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SAMPLING AND ANALYSIS PLAN

FINAL

Havana East Ash Pond Cells 1, 2, 3, and 4
Havana Power Station
Havana, Illinois

Project No. 2285
Revision 0
October 17, 2017

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SAMPLING AND ANALYSIS PLAN
FINAL

HAVANA EAST ASH POND CELLS 1, 2, 3, AND 4
HAVANA POWER STATION
HAVANA, ILLINOIS

Project No. 2285

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Revision 0

October 17, 2017

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ACRONYMS

°C	Degrees Celcius
CCR	Coal Combustion Residuals
CoC	Chain-of-Custody
DI	De-ionized
DOT	Department of Transportation
DQO	Data Quality Objective
EDD	Electronic Data Deliverable
HASP	Health and Safety Plan
IATA	International Air Transport Association
IDW	Investigative Derived Wastes
MDL	Method Detection Limit
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
mL/min	Milliliters per Minute
MS/MSD	Matrix Spike/Matrix Spike Duplicate
mV	MilliVolts
NELAP	National Environmental Laboratory Accreditation Program
NTU	Nephelometric Turbidity Unit
PPE	Personal Protective Equipment
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RL	Reporting Limit
SOP	Standard Operating Procedure
SSI	Statistically Significant Increase
SSL	Statistically Significant Level
µS/cm	Micro Siemens per Centimeter
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency

1 INTRODUCTION

1.1 Background

This Sampling and Analysis Plan (SAP) was prepared to document the procedures and techniques that will be used to fulfill the groundwater sampling and analysis program requirements of the United States Environmental Protection Agency (USEPA) Final Rule to regulate the disposal of Coal Combustion Residuals (CCR) as solid waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA) [40 CFR 257 Subpart D; published in 80 FR 21302-21501, April 17, 2015, referred to hereafter as the CCR Rule]. According to 40 CFR 257.91(f), the owner or operator of a CCR unit (or multi-unit) must obtain a certification from a qualified professional engineer stating that the groundwater monitoring system has been designed and constructed to meet the requirements of the rule; certification of the monitoring system at Havana East Ash Pond Cells 1, 2, 3, and 4 is provided in Appendix A.

The CCR Rule groundwater monitoring and corrective action criteria require an owner or operator of a CCR unit (or multi-unit) to install a system of monitoring wells and specify procedures for sampling these wells. In addition, the owner or operator must specify methods for analyzing the groundwater data collected to detect a release from the unit (or multi-unit). The CCR Rule establishes criteria for detection monitoring, assessment monitoring and corrective action groundwater monitoring. Once a groundwater monitoring system and groundwater monitoring program has been established for a CCR unit (or multi-unit), the owner or operator conducts detection monitoring. If a statistically significant increase (SSI) relative to background is detected in downgradient groundwater during detection monitoring, and the SSI cannot be attributed to another cause, then assessment monitoring is initiated. If there are downgradient concentrations detected in assessment monitoring at a statistically significant level (SSL) relative to a groundwater protection standard, and the SSL cannot be attributed to another cause, then corrective action monitoring is required.

As directly relevant to this SAP, the CCR Rule requires that the groundwater monitoring program include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of groundwater quality at the required background and downgradient wells. To that end the CCR Rule requires the owner or operator of the CCR unit (or multi-unit) to develop a sampling and analysis program that includes procedures and techniques for: (1) sample collection; (2)

sample preservation and shipment; (3) analytical procedures; (4) chain of custody control; and (5) quality assurance and quality control [40 CFR 257.93(a)].

1.2 Sampling Objectives

This SAP is intended to ensure that sample collection and analytical activities are conducted in accordance with acceptable protocols that meet data quality objectives (DQOs) as established by the CCR Rule. The information presented in this SAP will enable field personnel to collect field samples and measurements in a manner that meet the project DQOs.

1.3 Sampling and Analysis Plan

1.3.1 Technical Approach

Table 1 provides a Sampling and Analysis Summary for the monitoring program at Havana East Ash Pond Cells 1, 2, 3, and 4 CCR multi-unit. Table 1 includes the number of samples to be collected during a monitoring event, parameters, analytical methods, field quality control samples, sample containers, required preservatives and sample hold time requirements. A National Environmental Laboratory Accreditation Program (NELAP) certified laboratory is required to perform these analyses.

Table 2 provides a summary of information for each sampling location including well construction detail, screen placement and elevations of top of casing and screen position. In addition, Table 2 identifies the well and its hydraulic position is identified as background, upgradient, or downgradient to the monitored facility.

Figure 1 provides an overview of the site, sample locations and significant site features.

1.3.2 Communication Strategy

This SAP provides a communication strategy, which identifies project communication flow between project managers, field personnel and laboratories. The communication strategy is provided in a manner that visually depicts communication hierarchy. Refer to Figure 2 for the Communication Flow Chart.

2 MONITORING WELLS

Site-specific hydrogeologic information was used to determine the number and location of monitoring wells at the Site. Refer to Table 2 for a summary of monitoring well information.

3 FIELD MOBILIZATION AND SITE ACCESS

Prior to initiating field activities, personnel will review the project goