Yes Skin? No Ingestion? Yes
Health Hazards (Acute and Chronic):	Inhalation of powder may prove locally irritating to mucous membranes. Ingestion may cause discomfort and/or diarrhea. Eye contact may prove irritating.
Carcinogenicity:	NTP? No IARC Monographs? No OSHA Regulated? No
Signs and Symptoms of Exposure:	Exposure may irritate mucous membranes. May cause sneezing.
Medical Conditions Generally Aggravated by Exposure:	Not established. Unnecessary exposure to this product or any industrial chemical should be avoided. Respiratory conditions may be aggravated by powder.
Emergency and First Aid Procedures:	Eyes: Immediately flush eyes with water for at least 15 minutes. Call a physician. Skin: Flush with plenty of water. Ingestion: Drink large quantities of water or milk. Do not induce vomiting. If vomiting occurs administer fluids. See a physician for discomfort.

VII. PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken if Material is Released or Spilled:	Material foams profusely. Recover as much as possible and flush remainder to sewer. Material is biodegradable.
Waste Disposal Method:	Small quantities may be disposed of in sewer. Large quantities should be disposed of in accordance with local ordinances for detergent products.
Precautions to be Taken in Storing and Handling:	Material should be stored in a dry area to prevent caking.
Other Precautions:	No special requirements other than the good industrial hygiene and safety practices employed with any industrial chemical.

VIII. CONTROL MEASURES

Respiratory Protection (Specify Type):	Dust mask - Recommended
Ventilation:	Local Exhaust-Normal Special-Not Required Mechanical-Not Required Other-Not Required
Protective Gloves:	Impervious gloves are useful but not required.
Eye Protection:	Goggles are recommended when handling solutions.
Other Protective Clothing or Equipment:	None
Work/Hygienic Practices:	No special practices required

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH BUT NO WARRANTY IS EXPRESSED OR IMPLIED.

CORNELL

Material Safety Data Sheets

Division of Facilities Services

DOD Hazardous Material Information (ANSI Format)
For Cornell University Convenience Only

DISTILLED WATER

Section 1 - Product and Company Identification	Section 9 - Physical & Chemical Properties
Section 2 - Compositon/Information on Ingredients	Section 10 - Stability & Reactivity Data
Section 3 - Hazards Identification Including Emergency Overview	Section 11 - Toxicological Information
Section 4 - First Aid Measures	Section 12 - Ecological Information
Section 5 - Fire Fighting Measures	Section 13 - Disposal Considerations
Section 6 - Accidental Release Measures	Section 14 - MSDS Transport Information
Section 7 - Handling and Storage	Section 15 - Regulatory Information
Section 8 - Exposure Controls & Personal Protection	Section 16 - Other Information

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Cornell University does not in any way warrant or imply the applicability, viability or use of this information to any person or for use in any situation.

Section 1 - Product and Company Identification
DISTILLED WATER

Product Identification: DISTILLED WATER
Date of MSDS: 12/13/1995 **Technical Review Date:** 05/01/1996
FSC: 6810 **NIIN:** 00-682-6867
Submitter: D DG
Status Code: C
MFN: 01
Article: N
Kit Part: N

Manufacturer's Information

Manufacturer's Name: SPECIALTY PRODUCTS INC
Manufacturer's Address1: 1712 1ST AVE W
Manufacturer's Address2: BIRMINGHAM, AL 35208-5219
Manufacturer's Country: US
General Information Telephone: 205-833-3541
Emergency Telephone: 205-833-3541
Emergency Telephone: 205-833-3541
MSDS Preparer's Name: HMIS (VBA)
Proprietary: N
Reviewed: Y
Published: Y
CAGE: 1M628
Special Project Code: N

Item Description

Item Name: DISTILLED WATER,REAGENT
Item Manager: S9G
Specification Number: ASTM 1193
Type/Grade/Class: TYPE III
Unit of Issue: BX **Quantitative Expression:** 00000000006EA
Unit of Issue Quantity: 1
Type of Container: BOTTLE

Preparer Information

Preparer's Name: SPECIALTY PRODUCTS INC
Preparer's Address1: 1712 1ST AVE W
Preparer's Address2: BIRMINGHAM, AL 35208-5219
Preparer's CAGE: 1M628
Assigned Individual: N

Contractor Information

Contractor's Name: MCKESSON CORP MCKESSON CHEMICAL CO DIV
Contractor's Address1: 1734 HAYES AVE
Contractor's Address2: LONG BEACH, CA 90813
Contractor's Telephone: 415-983-9214
Contractor's CAGE: 1JK82

Contractor Information

Contractor's Name: SPECIALTY PRODUCTS INC
Contractor's Address1: 1712 1ST AVE W
Contractor's Address2: BIRMINGHAM, AL 35208-5219

Contractor's Telephone: UNKNOWN
Contractor's CAGE: 1M628

Section 2 - Compositon/Information on Ingredients
DISTILLED WATER

Ingredient Name: WATER, DISTILLED
Ingredient CAS Number: 7732-18-5 **Ingredient CAS Code:** M
RTECS Number: ZC0110000 **RTECS Code:** M
=WT: =WT Code:
=Volume: =Volume Code:
>WT: >WT Code:
>Volume: >Volume Code:
<WT: <WT Code:
<Volume: <Volume Code:
% Low WT: % Low WT Code:
% High WT: % High WT Code:
% Low Volume: % Low Volume Code:
% High Volume: % High Volume Code:
% Text: 100
% Enviromental Weight:
Other REC Limits: NONE RECOMMENDED
OSHA PEL: NOT ESTABLISHED **OSHA PEL Code:** M
OSHA STEL: OSHA STEL Code:
ACGIH TLV: NOT ESTABLISHED **ACGIH TLV Code:** M
ACGIH STEL: N/P **ACGIH STEL Code:**
EPA Reporting Quantity:
DOT Reporting Quantity:
Ozone Depleting Chemical: N

Section 3 - Hazards Identification, Including Emergency Overview
DISTILLED WATER

Health Hazards Acute & Chronic: NO HEALTH HAZARDS ARE EXPECTED, ACUTE OR CHRONIC.

Signs & Symptoms of Overexposure:
NONE

Medical Conditions Aggravated by Exposure:
NONE

LD50 LC50 Mixture: LD50 (ORAL RAT) IS UNKNOWN

Route of Entry Indicators:
Inhalation: NO
Skin: NO
Ingestion: NO

Carcenogenicity Indicators
NTP: NO

IARC: NO
OSHA: NO

Carcinogenicity Explanation: THIS COMPOUND CONTAINS NO INGREDIENTS AT CONCENTRATIONS OF 0.1% OR GREATER THAT ARE CARCINOGENS OR SUSPECT CARCINOGENS.

Section 4 - First Aid Measures
DISTILLED WATER

First Aid:
NO HAZARD; NO TREATMENT REQUIRED.

Section 5 - Fire Fighting Measures
DISTILLED WATER

Fire Fighting Procedures:
NO SPECIAL REQUIREMENTS.
Unusual Fire or Explosion Hazard:
NONE
Extinguishing Media:
N/R
Flash Point: Flash Point Text: NONE

Autoignition Temperature:
Autoignition Temperature Text: UNK
Lower Limit(s): N/R
Upper Limit(s): N/R

Section 6 - Accidental Release Measures
DISTILLED WATER

Spill Release Procedures:
NO SPECIAL REQUIREMENTS.

Section 7 - Handling and Storage
DISTILLED WATER

Handling and Storage Precautions:

Other Precautions:

Section 8 - Exposure Controls & Personal Protection
DISTILLED WATER

Repiratory Protection:
NO SPECIAL REQUIREMENTS.
Ventilation:
NO SPECIAL REQUIREMENTS
Protective Gloves:
NONE
Eye Protection: SAFETY GLASSES
Other Protective Equipment: NONE
Work Hygenic Practices: NONE
Supplemental Health & Safety Information: NONE

Section 9 - Physical & Chemical Properties
DISTILLED WATER

HCC: N1
NRC/State License Number: N/R
Net Property Weight for Ammo: N/R
Boiling Point: Boiling Point Text: 212F,100C
Melting/Freezing Point: Melting/Freezing Text: 32.0F,0.0C
Decomposition Point: Decomposition Text: UNKNOWN
Vapor Pressure: 18 **Vapor Density:** N/K
Percent Volatile Organic Content:
Specific Gravity: 1.0
Volatile Organic Content Pounds per Gallon:
pH: 7
Volatile Organic Content Grams per Liter:
Viscosity: N/R
Evaporation Weight and Reference: <1 (NBUAC=1)
Solubility in Water: COMPLETE
Appearance and Odor: LIQUID, COLORLESS, ODORLESS
Percent Volatiles by Volume: 100
Corrosion Rate: UNKNOWN

Section 10 - Stability & Reactivity Data
DISTILLED WATER

Stability Indicator: YES
Materials to Avoid:
NONE
Stability Condition to Avoid:
NONE
Hazardous Decomposition Products:
NONE
Hazardous Polymerization Indicator: NO
Conditions to Avoid Polymerization:
NOT RELEVANT

Section 11 - Toxicological Information
DISTILLED WATER

Toxicological Information:
N/P

Section 12 - Ecological Information
DISTILLED WATER

Ecological Information:
N/P

Section 13 - Disposal Considerations
DISTILLED WATER

Waste Disposal Methods:
FLUSH TO A SANITARY SEWER.

Section 14 - MSDS Transport Information
DISTILLED WATER

Transport Information:
N/P

Section 15 - Regulatory Information
DISTILLED WATER

SARA Title III Information:
N/P
Federal Regulatory Information:
N/P
State Regulatory Information:
N/P

Section 16 - Other Information
DISTILLED WATER

Other Information:
N/P

HMIS Transportation Information

Product Identification: DISTILLED WATER
Transporation ID Number: 82205
Responsible Party CAGE: 1M628
Date MSDS Prepared: 12/13/1995
Date MSDS Reviewed: 05/01/1996
MFN: 05/01/1996
Submitter: D DG
Status Code: C

Container Information
- **Unit of Issue:** BX
- **Container Quantity:** 1
- **Type of Container:** BOTTLE
- **Net Unit Weight:** 49.8 LBS

Article without MSDS: N
Technical Entry NOS Shipping Number:
Radioactivity:
Form:
Net Explosive Weight:
Coast Guard Ammunition Code:
Magnetism: N/P
AF MMAC Code:
DOD Exemption Number:
Limited Quantity Indicator:
Multiple Kit Number: 0
Kit Indicator: N
Kit Part Indicator: N
Review Indicator: Y
Additional Data:
NONE

Department of Transportation Information

DOT Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION
DOT PSN Code: ZZZ
Symbols: N/R
DOT PSN Modifier:
Hazard Class: N/R
UN ID Number: N/R
DOT Packaging Group: N/R
Label: N/R
Special Provision(s): N/R
Packaging Exception: N/R
Non Bulk Packaging: N/R
Bulk Packaging: N/R
Maximimum Quanity in Passenger Area: N/R
Maximimum Quanity in Cargo Area: N/R
Stow in Vessel Requirements: N/R
Requirements Water/Sp/Other: N/R

IMO Detail Information

IMO Proper Shipping Name: NOT REGULATED FOR THIS MODE OF TRANSPORTATION
IMO PSN Code: ZZZ
IMO PSN Modifier:
IMDG Page Number: N/R
UN Number: N/R
UN Hazard Class: N/R
IMO Packaging Group: N/R
Subsidiary Risk Label: N/R
EMS Number: N/R
Medical First Aid Guide Number: N/R

IATA Detail Information

IATA Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION
IATA PSN Code: ZZZ
IATA PSN Modifier:
IATA UN Id Number: N/R
IATA UN Class: N/R
Subsidiary Risk Class: N/R
UN Packaging Group: N/R
IATA Label: N/R
Packaging Note for Passengers: N/R
Maximum Quantity for Passengers: N/R
Packaging Note for Cargo: N/R
Maximum Quantity for Cargo: N/R
Exceptions: N/R

AFI Detail Information

AFI Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION
AFI Symbols:
AFI PSN Code: ZZZ
AFI PSN Modifier:
AFI UN Id Number: N/R
AFI Hazard Class: N/R
AFI Packing Group: N/R

AFI Label: N/R
Special Provisions: N/A
Back Pack Reference: N/A

HAZCOM Label Information

Product Identification: DISTILLED WATER
CAGE: 1M628
Assigned Individual: N
Company Name: SPECIALTY PRODUCTS INC
Company PO Box:
Company Street Address1: 1712 1ST AVE W
Company Street Address2: BIRMINGHAM, AL 35208-5219 US
Health Emergency Telephone: 205-833-3541
Label Required Indicator: N
Date Label Reviewed: 05/01/1996
Status Code: C
Manufacturer's Label Number: NONE
Date of Label: 05/01/1996
Year Procured: N/K
Organization Code: N
Chronic Hazard Indicator: N
Eye Protection Indicator: N/P
Skin Protection Indicator: N/P
Respiratory Protection Indicator: N/P
Signal Word: NONE
Health Hazard: None
Contact Hazard: None
Fire Hazard: None
Reactivity Hazard: None

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MATERIAL SAFETY DATA SHEET (MSDS)

Click here for the French version / Appuyer ici pour la version française

MATERIAL SAFETY DATA SHEET

EM SCIENCE

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Manufacturer.....:
EM SCIENCE
A Division of EM Industries
P.O. Box 70
480 Democrat Road
Gibbstown, N.J. 08027

Preparation Date.: 10/24/00

Information Phone Number.: 856-423-6300
Hours: Mon. to Fri. 8:30-5
Chemtrec Emergency Number: 800-424-9300
Hours: 24 hrs a day

Catalog Number(s):

MX0475 MX0480 MX0483 MX0484 MX0485 MX0487 MX0488
MX0489 MX0490 AX1699M MX0475P MX0482 MX0485P MX0485S
MX0488B MX0488P MX0485J MX0480P MX0472 0060248D 64753
MX0481 MX0491 MX0492 951P 1.06036 1.16715 1.06004
VW5790 MX0475PH 512768

Product Name:
Methanol
Synonyms:
Methyl Alcohol, Wood Alcohol
Chemical Family:
Aliphatic Alcohol
Formula:
CH_3OH
Molecular Weight.:
32.04

2. COMPOSITION / INFORMATION ON INGREDIENTS

Component	CAS #	Appr %
Metnanol	67-56-1	100%

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
FLAMMABLE LIQUID AND VAPOR.
VAPOR HARMFUL.
MAY BE FATAL OR CAUSE BLINDNESS IF SWALLOWED.
CANNOT BE MADE NON-POISONOUS.
MAY CAUSE DAMAGE TO LUNGS AND CENTRAL NERVOUS SYSTEM.
ABSORPTION THROUGH SKIN HARMFUL.

Appearance:
Colorless liquid, characteristic alcoholic odor

POTENTIAL HEALTH EFFECTS (ACUTE AND CHRONIC)

Symptoms of Exposure:
Toxic by ingestion and inhalation. Can be toxic by skin absorption. After ingestion or inhalation, initial symptoms may be only that of mild intoxication, but may become severe after 12 to 18 hours. Affects Central Nervous System, especially optic nerve. Marked impairment of vision and enlargement of the liver has been reported with chronic exposure. Chronic exposure may also cause damage to kidneys and Central Nervous System. Causes dizziness, nausea, muscle weakness, narcosis, respiratory failure. Ingestion can produce blindness (100 ml can be fatal). Prolonged or repeated skin contact may cause irritation. Fetal development abnormalities and effects on embryo or fetus has been reported from prolonged exposure to methyl alcohol in laboratory tests involving pregnant rats enlargement of the liver has been reported with chronic exposure.

Medical Cond. Aggravated by Exposure:
Skin conditions, eye problems, or impaired liver or kidney function.

Routes of Entry:
Inhalation, ingestion or skin contact.

Carcinogenicity:
The material is not listed (IARC, NTP, OSHA) as cancer causing agent.

4. FIRST AID MEASURES

Emergency First Aid:
GET MEDICAL ASSISTANCE FOR ALL CASES OF OVEREXPOSURE.
Skin: Wash thoroughly with soap and water.
Eyes: Immediately flush thoroughly with water for at least 15 minutes.
Inhalation: Remove to fresh air; give artificial respiration if breathing has stopped.
Ingestion: Get immediate medical attention. If medical attention is not immediately available, induce vomiting. Do not induce vomiting if patient is unconscious.
Remove contaminated clothing and wash before reuse.

5. FIRE FIGHTING MEASURES

Flash Point (F): 52F (tcc)
Flammable Limits LEL (%): 6.7
Flammable Limits UEL (%): 36.5
Extinguishing Media:
Use water spray, foam, dry chemical, or CO_2.

Fire Fighting Procedures:
Wear self-contained breathing apparatus.

Fire & Explosion Hazards:
Dangerous fire and explosive hazard. Closed containers may explode upon heating. Vapor can travel distances to ignition source and flash back. Hot organic chemical vapors or mists are susceptible to sudden spontaneous combustion when mixed with air. Ignition may occur at temperatures below published autoingnition or ignition temperatures. Ignition temperatures decrease with increasing vapor volume and vapor/air contact time and are influenced by pressure changes. Ignition may occur at typical elevated temperature process conditions, especially in process operating under vacuum if subjected to sudden ingress of air, or outside process equipment operating under elevated pressure if sudden escape of vapors or mists to the atmosphere occurs.

6. ACCIDENTAL RELEASE MEASURES

Spill Response:
Evacuate the area of all unnecessary personnel. Wear suitable protective equipment listed under Exposure / Personal Protection. Eliminate any ignition sources until the area is determined to be free from explosion or fire hazards. Contain the release and eliminate its source, if this can be done without risk. Take up and containerize for proper disposal as described under Disposal. Comply with Federal, State, and local regulations on reporting releases. Refer to Regulatory Information for reportable quantity and other regulatory data.
EM SCIENCE recommends Spill-X absorbent agents for various types of spills. Additional information on the Spill-X products can be provided through the EM SCIENCE Technical Service Department (856) 423-6300. The following EM SCIENCE Spill-X absorbent is recommended for this product:

SX0863 Solvent Spill Treatment Kit

7. HANDLING AND STORAGE

Handling & Storage:
Keep container closed. Store in a cool area away from ignition sources and oxidizers. Do not breath vapor or mist. Do not get in eyes, on skin, or on clothing. Electrically ground all equipment when handling this product.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT:

Ventilation, Respiratory Protection, Protective Clothing, Eye Protection:
Respiratory Protection: If workplace exposure limit(s) of product or any component is exceeded (see TLV/PEL), a NIOSH/MSHA approved air supplied respirator is advised in absence of proper environmental control. OSHA regulations also permit other NIOSH/MSHA respirators (negative pressure type) under specified conditions (see your safety equipment supplier). Engineering and/or administrative controls should be implemented to reduce exposure. Material should be handled or transferred in an approved fume hood or with adequate ventilation. Protective gloves must be worn to prevent skin contact (Butyl Rubber, Viton or equivalent) Safety glasses with side shields must be worn at all times.

Work/Hygenic Practices:
Wash thoroughly after handling. Do not take internally. Eye wash and safety equipment should be readily available.

EXPOSURE GUIDELINES

OSHA - PEL:

	TWA		STEL		CL		
Component	PPM	MG/M3	PPM	MG/M3	PPM	MG/M3	Skin
Methanol	200	260	250	325			X

ACGIH - TLV:

	TWA		STEL		CL		
Component	PPM	MG/M3	PPM	MG/M3	PPM	MG/M3	Skin
Methanol	200	262	250	328			X

If there are no exposure limit numbers listed in the Exposure Guidelines chart, this indicates that no OSHA or ACGIH exposure limts have been established.

9. PHYSICAL AND CHEMCIAL PROPERTIES

Boiling Point (C 760 mmHg) : 64.5C
Melting Point (C) : -98C
Specific Gravity (H_20 = 1) : 0.791
Vapor Pressure (mm Hg) : 97 20C
Percent Volatile by vol (%): 99.9+%
Vapor Density (Air = 1) : 1.1
Evaporation Rate (BuAc = 1): 5.91
Solubility in Water (%) : Miscible
Appearance :
Colorless liquid, characteristic alcoholic odor

10. STABILITY AND REACTIVITY

Stability: Yes

Hazardous Polymerization:
Does not occur

Hazardous Decomposition:
CO_x, Formaldehyde

Conditions to Avoid:
Heat; contact with ignition sources.

Materials To Avoid:

```
( ) Water
(X) Acids
( ) Bases
( ) Corrosives
(X) Oxidizers
(X) Other: Reactive metals
```

11. TOXICOLOGICAL INFORMATION

Toxicity Data

```
orl-hmn LDLo:  143 mg/kg  orl-rat LD50:  5628 mg/kg
ihl-rat LC50: 64000 ppm/4H  skn-rbt LD50:  15800 mg/kg
```

Toxicological Findings:
Test on laboratory animals indicate material may produce adverse mutagenic and reproductive effects.
Cited in Registry of Toxic Effects of Chemical Substances (RTECS)

12. DISPOSAL CONSIDERATIONS

EPA Waste Numbers: U154 D001

Treatment:
Incineration, fuels blending or recycle. Contact your local permitted waste disposal site (TSD) for permissible treatment sites.
ALWAYS CONTACT A PERMITTED WASTE DISPOSER (TSD) TO ASSURE COMPLIANCE WITH ALL CURRENT LOCAL, STATE AND FEDERAL REGULATIONS.

13. TRANSPORT INFORMATION

DOT Proper Shipping Name:
Methanol

DOT ID Number :
UN1230

14. REGULATORY INFORMATION

TSCA Statement:
The CAS number of this product is listed on the TSCA Inventory.

Component	SARA EHS (302)	SARA EHS TPQ (lbs)	CERCLA RQ (lbs)
Methanol			5000

Component	OSHA Floor List	SARA 313	DeMinimis for SARA 313 (%)
Methanol	Y	Y	1.0

If there is no information listed on the regulatory information chart, this indicates that the chemical is not covered by the specific regulation listed.

15. OTHER INFORMATION

Comments:
None

NFPA Hazard Ratings:

```
Health          : 1
Flammability    : 3
Reactivity      : 0
Special Hazards :
```

Revision History: 1/7/00 1/25/00 2/1/83 10/1/83 5/1/85 12/8/86 1/31/87 6/10/87 8/28/87 10/27/87 8/10/88 10/6/88 3/14/89 9/28/89 10/9/89 5/10/90 1/11/91 3/1/91 8/7/91 11/8/91 10/9/96 2/12/97 6/6/97 8/30/97 2/12/98 3/5/99 8/18/99

| = Revised Section

N/A = Not Available

N/E = None Established

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MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1 800-582-2537) for assistance.

HEXANE

MSDS Number: H2381 — ***Effective Date: 11/02/01***

1. Product Identification

Synonyms: Hexanes,Normal Hexane; Hexyl Hydride; Hexane 95%
CAS No.: 110-54-3 (n-hexane)
Molecular Weight: 86.18
Chemical Formula: CH3(CH2)4CH3 n-hexane
9262, 9304, 9308, N168

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Hexane	110-54-3	85 - 100%	Yes
Methylcyclopentane	96-37-7	1 - 2%	Yes
Trace amount of Benzene (10 ppm)	071-43-2	*	No

3. Hazards Identification

Emergency Overview

DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE. HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT.

AFFECTS THE CENTRAL AND PERIPHERAL NERVOUS SYSTEMS.

J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 2 - Moderate
Flammability Rating: 3 - Severe (Flammable)
Reactivity Rating: 0 - None
Contact Rating: 2 - Moderate
Lab Protective Equip: GOGGLES; LAB COAT; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER
Storage Color Code: Red (Flammable)

Potential Health Effects

The health hazards addressed are for the major component: n-hexane.

Inhalation:
Inhalation of vapors irritates the respiratory tract. Overexposure may cause lightheadedness, nausea, headache, and blurred vision. Greater exposure may cause muscle weakness, numbness of the extremities, unconsciousness and death.
Ingestion:
May produce abdominal pain, nausea. Aspiration into lungs can produce severe lung damage and is a medical emergency. Other symptoms expected to parallel inhalation.
Skin Contact:
May cause redness, irritation, with dryness, cracking.
Eye Contact:
Vapors may cause irritation. Splashes may cause redness and pain.
Chronic Exposure:
Repeated or prolonged skin contact may defat the skin and produce irritation and dermatitis. Chronic inhalation may cause peripheral nerve disorders and central nervous system effects.

Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders or eye problems or impaired respiratory function may be more susceptible to the effects of the substance. May affect the developing fetus.

4. First Aid Measures

Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion:
Aspiration hazard. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
Remove any contaminated clothing. Wipe off excess from skin. Wash skin with soap and

water for at least 15 minutes. Get medical attention if irritation develops or persists.
Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

Note to Physician:
BEI=2,5-hexadione in urine, sample at end of shift at workweeks end, 5 mg/g creatine. Also, measure n-hexane in expired air. Analgesics may be necessary for pain management, there is no specific antidote. Monitor arterial blood gases in cases of severe aspiration.

5. Fire Fighting Measures

Fire:
Flash point: -23C (-9F) CC
Autoignition temperature: 224C (435F)
Flammable limits in air % by volume:
lel: 1.2; uel: 7.7
Extremely Flammable Liquid and Vapor! Vapor may cause flash fire. Dangerous fire hazard when exposed to heat or flame.
Explosion:
Above flash point, vapor-air mixtures are explosive within flammable limits noted above. Contact with oxidizing materials may cause extremely violent combustion.Explodes when mixed @ 28C with dinitrogen tetraoxide. Sensitive to static discharge.
Fire Extinguishing Media:
Dry chemical, foam or carbon dioxide. Water may be ineffective.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Water spray may be used to keep fire exposed containers cool. Vapors can flow along surfaces to distant ignition source and flash back. Vapor explosion hazard exists indoors, outdoors, or in sewers.

6. Accidental Release Measures

Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! If a leak or spill has not ignited, use water spray to disperse the vapors, to protect personnel attempting to stop leak, and to flush spills away from exposures. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker SOLUSORB® solvent adsorbent is recommended for spills of this product.

7. Handling and Storage

Protect against physical damage. Store in a cool, dry well-ventilated location, away from direct sunlight and any area where the fire hazard may be acute. Store in tightly closed containers (preferably under nitrogen atmosphere). Outside or detached storage is preferred. Inside storage should be in a standard flammable liquids storage room or cabinet. Separate from oxidizing materials. Containers should be bonded and grounded for transfers to avoid static sparks. Storage and use areas should be No Smoking areas. Use non-sparking type tools and equipment. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
N-Hexane [110-54-3]:
-OSHA Permissible Exposure Limit (PEL): 500 ppm (TWA)
-ACGIH Threshold Limit Value (TLV): 50 ppm (TWA), Skin
other isomers of hexane
-ACGIH Threshold Limit Value (TLV): 500 ppm (TWA),1000ppm (STEL)
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded and engineering controls are not feasible, wear a supplied air, full-facepiece respirator, airlined hood, or full-facepiece self-contained breathing apparatus. Breathing air quality must meet the requirements of the OSHA respiratory protection standard (29CFR1910.134).
Skin Protection:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:
Clear, colorless liquid.
Odor:

Light odor.
Solubility:
Insoluble in water.
Specific Gravity:
0.66
pH:
No information found.
% Volatiles by volume @ 21C (70F):
100
Boiling Point:
ca. 68C (ca. 154F)
Melting Point:
ca. -95C (ca. -139F)
Vapor Density (Air=1):
3.0
Vapor Pressure (mm Hg):
130 @ 20C (68F)
Evaporation Rate (BuAc=1):
9

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage. Heat will contribute to instability.
Hazardous Decomposition Products:
May produce acrid smoke and irritating fumes when heated to decomposition.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Strong oxidizers.
Conditions to Avoid:
Heat, flames, ignition sources and incompatibles.

11. Toxicological Information

N-Hexane: Oral rat LD50: 28710 mg/kg. Irritation eye rabbit: 10 mg mild. Investigated as a tumorigen, mutagen and reproductive effector.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Hexane (110-54-3)	No	No	None
Methylcyclopentane (96-37-7)	No	No	None
Trace amount of Benzene (10 ppm) (071-43-2)	Yes	No	1

12. Ecological Information

Environmental Fate:
When released into the soil, this material may biodegrade to a moderate extent. When released into the soil, this material is not expected to leach into groundwater. When released into the soil, this material is expected to quickly evaporate. When released into water, this material may biodegrade to a moderate extent. When released to water, this material is expected to quickly evaporate. When released into the water, this material is expected to have a half-life between 1 and 10 days. This material has an estimated bioconcentration factor (BCF) of less than 100. This material has a log octanol-water partition coefficient of greater than 3.0. This material is not expected to significantly bioaccumulate. When released into the air, this material is expected to be readily degraded by reaction with photochemically produced hydroxyl radicals. When released into the air, this material is expected to have a half-life between 1 and 10 days.
Environmental Toxicity:
No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: HEXANES
Hazard Class: 3
UN/NA: UN1208
Packing Group: II
Information reported for product/size: 52L

International (Water, I.M.O.)

Proper Shipping Name: HEXANES
Hazard Class: 3
UN/NA: UN1208
Packing Group: II
Information reported for product/size: 52L

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\--------

Ingredient	TSCA	EC	Japan	Australia
Hexane (110-54-3)	Yes	Yes	Yes	Yes
Methylcyclopentane (96-37-7)	Yes	Yes	No	Yes
Trace amount of Benzene (10 ppm) (071-43-2)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Hexane (110-54-3)	Yes	Yes	No	Yes
Methylcyclopentane (96-37-7)	Yes	Yes	No	Yes
Trace amount of Benzene (10 ppm) (071-43-2)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\--------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Hexane (110-54-3)	No	No	Yes	No
Methylcyclopentane (96-37-7)	No	No	No	No
Trace amount of Benzene (10 ppm) (071-43-2)	No	No	Yes	No

--------\Federal, State & International Regulations - Part 2\--------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Hexane (110-54-3)	5000	No	No
Methylcyclopentane (96-37-7)	No	No	No
Trace amount of Benzene (10 ppm) (071-43-2)	10	U019	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: Yes Pressure: No
Reactivity: No (Mixture / Liquid)

WARNING:
THIS PRODUCT CONTAINS A CHEMICAL(S) KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER.

Australian Hazchem Code: 3[Y]E
Poison Schedule: No information found.
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: 1 Flammability: 3 Reactivity: 0
Label Hazard Warning:
DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE. HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. AFFECTS THE CENTRAL AND PERIPHERAL NERVOUS SYSTEMS.
Label Precautions:
Keep away from heat, sparks and flame.
Keep container closed.
Use only with adequate ventilation.
Wash thoroughly after handling.
Avoid breathing vapor or mist.
Avoid contact with eyes, skin and clothing.
Label First Aid:
Aspiration hazard. If swallowed, vomiting may occur spontaneously, but DO NOT INDUCE. If vomiting occurs, keep head below hips to prevent aspiration into lungs. Never give anything by mouth to an unconscious person. Call a physician immediately. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes. In all cases call a physician.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 8.
Disclaimer:
****

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Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

MSDS *Material Safety Data Sheet*

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals

All non emergency questions should be directed to Customer Service (1-800 582-2537) for assistance.

HYDROCHLORIC ACID, 0.01N to 0.2N VOLUMETRIC SOLUTIONS (0.04 to 0

MSDS Number: H2500 — ***Effective Date: 11/02/01***

1. Product Identification

Synonyms: None
CAS No.: Not applicable to mixtures.
Molecular Weight: Not applicable to mixtures.
Chemical Formula: Not applicable.
Product Codes: J.T. Baker: 0326, 5611, 5614, 5621
Mallinckrodt: 2853, H148, H156

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Hydrogen Chloride	7647-01-0	0.04 - 0.4%	Yes
Water	7732-18-5	> 99%	No

3. Hazards Identification

Emergency Overview

As part of good industrial and personal hygiene and safety procedure, avoid all unnecessary exposure to the chemical substance and ensure prompt removal from skin, eyes and clothing.

J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 0 - None
Flammability Rating: 0 - None
Reactivity Rating: 0 - None
Contact Rating: 1 - Slight
Lab Protective Equip: GOGGLES; LAB COAT
Storage Color Code: Orange (General Storage)

Potential Health Effects

Inhalation:
Not expected to be a health hazard.
Ingestion:
Large oral doses may cause gastrointestinal disturbances.
Skin Contact:
No adverse effects expected.
Eye Contact:
May cause irritation, redness and pain.
Chronic Exposure:
No information found.
Aggravation of Pre-existing Conditions:
No information found.

4. First Aid Measures

Inhalation:
Not expected to require first aid measures.
Ingestion:
Give several glasses of water to drink to dilute. If large amounts were swallowed, get medical advice.
Skin Contact:
Not expected to require first aid measures.
Eye Contact:
Wash thoroughly with running water. Get medical advice if irritation develops.

5. Fire Fighting Measures

Fire:
Not considered to be a fire hazard.
Explosion:
Not considered to be an explosion hazard.

Fire Extinguishing Media:
Use any means suitable for extinguishing surrounding fire.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Contain and recover liquid when possible. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust.

J. T. Baker NEUTRASORB® or TEAM® 'Low Na+' acid neutralizers are recommended for spills of this product.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Protect from freezing. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
Not applicable.
Ventilation System:
Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved):
Not expected to require personal respirator usage.
Skin Protection:
Wear protective gloves and clean body-covering clothing.
Eye Protection:
Safety glasses. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:

Clear, colorless solution.
Odor:
Odorless.
Solubility:
Infinitely soluble.
Specific Gravity:
ca. 1.0
pH:
No information found.
% Volatiles by volume @ 21C (70F):
> 99
Boiling Point:
ca. 100C (32F)
Melting Point:
ca. 0C (32F)
Vapor Density (Air=1):
Essentially the same as water.
Vapor Pressure (mm Hg):
Essentially the same as water.
Evaporation Rate (BuAc=1):
Essentially the same as water.

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage.
Hazardous Decomposition Products:
No information found.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
No incompatibility data found.
Conditions to Avoid:
No information found.

11. Toxicological Information

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Hydrogen Chloride (7647-01-0)	No	No	3
Water (7732-18-5)	No	No	None

12. Ecological Information

Environmental Fate:
No information found.
Environmental Toxicity:
No information found.

13. Disposal Considerations

Dilute with water and flush to sewer if local ordinances allow, otherwise, whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\--------

Ingredient	TSCA	EC	Japan	Australia
Hydrogen Chloride (7647-01-0)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Hydrogen Chloride (7647-01-0)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\--------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Hydrogen Chloride (7647-01-0)	5000	500*	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\--------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Hydrogen Chloride (7647-01-0)	5000	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: No Chronic: No Fire: No Pressure: No
Reactivity: No (Mixture / Liquid)

Australian Hazchem Code: No information found.
Poison Schedule: No information found.
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: 0 Flammability: 0 Reactivity: 0
Label Hazard Warning:
As part of good industrial and personal hygiene and safety procedure, avoid all unnecessary exposure to the chemical substance and ensure prompt removal from skin, eyes and clothing.
Label Precautions:
None.
Label First Aid:
Not applicable.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 8.
Disclaimer:
****

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****

Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

Product Number: 17078
Product Name: **Nitric acid**

Valid 05/2002 - 07/2002

Fluka Chemical Corp.
1001 West St. Paul
Milwaukee, WI 53233 USA
Tel: 414-273-3850

M A T E R I A L S A F E T Y D A T A S H E E T

SECTION 1. - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - -
CATALOG #: 17078
NAME: NITRIC ACID 65%

SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -
CAS #: 7697-37-2
EC NO: 231-714-2
SYNONYMS
ACIDE NITRIQUE (FRENCH) * ACIDO NITRICO (ITALIAN) * AQUA FORTIS * AZOTIC ACID * AZOTOWY KWAS (POLISH) * HYDROGEN NITRATE * KYSELINA DUSICNE (CZECH) * NITRIC ACID (ACGIH:OSHA) * SALPETERSAURE (GERMAN) SALPETERZUUROPLOSSINGEN (DUTCH) *

SECTION 3. - - - - - - - - - - HAZARDS IDENTIFICATION - - - - - - - - -
LABEL PRECAUTIONARY STATEMENTS
OXIDIZING
CORROSIVE
CONTACT WITH COMBUSTIBLE MATERIAL MAY CAUSE FIRE.
TOXIC IF SWALLOWED.
VERY TOXIC BY INHALATION.
CAUSES SEVERE BURNS.
TARGET ORGAN(S):
LUNGS
TEETH
DO NOT BREATHE VAPOR.
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE.
WEAR SUITABLE PROTECTIVE CLOTHING.
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).
PROTECT FROM LIGHT.

SECTION 4. - - - - - - - - - - FIRST-AID MEASURES- - - - - - - - - -
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES OR SKIN WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATE CLOTHING AND SHOES.
ASSURE ADEQUATE FLUSHING OF THE EYES BY SEPARATING THE EYELIDS WITH FINGERS.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOU
CALL A PHYSICIAN IMMEDIATELY.
WASH CONTAMINATED CLOTHING BEFORE REUSE.
DISCARD CONTAMINATED SHOES.

SECTION 5. - - - - - - - - - FIRE FIGHTING MEASURES - - - - - - - - - -
EXTINGUISHING MEDIA
NONCOMBUSTIBLE.
USE EXTINGUISHING MEDIA APPROPRIATE TO SURROUNDING FIRE CONDITIONS.
SPECIAL FIREFIGHTING PROCEDURES
WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO PREVENT CONTACT WITH SKIN AND EYES.
UNUSUAL FIRE AND EXPLOSIONS HAZARDS
EMITS TOXIC FUMES UNDER FIRE CONDITIONS.

SECTION 6. - - - - - - - - ACCIDENTAL RELEASE MEASURES- - - - - - - -
EVACUATE AREA.

WEAR SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES.
COVER WITH DRY-LIME, SAND, OR SODA ASH. PLACE IN COVERED CONTAINERS USING NON-SPARKING TOOLS AND TRANSPORT OUTDOORS.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLET

SECTION 7. - - - - - - - - - - HANDLING AND STORAGE- - - - - - - - - -
REFER TO SECTION 8.

SECTION 8. - - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - -
CHEMICAL SAFETY GOGGLES.
SAFETY SHOWER AND EYE BATH.
NIOSH/MSHA-APPROVED RESPIRATOR IN NONVENTILATED AREAS AND/OR FOR EXPOSURE ABOVE THE ACGIH TLV.
MECHANICAL EXHAUST REQUIRED.
RUBBER GLOVES.
AVOID BREATHING VAPOR.
DO NOT GET IN EYES, ON SKIN, ON CLOTHING.
AVOID PROLONGED OR REPEATED EXPOSURE.
WASH THOROUGHLY AFTER HANDLING.
CORROSIVE.
TOXIC.
KEEP TIGHTLY CLOSED.
PROTECT FROM LIGHT.
STORE IN A COOL DRY PLACE.

SECTION 9. - - - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - - - -
APPEARANCE AND ODOR
LIQUID.

SECTION 10. - - - - - - - - -STABILITY AND REACTIVITY - - - - - - - - -
INCOMPATIBILITIES
BASES
AMINES
ALKALI METALS
COPPER, COPPER ALLOYS
ALUMINUM
CORRODES STEEL
SENSITIVE TO LIGHT
HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS
TOXIC FUMES OF:
NITROGEN OXIDES

SECTION 11. - - - - - - - - - TOXICOLOGICAL INFORMATION - - - - - - - -
ACUTE EFFECTS
HARMFUL IF SWALLOWED, INHALED, OR ABSORBED THROUGH SKIN.
CAUSES BURNS.
MATERIAL IS EXTREMELY DESTRUCTIVE TO TISSUE OF THE MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT, EYES AND SKIN.
INHALATION MAY RESULT IN SPASM, INFLAMMATION AND EDEMA OF THE LARYNX AND BRONCHI, CHEMICAL PNEUMONITIS AND PULMONARY EDEMA.
SYMPTOMS OF EXPOSURE MAY INCLUDE BURNING SENSATION, COUGHING, WHEEZING, LARYNGITIS, SHORTNESS OF BREATH, HEADACHE, NAUSEA AND VOMITING.
RTECS #: QU5775000
NITRIC ACID
TOXICITY DATA
ORL-HMN LDLO:430 MG/KG YAKUD5 22,651,1980
UNR-MAN LDLO:110 MG/KG 85DCAI 2,73,1970
ONLY SELECTED REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES (RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR COMPLETE INFORMATION.

SECTION 12. - - - - - - - - - ECOLOGICAL INFORMATION - - - - - - - - -
DATA NOT YET AVAILABLE.

SECTION 13. - - - - - - - - - DISPOSAL CONSIDERATIONS - - - - - - - - -
FOR SMALL QUANTITIES: CAUTIOUSLY ADD TO A LARGE STIRRED EXCESS OF WATER. ADJUST THE PH TO NEUTRAL, SEPARATE ANY INSOLUBLE SOLIDS OR LIQUIDS AND PACKAGE THEM FOR HAZARDOUS-WASTE DISPOSAL. FLUSH THE AQUEOUS SOLUTION DOWN THE DRAIN WITH PLENTY OF WATER. THE HYDROLYSI AND NEUTRALIZATION REACTIONS MAY GENERATE HEAT AND FUMES WHICH CAN CONTROLLED BY THE RATE OF ADDITION.
OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

SECTION 14. - - - - - - - - - TRANSPORT INFORMATION - - - - - - - - -
CONTACT FLUKA CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

SECTION 15. - - - - - - - - - REGULATORY INFORMATION - - - - - - - - -
EUROPEAN INFORMATION

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EC INDEX NO: 007-004-00-1
OXIDIZING
CORROSIVE
R 35
CAUSES SEVERE BURNS.
S 23
DO NOT BREATHE VAPOR.
S 26
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE.
S 36
WEAR SUITABLE PROTECTIVE CLOTHING.
S 45
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).

REVIEWS, STANDARDS, AND REGULATIONS

OEL=MAK
ACGIH TLV-STEL 4 PPM DTLVS* TLV/BEI,1999
ACGIH TLV-TWA 2 PPM DTLVS* TLV/BEI,1999
MSHA STANDARD-AIR:TWA 2 PPM (5 MG/M3)
DTLVS* 3,181,1971
OSHA PEL (GEN INDU):8H TWA 2 PPM (5 MG/M3)
CFRGBR 29,1910.1000,1994
OSHA PEL (CONSTRUC):8H TWA 2 PPM (5 MG/M3)
CFRGBR 29,1926.55,1994
OSHA PEL (SHIPYARD):8H TWA 2 PPM (5 MG/M3)
CFRGBR 29,1915.1000,1993
OSHA PEL (FED CONT):8H TWA 2 PPM (5 MG/M3)
CFRGBR 41,50-204.50,1994
OEL-ARAB REPUBLIC OF EGYPT: TWA 2 PPM (5 MG/M3), JAN1993
OEL-AUSTRALIA: TWA 2 PPM (5 MG/M3), STEL 4 PPM, JAN1993
OEL-AUSTRIA: MAK 2 PPM (5 MG/M3), JAN1999
OEL-BELGIUM: TWA 2 PPM (5.2 MG/M3), STEL 4 PPM (10 MG/M3), JAN1993
OEL-DENMARK: TWA 2 PPM (5 MG/M3), JAN1999
OEL-FINLAND: TWA 2 PPM (5 MG/M3), STEL 5 PPM (13 MG/M3), SKIN, JAN1
OEL-FRANCE: VME 2 PPM (5 MG/M3), VLE 5 PPM (10 MG/M3), JAN1999
OEL-GERMANY: MAK 2 PPM (5 MG/M3), JAN1999
OEL-HUNGARY: STEL 5 MG/M3, JAN1993
OEL-JAPAN: OEL 2 PPM (5.2 MG/M3), JAN1999
OEL-NORWAY: TWA 2 PPM (5 MG/M3), JAN1999
OEL-THE PHILIPPINES: TWA 2 PPM (5 MG/M3), JAN1993
OEL-POLAND: MAC(TWA) 5 MG/M3, MAC(STEL) 10 MG/M3, JAN1999
OEL-RUSSIA: TWA 2 PPM, STEL 2 MG/M3, SKIN, JAN1993
OEL-SWEDEN: NGV 2 PPM (5 MG/M3), KTV 5 PPM (13 MG/M3), JAN1999
OEL-THAILAND: TWA 2 PPM (5 MG/M3), JAN1993
OEL-TURKEY: TWA 2 PPM (5 MG/M3), JAN1993
OEL-UNITED KINGDOM: LTEL 2 PPM (5 MG/M3), STEL 4 PPM (10 MG/M3), JAN1993
OEL IN ARGENTINA, BULGARIA, COLOMBIA, JORDAN, KOREA CHECK ACGIH TLV
OEL IN NEW ZEALAND, SINGAPORE, VIETNAM CHECK ACGIH TLV
NIOSH REL TO NITRIC ACID-AIR:10H TWA 2 PPM;STEL 4 PPM
NIOSH* DHHS #92-100,1992
NOHS 1974: HZD 50742; NIS 197; TNF 18088; NOS 101; TNE 132401
NOES 1983: HZD 50742; NIS 201; TNF 18239; NOS 120; TNE 297627; TFE 76316
EPA GENETOX PROGRAM 1988, NEGATIVE: CELL TRANSFORM.-SA7/SHE
EPA TSCA SECTION 8(B) CHEMICAL INVENTORY
EPA TSCA SECTION 8(D) UNPUBLISHED HEALTH/SAFETY STUDIES
EPA TSCA TEST SUBMISSION (TSCATS) DATA BASE, JANUARY 2001
NIOSH ANALYTICAL METHOD, 1994: ACIDS, INORGANIC, 7903
OSHA ANALYTICAL METHOD #ID-127

U.S. INFORMATION

THIS PRODUCT IS OR CONTAINS A COMPONENT THAT IS SUBJECT TO SARA313 REPORTING REQUIREMENTS.

SECTION 16. - - - - - - - - - - OTHER INFORMATION- - - - - - - - - - -

THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPOR BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. SIGMA, ALDRICH, FLUKA SHALL NOT BE HELD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLI OR FROM CONTACT WITH THE ABOVE PRODUCT. SEE REVERSE SIDE OF INVOICE PACKING SLIP FOR ADDITIONAL TERMS AND CONDITIONS OF SALE.

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MSDS *Material Safety Data Sheet*

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300
National Response in Canada
CANUTEC: 613-996-6666
Outside U.S. and Canada
Chemtrec: 703-527-3887
NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

SULFURIC ACID, 52 - 100 %

MSDS Number: S8234 — ***Effective Date: 02/18/02***

1. Product Identification

Synonyms: Oil of vitriol; Babcock acid; sulphuric acid
CAS No.: 7664-93-9
Molecular Weight: 98.08
Chemical Formula: H2SO4 in H2O
Product Codes:
J.T. Baker: 5030, 5137, 5374, 5802, 5815, 5889, 5897, 5960, 5961, 5971, 5997, 6902, 9673, 9674, 9675, 9676, 9679, 9680, 9681, 9682, 9684, 9687, 9691, 9693, 9694
Mallinckrodt: 2468, 2876, 2878, 2900, 2904, 3780, 4222, 5524, 5557, H644, H976, H996, V344, V651, XL003

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Sulfuric Acid	7664-93-9	52 - 100%	Yes
Water	7732-18-5	0 - 48%	No

3. Hazards Identification

Emergency Overview

POISON! DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR CONTACTED WITH SKIN. HARMFUL IF INHALED. AFFECTS TEETH. WATER REACTIVE. CANCER HAZARD. STRONG INORGANIC ACID MISTS CONTAINING SULFURIC ACID CAN CAUSE CANCER. Risk of cancer depends on duration and level of exposure.

SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 4 - Extreme (Poison)
Flammability Rating: 0 - None
Reactivity Rating: 2 - Moderate
Contact Rating: 4 - Extreme (Corrosive)
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Inhalation:
Inhalation produces damaging effects on the mucous membranes and upper respiratory tract. Symptoms may include irritation of the nose and throat, and labored breathing. May cause lung edema, a medical emergency.
Ingestion:
Corrosive. Swallowing can cause severe burns of the mouth, throat, and stomach, leading to death. Can cause sore throat, vomiting, diarrhea. Circulatory collapse with clammy skin, weak and rapid pulse, shallow respirations, and scanty urine may follow ingestion or skin contact. Circulatory shock is often the immediate cause of death.
Skin Contact:
Corrosive. Symptoms of redness, pain, and severe burn can occur. Circulatory collapse with clammy skin, weak and rapid pulse, shallow respirations, and scanty urine may follow skin contact or ingestion. Circulatory shock is often the immediate cause of death.
Eye Contact:
Corrosive. Contact can cause blurred vision, redness, pain and severe tissue burns. Can cause blindness.
Chronic Exposure:
Long-term exposure to mist or vapors may cause damage to teeth. Chronic exposure to mists containing sulfuric acid is a cancer hazard.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders or eye problems or impaired respiratory function may be more susceptible to the effects of the substance.

4. First Aid Measures

Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give

oxygen. Call a physician immediately.
Ingestion:
DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Call a physician immediately.
Skin Contact:
In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Excess acid on skin can be neutralized with a 2% solution of bicarbonate of soda. Call a physician immediately.
Eye Contact:
Immediately flush eyes with gentle but large stream of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Call a physician immediately.

5. Fire Fighting Measures

Fire:
Concentrated material is a strong dehydrating agent. Reacts with organic materials and may cause ignition of finely divided materials on contact.
Explosion:
Contact with most metals causes formation of flammable and explosive hydrogen gas.
Fire Extinguishing Media:
Dry chemical, foam or carbon dioxide. Do not use water on material. However, water spray may be used to keep fire exposed containers cool.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Structural firefighter's protective clothing is ineffective for fires involving this material. Stay away from sealed containers.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Neutralize with alkaline material (soda ash, lime), then absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker NEUTRASORB® or TEAM® 'Low Na+' acid neutralizers are recommended for spills of this product.

7. Handling and Storage

Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Protect from physical damage. Keep out of direct sunlight and away from heat, water, and incompatible materials. Do not wash out container and use it for other purposes. When diluting, always add the acid to water; never add water to the acid. When opening metal containers, use non-sparking tools because of the possibility of hydrogen gas being present. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
For Sulfuric Acid:
- OSHA Permissible Exposure Limit (PEL) -
1 mg/m3 (TWA)
- ACGIH Threshold Limit Value (TLV) -
1 mg/m3(TWA), 3 mg/m3 (STEL), A2 - suspected human carcinogen for sulfuric acid contained in strong inorganic acid mists.
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded and engineering controls are not feasible, a full facepiece respirator with an acid gas cartridge and particulate filter (NIOSH type N100 filter) may be worn up to 50 times the exposure limit, or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. If oil particles (e.g. lubricants, cutting fluids, glycerine, etc.) are present, use a NIOSH type R or P particulate filter. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres. Where respirators are required, you must have a written program covering the basic requirements in the OSHA respirator standard. These include training, fit testing, medical approval, cleaning, maintenance, cartridge change schedules, etc. See 29CFR1910.134 for details.
Skin Protection:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:
Clear oily liquid.
Odor:
Odorless.
Solubility:
Miscible with water, liberates much heat.
Specific Gravity:
1.84 (98%), 1.40 (50%), 1.07 (10%)
pH:
1 N solution (ca. 5% w/w) = 0.3; 0.1 N solution (ca. 0.5% w/w) = 1.2; 0.01 N solution (ca. 0.05% w/w) = 2.1.
% Volatiles by volume @ 21C (70F):
No information found.
Boiling Point:
ca. 290C (ca. 554F) (decomposes at 340C)
Melting Point:
3C (100%), -32C (93%), -38C (78%), -64C (65%).
Vapor Density (Air=1):
3.4
Vapor Pressure (mm Hg):
1 @ 145.8C (295F)
Evaporation Rate (BuAc=1):
No information found.

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage. Concentrated solutions react violently with water, spattering and liberating heat.
Hazardous Decomposition Products:
Toxic fumes of oxides of sulfur when heated to decomposition. Will react with water or steam to produce toxic and corrosive fumes. Reacts with carbonates to generate carbon dioxide gas, and with cyanides and sulfides to form poisonous hydrogen cyanide and hydrogen sulfide respectively.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Water, potassium chlorate, potassium perchlorate, potassium permanganate, sodium, lithium, bases, organic material, halogens, metal acetylides, oxides and hydrides, metals (yields hydrogen gas), strong oxidizing and reducing agents and many other reactive substances.
Conditions to Avoid:
Heat, moisture, incompatibles.

11. Toxicological Information

Toxicological Data:
Oral rat LD50: 2140 mg/kg; inhalation rat LC50: 510 mg/m3/2H; standard Draize, eye rabbit, 250 ug (severe); investigated as a tumorigen, mutagen, reproductive effector.
Carcinogenicity:
Cancer Status: The International Agency for Research on Cancer (IARC) has classified "strong inorganic acid mists containing sulfuric acid" as a known human carcinogen, (IARC category 1). This classification applies only to mists containing sulfuric acid and not to sulfuric acid or sulfuric acid solutions.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Sulfuric Acid (7664-93-9)	No	No	None
Water (7732-18-5)	No	No	None

12. Ecological Information

Environmental Fate:
When released into the soil, this material may leach into groundwater. When released into the air, this material may be removed from the atmosphere to a moderate extent by wet deposition. When released into the air, this material may be removed from the atmosphere to a moderate extent by dry deposition.
Environmental Toxicity:
LC50 Flounder 100 to 330 mg/l/48 hr aerated water/Conditions of bioassay not specified; LC50 Shrimp 80 to 90 mg/l/48 hr aerated water /Conditions of bioassay not specified; LC50 Prawn 42.5 ppm/48 hr salt water /Conditions of bioassay not specified.
This material may be toxic to aquatic life.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: SULFURIC ACID (WITH MORE THAN 51% ACID)
Hazard Class: 8

UN/NA: UN1830
Packing Group: II
Information reported for product/size: 440LB

International (Water, I.M.O.)

Proper Shipping Name: SULPHURIC ACID (WITH MORE THAN 51% ACID)
Hazard Class: 8
UN/NA: UN1830
Packing Group: II
Information reported for product/size: 440LB

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\--------

Ingredient	TSCA	EC	Japan	Australia
Sulfuric Acid (7664-93-9)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Sulfuric Acid (7664-93-9)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\--------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Sulfuric Acid (7664-93-9)	1000	1000	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\--------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Sulfuric Acid (7664-93-9)	1000	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: Yes
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: Yes (Pure / Liquid)

Australian Hazchem Code: 2P
Poison Schedule: None allocated.
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: 3 Flammability: 0 Reactivity: 2 Other: **Water reactive**
Label Hazard Warning:
POISON! DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR CONTACTED WITH SKIN. HARMFUL IF INHALED. AFFECTS TEETH. WATER REACTIVE. CANCER HAZARD. STRONG INORGANIC ACID MISTS CONTAINING SULFURIC ACID CAN CAUSE CANCER. Risk of cancer depends on duration and level of exposure.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe mist.
Keep container closed.
Use only with adequate ventilation.
Wash thoroughly after handling.
Do not contact with water.
Label First Aid:
In all cases call a physician immediately. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before re-use. Excess acid on skin can be neutralized with a 2% bicarbonate of soda solution. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 3.
Disclaimer:
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Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

Genium Publishing Corp.
One Genium Plaza
Schenectady, NY 12304-4690
(518) 377-8854

Material Safety Data Sheet Collection

Sodium Bisulfate **MSDS No. 218**

Date of Preparation: 11/87 Revision: A. 3/97

Section 1 - Chemical Product and Company Identification 49

Product/Chemical Name: Sodium Bisulfate
Chemical Formula: $NaHSO_4$
CAS Number: 7681-38-1
Synonyms: GBS, niter cake, sodium acid sulfate, sodium hydrogen sulfate, sodium pyrosulfate
Derivation: A by-product in the manufacture of hydrochloric acid and nitric acid
General Use: For liberating carbon dioxide in carbonic acid baths and fusion of minerals to make them soluble for analysis; in the manufacture of magnesia cements; paper, soap, food, perfumes, industrial cleaners; for metal pickling, bleaching and swelling leather, carbonizing wool; as a substitute for sulfuric acid in dyeing and a lab reagent.
Vendors: Consult the latest *Chemical Week Buyers' Guide.* (73)

Section 2 - Composition / Information on Ingredients

Sodium Bisulfate, ca 100% wt

OSHA PEL	ACGIH TLV	NIOSH REL	DFG (Germany) MAK
None established	None established	None established	None established

Section 3 - Hazards Identification

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Sodium bisulfate is colorless crystals or white fused lumps. It is corrosive to the eyes, skin, and mucous membranes. May burn on contact. Exposure to high levels can cause fluid build up in the lungs, causes rapid, severe shortness of breath, and death. Sodium bisulfate is noncombustible, but sulfur (SO_x) and sodium (Na_2O) oxides may be released during a fire.

Wilson Risk Scale
R 1
I 3
S 3
K 0

HMIS
H 3*
F 0
R 0
PPE†
*Chronic Effects
†Sec. 8

Potential Health Effects

Primary Entry Routes: Inhalation, ingestion or skin contact.
Target Organs: Eyes, skin, respiratory system.
Acute Effects:
Inhalation: Dust inhalation can cause nose, throat, and respiratory tract irritation. Exposure to high concentrations can cause pulmonary edema (fluid build up in the lungs).
Eye: Contact can cause severe irritation or burns. May cause blindness.
Skin: Contact can cause severe irritation or burns.
Ingestion: Causes oral, esophageal, and stomach burns; gastritis; gastrointestinal bleeding; perforations; necrosis; vomiting; and small intestine injury. Significant acid ingestion may cause metabolic acidosis.
Carcinogenicity: IARC, NTP, and OSHA do not list sodium bisulfate as a carcinogen.
Medical Conditions Aggravated by Long-Term Exposure: Respiratory conditions. *Note!* Smoking may further worsen respiratory conditions.
Chronic Effects: Based on the chronic effects caused by sulfuric acid, repeated exposure may lead to teeth erosion and/or emphysema.

Section 4 - First Aid Measures

Inhalation: Remove exposed person to fresh air, monitor for respiratory distress, and support breathing as needed. Keep the affected person warm and at rest. Get medical attention immediately.
Eye Contact: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician or ophthalmologist immediately.
Skin Contact: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. Get medical attention promptly.

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Ingestion: Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have the conscious and alert person drink 4 to 8 ounces of water. *Do not* induce vomiting. Consult physician immediately.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Note to Physicians: After an acute overexposure, perform chest x-ray and obtain blood gases. Because pulmonary edema may be delayed, medical observation is recommended for 24 to 48 hr after an acute overexposure. If pulmonary edema is present, consider PEEP.

Section 5 - Fire-Fighting Measures

Flash Point: Noncombustible solid
Autoignition Temperature: None reported.
LEL: None reported.
UEL: None reported.
Extinguishing Media: Use extinguishing agents suitable for surrounding fire. Avoid getting sodium bisulfate wet.
Unusual Fire or Explosion Hazards: If wet or moist, sodium bisulfate reacts with metals to form highly flammable and explosive hydrogen gas.
Hazardous Combustion Products: None. However, upon thermal oxidative decomposition sulfur oxides (SO_x) and sodium oxide (Na_2O) are released.
Fire-Fighting Instructions: Do not release runoff from fire control methods to sewers or waterways. If feasible and without undue risk, move containers from fire hazard area. Otherwise cool fire-exposed containers until well after fire is extinguished.
Fire-Fighting Equipment: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode.

NFPA
0
3 0
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Section 6 - Accidental Release Measures

Spill /Leak Procedures: Notify safety personnel, evacuate all unnecessary personnel, remove heat and ignition sources, and isolate and ventilate area. Cleanup personnel should protect against dust/mist inhalation and skin or eye contact.
Small Spills: Carefully scoop up dry spills. For liquid spills, take up with a noncombustible, inert absorbent such as sand or vermiculite. Place in appropriate container with cover for later disposal.
Large Spills
Containment: For large spills, dike far ahead of liquid spill for later disposal. Cover large dry spills with plastic sheet to prevent further dispersion. *Do not* release into sewers or waterways.
Cleanup: Avoid generating dusty conditions. *Do not* dry sweep. Use a vacuum (with HEPA filter).
Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).

Section 7 - Handling and Storage

Handling Precautions: Avoid dust/mist inhalation and skin and eye contact. Use with ventilation sufficient to reduce airborne concentrations to the lowest feasible levels. Wear protective gloves, goggles, faceshield, and clothing to prevent contact. Wear respiratory protection when necessary; consult your industrial hygienist on staff. Keep away from heat and ignition sources.
Storage Requirements: Store in tightly closed containers in a cool, well-ventilated area away from heat and ignition sources and incompatibles (see Sec. 10).

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Enclose operations and/or provide local exhaust ventilation at the site of chemical release to prevent dust dispersion into the work area. Isolating operations can also help reduce exposure.
Ventilation: Provide general or local exhaust ventilation systems to maintain airborne as low as possible. Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.
Administrative Controls: Consider preplacement and periodic medical exams with emphasis on the eyes, skin, and respiratory tract. Perform lung function tests. Educate workers about the hazards associated with sodium bisulfate. Train in work practices which minimize exposure.
Respiratory Protection: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved, full facepiece respirator with a high efficiency particulate filter, although powered-air purifying respirators provide greater protection. Pay close attention to the condition of the particulate filter being used, inspect for physical damage (i.e. rips or tears) and replace as needed. While wearing the filter, cartridge or canister respirator, you smell, taste, or otherwise detect sodium hydrogen sulfate, or if you are using a full facepiece respirator and you experience eye irritation, leave the area at once. Where high exposures exist, use a MSHA/NIOSH-approved, supplied-air respirator with a full facepiece operated in the positive pressure mode or with a full facepiece, hood, or helmet in

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the continuous flow mode, or use a MSHA/NIOSH-approved, self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or other positive pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

Protective Clothing/Equipment: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent skin contact. Wear protective eyeglasses or chemical safety goggles and faceshield, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.

Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.

Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Physical and Chemical Properties

Physical State: Solid
Appearance and Odor: Colorless crystals or white fused lumps.
Formula Weight: 120.06
Density: 2.435g/cm^3
pH (0.1 molar soln): 1.4
Water Solubility: Soluble in 2 parts water, 1 part boiling water
Other Solubilities: Sparingly soluble in alcohol
Boiling Point: Decomposes
Melting Point: 599 °F (315 °C)

Section 10 - Stability and Reactivity

Stability: Sodium bisulfate is stable at room temperature in closed containers under normal storage and handling conditions.
Polymerization: Hazardous polymerization cannot occur.
Chemical Incompatibilities: Include calcium hypochlorite; acetic anhydride + ethanol (may lead to ignition and vapor explosion); sodium carbonate + starch + calcium hypochlorite (explode when compressed).
Hazardous Decomposition Products: Thermal oxidative decomposition of sodium bisulfate can sulfur oxides (SO_x) and sodium oxide (Na_2O).

Section 11- Toxicological Information

Toxicity Data:*

Genetic Effects:
Microorganisms: 1000 ppm (-S9) caused mutations.

* Monitor NIOSH, *RTECS* (VZ1860000), for future toxicity data.

Section 12 - Ecological Information

Ecotoxicity: Data not found.
Environmental Fate: Data not found.

Section 13 - Disposal Considerations

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

Section 14 - Transport Information

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Sodium bisulfate
Shipping Symbols:
Hazard Class: 8
ID No.: UN2837
Packing Group: II*
Label: 8
Special Provisions (172.102): 8, T26

Packaging Authorizations
a) Exceptions: 173.154
b) Non-bulk Packaging: 173.202
c) Bulk Packaging: 173.242

Quantity Limitations
a) Passenger, Aircraft, or Railcar: 1 L
b) Cargo Aircraft Only: 30 L

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other:

EPA Regulations: Please refer to 49 CFR 173.137 for Packing Group II criteria. This data pertains to Packing Group II criteria: materials that cause full thickness destruction of intact skin tissue within an observation period of up to 14 days starting after the exposure time of more than 3 min but not more than 60 min.

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Section 15 - Regulatory Information

EPA Regulations:
RCRA Hazardous Waste (40 CFR 261.33): Not listed
RCRA Hazardous Waste Classification (40 CFR 261.22): Characteristic of Corrosivity, as aqueous* solution
CERCLA Hazardous Substance (40 CFR 302.4) as Unlisted Hazardous Waste, Characteristic of Corrosivity, as aqueous solution, specific per RCRA, Sec. 3001
CERCLA Reportable Quantity (RQ),100 lb (45.4 kg)
SARA Toxic Chemical (40 CFR 372.65): Not listed
SARA EHS (Extremely Hazardous Substance) (40 CFR 355): Not listed

OSHA Regulations:
Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A): Not listed

*As an aqueous solution with a pH less than or equal to 2.

Section 16 - Other Information

References: 136, 167, 190, 197, 209, 211.

Prepared By..... SK Poulose, BS/MJ Wurth, BS
Industrial Hygiene Review..... S Gilson, CIH
Medical Review..... T Thoburn, MD, MPH

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Genium Publishing Corporation
One Genium Plaza
Schenectady, NY 12304-4690 USA
(518) 377-8854

Sheet No. 3
Sodium Hydroxide

Issued: 10/77 Revision: C, 11/91

Section 1. Material Identification

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Sodium Hydroxide (NaOH) Description: Derived by electrolysis of sodium chloride brines, by reacting calcium chloride with sodium carbonate, or by electrolytic production using the diaphragm cell. Sodium hydroxide often contains as impurities minimal amounts of sodium chloride, sodium carbonate, sodium sulfate, sodium chlorate, iron, or nickel. Used to hydrolyze fats and form soaps; in making plastics to dissolve casein; in treating cellulose to make rayon and cellophane; in explosives, dyestuffs, electrolytic extraction of zinc, reclaiming rubber, tin plating, oxide coating, etching and electroplating, laundering and bleaching, pulp and paper manufacture; in vegetable oil refining; in peeling of fruits and vegetables in the food industry; and in veterinary medicine as a disinfectant.

Other Designations: CAS No. 1310-73-2; Aetznatron; caustic soda; Collo-Grillrein; Collo-Tapette; Feurs Rohp; Lewis-Red Devil Lye; soda, hydrate; soda lye; sodium hydrate.

Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[(73)] for a suppliers list.

Cautions: Sodium hydroxide is moderately toxic by ingestion and inhalation and can be seriously corrosive to eyes, skin, and mucous membranes.

R	0
I	2
S	4
K	0

NFPA: 0 (top), 3 (left), 1 (right), W (bottom); Alkali

HMIS
H 3
F 0
R 1
PPG*
* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Sodium hydroxide, ca 100%

1990 OSHA PEL
Ceiling: 2 mg/m³

1990 IDLH Level
250 mg/m³ (solution mists)

1991-92 ACGIH TLV
Ceiling: 2 mg/m³

1990 DFG (Germany) MAK
2 mg/m³

1990 NIOSH REL
Ceiling: 2 mg/m³

1985-86 Toxicity Data*
Rabbit, oral, LD_{Lo}: 500 mg/kg; no toxic effect noted
Rabbit, skin: 500 mg applied over 24 hr causes severe irritation
Mouse, intraperitoneal, LD_{50}: 40 mg/kg; toxic effects not yet reviewed

* See NIOSH, *RTECS* (WB4900000), for additional irritation, mutation, and toxicity data.

Section 3. Physical Data

Boiling Point: 2534 °F (1390 °C)
Melting Point: 605 °F (318.4 °C)
Vapor Pressure: 1 mm Hg at 1362 °F (739 °C)
pH (0.5% solution): 13
Molecular Weight: 40.01
Specific Gravity: 2.13 at 77 °F (25 °C)
Water Solubility: 1 g/0.9 ml water, 1 g/0.3 ml boiling water
Other Solubilities: 1 g/7.2 ml alcohol, 1 g/4.2 ml methanol, soluble in glycerol; insoluble in acetone and ether

Appearance and Odor: Odorless, hydroscopic (readily absorbs water) white flakes, cake, lumps, chips, pellets, or sticks.

Section 4. Fire and Explosion Data

Flash Point: None reported	Autoignition Temperature: None reported	LEL: None reported	UEL: None reported

Extinguishing Media: Although noncombustible as a solid, when in contact with moisture or water sodium hydroxide can generate enough heat to ignite surrounding combustibles. If possible without risk, remove containers from area. Use extinguishing agents suitable for surrounding fire. For small fire, use dry chemical, carbon dioxide (CO_2), or regular foam. Avoid water spray since water reacts with sodium hydroxide to generate substantial heat. If you must use water, be sure it is as cold as possible. For large fires, use fog or regular foam.

Unusual Fire or Explosion Hazards: Sodium hydroxide may melt and flow when heated.

Special Fire-fighting Procedures: Since fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Also, wear fully protective clothing. Structural firefighters' protective clothing provides limited protection. Apply cooling water to fire-exposed sides of container until fire is well out. *Do not* splatter or splash this material. Stay away from ends of tanks. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Sodium hydroxide is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur. Violent polymerization can occur when in contact with acrolein or acrylonitrile. Since sodium hydroxide readily absorbs water and carbon dioxide from air, keep containers tightly closed.

Chemical Incompatibilities: Sodium hydroxide generates large amounts of heat when in contact with water and may steam and splatter. It reacts with mineral acids to form corresponding salts; reacts with weak-acid gases like hydrogen sulfide, sulfur dioxide, and carbon dioxide; ignites when in contact with cinnamaldehyde or zinc; and has exploded when exposed to a mixture of chloroform and methane. Sodium hydroxide can be very corrosive to metals such as aluminum, tin, and zinc as well as to alloys such as steel, and may cause formation of flammable hydrogen gas. An increase in temperature and pressure occurs in closed containers when sodium hydroxide is mixed with: acetic anhydride, glacial acetic acid, chlorohydrin, chlorosulfonic acid, ethylene cyanohydrin, glyoxal, oleum, 36% hydrochloric acid, 48.7% hydrofluoric acid, 70% nitric acid, or 96% sulfuric acid.

Conditions to Avoid: Avoid generation of sodium hydroxide dusts, and contact with water, metals, and the chemicals listed above.

Hazardous Products of Decomposition: Thermal oxidative decomposition of sodium hydroxide can produce toxic sodium oxide (Na_2O) and sodium peroxide (Na_2O_2) fumes.

Section 6. Health Hazard Data

Carcinogenicity: In 1990 reports, the IARC, NTP, and OSHA do not list sodium hydroxide as a carcinogen (see Chronic Effects).

Summary of Risks: Sodium hydroxide is toxic by inhalation of dusts or mists, ingestion, or direct skin or eye contact. Damage is immediate and without prompt medical attention can become permanent. This strong, corrosive alkali dissolves any living tissue it contacts.

Medical Conditions Aggravated by Long-Term Exposure: None reported.

Target Organs: Eyes, digestive tract, respiratory system, and skin.

Primary Entry Routes: Ingestion, inhalation, and skin and eye contact.

Continue on next page

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Section 6. Health Hazard Data, *continued*

Acute Effects: Ingestion causes immediate burning of mouth, esophagus, and stomach; painful swallowing; excessive salivation; edematous (excess fluid in surrounding tissue) lips, chin, tongue, and pharynx covered with exudate (fluid oozed from swollen tissue); esophageal edema (swelling from fluid buildup in esophagus walls that can prevent all swallowing within hours); possibly edematous, gelatinous, and necrotic (localized tissue death) mucous membranes; vomiting (sometimes coffee grounds-like material due to digestive hemorrhage); and rapid, faint pulse; and cold, clammy skin. Death results commonly from shock, asphyxia (oxygen loss due to interrupted breathing), or pneumonia by the second or third day after ingestion. Dust inhalation can cause many small burns, temporary hair loss (in nasal passages since sodium hydroxide breaks down keratin), and possibly pulmonary edema (fluid in lungs). Skin contact causes slippery, soapy feeling that is not usually painful for 3 min after contact—even though skin damage begins immediately. It causes burns, keratin (hair and nails) destruction, and intracellular edema (excess fluid in skin cells), with damage progressing to severe burns, tissue corrosion, deep ulcerations, and permanent scarring if not immediately washed off. The cornea begins to corrode on contact. Disintegration and sloughing of conjunctival and corneal epithelium may progress to temporary or permanent corneal opacification (cloudiness, becoming impervious to light) or symblepharon (adhesion of lid to eyeball).

Chronic Effects: Dermatitis may result from repeated exposure to dilute solutions. Cases of squamous cell carcinoma (malignant tumors of epithelial origin) of the esophagus are reported 12 to 42 years after sodium hydroxide ingestion, although it is unclear whether the cancer results from scar formation caused by tissue destruction or directly from the chemical's possible carcinogenicity.

FIRST AID: Emergency personnel should protect against contamination.

Eyes: Gently lift the eyelids and flush immediately and continuously with flooding amounts of cold water until transported to an emergency medical facility. *Do not* allow victim to keep eyes tightly shut. *Warning!* Although splashed directly in only one eye, sodium hydroxide may affect the other eye's sight if prompt medical attention is not received. Consult a physician immediately.

Skin: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. *Be aware* that this substance can become very hot when in contact with water. For reddened or blistered skin, consult a physician. Wash affected area with soap and water.

Inhalation: Remove exposed person to fresh air and support breathing as needed.

Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have that *conscious and alert* person drink 1 to 2 glasses of water, followed by vinegar or fruit juice to neutralize the poison. *Do not induce vomiting!*

After first aid, get appropriate in-plant, paramedic, or community medical support.

Note to Physicians: Perform endoscopy in all suspected cases of sodium hydroxide ingestion. Perform blood analysis to determine if dehydration, acidosis, or other electrolyte imbalances have occurred.

Section 7. Spill, Leak and Disposal Procedures

Spill/Leak: Notify safety personnel, isolate hazard area, deny entry, and stay upwind of spills. Cleanup personnel should protect against vapor inhalation and skin or eye contact. Use water spray to disperse vapors, but do not spray directly on spills. For small dry spills, avoid excess dust generation by carefully scooping or vacuuming (with appropriate filter) into a suitable container (above 60 °C sodium hydroxide corrodes steel) for later disposal. For large dry spills, cover with plastic sheet or other impermeable layer and contain for later disposal. Follow applicable OSHA regulations (29 CFR 1910.120).

Environmental Transport: Sodium hydroxide is not mobile in solid form, although it absorbs moisture very easily. Once liquid, sodium hydroxide leaches rapidly into soil, possibly contaminating water sources.

Environmental Degradation: Ecotoxicity values: TLm, mosquito fish, 125 ppm/96 hr (fresh water); TLm, bluegill, 99 mg/48 hr (tap water).

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.22): Characteristic of corrosivity
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 1000 lb (454 kg) [* per Clean Water Act, Sec. 311 (b)(4)]
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
SARA Toxic Chemical (40 CFR 372.65): Not listed

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Since contact lens use in industry is controversial, establish your own policy.

Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. Select the respirator based on its suitability to provide adequate worker protection for the given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*

Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent any skin contact.

Ventilation: Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[(103)]

Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder contaminated work clothing before wearing. Remove this material from your shoes and clean personal protective equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Avoid physical damage to containers. Store in dry, well-ventilated area away from water, acids, metals, flammable liquids, and organic halogens. Keep containers tightly closed since sodium hydroxide can decompose to sodium carbonate and carbon dioxide upon exposure to air. Since corrosion occurs easily above 140 °F (60 °C), do not store or transport sodium hydroxide in aluminum or steel containers at temperatures near this level. Store containers in rooms equipped with trapped floor drains, curbs, or gutters.

Engineering Controls: To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control hazardous contaminants and to maintain concentrations at the lowest practical level.

Other Precautions: Consider preplacement and periodic medical examinations of exposed workers that emphasize eyes, skin, and respiratory tract. Consider a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. Inform employees of the possible hazards in using sodium hydroxide.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: Sodium hydroxide; dry, solid, flake, bead *or* granular
DOT Hazard Class: Corrosive material
ID No.: UN1823
DOT Label: Corrosive
DOT Packaging Exceptions: 173.244
DOT Packaging Requirements: 173.245b

IMO Shipping Name: Sodium hydroxide, solid
IMO Hazard Class: 8
ID No.: UN1823
IMO Label: Corrosive
IMDG Packaging Group: II

MSDS Collection **References:** 26, 38, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 139, 140, 143, 146, 148, 149, 153, 159, 161, 163

Prepared by: M Gannon, BA; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** W Silverman, MD; **Edited by:** ER O'Connor, MS

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AIR LIQUIDE

MATERIAL SAFETY DATA SHEET

Prepared to U.S. OSHA, CMA, ANSI and Canadian WHMIS Standards

1. PRODUCT IDENTIFICATION

CHEMICAL NAME; CLASS: ISOBUTYLENE

SYNONYMS: 2-Methylpropane; Isobutylene USP
CHEMICAL FAMILY: Alkane (hydrocarbon)
FORMULA: C_4H_8

PRODUCT USE:	Document Number: 20103 For fuel and synthetic chemical use; food additive, agricultural uses, aerosol propellant, refrigerant.
SUPPLIER/MANUFACTURER'S NAME: **ADDRESS:**	AIR LIQUIDE AMERICA CORPORATION 2700 Post Oak Drive Houston, TX 77056-8229
EMERGENCY PHONE:	CHEMTREC: 1-800-424-9300
BUSINESS PHONE:	General MSDS Information: 1-713/896-2896 Fax on Demand: 1-800/231-1366

2. COMPOSITION and INFORMATION ON INGREDIENTS

CHEMICAL NAME	CAS #	mole %	EXPOSURE LIMITS IN AIR					
			ACGIH		OSHA			
			TLV ppm	STEL ppm	PEL ppm	STEL ppm	IDLH ppm	OTHER ppm
Isobutylene	115-11-7	> 99%	There are no specific exposure limits for Isobutylene. Isobutylene is a simple asphyxiant (SA). Oxygen levels should be maintained above 19.5%.					
Maximum Impurities		< 1%	None of the trace impurities in this product contribute significantly to the hazards associated with the product. All hazard information pertinent to this product has been provided in this Material Safety Data Sheet, per the requirements of the OSHA Hazard Communication Standard (29 CFR 1910.1200) and State equivalents standards.					

NE = Not Established C = Ceiling Limit

NOTE: all WHMIS required information is included. It is located in appropriate sections based on the ANSI Z400.1-1993 format.

3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW: This product is a colorless, liquefied, flammable gas. The gas has an unpleasant odor similar to burning coal. Both the liquid and gas pose a serious fire hazard when accidentally released. Rapid evaporation of liquid from cylinder may cause frostbite. Flame or high temperature impinging on a localized area of the cylinder of this product can cause the cylinder to burst or rupture without activating the cylinder's relief devices. Isobutylene is an asphyxiant and presents a significant health hazard by displacing the oxygen in the atmosphere. Isobutylene can also be a narcotic at high concentrations. Provide adequate fire protection during emergency response situations.

SYMPTOMS OF OVER-EXPOSURE BY ROUTE OF EXPOSURE: The most significant route of over-exposure for this product is by inhalation.

INHALATION: Isobutylene also has some degree of anesthetic action and can be mildly irritating to the mucous membranes. High concentrations of this gas can cause an oxygen-deficient environment. It should be noted that before suffocation could occur, the lower flammability limit of Isobutylene in air would be exceeded; possibly causing an oxygen-deficient and explosive atmosphere. Individuals breathing an oxygen deficient atmosphere may experience symptoms which include headaches, ringing in ears, dizziness, drowsiness, unconsciousness, nausea, vomiting, and depression of all the senses. Under some circumstances of over-exposure, death may occur. The following effects associated with various levels of oxygen are as follows:

CONCENTRATION	SYMPTOM OF EXPOSURE
12-16% Oxygen:	Breathing and pulse rate increased, muscular coordination slightly disturbed.
10-14% Oxygen:	Emotional upset, abnormal fatigue, disturbed respiration.
6-10% Oxygen:	Nausea and vomiting, collapse or loss of consciousness.
Below 6%:	Convulsive movements, possible respiratory collapse, and death.

HAZARDOUS MATERIAL INFORMATION SYSTEM		
HEALTH	(BLUE)	0
FLAMMABILITY	(RED)	4
REACTIVITY	(YELLOW)	0
PROTECTIVE EQUIPMENT		B
EYES / RESPIRATORY / HANDS / BODY		
See Section 8		
For routine industrial applications		

OTHER POTENTIAL HEALTH EFFECTS: Contact with liquid or rapidly expanding gases (which are released under high pressure) may cause frostbite. Symptoms of frostbite include change in skin color to white or grayish-yellow. The pain after such contact can quickly subside.

HEALTH EFFECTS OR RISKS FROM EXPOSURE: An Explanation in Lay Terms. Over-exposure to this gas mixture may cause the following health effects:

ACUTE: The most significant hazard associated with this product is inhalation of oxygen-deficient atmospheres. Symptoms of oxygen deficiency include respiratory difficulty, ringing in ears, headaches, shortness of breath, wheezing, headache, dizziness, indigestion, nausea, and, at high concentrations, unconsciousness or death may occur. The skin of a victim of over-exposure may have a blue color. Contact with liquid or rapidly expanding gases (which are released under high pressure) may cause frostbite. Symptoms of frostbite include change in skin color to white or grayish-yellow. The pain after contact with liquid can quickly subside.

CHRONIC: There are currently no known adverse health effects associated with chronic exposure to the components of this compressed gas.

TARGET ORGANS: Respiratory system.

4. FIRST-AID MEASURES

RESCUERS SHOULD NOT ATTEMPT TO RETRIEVE VICTIMS OF EXPOSURE TO THIS PRODUCT WITHOUT ADEQUATE PERSONAL PROTECTIVE EQUIPMENT. At a minimum, Self-Contained Breathing Apparatus and Fire-Retardant Personal Protective equipment should be worn. Adequate fire protection must be provided during rescue situations.

Remove victim(s) to fresh air, as quickly as possible. Trained personnel should administer supplemental oxygen and/or cardio-pulmonary resuscitation, if necessary. Only trained personnel should administer supplemental oxygen.

4. FIRST-AID MEASURES (Continued)

SKIN EXPOSURE: Exposure to the liquefied gas can cause frostbite. Remove any clothing that may restrict circulation to any frozen area. Do not rub frozen parts as tissue damage may occur. As soon as practicable, place any affected area in warm water bath which has a temperature that does not exceed 105°F (40°C). NEVER USE HOT WATER. NEVER USE DRY HEAT. If area of frostbite is extensive, and if possible, remove clothing while showering with warm water. If warm water is not available, or is impractical to use, wrap the affected parts gently in blankets. Alternatively, if the fingers or hands are frostbitten, place the affected area of the body in the armpit. Encourage victim to gently exercise the affected part while being warmed. Seek immediate medical attention.

Frozen tissue is painless and appears waxy, with a possible yellow color. Frozen tissue will become swollen, painful and prone to infection when thawed. If the frozen part of the body has been thawed by the time medical attention has been obtained, cover the area with a dry sterile dressing and a large bulky protective covering.

EYE EXPOSURE: If liquid is splashed into eyes, or if irritation of the eye develops after exposure to liquid or gas, open victim's eyes while under gentle running water. Use sufficient force to open eyelids. Have victim "roll" eyes. Minimum flushing is for 15 minutes. Seek medical assistance immediately, preferably an ophthalmologist.

Victim(s) must be taken for medical attention. Rescuers should be taken for medical attention, if necessary. Take copy of label and MSDS to physician or other health professional with victim(s).

5. FIRE-FIGHTING MEASURES

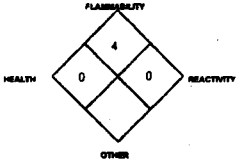
FLASH POINT: -10°C (< 14°F)

AUTOIGNITION TEMPERATURE: 465°C (869°F)

FLAMMABLE LIMITS (in air by volume, %):

Lower (LEL): 1.8%
Upper (UEL): 9.6%

NFPA RATING



FIRE EXTINGUISHING MATERIALS: Extinguish Isobutylene fires by shutting-off the source of the gas. Use water spray to cool fire-exposed containers, structures, and equipment.

UNUSUAL FIRE AND EXPLOSION HAZARDS: When involved in a fire, this material may decompose and produce toxic gases including carbon monoxide and carbon dioxide.

DANGER! Fires impinging (direct flame) on the outside surface of unprotected cylinders of this product can be very dangerous. Exposure to fire could cause a catastrophic failure of the cylinder releasing the contents into a fireball and explosion of released gas. The resulting fire and explosion can result in severe equipment damage and personnel injury or death over a large area around the cylinder. For massive fires in large areas, use unmanned hose holder or monitor nozzles; if this is not possible, withdraw from area and allow fire to burn.

Explosion Sensitivity to Mechanical Impact: Not sensitive.
Explosion Sensitivity to Static Discharge: Static discharge may cause this product to ignite explosively, if released.

SPECIAL FIRE-FIGHTING PROCEDURES: Structural fire-fighters must wear Self-Contained Breathing Apparatus and full protective equipment. Because of the potential for a BLEVE, evacuation of non-emergency personnel is essential. If water is not available for cooling or protection of cylinder exposures, evacuate the area. The North American Emergency Response Guidebook (Guide #115) recommends 0.5 miles. Other information for pre-planning can be found in the American Petroleum Institute Publications 2510 and 2510A.

6. ACCIDENTAL RELEASE MEASURES

LEAK RESPONSE: Evacuate immediate area. Uncontrolled releases should be responded to by trained personnel using pre-planned procedures. Proper protective equipment should be used. In case of a gas release, clear the affected area, protect people, and respond with trained personnel.

Eliminate any possible sources of ignition, and provide maximum explosion-proof ventilation. If the gas is leaking from cylinder or valve, contact the supplier. Adequate fire protection must be provided. Use only non-sparking tools and equipment during the response.

Minimum Personal Protective Equipment should be **Level B: fire-retardant protective clothing, gloves and Self-Contained Breathing Apparatus.** Use only non-sparking tools and equipment. Locate and seal the source of the leaking gas. Protect personnel attempting the shut-off with water-spray. Allow the gas to dissipate.

6. ACCIDENTAL RELEASE MEASURES (Continued)

Combustible gas concentration must be below 10% of the LEL (1.8%) prior to entry. Monitor the surrounding area for combustible gas levels and oxygen level. The atmosphere must have at least 19.5 percent oxygen before personnel can be allowed in the area without Self-Contained Breathing Apparatus. Attempt to close the main source valve prior to entering the area. If this does not stop the release (or if it is not possible to reach the valve), allow the gas to release in-place or remove it to a safe area and allow the gas to be released there.

THIS IS AN EXTREMELY FLAMMABLE GAS. Protection of all personnel and the area must be maintained.

7. HANDLING and USE

WORK PRACTICES AND HYGIENE PRACTICES: Be aware of any signs of dizziness or fatigue; exposures to fatal concentrations of this product could occur without any significant warning symptoms. Non-sparking tools should be used.

STORAGE AND HANDLING PRACTICES: Specific requirements are listed in NFPA 58. Cylinders should be stored upright (with valve-protection cap in place) and firmly secured to prevent falling or being knocked over. Cylinders can be stored in the open, but in such cases, should be protected against extremes of weather and from the dampness of the ground to prevent rusting. Cylinders should be stored in dry, well-ventilated areas away from sources of heat, ignition and direct sunlight. Keep storage area clear of materials which can burn. Do not allow area where cylinders are stored to exceed 52 °C (125 °F). Store containers away from heavily trafficked areas and emergency exits. Store away from process and production areas, away from elevators, building and room exits or main aisles leading to exits. Protect cylinders against physical damage.

Cylinders should be separated from oxygen cylinders, or other oxidizers, by a minimum distance of 20 ft., or by a barrier of non-combustible material at least 5 ft. high, having a fire-resistance rating of at least 0.5 hours. Isolate from other incompatible chemicals (refer to Section 10, Stability and Reactivity).

Storage areas must meet national electrical codes for Class 1 Hazardous Areas. Post "No Smoking or Open Flames" signs in storage or use areas. Consider installation of leak detection and alarm for storage and use areas. Have appropriate extinguishing equipment in the storage area (i.e. sprinkler system, portable fire extinguishers).

Keep the smallest amount on-site as is necessary. Full and empty cylinders should be segregated. Use a first-in, first-out inventory system to prevent full containers from being stored for long periods of time.

Use non-sparking ventilation systems, approved explosion-proof equipment, and appropriate electrical systems. Electrical equipment used in gas-handling operations, or located in storage areas, should be non-sparking or explosion proof. Use a check valve in the discharge line to prevent hazardous backflow. Never tamper with pressure relief devices in valves and cylinders.

SPECIAL PRECAUTIONS FOR HANDLING GAS CYLINDERS: Compressed gases can present significant safety hazards. The following rules are applicable to work situations in which cylinders are being used:

Before Use: Move cylinders with a suitable hand-truck. Do not drag, slide or roll cylinders. Do not drop cylinders or permit them to strike each other. Secure cylinders firmly. Leave the valve protection cap (where provided) in-place until cylinder is ready for use.

During Use: Use designated CGA fittings and other support equipment. Do not use adapters. Use piping and equipment adequately designed to withstand pressures to be encountered. Do not heat cylinder by any means to increase the discharge rate of the product from the cylinder. Do not use oils or grease on gas-handling fittings or equipment. Do not "crack" valve open before connecting it, since self-ignition may occur. Leak check system with leak detection solution, never with flame. Immediately contact the supplier if there are any difficulties associated with operating cylinder valve. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, casing a leak to occur. Use an adjustable strap wrench to remove over-tight or rusted caps. Never strike an arc on a compressed gas cylinder or make a cylinder part of an electric circuit.

After Use: Close main cylinder valve. Valves should be closed tightly. Replace valve protection cap. Mark empty cylinders "EMPTY".

NOTE: Use only DOT or ASME code containers designed for flammable gas storage. Earth-ground and bond all lines and equipment associated with this product. Close valve after each use and when empty.

STANDARD VALVE CONNECTIONS FOR U.S. AND CANADA: Use the proper connections, DO NOT USE ADAPTERS:

THREADED: 0-500 PSIG - CGA 510
PIN-INDEXED YOKE: Not Applicable.
ULTRA HIGH INTEGRITY: Not Applicable.

7. HANDLING and USE (Continued)

PROTECTIVE PRACTICES DURING MAINTENANCE OF CONTAMINATED EQUIPMENT: Follow practices indicated in Section 6 (Accidental Release Measures). Make certain application equipment is locked and tagged-out safely. Purge gas handling equipment with inert gas (i.e. nitrogen) before attempting repairs. Always use product in areas where adequate ventilation is provided.

8. EXPOSURE CONTROLS - PERSONAL PROTECTION

VENTILATION AND ENGINEERING CONTROLS: Use with adequate ventilation. Provide natural or explosion-proof ventilation adequate to ensure Isobutylene does not reach its lower flammability limit of 1.8%. Local exhaust ventilation is preferred, because it prevents gas dispersion into the work place by eliminating it at its source. If appropriate, install automatic monitoring equipment to detect the level of flammable gas.

RESPIRATORY PROTECTION: Maintain oxygen levels above 19.5% in the workplace. Use supplied air respiratory protection if oxygen levels are below 19.5% (air-purifying respirators will not function) or during emergency response to a release of this product. During an emergency situation, before entering the area, check for flammable gas level as well as oxygen-deficient atmospheres. If respiratory protection is required, follow the requirements of the Federal OSHA Respiratory Protection Standard (29 CFR 1910.134), or equivalent State standards.

EYE PROTECTION: Safety glasses.

HAND PROTECTION: Wear leather gloves when handling cylinders of this product. Otherwise, wear glove protection appropriate to the specific operation for which this product is used. Use low-temperature protective gloves when working with containers of Liquid Isobutylene.

BODY PROTECTION: Use body protection appropriate for task. Cotton clothing is recommended for use to prevent static electric build-up. Safety shoes are recommended when handling cylinders. Transfer of large quantities under pressure may require use of fire retardant clothing.

9. PHYSICAL and CHEMICAL PROPERTIES

GAS DENSITY @ 21.1°C (70°F) and 1 atm: 0.14957 lb/ft^3 (2.3959 kg/m^3)
BOILING POINT: -6.9°C (19.6°F)
FREEZING/MELTING POINT @ 10 psig: -140°C (-220.6°F)
SPECIFIC GRAVITY (air = 1) @ 21.1°C (70°F): 1.997
pH: Not applicable.
SOLUBILITY IN WATER vol/vol @37.8°C (100°F): Insoluble.
MOLECULAR WEIGHT: 56.108
EVAPORATION RATE (nBuAc = 1): Not applicable.
EXPANSION RATIO: Not applicable.
ODOR THRESHOLD: Not determined.
SPECIFIC VOLUME (ft^3/lb): 6.54
VAPOR PRESSURE @ 21.1°C (70°F) psig: 23.85
COEFFICIENT WATER/OIL DISTRIBUTION: Not applicable.

APPEARANCE AND COLOR: Colorless gas which is shipped as a liquefied gas under its own vapor pressure. The gas has an unpleasant odor similar to burning coal.

HOW TO DETECT THIS SUBSTANCE (warning properties): The unpleasant odor may be a warning property. In terms of leak detection, fittings and joints can be painted with a soap solution to detect leaks, which will be indicated by a bubble formation.

10. STABILITY and REACTIVITY

STABILITY: Stable.

DECOMPOSITION PRODUCTS: : When ignited in the presence of oxygen, this gas will burn to produce carbon monoxide, carbon dioxide.

MATERIALS WITH WHICH SUBSTANCE IS INCOMPATIBLE: Strong oxidizers (i.e. chlorine, bromine pentafluoride, oxygen, oxygen difluoride, and nitrogen trifluoride).

HAZARDOUS POLYMERIZATION: Will not occur.

CONDITIONS TO AVOID: Contact with incompatible materials and exposure to heat, sparks and other sources of ignition. Cylinders exposed to high temperatures or direct flame can rupture or burst.

11. TOXICOLOGICAL INFORMATION

TOXICITY DATA: The following toxicity data are applicable for pure Isobutylene.

LC50 (inhalation, rat) = 620,000 mg/kg/4 hours
LC50 (inhalation, mouse) = 415,000 mg/kg

SUSPECTED CANCER AGENT: Isobutylene is not found on the following lists: FEDERAL OSHA Z LIST, NTP, IARC, CAL/OSHA; therefore is not considered to be, nor suspected to be a cancer-causing agent by these agencies.

IRRITANCY OF PRODUCT: Isobutylene can cause some irritation to mucus membranes. In addition, contact with rapidly expanding gases can cause frostbite to exposed tissue.

SENSITIZATION TO THE PRODUCT: Isobutylene is not known to cause sensitization in humans.

REPRODUCTIVE TOXICITY INFORMATION: Listed below is information concerning the effects of Isobutylene on the human reproductive system.

Mutagenicity: No mutagenicity effects have been described for Isobutylene gas.
Embryotoxcity: No embryotoxic effects have been described for Isobutylene gas.
Teratogenicity: No teratogenicity effects have been described for this Isobutylene gas.
Reproductive Toxicity: No reproductive toxicity effects have been described for Isobutylene gas.

A mutagen is a chemical which causes permanent changes to genetic material (DNA) such that the changes will propagate through generation lines. An embryotoxin is a chemical which causes damage to a developing embryo (i.e. within the first eight weeks of pregnancy in humans), but the damage does not propagate across generational lines. A teratogen is a chemical which causes damage to a developing fetus, but the damage does not propagate across generational lines. A reproductive toxin is any substance which interferes in any way with the reproductive process.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Acute or chronic respiratory conditions may be aggravated by over-exposure to the components of this product.

BIOLOGICAL EXPOSURE INDICES (BEIs): Currently, Biological Exposure Indices (BEIs) are not applicable for Isobutylene.

RECOMMENDATIONS TO PHYSICIANS: Administer oxygen, if necessary; treat symptoms; reduce or eliminate exposure.

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL STABILITY: This gas will be dissipated rapidly in well-ventilated areas.

EFFECT OF MATERIAL ON PLANTS or ANIMALS: Any adverse effect on animals would be related to oxygen deficient environments. No adverse effect is anticipated to occur to plant-life.

EFFECT OF CHEMICAL ON AQUATIC LIFE: No evidence is currently available on this product's effects on aquatic life.

13. DISPOSAL CONSIDERATIONS

PREPARING WASTES FOR DISPOSAL: Waste disposal must be in accordance with appropriate Federal, State, and local regulations. Return cylinders with any residual product to Air Liquide. Do not dispose of locally.

For emergency disposal, secure the cylinder and slowly discharge the gas to the atmosphere in a well-ventilated area or outdoors, away from all sources of ignition.

14. TRANSPORTATION INFORMATION

THIS MATERIAL IS HAZARDOUS AS DEFINED BY 49 CFR 172.101 BY THE U.S. DEPARTMENT OF TRANSPORTATION.

		Alternate Description:
PROPER SHIPPING NAME:	Isobutylene	Petroleum gases, liquefied
HAZARD CLASS NUMBER and DESCRIPTION:	2.1 (Flammable Gas)	2.1 (Flammable Gas)
UN IDENTIFICATION NUMBER:	UN 1055	UN 1075
PACKING GROUP:	Not applicable.	Not applicable.
DOT LABEL(S) REQUIRED:	Flammable Gas	Flammable Gas

NORTH AMERICAN EMERGENCY RESPONSE GUIDEBOOK NUMBER (1996): 115

14. TRANSPORTATION INFORMATION (Continued)

MARINE POLLUTANT: Isobutylene is not classified by the DOT as Marine Pollutants (as defined by 49 CFR 172.101, Appendix B).

SPECIAL SHIPPING INFORMATION: Cylinders should be transported in a secure position, in a well-ventilated vehicle. The transportation of compressed gas cylinders in automobiles or in closed-body vehicles present serious safety hazards and should be discouraged.

NOTE: Shipment of compressed gas cylinders which have not been filled with the owners consent is a violation of Federal law (49 CFR, Part 173.301 (b).

TRANSPORT CANADA TRANSPORTATION OF DANGEROUS GOODS REGULATIONS: THIS MATERIAL IS CONSIDERED AS DANGEROUS GOODS. Use the above information for the preparation of Canadian Shipments.

15. REGULATORY INFORMATION

U.S. SARA REPORTING REQUIREMENTS: Isobutylene is not subject to the reporting requirements of Sections 302, 304 and 313 of Title III of the Superfund Amendments and Reauthorization Act.

U.S. SARA THRESHOLD PLANNING QUANTITY: Not applicable.

U.S. CERCLA REPORTABLE QUANTITY (RQ): Not applicable.

CANADIAN DSL INVENTORY STATUS: Isobutylene is listed on the Canadian DSL Inventory.

U.S. TSCA INVENTORY STATUS: Isobutylene is listed on the TSCA Inventory.

OTHER U.S. FEDERAL REGULATIONS:

- Isobutylene does not contain any Class I or Class II ozone depleting chemicals (40 CFR part 82).
- Isobutylene is subject to the reporting requirements of Section 112(r) of the Clean Air Act. The Threshold Quantity for of this gas is 10,000 pounds.
- Depending on specific operations involving the use of this product, the regulations of the Process Safety Management of Highly Hazardous Chemicals may be applicable (29 CFR 1910.119). Under this regulation Isobutylene is not listed in Appendix A, however, any process that involves a flammable gas on-site, in one location, in quantities of 10,000 lbs (4,553 kg) or greater is covered under this regulation unless it is used as a fuel.
- Isobutylene is listed as a Regulated Substance, per 40 CFR, Part 68, of the Risk Management for Chemical Releases as a flammable substance. The threshold quantity for Isobutane under this regulation is 10,000 lbs.

OTHER CANADIAN REGULATIONS: Isobutylene is categorized as a Controlled Product, Hazard Classes A, and B1 as per the Controlled Product Regulations.

U.S. STATE REGULATORY INFORMATION: Isobutylene is covered under specific State regulations, as denoted below:

Alaska - Designated Toxic and Hazardous Substances: Liquefied Petroleum Gas.
California - Permissible Exposure Limits for Chemical Contaminants:
Florida - Substance List: Isobutylene.
Illinois - Toxic Substance List: Liquefied Petroleum Gas.
Kansas - Section 302/313 List: No.
Massachusetts - Substance List: Isobutylene.
Minnesota - List of Hazardous Substances: Isobutylene.
Missouri - Employer Information/Toxic Substance List: Liquefied Petroleum Gas.
New Jersey - Right to Know Hazardous Substance List: Isobutylene.
North Dakota - List of Hazardous Chemicals, Reportable Quantities: No.
Pennsylvania - Hazardous Substance List: Isobutylene.
Rhode Island - Hazardous Substance List: Liquefied Petroleum Gas.
Texas - Hazardous Substance List: Liquefied Petroleum Gas.
West Virginia - Hazardous Substance List: Liquefied Petroleum Gas.
Wisconsin - Toxic and Hazardous Substances: Liquefied Petroleum Gas.

CALIFORNIA PROPOSITION 65: Isobutylene is not on the California Proposition 65 lists.

16. OTHER INFORMATION

MIXTURES: When two or more gases or liquefied gases are mixed, their hazardous properties may combine to create additional, unexpected hazards. Obtain and evaluate the safety information for each component before you produce the mixture. Consult an Industrial Hygienist or other trained person when you make your safety evaluation of the end product. Remember, gases and liquids have properties which can cause serious injury or death.

Further information can be found in the following pamphlets published by: Compressed Gas Association Inc. (CGA), 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102. Telephone: (703) 412-0900.

P-1 *"Safe Handling of Compressed Gases in Containers"*
P-14 *"Accident Prevention in Oxygen-Rich and Oxygen Deficient Atmospheres"*
SB-2 *"Oxygen Deficient Atmospheres"*
"Handbook of Compressed Gases"

PREPARED BY: CHEMICAL SAFETY ASSOCIATES, Inc.
9163 Chesapeake Drive, San Diego, CA 92123-1002
619/565-0302

Fax on Demand: 1-800/231-1366

AIR LIQUIDE

This Material Safety Data Sheet is offered pursuant to OSHA's Hazard Communication Standard, 29 CFR, 1910.1200. Other government regulations must be reviewed for applicability to this product. To the best of Air Liquide America Corporation's knowledge, the information contained herein is reliable and accurate as of this date; however, accuracy, suitability or completeness are not guaranteed and no warranties of any type, either express or implied, are provided. The information contained herein relates only to this specific product. If this product is combined with other materials, all component properties must be considered. Data may be changed from time to time. Be sure to consult the latest edition.

AERVOE® Material Safety Data Sheet

TO: MSDS USERS

Please find below the material safety data sheet as per your request.

The information presented in these forms is believed to be correct and sufficient to meet the requirements of OSHA Hazard Communication standard (29 CFR 1910.1200) concerning worker's right to know. In order for the information contained in the MSDS to be most helpful we recommend that these forms be made available to all those who handle or may otherwise be exposed to the product.

The following material safety data sheet covers the hazardous ingredients associated with more than one color aerosol product. As per 29 CFR 1900. 1200 paragraph (g); whenever the hazards associated with similar mixtures are the same, then one MSDS may be prepared to cover several products.

This MSDS covers the following Aervoe-Pacific aerosol products.

MARKING PAINT

REGULAR		*FLUORESCENT*	*16 oz. L.A.C.*		*HIGH DELIVERY*
201 RED	207 WHITE	220 RED	261S RED	270S FLUORESCENT RED	281 RED
202 YELLOW	208 HI VISIBILITY YELLOW	222 ORANGE	262S YELLOW	272S FLUORESCENT ORANGE	282 YELLOW
203 BLUE	209 LIGHT BLUE	224 GREEN	263S BLUE	274S FLUORESCENT GREEN	288 FLUORESCENT ORANGE
204 GREEN	210 SILVER	226 YELLOW	264S GREEN	275S FLUORESCENT RED/ORANGE	
205 ORANGE	212 PURPLE	227 BLUE	265S ORANGE	279S FLUORESCENT PINK	
206 BLACK	213 BROWN	229 PINK	266S BLACK		
		230 RED/ORANGE	267S WHITE		

PRODUCT NAME: MARKING PAINT - ALL COLORS **PRODUCT CODE:** 17A **HMIS CODES:** H 2 F 4 R 1 P X

SECTION I - MANUFACTURER IDENTIFICATION

MANUFACTURER'S NAME: Aervoe-Pacific Company, Inc.
INFORMATION PHONE: 775-782-0100
DATE REVISED: 01-31-01
ADDRESS: 1198 Mark Circle, Gardnerville, NV 89410
EMERGENCY PHONE: 1-800-424-9300
REASON REVISED: Updated

SECTION II - HAZARDOUS INGREDIENTS / SARA III INFORMATION
OCCUPATIONAL EXPOSURE LIMITS

HAZARDOUS COMPONENTS	WEIGHT PERCENT	OSHA PEL	ACGIH TLV	OTHER	LD50 SPECIES & ROUTE	LC50 SPECIES & ROUTE
*XYLENE (CAS 1330 20 7)	20	100 PPM	100 PPM		4300 mg / kg RAT (ORAL)	6700 PPM; 4 hr RAT (INHA)
MINERAL SPIRITS (CAS 8052 41 3)	<5.0%	100 PPM	100 PPM		N/A	N/A
ACETONE (CAS 67 64 1)	<5.0%	750 PPM	750 PPM		9750 mg / kg RAT (ORAL)	6700 PPM / 4 hr RAT (INHA)
*GLYCOL ETHER EB ACETATE (CAS 112 07 2)	1	N/A	N/A	N/A	N/A	N/A
*HEXANE (CAS 110 54 3)	12	50 PPM	50 PPM		28,710 mg / kg RAT (ORAL)	N/A
PROPANE (CAS 74 98 6)	10	1000 PPM	1000 PPM		N/A	N/A
ISOBUTANE (CAS 75 28 5)	<5.0%	800 PPM	800 PPM	ESTIMATED	N/A	57 PPH /15 min RAT (INHA)
NORMAL BUTANE (CAS 106 97 8)	5	600 PPM	600 PPM		N/A	658 mg / L; 4 hr RAT (INHA)

*Indicates toxic chemical(s) subject to the reporting requirements of section 313 of Title III and of 40 CFR 372.

NOTE: N/A applies to not available or not applicable

PRODUCT CODE: 17A

SECTION III - PHYSICAL / CHEMICAL CHARACTERISTICS

BOILING POINT: 10° F / -12° C **SPECIFIC GRAVITY (H20=1):** 0.9 **COEFFICIENT OF WATER/OIL DIST:** N/A
ODOR THRESHOLD: N/A **VAPOR DENSITY:** Heavier than air **SOLUBILITY IN WATER:** Negligible
EVAPORATION RATE: Faster than n-Butyl Acetate **APPEARANCE AND ODOR:** Opaque Liquid / Solvent Like Odor
COATING V.O.C.: 5.96 lbs / Imp gal 4.96 lbs / US gal 594 gms / ltr **FREEZING POINT:** N/A **pH:** N/A

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: -26° F / -32° C **METHOD USED:** Estimated **FLAMMABLE LIMITS IN AIR BY VOLUME - LOWER:** 0.8% **UPPER:** 9.6%
EXTINGUISHING MEDIA: Foam, Alcohol Foam, CO_2, Dry Chemical, Water Fog
SPECIAL FIRE FIGHTING PROCEDURES: Water spray may be ineffective, but water spray may be used to cool containers exposed to heat or fire to prevent pressure build up. Self-contained breathing apparatus should be used if product is involved in fire.
UNUSUAL FIRE AND EXPLOSION HAZARDS: Closed containers may explode due to pressure build up from extreme heat or fire. Aerosol spray is extremely flammable.
FLAMMABILITY: Yes - Flammable aerosol under conditions of sparks, flame, or hot surfaces.
SENSITIVITY TO IMPACT: Do not puncture **SENSITIVITY TO STATIC DISCHARGE:** Primarily vapors

SECTION V - REACTIVITY DATA

STABILITY: Stable **CONDITIONS TO AVOID:** High temperatures
INCOMPATIBILITY (MATERIALS TO AVOID): Strong oxidizing agents
HAZARDOUS DECOMPOSITION OR BY-PRODUCTS: Carbon Monoxide and Carbon Dioxide
HAZARDOUS POLYMERIZATION: Will not occur

SECTION VI - HEALTH HAZARD DATA

INHALATION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: May cause dizziness or nausea.
SKIN AND EYE CONTACT HEALTH RISKS AND SYMPTOMS OF EXPOSURE: SKIN - May cause irritation or burning sensation.
EYES - Primary irritation.
SKIN ABSORPTION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: May cause irritation or burning sensation.
INGESTION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: N/A
HEALTH HAZARDS (ACUTE AND CHRONIC): INHALATION - Anesthetic. Irritation of the respiratory tract, or nervous system depression (characterized by headache, dizziness, nausea or possible unconsciousness). SKIN OR EYE CONTACT - Primary irritation. Prolonged or repeated contact to skin may cause dermatitis - exercise due care.
CARCINOGENICITY: None known **NTP?** No **IARC MONOGRAPHS?** No **OSHA REGULATED?** No
TERATOGENICITY: N/A **MUTAGENICITY:** N/A **TOXICOLOGICALLY SYNERGISTIC PRODUCT:** N/A
MEDICAL CONDITION GENERALLY AGGRAVATED BY EXPOSURE: None known
EMERGENCY AND FIRST AID PROCEDURES: VAPORS - Remove from exposure and restore breathing, seek medical attention.
SPLASH - (SKIN) Wash affected area, remove contaminated clothing, see physician if any irritation persists.
SPLASH - (EYES) Flush immediately with water for 15 minutes and take to a physician.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Remove all sources of ignition - Flames, sparks, static electricity & electrical. Ventilate area, avoid run off into sewer by diking, and soak up with inert absorbent using non-sparking type tools.
WASTE DISPOSAL METHOD: Dispose of in accordance with local, state and federal regulations. Do not incinerate closed containers.
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Do not store above 120° F / 49° C. Do not store or use near heat, sparks or flame.
OTHER PRECAUTIONS: Do not get in eyes. Do not breathe vapors. Avoid skin contact. Do not take internally. Smoking while using this product must be strictly prohibited. In addition to all other hazards and precautions - dust from sanding the dry paint films should be treated as a nuisance dust with a **TLV of 10mg/cubic meter.**

SECTION VIII - CONTROL MEASURES

RESPIRATORY PROTECTION: Outdoors - Recommend an approved mechanical particulate filter to remove any airborne overspray. In restricted areas with poor ventilation, use a NIOSH approved Organic Cartridge Respirator. For concentrations above the exposure limit, use a positive air supplied respirator.
VENTILATION: All application areas should be adequately ventilated in order to keep the items in SECTION II below their exposure limits.
PROTECTIVE GLOVES: Impervious gloves (natural rubber) are recommended to prevent skin contact.
EYE PROTECTION: Safety glasses with side shields are recommended to prevent eye contact.
OTHER PROTECTIVE CLOTHING OR EQUIPMENT: Impervious apron (natural rubber) is recommended to prevent skin contact. Eye wash fountain and safety shower.
WORK / HYGIENIC PRACTICES: Avoid prolonged or repeated contact. Do not breathe vapors. Wash contaminated clothing prior to reuse.

SECTION IX - DISCLAIMER

THE INFORMATION CONTAINED HEREIN IS BELIEVED TO BE ACCURATE BUT IS NOT WARRANTED TO BE SO. NOTHING CONTAINED HEREIN CONSTITUTES A SPECIFICATION NOR IS IT INTENDED TO WARRANT SUITABILITY FOR THE INTENDED USE.

CORNELL

Material Safety Data Sheets

Division of Facilities Services

DOD Hazardous Material Information (ANSI Format)
For Cornell University Convenience Only

UNLEADED REGULAR GASOLINE

Section 1 - Product and Company Identification	Section 9 - Physical & Chemical Properties
Section 2 - Compositon/Information on Ingredients	Section 10 - Stability & Reactivity Data
Section 3 - Hazards Identification Including Emergency Overview	Section 11 - Toxicological Information
Section 4 - First Aid Measures	Section 12 - Ecological Information
Section 5 - Fire Fighting Measures	Section 13 - Disposal Considerations
Section 6 - Accidental Release Measures	Section 14 - MSDS Transport Information
Section 7 - Handling and Storage	Section 15 - Regulatory Information
Section 8 - Exposure Controls & Personal Protection	Section 16 - Other Information

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Cornell University does not in any way warrant or imply the applicability, viability or use of this information to any person or for use in any situation.

Section 1 - Product and Company Identification
UNLEADED REGULAR GASOLINE

Product Identification: UNLEADED REGULAR GASOLINE
Date of MSDS: 03/07/1988 **Technical Review Date:** 04/25/1988
FSC: 9130 **NIIN: LIIN:** 00B010045
Submitter: B DT
Status Code: C
MFN: 01
Article: N
Kit Part: N

Manufacturer's Information

Manufacturer's Name: AMOCO OIL COMPANY
Post Office Box: N/K
Manufacturer's Address1: 200 EAST RANDOLPH DRIVE
Manufacturer's Address2: CHICAGO, IL 60601
Manufacturer's Country: US
General Information Telephone: 312 856-3907
Emergency Telephone: 800 447-8735
Emergency Telephone: 800 447-8735
MSDS Preparer's Name: N/K
Proprietary: N
Reviewed: Y
Published: Y
CAGE: 15958
Special Project Code: N

Contractor Information

Contractor's Name: AMOCO OIL CO
Contractor's Address1: 200 E RANDOLPH DR MC 1408
Contractor's Address2: CHICAGO, IL 60601-6401
Contractor's Telephone: 312-856-3907
Contractor's CAGE: 15958

Section 2 - Compositon/Information on Ingredients
UNLEADED REGULAR GASOLINE

Ingredient Name: GASOLINE
Ingredient CAS Number: 8006-61-9 **Ingredient CAS Code:** M
RTECS Number: LX3300000 **RTECS Code:** M
=WT: =WT Code:
=Volume: =Volume Code:
>WT: >WT Code:
>Volume: >Volume Code:
<WT: <WT Code:
<Volume: <Volume Code:
% Low WT: % Low WT Code:
% High WT: % High WT Code:
% Low Volume: % Low Volume Code:
% High Volume: % High Volume Code:
% Text: N/K
% Enviromental Weight:
Other REC Limits: N/K
OSHA PEL: 300 PPM/500 STEL **OSHA PEL Code:** M
OSHA STEL: OSHA STEL Code:
ACGIH TLV: 300 PPM/500STEL;9192 **ACGIH TLV Code:** M
ACGIH STEL: N/P **ACGIH STEL Code:**
EPA Reporting Quantity:

DOT Reporting Quantity:
Ozone Depleting Chemical: N

Section 3 - Hazards Identification, Including Emergency Overview
UNLEADED REGULAR GASOLINE

Health Hazards Acute & Chronic: INHALATION:MODERATELY TOXIC FOR ACUTE EXPOSURES BY THIS ROUTE.EYE:NO SIGNIFICANT IRRITATION EXPECTED.INGESTION:HARMFUL IF SWALLOWED AND/OR ASPIRATED INTO LUNGS.

Signs & Symptoms of Overexposure:
INHALATION:EXCESSIVE EXPOSURES TO VAPORS WILL PRODUCE SYMPTOMS OF INTOXICATION,HEADACHE,DIZZINESS.AND NAUSEA.SKIN:PROLONGED OR REPEATED CONTACT CAN DEFAT THE SKIN AND LEAD TO IRRITATION.AND/OR DERMATI TIS.

Medical Conditions Aggravated by Exposure:
N/K

LD50 LC50 Mixture: N/K

Route of Entry Indicators:
Inhalation: YES
Skin: YES
Ingestion: YES

Carcenogenicity Indicators
NTP: N/P
IARC: N/P
OSHA: N/P

Carcinogenicity Explanation: N/K

Section 4 - First Aid Measures
UNLEADED REGULAR GASOLINE

First Aid:
IN CASE OF EYE CONTACT,FLUSH WITH PLENTY OF WATER.SKIN CONTACT.WASH EXPOSED SKIN WITH SOAP AND WATER.REMOVE CONTAMINATED CLOTHING.INCLUDING SHOES AND THOROUGHLY CLEAN AND DRY BEFORE REUSE.INHALATION:I F HARMFUL EFFECTS OCCUR.REMOVE TO UNCONTAMINATED AREA.GIVE ARTIFICIAL RESPIRATION IF NOT BREATHING.INGESTION:IF SWALLOWED.DO NOT INDUCE VOMITING.GET MEDICAL ATTENTION.

Section 5 - Fire Fighting Measures
UNLEADED REGULAR GASOLINE

Fire Fighting Procedures:
N/K
Unusual Fire or Explosion Hazard:
EXTREMELY FLAMMABLE VAPOR/AIR MIXTURES FORM.
Extinguishing Media:
DRY CHEMICAL B-C,CARBON DIOXIDE,WATER FOG.FOAM(WATER MAY BE INEFFECTIVE).

Flash Point: Flash Point Text: -45 F

Autoignition Temperature:
Autoignition Temperature Text: N/A
Lower Limit(s): 1.3%
Upper Limit(s): 7.6%

Section 6 - Accidental Release Measures
UNLEADED REGULAR GASOLINE

Spill Release Procedures:
REMOVE OR SHUT OFF ALL SOURCES OF IGNITION.USE WATER SPRAY TO DISPERSE VAPORS.INCREASE VENTILATION IF POSSIBLE.

Section 7 - Handling and Storage
UNLEADED REGULAR GASOLINE

Handling and Storage Precautions:

Other Precautions:

Section 8 - Exposure Controls & Personal Protection
UNLEADED REGULAR GASOLINE

Repiratory Protection:
AVOID BREATHING VAPOR AND/OR MIST.USE WITH ADEQUATE VENTILATION.
Ventilation:
N/K
Protective Gloves:
YES
Eye Protection: SAFETY GLASSES
Other Protective Equipment: WEAR PROTECTIVE CLOTHING AND GLOVES IF PROLONGED OR REPEATED CONTACT IS LIKELY.
Work Hygenic Practices: N/K
Supplemental Health & Safety Information: N/K

Section 9 - Physical & Chemical Properties
UNLEADED REGULAR GASOLINE

HCC:
NRC/State License Number:
Net Property Weight for Ammo:
Boiling Point: Boiling Point Text: 80F TO 430F
Melting/Freezing Point: Melting/Freezing Text: N/K
Decomposition Point: Decomposition Text: N/K
Vapor Pressure: 9-15 **D-323 Vapor Density:** 3 TO 4
Percent Volatile Organic Content:
Specific Gravity: H20=1 0.75
Volatile Organic Content Pounds per Gallon:
pH: N/K
Volatile Organic Content Grams per Liter:
Viscosity: N/P
Evaporation Weight and Reference: N/K

Solubility in Water: NEGLIGIBLE BELOW 0.1
Appearance and Odor: CLEAR,BRIGHT LIQUID.CHARACTERISTIC ODOR
Percent Volatiles by Volume: N/K
Corrosion Rate: N/K

Section 10 - Stability & Reactivity Data
UNLEADED REGULAR GASOLINE

Stability Indicator: YES
Materials to Avoid:
AVOID STRONG OXIDIZERS
Stability Condition to Avoid:
N/K
Hazardous Decomposition Products:
N/K
Hazardous Polymerization Indicator: N/P
Conditions to Avoid Polymerization:
N/K

Section 11 - Toxicological Information
UNLEADED REGULAR GASOLINE

Toxicological Information:
N/P

Section 12 - Ecological Information
UNLEADED REGULAR GASOLINE

Ecological Information:
N/P

Section 13 - Disposal Considerations
UNLEADED REGULAR GASOLINE

Waste Disposal Methods:
ENCLOSED-CONTROLLED INCINERATION IS RECOMMENDED UNLESS DIRECTED OTHERWISE BY APPLICABLE ORDINANCES.

Section 14 - MSDS Transport Information
UNLEADED REGULAR GASOLINE

Transport Information:
N/P

Section 15 - Regulatory Information
UNLEADED REGULAR GASOLINE

SARA Title III Information:
N/P
Federal Regulatory Information:
N/P
State Regulatory Information:
N/P

Section 16 - Other Information
UNLEADED REGULAR GASOLINE

Other Information:
N/P

HAZCOM Label Information

Product Identification: UNLEADED REGULAR GASOLINE
CAGE: 15958
Assigned Individual: N
Company Name: AMOCO OIL CO
Company PO Box:
Company Street Address1: 200 E RANDOLPH DR MC 1408
Company Street Address2: CHICAGO, IL 60601-6401 US
Health Emergency Telephone: 800 447-8735
Label Required Indicator: Y
Date Label Reviewed: 12/16/1998
Status Code: C
Manufacturer's Label Number:
Date of Label: 12/16/1998
Year Procured: N/K
Organization Code: G
Chronic Hazard Indicator: N/P
Eye Protection Indicator: N/P
Skin Protection Indicator: N/P
Respiratory Protection Indicator: N/P
Signal Word: N/P
Health Hazard:
Contact Hazard:
Fire Hazard:
Reactivity Hazard:

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MOUNTAIN CEMENT CO -- MOUNTAIN PORTLAND CEMENT-TYPE I-II LOW AL

MSDS Safety Information

FSC: 8030
MSDS Date: 05/15/1995
MSDS Num: BXPLX
LIIN: 00F040724
Product ID: MOUNTAIN PORTLAND CEMENT-TYPE I-II LOW ALKALI
MFN: 01
Responsible Party
Cage: MTCEM
Name: MOUNTAIN CEMENT CO
Address: 5 SAND CREEK RD
Box: 339
City: LARAMIE WY 82070-5000
Info Phone Number: 307-745-4879
Emergency Phone Number: 307-745-4879
Review Ind: Y
Published: Y

Preparer Co. when other than Responsible Party Co.

Cage: MTCEM
Name: MOUNTAIN CEMENT CO
Address: 5 SAND CREEK RD
Box: 339
City: LARAMIE WY 82070-5000

Contractor Summary

Cage: MTCEM
Name: MOUNTAIN CEMENT CO
Address: 5 SAND CREEK RD
Box: 339
City: LARAMIE WY 82070-5000
Phone: 307-745-4879

Ingredients

Cas: 65997-15-1
RTECS #: VV8770000
Name: PORTLAND CEMENT, CONTAINS: TRICALCIUM SILICATE, DICALCIUM SILICATE, TRICALCIUM ALUMINATE, TETRACALCIUM ALUMINOFERRATE
Other REC Limits: 50 MPPCF (MSHA)
ACGIH TLV: 10 MG/CUM (DUST)

Health Hazards Data

Route Of Entry Inds - Inhalation: YES
Skin: NO
Ingestion: NO
Carcinogenicity Inds - NTP: NO
IARC: NO
OSHA: NO
Effects of Exposure: WET CEMENT CAN DRY THE SKIN & CAUSE ALKLALI BURNS. EYES/INHALATION: CEMENT DUST CAN IRRITATE THE EYES & UPPER RESPIRATORY SYSTEM. CAN CAUSE INFLAMMATION OF THE LINING TISSUE OF THE INTERIOR OF THE NOS E & OF THE CORNEA. HYPERSENSITIVE INDIVIDUALS MAY DEVELOP AN ALLERGIC DERMATITIS.
Explanation Of Carcinogenicity: NONE
Signs And Symptoms Of Overexposure: WET CEMENT CAN DRY THE SKIN & CAUSE ALKALI BURNS. CEMENT DUST CAN IRRITATE THE EYES & UPPER RESPIRATORY

SYSTEM. CAN CAUSE INFLAMMATION OF THE LINING TISSUE OF THE INTERIOR OF THE NOSE & OF THE CORNEA. HYPERSENSITIVE INDIVIDUALS MAY DEVELOPAN ALLERGIC DERMATITIS.
First Aid: EYES: IRRIGATE IMMEDIATELY & REPEATEDLY W/WATER. SKIN: WASH W/SOAP & WATER. OBTAIN MEDICAL ATTENTION IN ALL CASES.

Handling and Disposal

Spill Release Procedures: USE DRY CLEANUP METHODS THAT DON'T DISPERSE THE DUST INTO THE AIR. AVOID BREATHING THE DUST.
Waste Disposal Methods: MATERIAL CAN BE DISPOSED OF AS COMMON WASTE/RETURNED TO THE CONTAINER FOR LATER USE IF IT IS NOT CONTAMINATED. DISPOSE OF IN ACCORDANCE W/LOCAL, STATE & FEDERAL REGULATIONS.
Handling And Storage Precautions: KEEP PRODUCT DRY UNTIL USED.
Other Precautions: AVOID BREATHING DUST & AVOID PROLONGED CONTACT W/WET CEMENT. PRECAUTIONS MUST BE OBSERVED BECAUSE CEMENT BURNS W/LITTLE WARNING-LITTLE HEAT IS SENSED.

Fire and Explosion Hazard Information

Unusual Fire/Explosion Hazard: NON COMBUSTIBLE/EXPLOSIVE.

Control Measures

Respiratory Protection: IN DUSTY ENVIRONMENTS, USE A NIOSH APPROVED RESPIRATOR.
Ventilation: LOCAL EXHAUST CAN BE USED TO CONTROL AIRBORNE DUST LEVELS
Protective Gloves: REQUIRED
Eye Protection: TIGHT FITTING GOGGLES
Other Protective Equipment: BARRIER CREAMS, BOOTS, PROTECTIVE CLOTHING
Work Hygienic Practices: WASH THOROUGHLY AFTER HANDLING.

Physical/Chemical Properties

Spec Gravity: 3-3.2
Solubility in Water: SLIGHT
Appearance and Odor: GREY POWDER W/NO ODOR
Percent Volatiles by Volume: 0

Reactivity Data

Stability Indicator: YES
Materials To Avoid: NONE
Hazardous Decomposition Products: NONE
Hazardous Polymerization Indicator: NO

Toxicological Information

Ecological Information

MSDS Transport Information

Regulatory Information

Other Information

HAZCOM Label

Product ID: MOUNTAIN PORTLAND CEMENT-TYPE I-II LOW ALKALI
Cage: MTCEM

Company Name: MOUNTAIN CEMENT CO
Street: 5 SAND CREEK RD
PO Box: 339
City: LARAMIE WY
Zipcode: 82070-5000
Health Emergency Phone: 307-745-4879
Label Required IND: Y
Date Of Label Review: 12/16/1998
Status Code: C
Label Date: 12/16/1998
Origination Code: G
Hazard And Precautions: WET CEMENT CAN DRY THE SKIN & CAUSE ALKLALI BURNS. EYES/INHALATION: CEMENT DUST CAN IRRITATE THE EYES & UPPER RESPIRATORY SYSTEM. CAN CAUSE INFLAMMATION OF THE LINING TISSUE OF THE INTERIOR OF THE NOS E & OF THE CORNEA. HYPERSENSITIVE INDIVIDUALS MAY DEVELOP AN ALLERGIC DERMATITIS. WET CEMENT CAN DRY THE SKIN & CAUSE ALKALI BURNS. CEMENT DUST CAN IRRITATE THE E YES & UPPER RESPIRATORY SYSTEM. CAN CAUSE INFLAMMATION OF THE LINING TISSUE OF THE INTERIOR OF THE NOSE & OF THE CORNEA. HYPERSENSITIVE INDIVIDUALS MAY DEVELOP AN ALLERGIC DERMATITIS.

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U. S. SILICA COMPANY

MSDS - MATERIAL SAFETY DATA SHEET

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Names/Trade Names:

Silica Sand sold under various names: ASTM TESTING SANDS • GLASS SAND • FLINT SILICA • DM-SERIES • F-SERIES • FOUNDRY SANDS • FJ-SERIES • FP-SERIES • H-SERIES • L-SERIES • N-SERIES • NJ-SERIES • OK-SERIES • P-SERIES • T-SERIES • HYDRAULIC FRACING SANDS • MIN-U-SIL® • MYSTIC WHITE® • #1 DRY • #1 SPECIAL • PENN SAND® • Q-ROK® • SIL-CO-SIL® • SUPERSIL®.

Synonyms/Common Names: Sand, Silica Sand, Quartz, Crystalline Silica, Flint, Ground Silica.

Manufacturer's Name:
U. S. Silica Company
P. O. Box 187
Berkeley Springs, WV 25411

Emergency Telephone Number: **304-258-2500**
304-258-8295 (fax)

Date Prepared: September 15, 2000

SECTION 2 - COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients:

	Chemical Formula	Typical %, By Weight	CAS #
Crystalline Silica (quartz)	SiO_2	99.0 - 99.9	14808-60-7
Aluminum Oxide	Al_2O_3	< .8	1344-28-1
Iron Oxide	Fe_2O_3	< .1	1309-37-1
Titanium Oxide	TiO_2	< .1	13463-67-7

Exposure Limits for Hazardous Ingredients:

	OSHA PEL	ACGIH TLV	NIOSH REL
Crystalline Silica (Quartz)	10 mg/m^3 / % SiO_2+2	.05	.05

The exposure limits are time-weighted average concentrations for an 8-hour workday and a 40-hour workweek.

Crystalline silica exists in several forms, the most common of which is quartz. If crystalline silica (quartz) is heated to more than 870°C, it can change to a form of crystalline silica known as trydimite, and if crystalline silica (quartz) is heated to more than 1470°C, it can change to a form of crystalline silica known as cristobalite. The OSHA PEL for crystalline silica as trydimite and cristobalite is one-half of the OSHA PEL for crystalline silica (quartz).

SECTION 3 - HAZARD IDENTIFICATION

EMERGENCY OVERVIEW:

The U. S. Silica Company material is a white or tan sand, or ground sand. It is not flammable, combustible or explosive. It does not cause burns or severe skin or eye irritation. A single exposure will not result in serious adverse health effects. Crystalline silica (quartz) is not known to be an environmental hazard.

Crystalline silica (quartz) is incompatible with hydrofluoric acid, fluorine, chlorine trifluoride or oxygen difluoride.

POTENTIAL HEALTH EFFECTS:

Inhalation:

a. Silicosis — Respirable crystalline silica (quartz) can cause silicosis, a fibrosis (scarring) of the lungs. Silicosis may be progressive; it may lead to disability and death.

b. Cancer — Crystalline silica (quartz) inhaled from occupational sources is classified as carcinogenic to humans.

c. Autoimmune Diseases — There are some studies that show excess numbers of cases of scleroderma and other connective tissue disorders in workers exposed to respirable crystalline silica.

d. Tuberculosis — Silicosis increases the risk of tuberculosis.

e. Nephrotoxicity — There are some studies that show an increased incidence of chronic kidney disease and end-stage renal disease in workers exposed to respirable crystalline silica.

Eye Contact: Crystalline silica (quartz) may cause abrasion of the cornea.

Skin Contact: Not applicable.

Ingestion: Not applicable.

Chronic Effects: The adverse health effects -- silicosis, cancer, autoimmune diseases, tuberculosis, and nephrotoxicity -- are chronic effects.

Signs and Symptoms of Exposure: Generally, there are no signs or symptoms of exposure to crystalline silica (quartz).

Medical Conditions Generally Aggravated by Exposure: The condition of individuals with lung disease (e.g., bronchitis, emphysema, chronic obstructive pulmonary disease) can be aggravated by exposure.

See Section 11, Toxicological Information, for additional detail on potential adverse health effects.

SECTION 4 - FIRST AID MEASURES

Inhalation: No specific first-aid is necessary since the adverse health effects associated with exposure to crystalline silica (quartz) result from chronic exposures. If there is a gross inhalation of crystalline silica (quartz), remove the person immediately to fresh air, give artificial respiration as needed, seek medical attention as needed.

Eye Contact: Wash immediately with water. If irritation persists, seek medical attention.

Skin Contact: Not applicable.

Ingestion: Not applicable.

SECTION 5 - FIRE FIGHTING MEASURES

Crystalline silica (quartz) is not flammable, combustible or explosive.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

Spills: Use dustless methods (vacuum) and place into closable container for disposal, or flush with water. Do not dry sweep. Wear protective equipment specified below.

Waste Disposal Method: See Section 13.

SECTION 7 - HANDLING AND STORAGE

Precautions During Handling and Use: Do not breath dust. Use adequate ventilation and dust collection. Keep airborne dust concentrations below PEL. Do not rely on your sight to determine if dust is in the air. Silica may be in the air without a visible dust cloud. If dust cannot be kept below permissible limits, wear a respirator approved for silica dust when using, handling, storing or disposing of this product or bag. Practice good housekeeping. Do not permit dust to collect on walls, floors, sills, ledges, machinery, or equipment. Maintain, clean, and fit test respirators in accordance with OSHA regulations. Maintain and test ventilation and dust collection equipment. Wash or vacuum clothing that has become dusty. See also control measures in Section 8.

Precautions During Storage: Avoid breakage of bagged material or spills of bulk material. See control measures in Section 8.

Do not use U. S. Silica Company materials for sandblasting.

The OSHA Hazard Communication Standard, 29 CFR Sections 1910.1200, 1915.1200, 1917.28, 1918.90, 1926.59 and 1928.21, and state and local worker or community "right-to-know" laws and regulations should be strictly followed. WARN YOUR EMPLOYEES (AND YOUR CUSTOMERS IN CASE OF RESALE) BY POSTING AND OTHER MEANS OF THE HAZARDS AND THE REQUIRED OSHA PRECAUTIONS. PROVIDE TRAINING FOR YOUR EMPLOYEES ABOUT THE OSHA PRECAUTIONS.

See also American Society for Testing and Materials (ASTM) standard practice E 1132-99a, "Standard Practice for Health Requirements Relating to Occupational Exposure to Respirable Crystalline Silica."

SECTION 8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

Local Exhaust: Use sufficient local exhaust to reduce the level of respirable crystalline silica to below the PEL. See ACGIH "Industrial Ventilation, A Manual of Recommended Practice" (latest edition).

Respiratory Protection: The following chart specifies the types of respirators which may provide respiratory protection for crystalline silica.

Particulate Concentration	MINIMUM RESPIRATORY PROTECTION*
10 x PEL or less	Any particulate respirator, except single-use or quarter-mask respirator. Any fume respirator or high efficiency particulate filter respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
50 x PEL or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
500 x PEL or less	A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
Greater than 500 x PEL or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.

***Use only NIOSH-approved or MSHA-approved equipment. See 29 CFR §1910.134 and 42 CFR §84.**

See also ANSI standard Z88.2 (latest revision) "American National Standard for Respiratory Protection".

Permissible Exposure Levels:

Component	CAS No.	Percentage (by wt.)	Exposure Guidelines						
			OSHA		ACGIH		NIOSH		
			TWA	STEL	TWA	STEL	TWA	STEL	Unit
Crystalline Silica (quartz)	14808-60-7	99.0-99.9	$\frac{10}{\% SiO_2 + 2}$	None	.05	None	.05	None	mg/m³

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	White or tan sand; granular, crushed, or ground.		
Boiling Point:	4046°F	**Odor**:	None
Vapor Pressure (mm Hg.):	None	**Specific Gravity (Water = 1)**:	2.65
Vapor Density (Air = 1):	None	**Melting Point**:	3110°F
Solubility in Water:	Insoluble in water	**Evaporation Rate (Butyl Acetate = 1)**:	None

SECTION 10 - STABILITY AND REACTIVITY

Stability: Crystalline silica (quartz) is stable.

Incompatibility (Materials to Avoid): Contact with powerful oxidizing agents, such as fluorine, chlorine trifluoride and oxygen difluoride, may cause fires.

Hazardous Decomposition or Byproducts: Silica will dissolve in hydrofluoric acid and produce a corrosive gas - silicon tetrafluoride.

Hazardous Polymerization: Will not occur.

SECTION 11 - TOXICOLOGICAL INFORMATION

A. SILICOSIS

The major concern is silicosis, caused by the inhalation and retention of respirable crystalline silica dust. Silicosis can exist in several forms, chronic (or ordinary), accelerated, or acute.

Chronic or Ordinary Silicosis (often referred to as Simple Silicosis) is the most common form of silicosis, and can occur after many years of exposure to relatively low levels of airborne respirable crystalline silica dust. It is further defined as either simple or complicated silicosis.

Simple silicosis is characterized by lung lesions (shown as radiographic opacities) less than 1 centimeter in diameter, primarily in the upper lung zones. Often, simple silicosis is not associated with symptoms, detectable changes in lung function or disability.

Simple silicosis may be progressive and may develop into complicated silicosis or progressive massive fibrosis (PMF). Complicated silicosis or PMF is characterized by lung lesions (shown as radiographic opacities) greater than 1 centimeter in diameter. Although there may be no symptoms associated with complicated silicosis or PMF, the symptoms, if present, are shortness of breath, wheezing, cough and sputum production. Complicated silicosis or PMF may be associated with decreased lung function and may be disabling. Advanced complicated silicosis or PMF may lead to death. Advanced complicated silicosis or PMF can result in heart disease secondary to the lung disease (cor pumonale).

Accelerated Silicosis can occur with exposure to high concentrations of respirable crystalline silica over a relatively short period; the lung lesions can appear within five (5) years of the initial exposure. The progression can be rapid. Accelerated silicosis is similar to chronic or ordinary silicosis, except that the lung lesions appear earlier and the progression is more rapid.

Acute Silicosis can occur with exposures to very high concentrations of respirable crystalline silica over a very short time period, sometimes as short as a few months. The symptoms of acute silicosis include progressive shortness of breath, fever, cough and weight loss. Acute silicosis is fatal.

B. CANCER

IARC - The International Agency for Research on Cancer ("IARC") concluded that there was "*sufficient evidence* in humans for the carcinogenicity of crystalline silica in the forms of quartz or cristobalite from occupational sources", and that there is "*sufficient evidence* in experimental animals for the carcinogenicity of quartz and cristobalite." The overall IARC evaluation was that "crystalline silica inhaled in the form of quartz or cristobalite from occupational sources is *carcinogenic to humans (Group 1)*." The IARC evaluation noted that "carcinogenicity was not detected in all industrial circumstances studies. Carcinogenicity may be dependent on inherent characteristics of the crystalline silica or on external factors affecting its biological activity or distribution of its polymorphs." For further information on the IARC evaluation, see IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 68, "Silica, Some Silicates..." (1997).

NTP - The National Toxicology Program, in its Ninth Annual Report on Carcinogens, classified "silica, crystalline (respirable)" as a known human carcinogen.

OSHA - Crystalline silica (quartz) is not regulated by the U. S. Occupational Safety and Health Administration as a carcinogen.

There have been many articles published on the carcinogenicity of crystalline silica, which the reader should consult for additional information; the following are examples of recently published articles: (1) "Crystalline Silica and Lung Cancer: The Problem of Conflicting Evidence", Indoor Built Environ. Volume 8, pp. 121-126 (1998); (2) "Crystalline Silica and the risk of lung cancer on the potteries", Occup. Environ. Med., Volume 55, pp. 779-785 (1998); (3) "Is Silicosis Required for Silica-Associated Lung Cancer?", American Journal of Industrial Medicine, Volume 37, pp. 252-259 (2000); (4) " Silica, Silicosis, and Lung Cancer: A Risk Assessment", American Journal of Industrial Medicine, Volume 38, pp. 8-18 (2000); (5) "Silica, Silicosis, and Lung Cancer: A Response to a Recent Working Group Report", Journal of Occupational and Environmental Medicine, Volume 42, pp. 704-720 (2000).

C. AUTOIMMUNE DISEASES

There is evidence that exposure to respirable crystalline silica (without silicosis) or that the disease silicosis is associated with the increased incidence of several autoimmune disorders, -- scleroderma, systemic lupus erythematosus, rheumatoid arthritis and diseases affecting the kidneys. For a review of the subject, the following may be consulted: "Occupational Exposure to Crystalline Silica and Autoimmune Disease", Environmental Health Perspectives, Volume 107, Supplement 5, pp. 793-802 (1999); "Occupational Scleroderma", Current Opinion in Rheumatology, Volume 11, pp. 490-494 (1999).

D. TUBERCULOSIS

Individuals with silicosis are at increased risk to develop pulmonary tuberculosis, if exposed to persons with tuberculosis. The following may be consulted for further information: Occupational Lung Disorders, Third Edition, Chapter 12, entitled "Silicosis and Related Diseases", Parkes, W. Raymond (1994); "Risk of pulmonary tuberculosis relative to silicosis and exposure to silica dust in South African gold miners." Occup Environ Med., Volume 55, pp.496-502 (1998).

E. KIDNEY DISEASE

There is evidence that exposure to respirable crystalline silica (without silicosis) or that the disease silicosis is associated with the increased incidence of kidney diseases, including end stage renal disease. For additional information on the subject, the following may be consulted: "Kidney Disease and Silicosis", Nephron, Volume 85, pp. 14-19 (2000).

SECTION 12 - ECOLOGICAL INFORMATION

Crystalline silica (quartz) is not known to be ecotoxic; i.e., there is no data which suggests that crystalline silica (quartz) is toxic to birds, fish, invertebrates, microorganisms or plants. For additional information on crystalline silica (quartz), see Sections 9 (physical and chemical properties) and 10 (stability and reactivity) of this MSDS.

SECTION 13 - DISPOSAL CONSIDERATIONS

General: The packaging and material may be landfilled; however, material should be covered to minimize generation of airborne dust.

RCRA: Crystalline silica (quartz) is not classified as a hazardous waste under the Resource Conservation and Recovery Act, or its regulations, 40 CFR §261 et seq.

The above applies to materials as sold by U.S. Silica Company. The material may be contaminated during use, and it is the responsibility of the user to assess the appropriate disposal of the used material.

SECTION 14 - TRANSPORT INFORMATION

Crystalline silica (quartz) is not a hazardous material for purposes of transportation under the U. S. Department of Transportation Table of Hazardous Materials, 49 CFR §172.101.

SECTION 15 - REGULATORY INFORMATION

UNITED STATES (FEDERAL AND STATE)

TSCA No.: Crystalline silica (quartz) appears on the EPA TSCA inventory under the CAS No. 14808-60-7.

RCRA: Crystalline silica (quartz) is not classified as a hazardous waste under the Resource Conservation and Recovery Act, or its regulations, 40 CFR §261 et seq.

CERCLA: Crystalline silica (quartz) is not classified as a hazardous substance under regulations of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), 40 CFR §302.

Emergency Planning and Community Right to Know Act: Crystalline silica (quartz) is not an extremely hazardous substance under Section 302 and is not a toxic chemical subject to the requirements of Section 313.

Clean Air Act: Crystalline silica (quartz) mined and processed by U.S. Silica Company was not processed with or does not contain any Class I or Class II ozone depleting substances.

FDA: Silica is included in the list of substances that may be included in coatings used in food contact surfaces, 21 CFR §175.300(b)(3)(xxvi).

NTP: Respirable crystalline silica (quartz) is classified as a carcinogen.

OSHA Carcinogen: Crystalline silica (quartz) is not listed.

California Proposition 65: Crystalline silica (quartz) is classified as a substance known to the State of California to be a carcinogen.

CANADA

Domestic Substances List: U. S. Silica Company products, as naturally-occurring substances, are on the Canadian DSL.

WHMIS Classification: D2A

OTHER

EINECS No.: 238-878-4

EEC Label (Risk/Safety Phrases): R 48/20, R 40/20, S22, S38

IARC: Crystalline silica (quartz) is classified in IARC Group 1.

National, state, provincial or local emergency planning, community right-to-know or other laws, regulations or ordinances may be applicable--consult applicable national, state, provincial or local laws.

SECTION 16 - OTHER INFORMATION

Hazardous Material Information System (HMIS):

Health	*
Flammability	0
Reactivity	0
Protective Equipment	E

* For further information on health effects, see Sections 3 and 11 of this MSDS.

National Fire Protection Association (NFPA):

Health	0
Flammability	0
Reactivity	0

Web Sites with Information about Effects of Crystalline Silica Exposure:

http://www.osha.gov - The Occupational Safety and Health Administration Home Page, click on "Technical Links", then click on "silica, crystalline".

http://www.cdc.gov/niosh/silicpag.html - NIOSH Hotlinks to Silicosis Prevention.

U. S. SILICA COMPANY DISCLAIMER

The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind, express or implied, is made with respect to the information contained herein. We accept no responsibility and disclaim all liability for any harmful effects which may be caused by purchase, resale, use or exposure to our silica. Customers-users of silica must comply with all applicable health and safety laws, regulations, and orders, including the OSHA Hazardous Communication Standard.

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MATERIAL SAFETY DATA SHEET Page 01 of 05

Tak Pak(R) 712 Accelerator Metered Mist
18636

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: Tak Pak(R) 712 Accelerator Metered Mist
Item No.: 18636
Product Type: Activator

2. COMPOSITION, INFORMATION ON INGREDIENTS

Ingredients	CAS No.	%
ISOPROPYL ALCOHOL	67-63-0	70-75
ISOBUTANE	75-28-5	15-20
PROPANE	74-98-6	10-15
N,N-Dialkyltoluidine	99-97-8	1-3
HYDROQUINONE	123-31-9	0.01-0.1

Ingredients which have exposure limits

Exposure Limits (TWA) Ingredients	ACGIH (TLV)	OSHA (PEL)	OTHER
ISOPROPYL ALCOHOL	400 ppm TWA 983 mg/m3	400 ppm TWA 980 mg/m3	400 ppm TWA DuPont AEL
PROPANE	2500 ppm	1000 ppm 1800 mg/m3	None
HYDROQUINONE	2 mg/m3 TWA	2 mg/m3 TWA	2 mg/m3 TWA 4 mg/m3 STEL

Exposure Limits (STEL) Ingredients	ACGIH (TLV)	OSHA (PEL)
ISOPROPYL ALCOHOL	500 ppm 1230 mg/m3	500 ppm 1225 mg/m3
PROPANE	Asphyxiant	Asphyxiant

3. HAZARDS IDENTIFICATION

Toxicity: Eye and skin irritant. Also see "Signs and symptoms of exposure".
Primary Routes of Entry: Inhalation, ingestion, skin and eye contact.
Signs and Symptoms of Exposure: Headache, nausea, dizziness, vomiting, drowziness, irritation of respiratory tract, loss of consciousness, pulmonary edema, temporary corneal damage, gastrointestinal irritation, central nervous system depression.
Existing Conditions Aggravated by Exposure: Isopropyl alcohol:

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MATERIAL SAFETY DATA SHEET Page 02 of 05

Product Name: Tak Pak(R) 712 Accelerator Metered Mist

Item No.: 18636

3. HAZARDS IDENTIFICATION (continued)

Skin disorders, eye problems, respiratory disorder

Ingredients	Literature Referenced Target Organ and Other Health Effects	Carcinogen NTP	IARC	OSHA
ISOPROPYL ALCOHOL	ALG BLO CNS IRR KID	NO	N/A	NO
ISOBUTANE	CAR CNS LUN	NO	NO	NO
PROPANE	CAR CNS IRR	NO	NO	NO
N,N-Dialkyltoluidine	ALG MUT	NO	NO	NO
HYDROQUINONE	BLO BNM CNS EYE IMM IRR LIV MUT SKI THY	NO	N/A	NO

Abbreviations

N/A Not Applicable
BLO Blood
CAR Cardiac
EYE Eyes
IRR Irritant
LIV Liver
MUT Mutagen
THY Thyroid
ALG Allergen
BNM Bone Marrow
CNS Central nervous system
IMM Immune system
KID Kidney
LUN Lung
SKI Skin

4. FIRST AID MEASURES

Ingestion: Do not induce vomiting. Keep individual calm. Obtain medical attention.
Inhalation: Remove to fresh air. If symptoms persist, obtain medical attention.
Skin Contact: Wash with soap and water.
Eye Contact: Flush at least 15 minutes with water. Obtain medical attention.

5. FIRE FIGHTING MEASURES

Flash Point: 53°F (Base) Method: Tag Closed Cup
-165°F (Propellants) Method: Open Cup
Recommended Extinguishing Agents: Carbon dioxide, foam, dry chemical
Special Firefighting Procedures: Not available
Hazardous Products formed by Fire or Thermal Decomp Oxides of carbon
Unusual Fire or Explosion Hazards: Distant ignition sources may ignite vapors traveling with moving air currents.

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MATERIAL SAFETY DATA SHEET Page 03 of 05

Product Name: Tak Pak(R) 712 Accelerator Metered Mist
Item No.: 18636

5. FIRE FIGHTING MEASURES (continued)

Explosive Limits:
(% by volume in air) Lower 1.2% N,N-Dialkyltoluidine

	2.0% Isopropyl alcohol 1.8% Isobutane 2.1% Propane
(% by volume in air)Upper	7% N,N-Dialkyltoluidine 12.7 at 200°F Isopropyl alcohol 8.4% Isobutane 9.8% Propane

6. ACCIDENTAL RELEASE MEASURES

Steps to be taken in case of spill or leak:	Remove sources of ignition. Allow to evaporate with good ventilation.

7. HANDLING AND STORAGE

Safe Storage:	Store below 110°F away from sources of ignition.
(Contact Loctite Customer	Service 1-800-243-4874 for shelf life information)
Handling:	Avoid prolonged breathing vapor. Keep away from eyes. Avoid prolonged skin contact.

8. EXPOSURE CONTROLS, PERSONAL PROTECTION

Eyes:	Safety glasses or goggles.
Skin:	Rubber or plastic gloves.
Ventilation:	Provide adequate local ventilation to maintain vapor concentration below TLV.
Respiratory	Not available
	See Section 2 for Exposure Limits.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear liquid
Odor:	Alcoholic
Boiling Point:	180°F
pH:	Does not apply
Solubility in Water:	95-100%
Specific Gravity	0.79
Volatile Organic Compound (EPA Method 24)	99.9%; 789 grams/liter
Vapor Pressure:	33 mm at 70°F
Vapor Density:	2.1
Evaporation Rate (Ether = 1)	7.7

10. STABILITY AND REACTIVITY

Stability:	Stable
Hazardous Polymerization:	Will not occur
Incompatibility:	Strong oxidizing agents, aluminum, nitric acid, sulfuric acid, amines, ammonia, halogen acids and chlorides, aldehydes
Conditions to Avoid:	Not available
Hazardous Decomposition Products (non-thermal):	None

11. TOXICOLOGICAL INFORMATION

See Section 3.

12. ECOLOGICAL INFORMATION

No data available

13. DISPOSAL CONSIDERATIONS

Recommended methods of disposal:	Incinerate following EPA and local regulations. Do not incinerate cans still under pressure.
EPA Hazardous Waste Number	D001 - Hazardous waste per 40CFR 261.21

14. TRANSPORTATION INFORMATION

DOT (49 CFR 172)	
Domestic Ground Transport	
Proper Shipping Name:	Consumer Commodity
Hazard Class or Division:	ORM-D
Identification Number:	None
Marine Pollutant:	None
IATA	
Proper Shipping Name:	Aerosols, flammable
Class or Division:	Class 2.1
UN or ID Number:	UN 1950

15. REGULATORY INFORMATION

CA Proposition 65: Not available

16. OTHER INFORMATION

Estimated NFPA(R) Code:	
Health Hazard:	2
Fire Hazard:	4

16. OTHER INFORMATION (continued)

Reactivity Hazard:	0
Specific Hazard:	Does not apply
Estimated HMIS(R) Code:	
Health Hazard:	2
Flammability Hazard:	4
Reactivity Hazards:	0
Personal Protection:	See Section 8.

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HMIS is a registered trademark of the National Paint and Coatings Assn.

Prepared By: Stephen Repetto

Title:	Research Chemist, Environmental Health & Safety
Company:	Loctite Corp., 1001 Tr Br Cr, Rocky Hill CT 06067
(24hr.) Phone:	(860) 571-5100
Revision Date:	January 26, 1999 Revision: 0014

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MATERIAL SAFETY DATA SHEET

Loctite(R) Prism(R) 410 Black Toughened Inst Adh
41045

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
Item No.: 41045
Product Type: Cyanoacrylate Ester

2. COMPOSITION, INFORMATION ON INGREDIENTS

Ingredients	CAS No.	%
Ethyl cyanoacrylate	7085-85-0	85-90
Ethylene copolymer rubber	54545-50-5	5-10
SILICA, AMORPHOUS, FUMED, CRYSTALLINE-FREE	112945-52-5	3-5
CARBON BLACK	1333-86-4	1-3
HYDROQUINONE*	0123-31-9	1-1.5
PHTHALIC ANHYDRIDE*	85-44-9	0.1-1

* This component is listed as a SARA Section 313 Toxic Chemical.

Ingredients which have exposure limits

Exposure Limits (TWA) Ingredients	ACGIH (TLV)	OSHA (PEL)	OTHER
Ethyl cyanoacrylate	0.2 ppm TWA	None	None
SILICA, AMORPHOUS, FUMED, CRYSTALLINE-FREE	10 mg/m3 TWA	6 mg/m3 TWA	3 mg/m3 TWA resp. dust
CARBON BLACK	3.5 mg/m3 TWA	3.5 mg/m3 TWA	5ppm
HYDROQUINONE	2 mg/m3 TWA	2 mg/m3 TWA	2 mg/m3 TWA 4 mg/m3 STEL
PHTHALIC ANHYDRIDE	1 ppm TWA	1 ppm TWA	None

Exposure Limits (STEL) Ingredients	ACGIH (TLV)	OSHA (PEL)

3. HAZARDS IDENTIFICATION

Toxicity: Skin contact may cause burns.
Bonds skin rapidly and strongly.
Skin and eye irritant.
Estimated oral LD50 more than 5000mg/kg.
Estimated dermal LD 50 more than 2000 mg/kg.

Primary Routes of Entry: None known

Signs and Symptoms of Exposure: Vapor is irritating to eyes and mucous membranes

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MATERIAL SAFETY DATA SHEET

Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
Item No.: 41045

3. HAZARDS IDENTIFICATION (continued)

above TLV. Exposure to vapors above the established limits may cause symptoms of non-allergic asthma.

Existing Conditions Aggravated by Exposure: None known

Ingredients	Literature Referenced Target Organ and Other Health Effects	Carcinogen NTP	IARC	OSHA
Ethyl cyanoacrylate	ALG IRR RES	NO	NO	NO
Ethylene copolymer rubber	No Data	NO	NO	NO
SILICA, AMORPHOUS, FUMED, CRYSTALLINE-FREE	NUI	NO	N/A	NO
CARBON BLACK	RES	NO	2B	NO
HYDROQUINONE	AC3 BLO BNM CNS EYE IMM IRR MUT SKI	NO	N/A	NO
PHTHALIC ANHYDRIDE	AC4 ALG COR IRR RES	NO	NO	NO

Abbreviations

N/A Not Applicable	2B Possibly carcinogenic to humans
AC3 ACGIH animal carcinogen.	AC4 ACGIH-Unclassifiable as human carc.
ALG Allergen	BLO Blood
BNM Bone Marrow	CNS Central nervous system
COR Corrosive	EYE Eyes
IMM Immune system	IRR Irritant
MUT Mutagen	NUI Nuisance dust
RES Respiratory	SKI Skin

4. FIRST AID MEASURES

Ingestion: Ingestion is not likely. See supplemental page for emergency procedures.

Inhalation: Remove to fresh air. If symptoms persist, obtain medical attention.

Skin Contact: Soak in warm water. See supplemental page for emergency procedures.

Eye Contact: Flush with water. See supplemental page for emergency procedures.

5. FIRE FIGHTING MEASURES

Flash Point: 150 - 200°F Method: Tag Closed Cup

Recommended Extinguishing Agents: Carbon dioxide, foam, dry chemical

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Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
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5. FIRE FIGHTING MEASURES (continued)

Special Firefighting Procedures: Not available

Hazardous Products formed by Fire or Thermal Decomp Irritating organic vapors

Unusual Fire or Explosion Hazards: None

Explosive Limits:
(% by volume in air) Lower 1.7% Phthalic anhydride
(% by volume in air) Upper 10.5% Phthalic anhydride

6. ACCIDENTAL RELEASE MEASURES

Steps to be taken in case of spill or leak: Flood with water to polymerize. Soak up with an inert absorbent. Store in a closed container until disposal.

7. HANDLING AND STORAGE

Safe Storage: Store at or below 75 deg. F
(Contact Loctite Customer Service 1-800-243-4874 for shelf life information)
Handling: Avoid contact with skin and eyes. Avoid breathing vapor.

8. EXPOSURE CONTROLS, PERSONAL PROTECTION

Eyes: Safety glasses or goggles.
Skin: Nitrile or polyethylene gloves and aprons. Do not use cotton. See supplemental page for additional information.
Ventilation: Positive down-draft exhaust ventilation should be provided to maintain vapor concentration below TLV.
Respiratory Not available

See Section 2 for Exposure Limits.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Black viscous liquid
Odor: Pungent
Boiling Point: More than 300°F
pH: Does not apply
Solubility in Water: Polymerized
Specific Gravity 1.07
Volatile Organic Compound (EPA Method 24) 84.1%; 900 grams per liter

Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
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9. PHYSICAL AND CHEMICAL PROPERTIES (continued)

Less than 20 g/l (California SCAQMD method 316B)
Vapor Pressure: Less than 0.2mm at 80°F
Vapor Density: Approximately 3
Evaporation Rate (Ether = 1) Not available

10. STABILITY AND REACTIVITY

Stability: Stable

Hazardous Polymerization: Will not occur
Incompatibility: Polymerized by contact with water, alcohols, amines, alkalies.
Conditions to Avoid: Not available
Hazardous Decomposition Products (non-thermal): None

11. TOXICOLOGICAL INFORMATION

See Section 3.

12. ECOLOGICAL INFORMATION

No data available

13. DISPOSAL CONSIDERATIONS

Recommended methods of disposal: Polymerize as above. Incinerate in accordance with EPA and local regulations.
EPA Hazardous Waste Number NH - Not a RCRA Hazardous Waste Material

14. TRANSPORTATION INFORMATION

DOT (49 CFR 172)
Domestic Ground Transport
Proper Shipping Name: Unrestricted (Not more than 450 liters); Combustible liquids, n.o.s. (Cyanoacrylate ester) (More than 450 liters)
Hazard Class or Division: Unrestricted (Not more than 450 liters) Combustible liquid (More than 450 liters)
Identification Number: None (Not more than 450 liters); NA 1993 (More than 450 liters)
Marine Pollutant: None
IATA
Proper Shipping Name: Unrestricted (Not more than one pint); Aviation regulated liquid, n.o.s., (Cyanoacrylate

Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
Item No.: 41045

14. TRANSPORTATION INFORMATION (continued)

Ester) (More than one pint)
Class or Division: Unrestricted (Not more than one pint); Class 9 (More than one pint)
UN or ID Number: None (Not more than one pint) UN 3334 (More than one pint)

15. REGULATORY INFORMATION

CA Proposition 65: No California Proposition 65 chemicals are known to be present.

16. OTHER INFORMATION

Estimated NFPA(R) Code:

Health Hazard: 2
Fire Hazard: 2
Reactivity Hazard: 1
Specific Hazard: Does not apply

Estimated HMIS(R) Code:
Health Hazard: 2
Flammability Hazard: 2
Reactivity Hazards: 1
Personal Protection: See Section 8.

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Prepared By: Stephen Repetto
Title: Research Chemist, Environmental Health & Safety
Company: Loctite Corp., 1001 Tr Br Cr, Rocky Hill CT 06067
(24hr.) Phone: (860) 571-5100
Revision Date: September 21, 2000 Revision: 0035

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ROCKY HILL, CONNECTICUT 06067
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Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
Item No.: 41045

Supplement

INFORMATION FOR FIRST AID AND CASUALTY ON TREATMENT FOR ADHESION OF HUMAN SKIN TO ITSELF IF CAUSED BY CYANOACRYLATE ADHESIVES

Cyanoacrylate adhesive is a very fast setting and strong adhesive. It bonds human tissue including skin in seconds. Experience has shown that accidents due to cyanoacrylates are handled best by passive, nonsurgical first aid. Treatment of specific types of accidents are given below.

SKIN CONTACT
Remove excess adhesive. Soak in warm, soapy water. The adhesive will come loose from the skin in several hours. Cured adhesive does not present a health hazard even when bonded to the skin.

Avoid contact with clothes, fabrics, rags, or tissue. Contact with these materials may cause polymerization. The polymerization of large amounts of adhesive will generate heat causing smoke, skin burns, and strong, irritating vapors. Wear nitrile or polyethylene gloves and apron when handling large amounts of adhesive.

SKIN ADHESION
First immerse the bonded surfaces in warm, soapy water. Peel or roll the surfaces apart with the aid of a blunt edge, e.g. a spatula or a teaspoon handle; then remove adhesive from the skin with soap and water. Do not try to pull surfaces apart with a direct opposing action.

EYELID TO EYELID OR EYEBALL ADHESION
In the event that eyelids are stuck together or bonded to the eyeball, wash thoroughly with warm water and apply a gauze patch. The eye will open without further action, typically in 1-4 days. There will be no residual damage. Do not try to open the eyes by manipulation.

ADHESIVE ON THE EYEBALL

Cyanoacrylate introduced into the eyes will attach itself to the eye protein and will disassociate from it over intermittent periods, generally covering several hours. This will cause periods of weeping until clearance is achieved. During the period of contamination, double vision may be experienced together with a lachrymatory effect, and it is important to understand the cause and realize that disassociation will normally occur within a matter of hours, even with gross contamination.

MOUTH
If lips are accidentally stuck together, apply lots of warm water to the lips and encourage maximum wetting and pressure from saliva inside the mouth. Peel or roll lips apart. Do not try to pull the lips

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Product Name: Loctite(R) Prism(R) 410 Black Toughened Inst Adh
Item No.: 41045

Supplement

with direct opposing action.

It is almost impossible to swallow cyanoacrylate. The adhesive solidifies and adheres in the mouth. Saliva will lift the adhesive in one half to two days. In case a lump forms in the mouth, position the patient to prevent ingestion of the lump when it detaches.

BURNS
Cyanoacrylates give off heat on solidification. In rare cases a large drop will increase in temperature enough to cause a burn.
Burns should be treated normally after the lump of cyanoacrylate is released from the tissue as described above.

SURGERY
It should never be necessary to use such a drastic method to separate accidentally bonded skin.

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MAGNALUBE-G
GREASES

11-51 44th ROAD, LONG ISLAND CITY, NEW YORK 11101

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• FAX: (718) 729-2690
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MATERIAL SAFETY DATA SHEET
MAGNALUBE-G — TEFLON/PETROLEUM GREASE

MANUFACTURER:
SAUNDERS ENTERPRISES, INC.
11-51 44TH ROAD
LONG ISLAND CITY, N.Y. 11101

EMERGENCY HEALTH INFORMATION: (718) 729-1000
EMERGENCY SPILL INFORMATION: (718) 729-2628
OTHER PRODUCT SAFETY INFO: (718) 729-2671

COMPOSITION/INFORMATION ON INGREDIENTS	CAS NUMBER	PERCENTAGE
LUBRICATING BASE OIL	* SEE BELOW	78%
SEVERELY REFINED PETROLEUM DISTILLATE		
ACGIH-TLV-5MG/M CUBED10MG/M3 (MIST) ACGIH STEL		
ORGANIC POLYUREA THICKENER	)	
(TSCA PROPRIETY COMPOUND EPA FILE #26847 NON-HAZARDOUS)	)	22%
TEFLON	#9002-84-0)	

*THE BASE OIL MAY BE A MIXTURE OF ANY OF THE FOLLOWING: CAS 64741884, CAS 64741895, CAS 64741964, CAS 64741975, CAS 64742014, CAS 64742525, CAS 64742536, CAS 64742547, CAS 64742627, CAS 64742650, OR CAS 72623837.

COMPOSITION COMMENT:
ALL THE COMPONENTS OF THIS MATERIAL ARE ON THE TOXIC SUBSTANCES CONTROL ACT CHEMICAL SUBSTANCES INVENTORY.

THIS PRODUCT FITS THE ACGIH DEFINITION FOR MINERAL OIL MIST. THE ACGIH TLV IS 5 MG/M3. THE OSHA PEL IS 5 MG/M3.

HAZARDS IDENTIFICATION

POTENTIAL HEALTH EFFECTS:
EYE:
NOT EXPECTED TO CAUSE PROLONGED OR SIGNIFICANT EYE IRRITATION.
SKIN:
CONTACT WITH THE SKIN IS NOT EXPECTED TO CAUSE PROLONGED OR SIGNIFICANT IRRITATION. SKIN CONTACT MAY CAUSE DRYING OR DEFATTING OF THE SKIN. NOT EXPECTED TO BE HARMFUL TO INTERNAL ORGANS IF ABSORBED THROUGH THE SKIN.
HIGH-PRESSURE EQUIPMENT INFORMATION:
ACCIDENTIAL HIGH-VELOCITY INJECTION UNDER THE SKIN OF MATERIALS OF THIS TYPE MAY RESULT IN SERIOUS INJURY. SEEK MEDICAL ATTENTION AT ONCE SHOULD AN ACCIDENT LIKE THIS OCCUR. THE INITIAL WOUND AT THE INJECTION SITE MAY NOT APPEAR TO BE SERIOUS AT FIRST; BUT, IF LEFT UNTREATED, COULD RESULT IN DISFIGUREMENT OR AMPUTATION OF THE AFFECTED PART.
INGESTION:
IF SWALLOWED, THIS SUBSTANCE IS CONSIDERED PRACTICALLY NON-TOXIC TO INTERNAL ORGANS.
INHALATION:
NOT EXPECTED TO BE HARMFUL IF INHALED. CONTAINS A PETROLEUM-BASED MINERAL PROLONGED OR REPEATED INHALATION OF OIL MIST AT AIRBORNE LEVELS ABOVE THE RECOMMENDED MINERAL OIL MIST EXPOSURE LIMIT.
SIGNS AND SYMPTOMS OF EXPOSURE:
SKIN DEFATTING: MAY INCLUDE DRYING AND REDDENING OF THE SKIN.

Magnalube is a registered trademark of Saunders Enterprises Inc. The exclusive manufacturer of Magnalube Greases.

FIRST AID MEASURES

EYE:
NO SPECIFIC FIRST AID MEASURES ARE REQUIRED BECAUSE THIS MATERIAL IS NOT EXPECTED TO CAUSE EYE IRRITATION. AS A PRECAUTION REMOVE CONTACT LENSES, IF WORN, AND FLUSH EYES WITH WATER.
SKIN:
REMOVE CONTAMINATED CLOTHING AND SHOES. USE A WATERLESS HAND CLEANER, MINERAL OIL, OR PETROLEUM JELLY TO REMOVE THE MATERIAL. THEN WASH SKIN WITH SOAP AND WATER. WASH OR CLEAN CONTAMINATED CLOTHING AND SHOES BEFORE REUSE.
INGESTION:
NO SPECIFIC FIRST AID MEASURES ARE REQUIRED BECAUSE THIS MATERIAL IS NOT EXPECTED TO BE HARMFUL IF SWALLOWED. DO NOT INDUCE VOMITING. AS A PRECAUTION, GIVE THE PERSON A GLASS OF WATER OR MILK TO DRINK AND GET MEDICAL ADVICE. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON.
INHALATION:
IF EXPOSED TO EXCESSIVE LEVELS OF MATERIAL IN THE AIR, MOVE THE EXPOSED PERSON TO FRESH AIR. GET MEDICAL ATTENTION IF COUGHING OR RESPIRATORY DISCOMFORT OCCURS.
NOTE TO PHYSICIANS:
IN AN ACCIDENT INVOLVING HIGH-PRESSURE EQUIPMENT, THIS PRODUCT MAY BE INJECTED UNDER THE SKIN. SUCH AN ACCIDENT MAY RESULT IN A SMALL SOMETIMES BLOODLESS, PUNCTURE WOUND. HOWEVER, BECAUSE OF ITS DRIVING FORCE, MATERIAL INJECTED INTO A FINGERTIP CAN BE DEPOSITED INTO THE PALM OF THE HAND. WITHIN 24 HOURS, THERE IS USUALLY A GREAT DEAL OF SWELLING, DISCOLORATION, AND INTENSE THROBBING PAIN. IMMEDIATE TREATMENT AT A SURGICAL EMERGENCY CENTER IS RECOMMENDED.

FIRE FIGHTING MEASURES

FIRE CLASSIFICATION:
CLASSIFICATION (29 CFR 1910.1200): NOT CLASSIFIED BY OSHA AS FLAMMABLE OR COMBUSTIBLE.
FLAMMABLE PROPERTIES:
FLASH POINT: (COC) >455F (>235C)
AUTOIGNITION: NDA
FLAMMABILITY LIMITS (% BY VOLUME IN AIR): LOWER: NA UPPER: NA
EXTINGUISHING MEDIA: CO2, DRY CHEMICAL, FOAM AND WATER FOG.
NFPA RATINGS: HEALTH 1, FLAMMABILITY 1, REACTIVITY 0.
FIRE FIGHTING INSTRUCTIONS:
THIS MATERIAL WILL BURN ALTHOUGH IT IS NOT EASILY IGNITED.
COMBUSTION PRODUCTS:
NORMAL COMBUSTION FORMS CARBON DIOXIDE, WATER VAPOR AND MAY PRODUCE OXIDES OF SULFUR, NITROGEN AND PHOSPHORUS. COMBUSTION MAY FORM OXIDES OF CALCIUM AND H2S. INCOMPLETE COMBUSTION CAN PRODUCE CARBON MONOXIDE.

ACCIDENTAL RELEASE MEASURES

CLEAN UP SPILLS IMMEDIATELY, OBSERVING PRECAUTIONS IN EXPOSURE CONTROLS/ PERSONAL PROTECTION SECTION.

HANDLING AND STORAGE

HANDLING & STORAGE: NO SPECIAL REQUIREMENTS.

EXPOSURE CONTROLS/PERSONAL PROTECTION

GENERAL CONSIDERATIONS:
CONSIDER THE POTENTIAL HAZARDS OF THIS MATERIAL (SEE HAZARDS IDENTIFICATION) APPLICABLE EXPOSURE LIMITS, JOB ACTIVITIES, AND OTHER SUBSTANCES IN THE WORK PLACE WHEN DESIGNING ENGINEERING CONTROLS AND SELECTING PERSONAL PROTECTIVE EQUIPMENT. IF ENGINEERING CONTROLS OR WORK PRACTICES ARE NOT ADEQUATE TO PREVENT EXPOSURE TO HARMFUL LEVELS OF THIS MATERIAL, THE PERSONAL PROTECTIVE EQUIPMENT LISTED BELOW IS RECOMMENDED. THE USER SHOULD READ AND UNDERSTAND ALL INSTRUCTIONS AND LIMITATIONS SUPPLIED WITH THE EQUIPMENT SINCE PROTECTION IS USUALLY PROVIDED FOR A LIMITED TIME OR UNDER CERTAIN CIRCUMSTANCES.

ENGINEERING CONTROLS:
USE IN A WELL-VENTILATED AREA. IF USER OPERATIONS GENERATE AN OIL MIST, USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION, OR OTHER ENGINEERING CONTROLS TO CONTROL AIRBORNE LEVELS BELOW THE RECOMMENDED MINERAL OIL MIST EXPOSURE LIMITS.

PERSONAL PROTECTIVE EQUIPMENT:
EYE/FACE PROTECTION:
NO SPECIAL EYE PROTECTION IS NORMALLY REQUIRED.
SKIN PROTECTION:
WEAR PROTECTIVE CLOTHING IF ENGINEERING CONTROLS OR WORK PRACTICES ARE NOT ADEQUATE TO PREVENT SKIN CONTACT. SELECTION PF PROTECTIVE CLOTHING MAY INCLUDE GLOVES, APRON, BOOTS, AND COMPLETE FACIAL PROTECTION DEPENDING ON OPERATIONS CONDUCTED. SUGGESTED MATERIALS FOR PROTECTIVE GLOVES INCLUDE: (NITRILE) (VITON) SILVER SHIELD).
RESPIRATORY PROTECTION:
NO RESPIRATORY PROTECTION IS NORMALLY REQUIRED. IF USER OPERATIONS GENERATE AN OIL MIST, DETERMINE IF AIRBORNE CONCENTRATIONS ARE BELOW THE RECOMMENDED MINERAL OIL MIST EXPOSURE LIMITS. IF NOT WEAR A NIOSH APPROVED RESPIRATOR THAT PROVIDES ADEQUATE PROTECTION FROM MEASURED CONCENTRATIONS OF THIS MATERIAL. USE THE FOLLOWING ELEMENTS FOR AIR-PURIFYING RESPIRATORS: PARTICULATE.

PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL DESCRIPTION:	GREEN GREASE
p/H:	NDA
VAPOR PRESSURE:	NDA
VAPOR DENSITY	(AIR=1)
BOILING POINT:	NDA
FREEZING POINT:	NDA
MELTING POINT:	NDA
SOLUBILITY:	SOLUBLE IN HYDROCARBON SOLVENTS; INSOLUBLE IN WATER.
SPECIFIC GRAVITY:	1.02 @ 15.6/15.5C
EVAPORATION RATE	NA
VISCOSITY:	>100 SUS @ 100F
PRECENT VOLATILE (VOL):	NA

STABILITY AND REACTIVITY

HAZARDOUS DECOMPOSITION PRODUCTS:
NO DATA AVAILABLE.
CHEMICAL STABILITY:
STABLE.
CONDITIONS TO AVOID:
NO DATA AVAILABLE.
INCOMPATIBILITY WITH OTHER MATERIALS:
MAY REACT WITH STRONG OXIDIZING AGENTS, SUCH AS CHLORATES, PEROXIDES, ETC.
HAZARDOUS POLYMERIZATION:
POLYMERIZATION WILL NOT OCCUR.

TOXICOLOGICAL INFORMATION

EYE EFFECTS:
THE EYE IRRITATION HAZARD IS BASED ON DATA FOR A SIMILAR MATERIAL.
SKIN EFFECTS:
THE SKIN IRRITATION HAZARD IS BASED ON DATA FOR A SIMILAR MATERIAL.
ACUTE INHALATION EFFECTS:
THE ACUTE RESPIRATORY TOXICITY IS BASED ON DATA FOR A SIMILAR MATERIAL.
ADDITIONAL TOXICOLOGY INFORMATION:
THIS PRODUCT CONTAINS PETROLEUM BASE OILS WHICH MAY BE REFINED BY VARIOUS PROCESSES INCLUDING SEVERE SOLVENT EXTRACTION, SEVERE HYDROCRACKING, OR SEVERE HYDROTREATING. NONE OF THE OILS REQUIRES A CANCER WARNING UNDER THE OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200). THESE OILS HAVE NOT BEEN LISTED IN THE NATIONAL TOXICOLOGY PROGRAM (NTP) ANNUAL REPORT NOR HAVE THEY BEEN CLASSIFIED BY THE INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC) AS; CARCINOGNIC TO HUMANS (GROUP 1), PROBABLY CARCINOGENIC TO HUMANS (GROUP 2A), OR POSSIBLY CARCINOGENIC TO HUMANS (GROUP 2B).

ECOLOGICAL INFORMATION

ECOTOXICITY:
NO DATA AVAILABLE.
ENVIRONMENTAL FATE:
THIS MATERIAL IS NOT EXPECTED TO BE READILY BIODEGRADABLE.

DISPOSAL CONSIDERATIONS

OIL COLLECTION SERVICES ARE AVAILABLE FOR USED OIL RECYCLING OR DISPOSAL. PLACE CONTAMINATED MATERIALS IN CONTAINERS AND DISPOSE OF IN A MANNER CONSISTENT WITH APPLICABLE REGULATIONS. CONTACT YOUR LOCAL ENVIRONMENTAL OR HEALTH AUTHORITIES FOR APPROVED DISPOSAL OR RECYCLING METHODS.

TRANSPORT INFORMATION

TRANSPORTATION INFORMATION:
THE DESCRIPTION SHOWN MAY NOT APPLY TO ALL SHIPPING SITUATIONS. CONSULT 49CFR, OR APPROPRIATE DANGEROUS GOODS REGULATIONS. FOR ADDITIONAL DESCRIPTION REQUIREMENTS (E.G. TECHNICAL NAME AND MODE-SPECIFIC OR QUANTITY-SPECIFIC SHIPPING REQUIREMENTS.

DOT SHIPPING NAME:	NONE	DOT HARZARD CLASS:	NONE
DOT IDENTIFICATION #:	NONE	DOT PACKING GROUP:	N/A

ADDITIONAL INFO: PETROLEUM LUBRICATING GREASE - NOT HAZARDOUS BY US DOT.
ADR/RID HAZARD CLASS - NOT APPLICABLE.

REGULATORY INFORMATION

SARA 311 CATEGORIES:	1. IMMEDIATE (ACUTE) HEALTH EFFECTS:	NO
	2. DELAYED (CHRONIC) HEALTH EFFECTS:	NO
	3. FIRE HAZARD:	NO
	4. SUDDEN RELEASE OF PRESSURE HAZARD:	NO
	5. REACTIVITY HAZARD:	NO

FOOD CONTACT STATUS

USDA: H-2 STATUS: THIS PRODUCT IS ACCEPTABLE TO THE USDA FOR USE AS A LUBRICATE IN OFFICIAL MEAT AND POULTRY ESTABLISHMENTS PROVIDED THERE IS NO POSSIBILITY OF THE LUBRICANT OR LUBICATED PART CONTACTING EDIBLE PRODUCTS.

OTHER INFORMATION

NFPA RATINGS: HEALTH 1; FLAMMABILITY 1, REACTIVITY 0,
HMIS RATINGS: HEALTH 1, FLAMMABILITY 1, REACTIVITY 0,
(0-LEAST, 1-SLIGHT, 2-MODERATE, 3-HIGH, 4-EXTREME, PPE - PERSONAL PROTECTION EQUIPMENT INDEX RECOMMENDATION - CHRONIC EFFECT INDICATOR). THESE VALUES ARE OBTAINED USING THE GUIDELINES OR PUBLISHED EVALUATIONS PREPARED BY THE NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) OR THE NATIONAL PAINT AND COATING ASSOCIATION (FOR HMIS RATINGS).

ABBREVIATIONS THAT MAY HAVE BEEN USED IN THIS DOCUMENT:

TLV	- THRESHOLD LIMIT VALUE	TWA	- TIME WEIGHTED AVERAGE
STEL	- SHORT-TERM EXPOSURE LIMIT	TPQ	- THRESHOLD PLANNING QUANTITY
RQ	- REPORTABLE QUANTITY	PEL	- PERMISSIBLE EXPOSURE LIMIT
C	- CEILING LIMIT	CAS	- CHEMICAL ABSTRACT SERVICE NUMBER
A1-5	- APPENDIX A CATEGORIES	0	- CHANGE HAS BEEN PROPOSED
NDA	- NO DATA AVAILABLE	NA	- NOT APPLICABLE

Kerby Saunders

KERBY SAUNDERS
PRESIDENT

ISSUED: AUGUST 16, 2000
SUPERSEDES: MARCH 13, 2000

THE ABOVE INFORMATION IS BASED ON THE DATA OF WHICH WE ARE AWARE AND IS BELIEVED TO BE CORRECT AS OF THE DATE HEREOF. SINCE THIS INFORMATION MAY BE APPLIED UNDER CONDITIONS BEYOND OUR CONTROL AND WITH WHICH WE MAY BE UNFAMILIAR AND SINCE DATA MADE AVAILABLE SUBSEQUENT TO THE DATE HEREOF MAY SUGGEST MODIFICATION OF THE INFORMATION, WE DO NOT ASSUME ANY RESPONSIBILITY FOR THE RESULTS OF ITS USE. THIS INFORMATION IS FURNISHED UPON CONDITIONS THAT THE PERSON RECEIVING IT SHALL MAKE HIS OWN DETERMINATION OF THE SUITABILITY OF THE MATERIAL FOR HIS PARTICULAR PURPOSE.

-----MATERIAL SAFETY DATA SHEET-----

AURICAL COMPANY 383 BEACH ROAD BURLINGAME, CA 94010-2005
Factory Telephone: (650)-872-2800 fax: (650) 872-2227 Toll Free (800) 615-8870
Prepared: November 20, 1994. Revised: July 1, 2008.

This information is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability, or fitness for any particular use, or any other warranty, express or implied, with respect to this information, and we assume no liability resulting from the use of this information. Users should make their own investigations to determine the suitability of the information for their particular needs and purposes.

-----SUBSTANCE IDENTIFICATION-----

SUBSTANCE: ------Potassium Chloride Aqueous Solution, Dilute
Trade names/synonyms: This material is also known as Conductivity Standard, at all levels. Also known as Catalog Number 3-xxxx-x.
Cercla ratings (scale 0-3): health=0 fire=0 reactivity=0 persistence=0
Nfpa ratings (scale 0-4): health=0 fire=0 reactivity=0

-----COMPONENTS AND CONTAMINANTS---

Component: potassium chloride CAS# 7447-40-7 percent: <10.0
Component: water CAS# 7732-18-5 percent: 90+
Other contaminants: Antimicrobials and other additives less than 0.2% *Trade Secrets*.

Exposure limits: No occupational exposure limits established by osha, acgih or niosh.

-----PHYSICAL DATA-----

Description: clear, colorless liquid.
Approx. boiling point: 212°F (100°C). Approx. melting point: 32°F (0°C)
Vapor pressure: 14 torr @20°C Evap. Rate: (ether=1) >1
pH 4-8 Solubility in water: complete Vapor density: 0.7 (H_2O)

-----FIRE AND EXPLOSION DATA-----

Fire and explosion hazard: no fire hazard when exposed to heat or flame.
Flash point: not applicable

-----TOXICITY-----

potassium chloride:
Carcinogen status: none.
Local effects: irritant - skin, eye.
Acute toxicity level: no data available.
Target effects: no data available.

-----HEALTH EFFECTS AND FIRST AID-----

INHALATION: POTASSIUM CHLORIDE
ACUTE EXPOSURE - MAY CAUSE IRRITATION. CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE IRRITATION. FIRST AID - REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, PERFORM ARTIFICIAL RESPIRATION. KEEP PERSON WARM AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY. GET MEDICAL ATTENTION.

SKIN CONTACT: POTASSIUM CHLORIDE
ACUTE EXPOSURE - MAY CAUSE IRRITATION. CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE DERMATITIS. FIRST AID - REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY, WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES).

EYE CONTACT: POTASSIUM CHLORIDE .
ACUTE EXPOSURE-DIRECT CONTACT MAY CAUSE IRRITATION, REDNESS AND PAIN. CHRONIC EXPOSURE-REPEATED OR PROLONGED EXPOSURE MAY CAUSE CONJUNCTIVITIS FIRST AID - WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER OR NORMAL SALINE, OCCASIONALLY LIFTING UPPER AND LOWER LIDS UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION POTASSIUM CHLORIDE .
ACUTE EXPOSURE - MAY CAUSE NAUSEA, VOMITING AND DIARRHEA. CHRONIC EXPOSURE - NOT REPORTED TO OCCUR IN HUMANS FIRST AID - IF VICTIM IS CONSCIOUS, IMMEDIATELY GIVE 2-4 GLASSES OF WATER, AND INDUCE VOMITING BY TOUCHING FINGER TO BACK OF THROAT, GET MEDICAL ATTENTION IMMEDIATELY.

-----REACTIVITY-----

Reactivity: stable under normal temperatures and pressures.
Incompatibilities: none known. Decomposition: none known. Polymerization: none known.

-----STORAGE AND DISPOSAL-----

Observe all federal, state and local regulations when storing or disposing of this substance. For assistance, contact the district director of the environmental protection agency.
Storage conditions to avoid: store away from incompatible substances.
Water spills: The California safe drinking water and toxic enforcement act of 1986 (prop 65) prohibits contaminating any known source of drinking water with substances known to cause cancer and/or reproductive toxicity.

Occupational spill: Flush with water and mop up.

-----PROTECTIVE EQUIPMENT-----

Special equipment not needed. Due caution in handling any chemical solution is recommended.

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-----SUBSTANCE IDENTIFICATION-----

SUBSTANCE: ---pH 10.00 Calibrating Buffer---
trade names/synonyms: This material is also known by various catalog numbers.
Cercla ratings (scale 0-3): health=0 fire=0 reactivity=0 persistence=0
nfpa ratings (scale 0-4): health=0 fire=0 reactivity=0
SARA Title III (§ 313) Not Available.

-----COMPONENTS AND CONTAMINANTS---

Component: sodium carbonate CAS# 497-19-8 Percent:<2.0
Component: sodium bicarbonate CAS# 144-55-8 Percent:<2.0
Component: water CAS# 7732-18-5 Percent: >95
Other contaminants: none
Exposure limits: no occupational exposure limits established by osha, acgih or niosh.

-----PHYSICAL DATA-----

Description: clear, colorless liquid which may be color coded blue for user convenience.
Approx. boiling point: 212°F (100°C). Approx. melting point: 32°F (0°C)
Vapor pressure: 14torr @20°C Evap. Rate: (ether=1) >1
pH: 10.0 Solubility in water: complete Vapor density: 0.7 (H_2O)

-----FIRE AND EXPLOSION DATA-----

Fire and explosion hazard: negligible fire hazard when exposed to heat or flame.
Flash point: not applicable
Fire fighting media: dry chemical, carbon dioxide, water spray or regular foam. (1990 emergency response guidebook, dot p-5800.5) for larger fires, use water spray, fog or regular foam (1990 emergency response guidebook, dot p-5800.5)
Fire fighting: move container from fire area if it can be done without risk. Do not scatter spilled material with high-pressure water streams. Dike fire-control water for later disposal . (1990 emergency response guidebook, dot p-5800.5 Pg. 31) Use agents suitable for the type of surrounding fire. Avoid breathing hazardous vapors, stay upwind of the fire.

-----TOXICITY-----

potassium carbonate; potassium bicarbonate:
carcinogen status: none.
local effects: irritant - inhalation, skin, eye.
acute toxicity level: no data available.
target effects: no data available.
medical conditions agravated by exposure: no data available.

-----HEALTH EFFECTS AND FIRST AID-----

INHALATION:
POTASSIUM CARBONATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE IRRITATION.
CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE IRRITATION.
FIRST AID - REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, PERFORM ARTIFICIAL RESPIRATION. KEEP PERSON WARM AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
POTASSIUM CARBONATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE IRRITATION.
CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE DERMATITIS.
FIRST AID - REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY, WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
POTASSIUM CARBONATE: IRRITANT.
ACUTE EXPOSURE-DIRECT CONTACT MAY CAUSE IRRITATION, REDNESS AND PAIN.
CRONIC EXPOSURE-REPEATED OR PROLONGED EXPOSURE MAY CAUSE CONJUNCTIVITIS
FIRST AID - WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER OR NORMAL SALINE, OCCASIONALLY LIFTING UPPER AND LOWER LIDS UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION
POTASSIUM CARBONATE: IRRITANT.
ACUTE EXPOSURE - MAY CAUSE NAUSEA, VOMITING AND DIARRHEA.
CRONIC EXPOSURE - NOT REPORTED TO OCCUR IN HUMANS
FIRST AID - IF VICTIM IS CONSCIOUS, IMMEDIATELY GIVE 2-4 GLASSES OF WATER, AND INDUCE VOMITING BY TOUCHING FINGER TO BACK OF THROAT, GET MEDICAL ATTENTION IMMEDIATELY.

-----REACTIVITY-----

Reactivity: stable under normal temperatures and pressures.
Incompatibilities: May release carbon dioxide when exposed to acids or acidic materials.
Decomposition: thermal decomposition may release carbona dioxide gas.
Polymerization: hazardous polymerization has not been reported to occur under normal temperatures and pressures.

-----STORAGE AND DISPOSAL-----

Observe all federal, state and local regulations when storing or disposing of this substance. For assistance, contact the district director of the environmental protection agency.

Water spills: The California safe drinking water and toxic enforcement act of 1986 (prop 65) prohibits contaminating any known source of drinking water with substances known to cause cancer and/or reproductive toxicity.

Occupational spill: Stop leak if you can do it without risk. For small spills, take up with sand or other absorbent materials and place into clean, dry containers for later disposal. Keep unnecessary people away, isolate hazard area and deny entry.

-----PROTECTIVE EQUIPMENT-----

When using, wear eye protection to prevent contact.

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-----SUBSTANCE IDENTIFICATION-----

SUBSTANCE: ---pH 7.00 Calibrating Buffer---
Trade names/synonyms: This material is also known by various catalog numbers.
Cercla ratings (scale 0-3): health=0 fire=0 reactivity=0 persistence=0
Nfpa ratings (scale 0-4): health=0 fire=0 reactivity=0
SARA Title III (§ 313) Not Available.

-----COMPONENTS AND CONTAMINANTS---

Component: potassium phosphate, monobasic CAS# 7778-77-0 percent: <1.0
Component: sodium phosphate, dibasic CAS# 7558-79-4 percent: <0.2
Component: water CAS# 7732-18-5 percent: >98.
Other contaminants: none

Exposure limits:
No occupational exposure limits established by osha, acgih or niosh.

-----PHYSICAL DATA-----

Description: clear, colorless liquid which may be color coded for user convenience according to pH.
Approx. boiling point: 212°F (100°C). Approx. melting point: 32°F (0°C)
Vapor pressure: 14 torr @20°C Evap. Rate: (ether=1) >1
pH: 7.0 Solubility in water: complete Vapor density: 0.7 (H_2O)

-----FIRE AND EXPLOSION DATA-----

Fire and explosion hazard: negligible fire hazard when exposed to heat or flame.
Flash point: not applicable
A media: dry chemical, carbon dioxide, water spray or regular foam. (1990 emergency response guidebook, dot p-5800.5) For larger fires, use water spray, fog or regular foam. (1990 emergency response guidebook, dot p-5800.5)
A: Move container from fire area if it can be done without risk. Do not scatter spilled material with high-pressure water streams. Dike fire-control water for later disposal. (1990 emergency response guidebook, dot p-5800.5 Pg. 31) Use agents suitable for the type of surrounding fire. Avoid breathing hazardous vapors, stay upwind of the fire.

-----TOXICITY-----

potassium phosphate, monobasic; sodium phosphate, dibasic:
Carcinogen status: none.
Local effects: irritant - inhalation, skin, eye.
Acute toxicity level: no data available.
Target effects: no data available.
medical conditions agravated by exposure: no data available.

-----HEALTH EFFECTS AND FIRST AID-----

INHALATION:
SODIUM & POTASSIUM PHOSPHATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE IRRITATION.
CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE IRRITATION.
FIRST AID - REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, PERFORM ARTIFICIAL RESPIRATION. KEEP PERSON WARM AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
SODIUM & POTASSIUM PHOSPHATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE IRRITATION.
CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE DERMATITIS.
FIRST AID - REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY, WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
SODIUM & POTASSIUM PHOSPHATE:IRRITANT.
ACUTE EXPOSURE-DIRECT CONTACT MAY CAUSE IRRITATION, REDNESS AND PAIN.
CRONIC EXPOSURE-REPEATED OR PROLONGED EXPOSURE MAY CAUSE CONJUNCTIVITIS
FIRST AID - WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER OR NORMAL SALINE, OCCASIONALLY LIFTING UPPER AND LOWER LIDS UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION
SODIUM & POTASSIUM PHOSPHATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE NAUSEA, VOMITING AND DIARRHEA.
CRONIC EXPOSURE - NOT REPORTED TO OCCUR IN HUMANS
FIRST AID - IF VICTIM IS CONSCIOUS, IMMEDIATELY GIVE 2-4 GLASSES OF WATER, AND INDUCE VOMITING BY TOUCHING FINGER TO BACK OF THROAT, GET MEDICAL ATTENTION IMMEDIATELY.

-----REACTIVITY-----

Reactivity: stable under normal temperatures and pressures.
Incompatibilities: none known.
Decomposition: none known.
Polymerization: none known.

-----STORAGE AND DISPOSAL-----

Observe all federal, state and local regulations when storing or disposing of this substance. For assistance, contact the district director of the environmental protection agency.
Storage conditions to avoid: store away from incompatible substances.
Water spills: The California safe drinking water and toxic enforcement act of 1986 (prop 65) prohibits contaminating any known source of drinking water with substances known to cause cancer and/or reproductive toxicity.
Occupational spill: Stop leak if you can do it without risk. For small spills, take up with sand or other absorbent materials and place into clean, dry containers for later disposal.

-----PROTECTIVE EQUIPMENT-----

When using, wear eye protection to prevent contact.

----- MATERIAL SAFETY DATA SHEET -----

AURICAL COMPANY 383 BEACH ROAD BURLINGAME, CA 94010-2005
Factory Telephone: (650)-872-2800 fax: (650) 872-2227 Toll Free (800) 615-8870
Prepared: November 20, 1994. Revised: July 1, 2008.

This information is believed to be accurate and represents the best information currently available to us. however, we make no warranty of merchantability, or fitness for any particular use, or any other warranty, express or implied, with respect to this information, and we assume no liability resulting from the use of this information. Users should make their own investigations to determine the suitability of the information for their particular needs and purposes.

-----SUBSTANCE IDENTIFICATION-----

SUBSTANCE: pH 4.00 Calibrating Buffer
Trade names/synonyms: This material is also known by various catalog numbers.
Cercla ratings (scale 0-3): health=0 fire=0 reactivity=0 persistence=0
Nfpa ratings (scale 0-4): health=0 fire=0 reactivity=0
SARA Title III (§ 313) Not Available.

-----COMPONENTS AND CONTAMINANTS---

Component: potassium hydrogen phthalate CAS# 877-24-7 Percent: <2.0
Component: water CAS# 7732-18-5 percent: >98
Other contaminants: none

Exposure limits:
No occupational exposure limits established by osha, acgih or niosh.

-----PHYSICAL DATA-----

Description: clear, colorless liquid which may be color coded red for user identification.
Approx. boiling point: 212°F (100°C). Approx. melting point: 32°F (0°C)
Vapor pressure: 14 torr @20°C Evap. Rate: (ether=1) >1
pH: 4.0 Solubility in water: complete Vapor density: 0.7 (H_2O)

-----FIRE AND EXPLOSION DATA-----

Fire and explosion hazard: No fire hazard when exposed to heat or flame.
Flash point: not applicable
Fire fighting media: dry chemical, carbon dioxide, water spray or regular foam. (1990 emergency response guidebook, dot p-5800.5) For larger fires, use water spray, fog or regular foam. (1990 emergency response guidebook, dot p-5800.5)
Fire fighting: Move container from fire area if it can be done without risk. Do not scatter spilled material with high-pressure water streams. Dike fire-control water for later disposal . (1990 emergency response guidebook, dot p-5800.5 Pg. 31) Use agents suitable for the type of surrounding fire. Avoid breathing hazardous vapors, stay upwind of the fire.

-----TOXICITY-----

potassium hydrogen phthalate:
Carcinogen status: Possible carcinogen-not fully evaluated at this time.
Local effects: irritant - inhalation, skin, eye.
Acute toxicity level: no data available.
Target effects: possible estrogenic effect; no final data available.
medical conditions aggravated by exposure: no data available.

-----HEALTH EFFECTS AND FIRST AID-----

INHALATION:
POTASSIUM HYDROGEN PHTHALATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE IRRITATION.
CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE IRRITATION.
FIRST AID - REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, PERFORM ARTIFICIAL RESPIRATION. KEEP PERSON WARM AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
POTASSIUM HYDROGEN PHTHALATE:IRRITANT.
ACUTE EXPOSURE - MAY CAUSE IRRITATION.
CHRONIC EXPOSURE - REPEATED OR PROLONGED EXPOSURE MAY CAUSE DERMATITIS.
FIRST AID - REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY, WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
POTASSIUM HYDROGEN PHTHALATE: IRRITANT.
ACUTE EXPOSURE-DIRECT CONTACT MAY CAUSE IRRITATION, REDNESS AND PAIN.
CRONIC EXPOSURE-REPEATED OR PROLONGED EXPOSURE MAY CAUSE CONJUNCTIVITIS
FIRST AID - WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER OR NORMAL SALINE, OCCASIONALLY LIFTING UPPER AND LOWER LIDS UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION
POTASSIUM HYDROGEN PHTHALATE: IRRITANT.
ACUTE EXPOSURE - MAY CAUSE NAUSEA, VOMITING AND DIARRHEA.
CRONIC EXPOSURE - NOT REPORTED TO OCCUR IN HUMANS
FIRST AID - IF VICTIM IS CONSCIOUS, IMMEDIATELY GIVE 2-4 GLASSES OF WATER, AND INDUCE VOMITING BY TOUCHING FINGER TO BACK OF THROAT, GET MEDICAL ATTENTION IMMEDIATELY.

-----REACTIVITY-----

Reactivity: stable under normal temperatures and pressures.
Incompatibilities: AFFECTED BY STRONG OXIDIZERS WHEN DRY.
Decomposition: NONE KNOWN WHILE IN SOLUTION.
Polymerization: NONE KNOWN WHILE IN SOLUTION.

-----STORAGE AND DISPOSAL-----

Observe all federal, state and local regulations when storing or disposing of this substance. for assistance, contact the district director of the environmental protection agency.

-----PROTECTIVE EQUIPMENT-----

When using, wear eye protection to prevent contact.

16. OTHER INFORMATION

NFPA Hazard Ratings:

Health:	0
Flammability:	0
Reactivity:	0
Special Hazards:	None known.

The information contained herein is provided in good faith and is believed to be correct as of the date hereof. However, NCL of Wisconsin, Inc. makes no representation as to the comprehensiveness or accuracy of the information. It is expected that individuals receiving the information will exercise their independent judgement in determining its appropriateness for a particular purpose. Accordingly, NCL of Wisconsin, Inc. will not be responsible for damages of any kind resulting from the use of or reliance upon such information.

END OF MATERIAL SAFETY DATA SHEET

MATERIAL SAFETY DATA SHEET

NCL of Wisconsin, Inc.
P.O. Box 8
Birnamwood, WI 54414
Emergency Telephone No: 800-424-9300 (Chemtrec)

PRODUCT NAME: AMMONIA STANDARDS, 0.2 ppm - 1000 ppm

NCL CATALOG NUMBERS: Including, but not limited to:

A-37J:	Ammonia Standard, 0.2 ppm as N
A-37C:	Ammonia Standard, 1.0 ppm as N
A-37G:	Ammonia Standard, 2.0 ppm as N
A-37M:	Ammonia Standard, 3.0 ppm as N
A-37F:	Ammonia Standard, 5.0 ppm as N
A-37B:	Ammonia Standard, 10.0 ppm as N
A-37H:	Ammonia Standard, 20.0 ppm as N
A-37K:	Ammonia Standard, 30.0 ppm as N
A-37L:	Ammonia Standard, 50.0 ppm as N
A-37A:	Ammonia Standard, 100 ppm as N
A-37:	Ammonia Standard, 1000 ppm as N

Date of this revision: 10/16/2008

1. CHEMICAL PRODUCT IDENTIFICATION

Trade name: None.
Chemical Formula: Solutions of Ammonium Chloride in water.
Formula CAS No: Not applicable.
Molecular Weight: Not applicable.

2. COMPOSITION

Component	CAS#	Approx %
Water	7732-18-5	>99.5
Ammonium Chloride	12125-02-9	<0.5

3. HAZARD IDENTIFICATION

May be harmful if swallowed. Do not get in eyes, on skin or on clothing. Minimal contact, as with all chemicals, is a good policy to follow. Remove and wash contaminated clothing before re-use.
Routes of entry: Ingestion, inhalation.
Carcinogenicity: This material is not listed (IARC, NTP, OSHA) as a cancer causing agent.

4. FIRST AID MEASURES

Ingestion: If swallowed, wash out mouth with water provided person is conscious. Call a physician immediately.
Inhalation: Remove to fresh air. Give artificial respiration if breathing has stopped.
Eyes: Immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention.
Skin: Immediately flush skin with plenty of water. Get medical attention if irritation develops.

5. FIRE FIGHTING MEASURES

Flash Point: Not Applicable.
Flammable Limits (LEL): Not Applicable.
Flammable Limits (UEL): Not Applicable.
Fire: Wear self-contained breathing apparatus and protective clothing.
Fire Extinguishing Media: Use any suitable means for surrounding materials.
Explosion Hazards: Thermal decomposition produces toxic fumes.

6. ACCIDENTAL RELEASE MEASURES

Evacuate area of non-essential personnel. Eliminate ignition sources.
Scoop up material and transfer to a container for proper disposal.
Ensure compliance with Federal, State, and local regulations.

7. HANDLING AND STORAGE

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Avoid contact with eyes and skin.

8. EXPOSURE CONTROLS

Airborne Exposure Limits:
None established for product.
For 100% Ammonium Chloride (product contains <0.5%)
ACGIH Threshold Limit Value (TLV): 10 ppm (TWA); 20 mg/cu.m (STEL)
Ventilation System: Local ventilation is usually sufficient when handling this material.
Skin Protection: Rubber or neoprene gloves.
Eye Protection: Use chemical safety goggles. Contact lenses should not be worn when working with this material.
Maintain eye-wash fountain and quick-drench facilities in work area.

9. PHYSICAL CHEMICAL PROPERTIES

Appearance: Clear, colorless liquid.
Odor: None.
Solubility: Infinitely soluble in water.
Boiling Point: Essentially the same as water.
Melting Point: Essentially the same as water.
Specific Gravity: 1.0
Vapor Density (Air=1): Essentially the same as water.
Vapor Pressure (mm Hg): Essentially the same as water.
Evaporation Rate: Essentially the same as water.

10. STABILITY AND REACTIVITY

Stability: Stable under ordinary conditions of use and storage.
Hazardous Decomposition Products: When heated to decomposition, can emit toxic gases.
Hazardous Polymerization: This substance does not polymerize.
Incompatibilities: Extreme heat. Reaction with hydrogen cyanide can produce explosive nitrogen trichloride. Explosive reaction occurs with potassium chlorate or bromine trifluoride. Violent reaction occurs with bromine pentafluoride, NO3, and IF7.

11. TOXICOLOGICAL INFORMATION

No toxicity data for product.
For 100% Ammonium Chloride (product contains <0.5%):
orl-rat LD50: 1650 mg/kg
orl-dog LDLo: 600 mg/kg

12. ECOLOGICAL INFORMATION

None found.

13. DISPOSAL CONSIDERATIONS

EPA Waste Number: None.
Ensure compliance with Federal, State, and local regulations.

14. TRANSPORT INFORMATION

DOT Shipping Name: Not Regulated.
DOT Number: None.

15. REGULATORY INFORMATION

The CAS numbers of all components of this solution are listed on the TSCA Inventory.

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1 - PRODUCT IDENTIFICATION

PRODUCT NAME: ORP STANDARD 100milliVolt vs. Ag|AgCl
Trade names/synonyms: This material is also known as: ORP STANDARD - 100 mV.
PRECAUTIONARY LABELING

HEALTH - 1 SLIGHT
FLAMMABILITY - 0 NONE
REACTIVITY - 1 SLIGHT
CONTACT - 1 SLIGHT

HAZARD RATINGS ARE 0 TO 4 (0 = NO HAZARD; 4 = EXTREME HAZARD).
LABORATORY PROTECTIVE EQUIPMENT

GOGGLES & SHIELD; LAB COAT & APRON; PROPER GLOVES

PRECAUTIONARY LABEL STATEMENTS
DO NOT GET IN EYES, ON SKIN, ON CLOTHING. IN CASE OF SPILL NEUTRALIZE WITH SODA ASH OR LIME. FLUSH WITH PLENTY OF WATER.

2 - HAZARDOUS COMPONENTS - POTENTIALLY

COMPONENT	%	CAS NO.
Potassium Ferricyanide	< 1%	13746-66-2
Potassium Ferrocyanide	< 1%	14459-95-1

2A - NON-HAZARDOUS COMPONENTS - FOR INFORMATION ONLY

COMPONENT	%	CAS NO.
POTASSIUM CHLORIDE		
AS A SOLID	<1	7447-40-7
WATER	90+	7732-18-5

3 - PHYSICAL DATA

BOILING POINT: 100 C (212 F) VAPOR PRESSURE(MM HG): N/A
MELTING POINT: 0 C (32 F) VAPOR DENSITY(AIR=1): N/A
SPECIFIC GRAVITY: 1.+ EVAPORATION RATE: N/A
(H2O=1) (BUTYL ACETATE=1)
SOLUBILITY(H2O): APPRECIABLE (MORE THAN 10 %) % VOLATILES BY VOLUME: 0
APPEARANCE & ODOR: WATER WHITE SOLUTION.

4 - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (CLOSED CUP N/A NFPA 704M RATING: 3-0-2 W
FLAMMABLE LIMITS: UPPER - N/A % LOWER - N/A %
FIRE EXTINGUISHING MEDIA

USE DRY CHEMICAL OR CARBON DIOXIDE..

SPECIAL FIRE-FIGHTING PROCEDURES

FIREFIGHTERS SHOULD WEAR PROPER PROTECTIVE EQUIPMENT AND SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN POSITIVE PRESSURE MODE.

UNUSUAL FIRE & EXPLOSION HAZARDS -- NOT APPLICABLE

TOXIC GASES PRODUCED -- **HYDROGEN CYANIDE**

5 - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE (TLV/TWA): 1 MG/M3 (PPM) FOR INGREDIENTS
PERMISSIBLE EXPOSURE LIMIT (PEL): 1 MG/M3 (PPM) FOR INGREDIENTS
TOXICITY: LD50 (ORAL-RAT)(MG/KG) - 2140 FOR INGREDIENTS
CARCINOGENICITY: NTP: NO IARC: NO Z LIST: NO OSHA REG: NO
EFFECTS OF OVEREXPOSURE - CYANURIA
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE -- NONE IDENTIFIED
ROUTES OF ENTRY -- INHALATION, INGESTION, EYE CONTACT, SKIN CONTACT

EMERGENCY AND FIRST AID PROCEDURES

GET MEDICAL ATTENTION.
IF SWALLOWED, GIVE LARGE AMOUNTS OF WATER AND SODIUM BICARBONATE.
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES OR SKIN WITH PLENTY OF SOAP AND WATER FOR AT LEAST 15 MINUTES.

6 - REACTIVITY DATA

STABILITY: STABLE HAZARDOUS POLYMERIZATION: WILL NOT OCCUR
CONDITIONS TO AVOID: HEAT
INCOMPATIBLES: **ALL ACIDS.**
DECOMPOSITION PRODUCTS: **HYDROGEN CYANIDE**

7 - SPILL AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN THE EVENT OF A SPILL OR DISCHARGE
WEAR SELF-CONTAINED BREATHING APPARATUS AND FULL PROTECTIVE CLOTHING.
STOP LEAK IF YOU CAN DO SO WITHOUT RISK. DO NOT USE WATER.
NEUTRALIZE SPILL AND/OR WASHINGS WITH SODA ASH OR LIME.
WITH CLEAN SHOVEL, PLACE MATERIAL INTO CLEAN, DRY CONTAINER AND COVER.
MOVE CONTAINER(S) FROM SPILL AREA.

CALCIUM CARBONATE OR CALCIUM HYDROXIDE ARE SUGGESTED AS LOW Na+ ACID NEUTRALIZERS.
DISPOSAL PROCEDURE: DISPOSE IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL ENVIRONMENTAL REGULATIONS.
EPA HAZARDOUS WASTE NUMBER: NOT APPLICABLE

8 - PROTECTIVE EQUIPMENT

VENTILATION: USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLV REQUIREMENTS.
RESPIRATORY PROTECTION: NONE REQUIRED WHERE APPROPRIATE VENTILATION CONDITIONS EXIST. IF THE TLV IS EXCEEDED, A SELF-CONTAINED BREATHING APPARATUS IS ADVISED.
EYE/SKIN PROTECTION: SAFETY GOGGLES AND FACE SHIELD, UNIFORM, PROTECTIVE SUIT, RUBBER GLOVES ARE RECOMMENDED.

9 - STORAGE AND HANDLING PRECAUTIONS

KEEP CONTAINER TIGHTLY CLOSED AS FOR ANY GENERAL CHEMICAL STORAGE AREA.

10 - TRANSPORTATION DATA AND ADDITIONAL INFORMATION

DOMESTIC (D.O.T.)
PROPER SHIPPING NAME: CHEMICALS, N.O.S. (NON-REGULATED) INTERNATIONAL (I.M.O.)
PROPER SHIPPING NAME: CHEMICALS, N.O.S. (NON-REGULATED)
--END OF DOCUMENT--

DRAFT

REMEDIAL DESIGN PROJECT OPERATIONS PLAN
APPENDIX E

COMMUNITY RELATIONS SUPPORT PLAN

Industri-plex Operable Unit 2
(including Wells G&H Operable Unit 3) Superfund Site
Woburn, Massachusetts

Prepared by:

Haley & Aldrich, Inc.
465 Medford Street
Boston, Massachusetts 02129

March 2011

DRAFT

Disclaimer: This document is a DRAFT document prepared by the Settling Defendants under a government Consent Decree. This document has not undergone formal review by the EPA and MassDEP. The opinions, findings, and conclusions, expressed are those of the author and not those of the U.S. Environmental Protection Agency or the Massachusetts Department of Environmental Protection.

DRAFT

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LIST OF ACRONYMS

Acronym	Agency/Organization/Definition
ASC	Aberjona Study Coalition
CBCA	Cranberry Bog Conservation Area
CD	Consent Decree
CRSP	Community Relations Support Plan
EPA	United States Environmental Protection Agency
FSP	Field Sampling Plan
GSIP	Groundwater/Surface Water Investigation Plan
HASP	Site-specific Health & Safety Plan
HBHA	Halls Brook Holding Area
MassDEP	Massachusetts Department of Environmental Protection
OU	Operable Unit
OU1	Industri-plex Superfund Site Operable Unit No. 1
OU2	Industri-plex Superfund Site Operable Unit No. 2
PDIs	Pre-Design Investigations
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objectives
RD/RA	Remedial Design/Remedial Action
RDWP	Remedial Design Work Plan
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SMP	Site Management Plan
SOW	Statement of Work
SWMP	Surface Water Monitoring Plan
TAG	Technical Assistance Grant
VOCs	Volatile Organic Compounds

1.0 INTRODUCTION

Haley & Aldrich, Inc. has prepared this Community Relations Support Plan (CRSP) for the Industri-plex OU2 Superfund Site Operable Unit No. 2, Woburn, Massachusetts (hereinafter, Industri-plex OU2 or Site) on behalf of the companies that will be performing the work, Pharmacia Corporation by its Attorney-in-Fact Monsanto Company and Stauffer Management Company LLC as litigation agent for Bayer CropScience, Inc. (the Companies). This CRSP was prepared in accordance with the Consent Decree that was lodged on 27 February 2008 with the United States District Court for the District of Massachusetts in connection with Civil Action No. 1:08-cv-10325 (the CD), and with the Remedial Design/Remedial Action (RD/RA) Statement of Work (SOW) that is attached as Appendix D to the CD.

This CRSP is designed to support the United States Environmental Protection Agency's (EPA's) Community Relations Plan for the Site RD/RA. In the Superfund cleanup process, the RD is a detailed investigation and engineering analysis conducted where the technical specifications for the cleanup remedies and technologies are designed based on the requirements of the CD and SOW. The RA involves the implementation of the work described in the design.

EPA is the lead agency responsible for managing the removal and cleanup activities at the Industri-plex OU2 Superfund Site. EPA's New England Office, located in Boston, Massachusetts will oversee the RD/RA, and direct all community involvement activities for the Site.

The Companies have retained ***de maximis, inc.*** (de maximis) as their Supervising Contractor, responsible for directing and supervising the RD/RA work. Bruce R. Thompson of de maximis has been appointed as the Project Coordinator with responsibility for the administration of the RD/RA.

de maximis will support EPA's community involvement efforts throughout the RD/RA. de maximis is committed to promoting effective communication with all affected stakeholders.

1.1 CRSP Objectives

The Companies and de maximis are committed to effective community involvement and recognize the importance of fostering public understanding and trust throughout the RD technical investigation and engineering analyses. de maximis will coordinate with EPA on a regular and frequent basis, and will plan and implement appropriate technical and community involvement support as directed by EPA.

In order to assure regular and effective communication with the community, the objectives of this CRSP are:

- through openness, a demonstrated willingness to listen and respond to concerns, and overall outreach efforts will result in community understanding of and support for the project
- to develop and maintain a working relationship with local stakeholders
- to develop and maintain a working relationship with local citizen advisory groups
- produce documents and oral presentations in plain, jargon-free language

de maximis will support these objectives by providing, as directed by EPA:

- technical information in easy-to-understand language
- appropriate technical experts to discuss project issues at small group and public meetings
- fact sheets and newsletters for EPA review and distribution to the Industri-plex OU2 Superfund Site mailing list

1.2 CRSP Organization

Following this introductory section, the CRSP is organized as follows:

- Section 2 provides a summary of the Industri-plex OU2 Superfund Site and its history and current conditions
- Section 3 describes the communities potentially affected by cleanup of the Industri-plex OU2 Superfund Site
- Section 4 presents the community involvement support activities recommended by de maximis
- Attachment E1 – de maximis Project Coordinator/Point of Contact
- Attachment E2 – Local Officials
- Attachment E3 – Federal and State Elected Officials
- Attachment E4 – Environmental and Active Citizen Groups
- Attachment E5 – Media Contacts
- Attachment E6 – Proposed Meeting Locations and Information Repository Locations

2.0 SITE DESCRIPTION AND PROJECT ORGANIZATION

This section presents a description of the Site and its history, as well as the RD/RA project organization.

2.1 Site Setting

Situated in North Woburn, the Industri-plex OU2 Site is primarily contaminated with metals and buried animal hide wastes. From 1853 to 1931, the Industri-plex OU2 Superfund Site operated as chemical manufacturing facility, producing lead-arsenic insecticides, acetic acid, and sulfuric acid for local textile, leather, and paper manufacturing industries. Chemicals manufactured by other industries at the site include phenol, benzene, and toluene. In addition, a manufacturer of glue from raw animal hide and chrome-tanned hide wastes operated on the site from 1934 to 1969.

During redevelopment of Industri-plex OU2 in the 1970s, mixed industrial by-products and wastes produced during former chemical and glue manufacturing activities were exposed. Residues from animal hide wastes used in the manufacture of glue were moved from on-site buried pits to piles near swampy areas of the site.

As discussed below, a comprehensive remedy for these former manufacturing areas has been implemented as the "Industri-plex OU2 Superfund Site Operable Unit 1" (OU1) remedy for the Site. The successful implementation of the OU1 remedy resulted in the Anderson Regional Transportation Center.

The Wells G&H Superfund Site consists of approximately 330 acres situated in East Woburn, Massachusetts, approximately 1 mile downstream of the Industri-plex OU2 Superfund Site along the Aberjona River.

Figure 2.1-1 shows the locations of the Industri-plex OU2 and Wells G&H Superfund Sites.

2.2 Site Superfund History

In 1983, the EPA identified two Superfund sites along the Aberjona River in Woburn, Massachusetts: the Industri-plex OU2 and Wells G&H Superfund Sites. The Industri-plex OU2 Superfund Site consists of two distinct operable units (OUs), distinct study areas based on the nature of contamination present, and the Well G&H Superfund Site consists of three OUs.

In 1986, a Record of Decision (ROD) was issued by EPA for the Industri-plex Superfund Site, defining Industri-plex OU1 as 245 acres located near the intersection of Commerce Way and Atlantic Avenue in Woburn, also referred to as the Northern Study Area. The OU1 remedy included the following major elements: 1) Design and construct permeable caps over approximately 105 acres of soils and sediments contaminated with lead, arsenic, and chromium. This portion of the remedy serves to prevent physical contact with the contaminated soils and sediments, including the West, East-Central and South Hide Piles; 2) Design and construct an impermeable cap over the approximately 5 acres of East Hide Pile, and a gas collection and treatment system. This portion of the remedy serves to prevent the infiltration of water through the hide pile, and prevent the release of hydrogen sulfide gas into the atmosphere; 3) Conduct a Groundwater and Surface Water Investigation Plan (GSIP) to evaluate the degree of groundwater and surface water contamination from the OU1 Site; and 4) Design and implement Institutional Controls for the site which will restrict future land use. The purpose of the Institutional

Controls is to preserve the effectiveness of the remedy, so that human health and the environment remains protected, and allow each property owner the fullest possible use of their property.

The Companies began designing the cleanup remedies in 1989. Design of the site permeable and impermeable cap was finalized in 1992. Construction of the permeable and impermeable cap began in 1993. Currently, the impermeable cap, gas collection and treatment system, and the permeable cap are complete. In the early 1990's, the Companies conducted two phases of the GSIP. Between 1999 and 2004, the Companies implemented an EPA approved comprehensive third/ Final GSIP investigation (see below).

The Wells G&H Superfund Site was placed on the EPA's National Priorities List in September 1983. The Wells G&H Superfund Site is primarily contaminated with volatile organic compounds (VOCs) for which the Companies have no responsibility. In 1989, the EPA issued a Record of Decision (ROD) for the Wells G&H Superfund Site Operable Unit No. 1 (Wells G&H OU1) specifying a groundwater cleanup remedy for five source area properties contributing to VOC groundwater contamination. The 1989 ROD, in conjunction with the 1991 Explanation of Significant Differences and CD, designated two other operable units within the Wells G&H Superfund Site: the second operable unit, Wells G&H Superfund Site Operable Unit No. 2 (Wells G&H OU2), the Central Area Aquifer Study, for the investigation of groundwater not included within Wells G&H OU1; and a third operable unit, Wells G&H Superfund Site Operable Unit No. 3 (Wells G&H OU3), referred to as the Aberjona River Study Area or Southern Study Area, for investigation of surface water and sediment contamination along the Aberjona River and its associated wetlands.

As a result of the similar sediment contamination at the Industri-plex OU1 and Wells G&H OU3, these areas were merged into a single OU, Industri-plex OU2, establishing one comprehensive cleanup plan for the Aberjona River and associated wetlands. Hereinafter, this area of concern will be referred to as the "Site" or "Industri-plex OU2." The location of Industri-plex OU2 is shown on Figure 2.2-1.

Industri-plex OU2 consists of a portion of the Aberjona River system from Industri-plex OU1 at Commerce Way and Atlantic Avenue in Woburn, south through the Wells G & H Superfund Site, to the Mystic Lakes where the river discharges, passing through the towns of Woburn and Winchester, and discharging in Medford and Arlington. The EPA issued the final Remedial Investigation/Feasibility Study (RI/FS) for the Industri-plex OU2 Site in June 2005, focusing on the investigation of groundwater, surface water, sediment, and soil contamination within the Site.

The EPA issued a ROD for Industri-plex OU2 in January 2006. The selected remedy for OU2 is an approach that utilizes source control, exposure control or prevention, and management of migration components to address the risks identified by EPA. The work proposed for OU2 serves as the final remedy for the Industri-plex Superfund Site (OU1 and OU2), and Wells G&H OU3.

Additional information on the site history, property ownership, usage, etc. is provided in the 2006 ROD, and Administrative Record for Industri-plex OU2.

2.3 Project Organization

The Companies are responsible for the design, construction, and maintenance of the selected remedy outlined in the RD/RA CD and SOW. As mentioned previously, the Companies have designated de maximis as their Supervising Contractor, and Bruce R. Thompson of de maximis as the Project Coordinator with responsibility for the administration of all actions called for in the 2008 CD. The Companies have retained Haley & Aldrich, Inc. (Haley & Aldrich), Geosyntec Consultants, Inc. (Geosyntec), and Roux Associates, Inc. (Roux) to conduct the RD. Haley & Aldrich has prepared the Remedial Design Work Plan (RDWP) with input from de maximis, Geosyntec, and Roux. During the

RD process, Roux will perform the surface water monitoring, while Geosyntec will focus on the technical, hydrogeological, and geochemical aspects of the RD.

The following table provides a summary of the Technical Team acting on behalf of the Companies, and their responsibilities.

TABLE 2.3-1
RD TECHNICAL TEAM AND RESPONSIBILITIES

de maximis, inc. Supervising Contractor Bruce Thompson Project Coordinator Responsible for managing all activities required by the CD Statement of Work	
Haley & Aldrich, Inc.	Responsible for preparing and implementing a comprehensive RDWP
Geosyntec Consultants, Inc.	Responsible for peer review with focus on surface water flow modeling
Roux Associates, Inc.	Responsible for preparing and implementing the Surface Water Monitoring Plan (SWMP)

2.4 Project Objectives

The primary objective of the RD phase is to assess Site conditions in relation to the remedy components. The remedy components have been selected to achieve the response action objectives (RAOs) and Performance Standards for the Site, as established in the RD/RA CD and SOW. The results of
Pre-Design Investigations will support the engineering of technical specifications for cleanup remedies and technologies. The final plan for RD will be implemented under the Remedial Action (RA) phase of the Superfund cleanup program.

- The RAOs, Performance Standards, and scope of the remedy are detailed in the ROD and SOW, and are discussed in the RDWP.

2.5 RD Organization

Sixteen (16) discrete Pre-Design Investigations (PDIs) are described in the RDWP. Individual work plans for each PDI are presented in the Field Sampling Plan (FSP). The results of the PDIs will guide the RD. The 16 PDIs are:

- PDI-1: HBHA Pond Sediment Dredging
- PDI-2: Wells G&H and CBCA Wetlands Sediment Dredging/Excavation
- PDI-3: Groundwater Investigation
  - PDI-3A: Groundwater Discharge Evaluation to HBHA Pond
  - PDI-3B: Sitewide Groundwater Plume Investigation
- PDI-4: HBHA Pond COC Transformation Processes & Studies
  - PDI-4A: Estimating Residence Times
  - PDI-4B: COC Transformation Processes
  - PDI-4C: Surface Water Profiling
- PDI-5: Tank Treatability Studies
- PDI-6: Geotechnical Investigations
  - PDI-6A: HBHA-4 Cofferdam and Storm Flow Bypass
  - PDI-6B: Halls Brook Storm Bypass/Holding & Dissipation Systems
  - PDI-6C: Atlantic Avenue Drainway and BECO Drainway Storm Energy Dissipation Systems
- PDI-7: HBHA Flood-routing Modeling Analysis
- PDI-8: HBHA Pond Hydrodynamic Modeling
- PDI-9: West Hide Pile Investigations and Assessment
  - PDI-9A: WHP & EHP Investigations and Assessment
  - PDI-9B: WHP Enhanced Bioremediation Studies
  - PDI-9C: Additional Actions to Address Unacceptable Risk(s)
- PDI-10: Impermeable Cap
- PDI-11: Permeable Caps
- PDI-12: Soil & Groundwater Institutional Controls
  - PDI-12A: Soil IC Delineation
  - PDI-12B: Groundwater IC Delineation
  - PDI-12C: Remedy Monitoring, Protection and Permanent Access
  - PDI-12D: IC Studies
- PDI-13: Studies to Locate Property for Wetland Mitigation
- PDI-14: Ammonia Background Investigation
- PDI-15: HBHA Pond Aeration Pilot Test
- PDI-16: Cofferdam Simulation Pilot Test

The RDWP is comprised of interrelated plans that will guide the completion of the RD investigation.

The first plan is the RDWP. The RDWP provides an overview of the Site and how the RD process will be implemented. It presents a summary of the physical setting, operation history, structures and features, and previous site investigations. The RDWP provides context for the proposed PDIs, describing how data collected during the PDI will support the RD. The RDWP presents the RD approach, including the technology approach, design conditions, remedy plans for sediment removal, excavation, dewatering, and surface treatment, the air monitoring and citizen participation plans, design methodology, and long-term monitoring and maintenance requirements. Finally, the RDWP includes a detailed description of the roles and responsibilities of project participants, and a project schedule showing the expected duration of each major phase of the project and the steps in the process.

Specific plans that identify the scope of investigative work to be performed and establish procedures to guide work tasks and community and agency liaison activities are provided as appendices to the RDWP. These plans are as follows:

- **Appendix A: Site Management Plan (SMP)**
  The SMP provides a written understanding and commitment of how various property aspects will be managed, such as access, security, contingency procedures, management responsibilities, field activity schedule, air monitoring, investigation-derived waste disposal, and data handling.

- **Sampling and Analysis Plan (SAP)**
  The SAP ensures that sampling and data collection activities will be comparable to and compatible with previous EPA and MassDEP data collection activities while providing a mechanism for planning and approving field activities. The SAP is comprised of two documents, a Quality Assurance Project Plan (QAPP) and a Field Sampling Plan (FSP).

- **Appendix B: Quality Assurance Project Plan (QAPP)**
  The QAPP documents the site-specific objectives, policies, organizations, functional `activities, sampling and analysis activities, and specific quality assurance/quality control activities designed to achieve the data quality objectives of the RD. The QAPP provides the sampling, analytical, and data validation procedures, as well as quality assurance and quality control requirements in accordance with EPA requirements and guidance.

- **Appendix C: Field Sampling Plan (FSP)**
  The FSP describes the sampling and analysis activities for each PDI.

- **Appendix D: Site-Specific Health and Safety Plan (HASP)**
  The HASP presents the health and safety measures to be implemented during the Site work, including hazard assessments of project tasks, protective measures to be taken, and contingency planning.

- **Appendix E: Community Relations Support Plan (CRSP)**
  The CRSP provides a written understanding and commitment of how the Companies will support the EPA's Community Involvement Program at the Site.

- **Surface Water Monitoring Plan (SWMP)**
  The SWMP describes monitoring of surface water stage, flow, and water quality along the Aberjona River between HBHA and the Mystic Lakes, including the Wells G&H Wetlands and the Cranberry Bog Conservation Area (CBCA). The SWMP was prepared and submitted by Roux Associates under separate cover.

3.0 COMMUNITY STAKEHOLDERS BACKGROUND

The Industri-plex Superfund Site is located in North Woburn, Massachusetts. The Aberjona River flows from its headwaters in Reading through Woburn and Winchester before discharging to the Mystic Lakes located in Medford and Arlington. The Aberjona River flows adjacent to the Industri-plex OU2 Superfund Site, becoming channelized along Commerce Way prior to merging with flow from the Halls Brook Holding Area at Mishawum Road in North Woburn. The Aberjona River Watershed also encompasses the surrounding communities of Wilmington, Reading, and Stoneham, as shown on Figure 3-1. The Aberjona Study Coalition (ASC), an environmental group actively participating in the Superfund process, represents the communities through which the Aberjona River flows. For this reason, it is included in this section as a key community stakeholder.

Below is a brief description of each town through which the Aberjona River flows, from the Industri-plex OU2 Superfund Site area downstream to the Mystic Lakes.

3.1 Woburn Community Profile

Woburn, a small city located approximately 10 miles northwest of Boston, occupies 13 square miles and has a population of approximately 37,000 people. The city was first settled in 1640, and at one time encompassed the towns of Wilmington, Burlington, and Winchester; these communities broke off into separate townships in 1730, 1799, and 1850 respectively. Today, Woburn is bordered by Wilmington to the north, Stoneham and Reading to the east, Winchester to the south, and Burlington and Lexington to the west.

Woburn's city government consists of a City Council and Mayor. The city is divided into seven wards, and each ward is represented by a Ward Alderman elected by the residents of the ward. There are also two Aldermen at Large elected by the residents of the entire city. There are nine members of the City Council, each serving a two-year term. The City Council has appointed more than 35 permanent and ad hoc boards and committees to assist with the City's services and businesses. The Woburn Redevelopment Authority was awarded a grant by the EPA to develop a Land Use Plan for Wells G&H Superfund Site. The activities proposed in the Land Use Plan will complement and build upon the ongoing environmental mitigation efforts of both the EPA and the private sector. (http://cityofwoburn.com)

3.2 Winchester Community Profile

Winchester, a town located approximately 8 miles north of Boston, occupies 6 square miles and has a population of approximately 20,500 people. Winchester was first settled in the 1640s, during which time the area was known as Waterfield, in reference to its many ponds and rivers, including the Aberjona River. Through the mid-1800s, Winchester included parts of what are today Medford, Cambridge, and Woburn. The town of Winchester was officially incorporated in 1850. Today, Winchester is bordered by Woburn to the north, Stoneham to the east, Medford and Arlington to the south, and Lexington to the west.

Winchester's town government consists of a Board of Selectmen, Town Manager, and Town Meeting. The five-member Board of Selectmen is elected at large and responsible for governing the town. The Town Manager is appointed by the Board of Selectmen to administer the daily operations of the town government. The Town Meeting is made up of 192 representatives, elected from each of the eight precincts. The Board of Selectmen has appointed more than 40 permanent and ad hoc boards and commissions to assist with town management. (www.winchester.us)

3.3 Medford Community Profile

The city of Medford, located on the Mystic River, is located less than five miles north of Boston. The city of 8.6 square miles has a population of approximately 55,800 residents. Medford was first settled in 1630, and was established as a city in 1892. The city was a center of industry through the 1800s and mid-1900s for the manufacture of brick, rum, and clipper ships. Medford is bordered by Stoneham to the north, Malden to the east, Somerville to the south, Arlington to the west, and Winchester to the northwest.

Medford's city government consists of a Mayor and seven-member City Council. The city has appointed more than 25 permanent and ad hoc boards and committees to assist with city management. (www.medford.org)

3.4 Arlington Community Profile

The town of Arlington is located six miles northwest of Boston. The town of approximately 5.5 square miles has a population of 42,000 residents. The town was first settled in 1635 as a village within the boundaries of Cambridge. In 1807, the town of Arlington and what is now Belmont were separated from Cambridge and incorporated as West Cambridge. In 1867, the town name was changed to Arlington to honor those buried at Arlington National Cemetery. Arlington was an industrial and agricultural town through the 1800s and early 1900s, with a number of mills, gardens, greenhouses, and a large ice industry. At one time, Arlington included what are now the town of Belmont, as well as areas of Charlestown and West Cambridge. Today, Arlington is bordered to the north by Winchester, by Medford to the northeast, Somerville to the east, Cambridge to the southeast, Belmont to the south, and Lexington to the west.

The town of Arlington is governed by a five-member Board of Selectmen, elected at large. A Town Manager is appointed by the Board of Selectmen to manage the daily operations of the government. The Town Meeting is made up of 252 representatives, elected from each of the 21 precincts. The Board of Selectmen has appointed over 40 permanent and ad hoc boards and commissions to assist with the management of the town. (www.town.arlington.ma.us)

3.5 Aberjona Study Coalition

Aberjona Study Coalition (ASC) is a volunteer citizen's environmental group that operates on behalf of the residents of the communities it represents, educating the community and providing a unified voice when interacting with government agencies. ASC represents the communities within the Aberjona watershed, including Wilmington, Woburn, Winchester, Reading, Stoneham, Medford, and Arlington. Represented on the ASC Board of Directors are the Woburn Neighborhood Association, Inc., Woburn Residents Environmental Network, and Concerned Citizens Network, Friends of the Upper Mystic Lake, Mystic River Watershed Association, and the Medford Boat Club. The stated primary function of ASC is to assure that investigation and remediation of the Site is completed in accordance with the ROD and CD with effective well-informed input from the affected residents, businesses, and community organizations, with the overarching goal of improving the water and sediment quality of the Aberjona River, Upper and Lower Mystic Lakes, and the downstream Mystic River.

ASC received an EPA Technical Assistance Grant (TAG) in June 2006, enabling them to work with independent technical consultants to interpret and help the community understand technical information about the Site and its impacts on the community. The EPA provided an additional TAG to the ASC in March 2008.

4.0 COMMUNITY INVOLVEMENT SUPPORT ACTIVITIES

In accordance with the 2008 CD, EPA will perform a number of community involvement activities. The Companies will take an active role in supporting the EPA in these efforts by implementing this CRSP.

The overarching goal of the community involvement activities is to promote two-way communication between the citizens of Woburn, Winchester, Medford, Arlington, and surrounding communities, and the EPA, as well as to encourage community involvement in Site activities. By using the community involvement support activities outlined in this plan, EPA will ensure that the public is kept informed about Site activities and progress, and provide opportunities for the community's involvement in the Superfund cleanup program.

As directed by EPA, de maximis will coordinate technical and procedural communication among the government agencies, local officials and leaders, and environmental groups involved in the cleanup. When requested by EPA, de maximis will provide the appropriate technical specialists to meet and discuss project information with community residents, officials, and citizen advisory groups, and will always strive to provide timely, factual, and easy-to-understand information in all communications with the public.

This plan establishes three primary areas as the focus for community relations:

- develop and maintain a working relationship with local and state leaders
- develop and maintain a working relationship with local citizen advisory groups
- produce documents and oral presentations in plain and jargon-free language

Upon request from EPA, de maximis and appropriate members of the project team will meet with community groups on an as-needed basis to discuss Site progress.

To support the EPA in maintaining a working relationship with local and state leaders and citizen advisory groups, de maximis will support the flow of project information to appropriate parties by providing timely and accurate project information to the EPA. de maximis and the project team will produce public documents and oral presentations in plain, jargon-free language. Upon request from the EPA, de maximis will prepare draft articles for newsletters and technical summaries for fact sheets. All draft material will be sent to EPA for review and approval. Documents developed to inform the public about Site activities will be written with a minimum of scientific terminology and acronyms, so an audience without technical training will find the material easy to understand. Technical specialists making presentations at meetings will strive to prepare material in a similar manner. Presentations will be clear, concise, and geared to a non-technical audience.

This CRSP is based on past project-related public comment, and addresses issues raised in comments as being important to the community. de maximis is aware that community issues and concerns will change over time. However, the activities listed below provide a strong foundation for the de maximis' plan for community relations and involvement, and will be used to address new issues or concerns that arise during the RD. Community involvement activities are labeled as either "required" by the EPA or CD, or "recommended" as a tool that de maximis believes will help further the EPA goals for community relations.

4.1 Provide Point of Contact (Recommended)

de maximis will support EPA by establishing one central point of contact for the team. The Site Point of Contact is the individual that citizens can contact to get the latest information. Citizens can request the latest information when they want it, rather than having to wait for a meeting or a fact sheet. This provides an opportunity for individuals who do not have access to the Internet to get up-to-date information.

The Point of Contact for all Site information is:

Mr. Bruce Thompson
de maximis, inc.
200 Day Hill Road, Suite 200
Windsor, CT 06095
Tel. 860.298.0541
brucet@demaximis.com

Mr. Thompson will provide prompt, accurate, and consistent responses to community inquiries and will coordinate these efforts through EPA.

Mr. Thompson will work with the Woburn, Winchester, Medford, Arlington, and surrounding communities, the ASC, EPA's Remedial Project Manager, and EPA's Community Involvement Coordinator to address community issues and plan appropriate community involvement activities throughout the RD/RA as required. The following table lists the EPA Region 1 and MassDEP representatives that are Points of Contact for information regarding the cleanup activities at the Site.

TABLE 4.1-1
RD EPA REGIONAL CONTACTS

Joseph LeMay	EPA Remedial Project Manager	5 Post Office Square Suite 100 Mail Code: OSSR07-4 Boston, MA 02109-3912 Tel: 617.918.1440	617.918.1323	LeMay.Joe@epa.gov
Doug Gutro	EPA Community Involvement Coordinator	5 Post Office Square Suite 100 Mail Code: OSSR07-4 Boston, MA 02109-3912 Tel: 617.918.1440	617.918.1021	Gutro.Doug@epa.gov
Jennifer McWeeney	MassDEP Project Manager	One Winter Street Boston, MA 02108	617.654.6560	Jennifer.McWeeney@state.ma.us

4.2 Maintain a Complete and Accurate Mailing List (Required)

de maximis will assist EPA in maintaining a complete and accurate mailing list for the Site. The objective of the mailing list is to facilitate the distribution of Site information to all interested parties who need or want to be kept informed about Site activities. de maximis will support EPA by soliciting interested parties that wish to be added to the list via meeting attendance records, communication records, fact sheets, newspaper articles, website/email communications, and community meetings and

providing EPA with additions and/or deletions to the mailing list so revisions can be made on a regular basis.

4.3 Maintain an Information Repository and Administrative Record (Required)

de maximis will assist EPA in maintaining the local Information Repository and Administrative Record for the Site. Site information will continue to be maintained at the Woburn Public Library located at 45 Pleasant Street in Woburn.

de maximis will provide EPA with the additional copies of reports and Site-related documents for timely placement in the Information Repository and Administrative Record. In addition, electronic copies of reports and other Site-related documents will be available on the EPA website.

4.4 Prepare and Distribute Information Fact Sheets (Recommended)

de maximis will assist EPA in preparing and distributing fact sheets and technical summaries providing citizens with current, accurate, easy-to-read, easy-to-understand information about the Site and related investigations. de maximis will assist in preparing draft fact sheets for EPA's review. Copies of all fact sheets and technical summaries will be available at the Woburn Public Library, and the project website. de maximis, in consultation with EPA and the community, will decide on appropriate topics as the RD proceeds. Topics may include some of the following:

- What to expect during the RD/RA Process
- Schedule for the RD/RA Process
- Technology Facts/Descriptions

de maximis will assist EPA in preparing and distributing fact sheets throughout the project.

4.5 Community Relations Plan

EPA will develop a revised Community Relations Plan (CRP) to describe public information and public involvement activities anticipated during the RD/RA.

4.6 Include Community Representative at Key Technical Meetings (Recommended)

ASC, a major project stakeholder representing all the communities located within the Aberjona River watershed, has expressed interest in attending key technical meeting between EPA and de maximis as a non-participating observer.

4.7 Press Releases and Public Notices (Required)

de maximis will assist EPA in preparing press releases and public notices to be placed in the local newspaper and on the project website. These press releases and public notices will be developed to inform the public of significant events involving the Site including meeting announcements, availability of documents for review, or other significant events. de maximis will support EPA in providing the press releases and public notices to the selected newspapers, as required by EPA. Appendix F provides a list of area newspapers and radio stations.

4.8 Hold Public Meetings (Required)

de maximis will assist EPA in holding public meetings periodically throughout the RD process. The purpose of public meetings is to update the community on significant site developments and to address community questions, concerns, ideas and comments. de maximis will provide the appropriate specialists to prepare for, attend, and make presentations at the public meetings. Meetings to discuss the results of the RD fieldwork, the final RD, and prior to implementing the RA are expected.

4.9 Projected Schedule for Community Involvement Activities

The following table outlines a schedule for community involvement activities. This schedule is subject to change based on EPA or community needs.

TABLE 4.10-1
SCHEDULE FOR COMMUNITY INVOLVEMENT ACTIVITIES

Activity	Schedule
Provide point of contact	Established
Maintain a complete and accurate mailing list	Ongoing, throughout RD
Maintain an information repository and administrative record	Ongoing, throughout RD
Prepare and issue public notices and press releases	As needed
Hold public meetings	As needed, and during public comment periods

REFERENCES

1. http://cityofwoburn.com, City of Woburn website.

2. http://www.medford.org/Pages/indx, City of Medford website.

3. http://www.town.arlington.ma.us, Town of Arlington website.

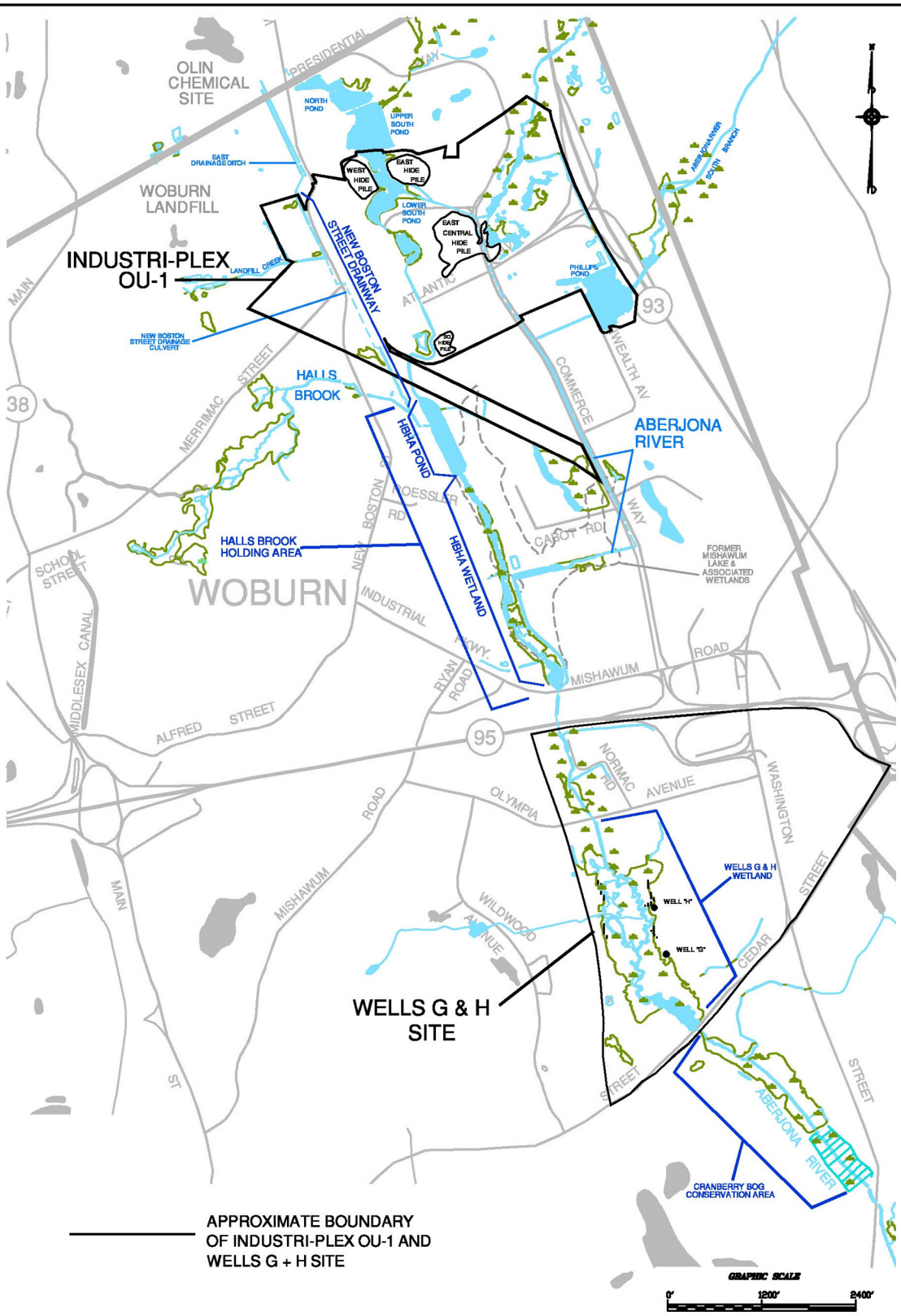
4. United States Census Bureau, "Census 2000 Data for the State of Massachusetts, Town of Arlington; City of Medford; Town of Winchester; City of Woburn," 2000.

5. United States District Court for the District of Massachusetts Eastern Division, "Consent Decree: United States of America v. Bayer CropScience Inc. and Pharmacia Corporation," February 2008.

6. United States Environmental Protection Agency, "Fact Sheet for EPA New England Superfund Site Industri-plex," http://www.epa.gov/region1/superfund/sites/Industri-plex, 28 February 2008.

7. United States Environmental Protection Agency, "Record of Decision, Industri-plex Superfund Site Operable Unit-2 (and Including Wells G&H Superfund Site Operable Unit-3 Aberjona River Study)," January 2006.

8. www.winchester.us, Town of Winchester website.



Note:

1. FIGURE ADAPTED FROM UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, "RECORD OF DECISION, INDUSTRI-PLEX SUPERFUND SITE OPERABLE UNIT-2", JANUARY 2006, FIGURE A-1

HALEY & ALDRICH

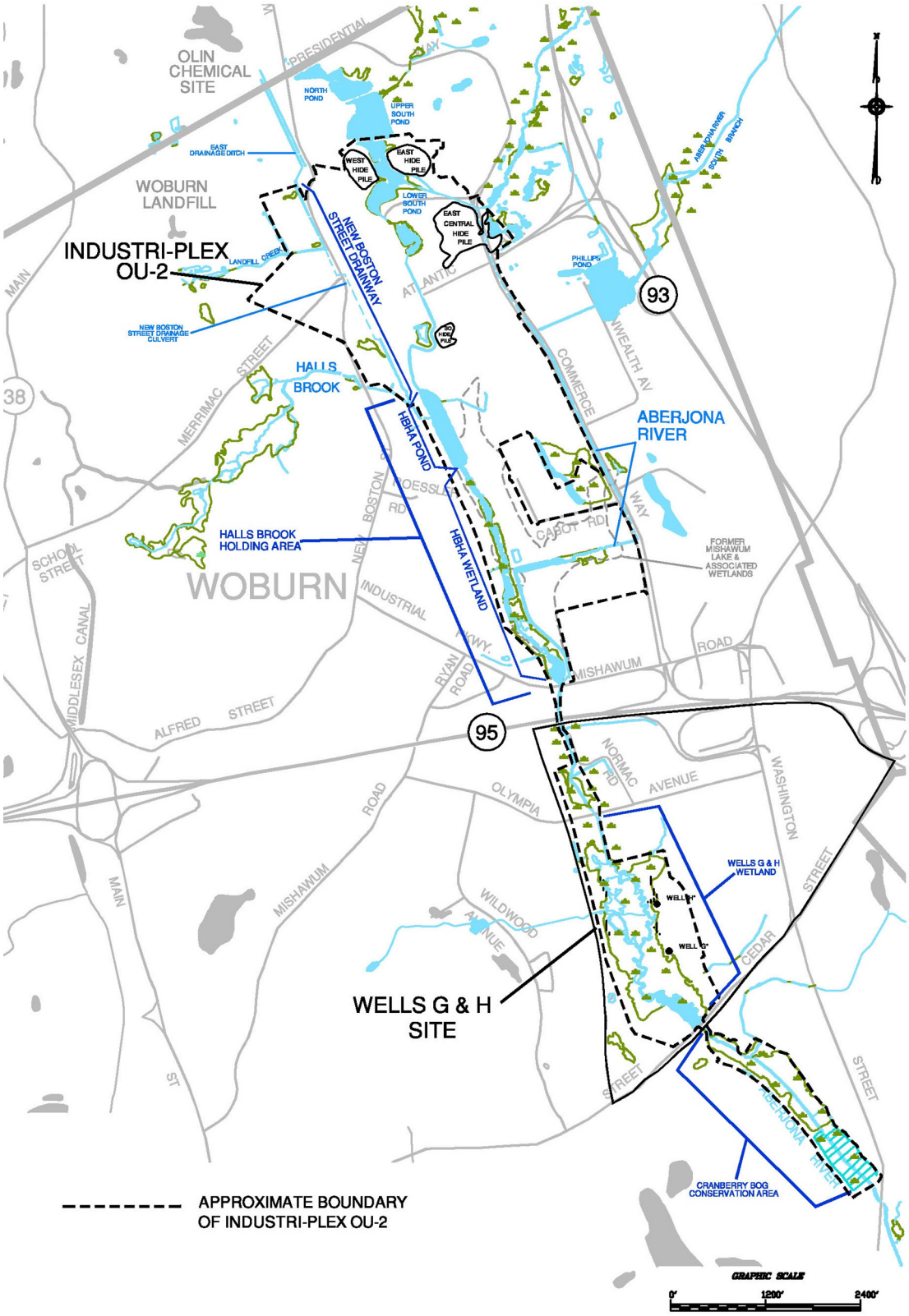
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

INDUSTRI-PLEX AND WELLS G&H SUPERFUND SITES LOCATIONS

SCALE: NONE
MARCH 2011

FIGURE 2.1-1

\\bos\common\33020\030\CRSP\Revised per EPA_Feb 2010\Figures\Figure 2.1-1 2010-0205-HAI-OU1SITEPLAN-F.vsd



Note:

1. FIGURE ADAPTED FROM UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, "RECORD OF DECISION, INDUSTRI-PLEX SUPERFUND SITE OPERABLE UNIT-2", JANUARY 2006, FIGURE A-3

HALEY & ALDRICH

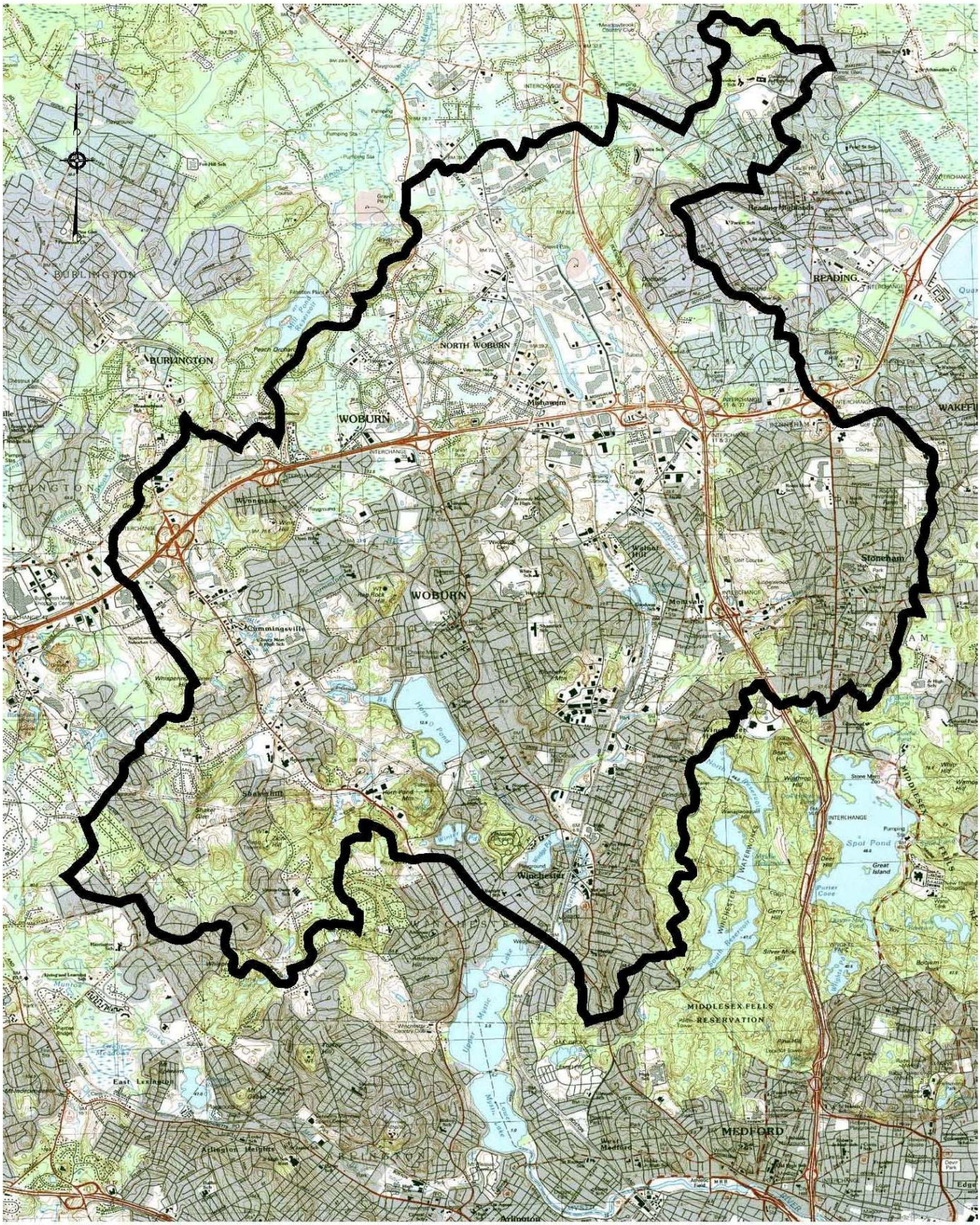
REMEDIAL DESIGN
INDUSTRI-PLEX SITE OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

INDUSTRI-PLEX OPERABLE UNIT-2 SITE LOCATION

SCALE: NONE
MARCH 2011

FIGURE 2.2-1

\\bos\common\33020\030\CRSP\Revised per EPA_Feb 2010\Figures\Figure 2.2-1 2010-0205-HAI-OU2SITEPLAN-F.vsd



NOTE:

1. FIGURE ADAPTED FROM TETRA TECH NUS, INC, "INDUSTRI-PLEX SUPERFUND SITE - SOUTHERN AREA MSGRP STUDY", 30 APRIL 2003, FIGURE 2-1 (ABERJONA RIVER WATERSHED)
2. USGS MAPPING (GEO-TIFFs) FROM MASSACHUSETTS GIS, NAD 83, IN METERS (OBTAINED 9/02)
3. LOCATION OF THE OUTLINE OF ABERJONA WATERSHED ADAPTED FROM AURILIO, ANNA, C., ET AL., "SOURCES OF DISTRIBUTION OF ARSENIC IN THE ABERJONA WATERSHED", NOVEMBER 1994, FIGURE 1 (LOCATION OF ABERJONA WATERSHED)

HALEY & ALDRICH

INDUSTRI-PLEX OPERABLE UNIT-2 SUPERFUND SITE
WOBURN, MASSCHUSETTS

ABERJONA RIVER WATERSHED

SCALE: 1:60.000
MARCH 2011

FIGURE 3-1

\\bos\common\33020\030\CRSP\Revised per EPA_Feb 2010\Figures\2010-0205-HAI-Figure3-F.xls

DRAFT

ATTACHMENT E1

de maximis Project Coordinator/Point of Contact

DRAFT

de maximis Project Coordinator/Point of Contact

Bruce Thompson
de maximis, inc.
200 Day Hill Road, Suite 200
Windsor, CT 06095
Tel: 860.298.0541
brucet@demaximis.com

ATTACHMENT E2

Local Officials

DRAFT

Local Officials

1. City of Woburn

City Mayor
Scott Galvin
City Hall
10 Common Street
Woburn, MA 01801
Tel: 781.897.5901
mayor@cityofwoburn.com

City Council
10 Common Street
Woburn, MA 01801
Tel: 781.897.5850
wcampbell@cityofwoburn.com

Woburn Redevelopment Authority
WRA Office, Woburn Square
371 Main Street
Woburn, MA 01801
Tel: 781.935.3010
borcheltdj@wrawoburn.org

2. Town of Winchester

Board of Selectmen
2nd Floor, Town Hall
71 Mt. Vernon Street
Winchester, MA 01890

Town Manager
Melvin Kleckner
2nd Floor, Town Hall
71 Mt. Vernon Street
Winchester, MA 01890
Tel: 781.721.7133

3. City of Medford

City Mayor
Michael McGlynn
Medford City Hall, Room 202
85 George P. Hassett Drive
Medford, MA 02155
Tel: 781.393.2408 or 781.393.2409

Local Officials
(continued)

City Council
Edward Finn/City Clerk
Medford City Hall, Room 207
85 George P. Hassett Drive
Medford, MA 02155
Tel: 781.393.2425

4. Town of Arlington

Board of Selectmen
Marie A. Krepelka/Board Administrator
Town Hall, 2nd Floor
730 Mass Avenue
Arlington, MA 02476
Tel: 781.316.3020

Town Manager
Brian Sullivan
Town Hall Annex, 1st Floor
730 Mass Avenue
Arlington, MA 02476
Tel: 781.316.3010

ATTACHMENT E3

Federal and State Elected Officials

DRAFT

Federal and State Elected Officials

1. Federal Elected Officials

Senator Scott Brown
2400 JFK Federal Building
55 New Sudbury Street
Boston, MA 02203
Tel. 617.565.3170

Senator John Kerry
1 Bowdoin Square
Boston, MA 02114
Tel: 617.565.8519

Congressman Ed Markey
5 High Street, Suite 101
Medford, MA 02155
Tel: 781.369.2900

2. State Elected Officials

State Senator Patricia Jehlen (Medford, Somerville, Woburn, Winchester)
State House, Room 513
Boston, MA 02133
Tel: 617.722.1578
patricia.jehlen@state.ma.us

State Senator Richard Tisei (Woburn, Arlington, Billerica, Burlington, Lexington)
State House, Room 518
Boston, MA 02133
Tel: 617.722.1206
richard.tisei@state.ma.us

State Representative William Brownsberger (Arlington, Belmont, Cambridge)
State House, Room 23
Boston, MA 02133
Tel: 617.722.2140
rep.williambrownsberger@hou.state.ma.us

State Representative Jason M. Lewis (Winchester, Stoneham)
585A Main Street
Winchester, MA 01890
Tel: 781.722.2060
rep.jasonlewis@hou.state.ma.us

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Federal and State Elected Officials
(continued)

State Representative Paul Donato (Malden, Medford)
271 Spring Street
Medford, MA 02155
Tel: 781.395.1683
rep.pauldonato@hou.state.ma.us

State Representative Jay Kaufman (Woburn, Arlington)
State House, Room 156
Boston, MA 02133
Tel: 617.722.2240
rep.jaykaufman@hou.state.ma.us

State Representative James J. Dwyer (Reading, Stoneham, Woburn)
State House, Room 167
Boston, MA 02133
Tel: 617.722.2014
rep.jamesjdwyer@hou.state.ma.us

State Representative Carl Sciortino, Jr. (Medford, Somerville)
State House, Room 175
Boston, MA 02133
Tel: 617.722.2018
rep.carlsciortino@hou.state.ma.us

ATTACHMENT E4

Environmental and Active Citizen Groups

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Environmental and Active Citizens Groups

Aberjona Study Coalition, Inc.
1083 Main Street
Woburn, MA 01801
Tel: 781.935.2438
info@aberjonastudy.org

Woburn Neighborhood Association, Inc.
Michael Raymond
10 North Maple Street
Woburn, MA 01801
Tel: 781.935.2438
fitwalker1@aol.com

Woburn Residents Environmental Network (WREN)
Fel Medeiros
3 Lafayette Place
Woburn, MA 01801
Tel: 781.526.0810
fsmedeiros@aol.com

The Mystic River Watershed Association
20 Academy Street, Suite 203
Arlington, MA 02476
Tel: 781.316.3438

Concerned Citizens Network of Wilmington
Kathleen Barry
Tel: 978.658.7754

ATTACHMENT E5

Media Contacts

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Media Contacts

1. Newspapers

Woburn Advocate
Kathleen Ragsdale, editor
Tel: 978.371.5709
Fax: 978.371.0958

Woburn Daily Times Chronicle
Tel: 781.933.3700
Fax: 781.932.3321

Winchester Star
Rory Schuler, editor
Tel: 781.729.6100
Fax: 781.674.7735

Medford Transcript
Nell Escobar Coakley, editor
Tel: 781.363.1982
Fax: 781.393.1821

Arlington Advocate
Nicole Laskowski, editor
Tel: 781.674.7726
Fax: 781.674.7735

Boston Globe
Tel: 617.929.3100
Fax: 617.929.2019

Boston Herald
Tel: 617.426.3000
Fax: 617.542.1315

AP-Boston
Tel: 617.357.8100
Fax: 617.338.8125

2. Radio Stations

WBUR Radio
Tel: 617.353.0770

ATTACHMENT E6

Meeting Locations and Information Repository Locations

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Meeting Locations and Information Repository Locations

1. Meeting Locations

Shamrock Elementary School
60 Green Street
Woburn, MA 01801
Tel: 781.937.8241

2. Information Repository Locations

Woburn Public Library
45 Pleasant Street
Woburn, MA 01801
Tel: 781.933.0148

EPA New England Records Center
5 Post Office Square, Suite 100
Mail Code: OSSR07-4
Boston, MA 02109-3912
Tel: 617.918.1440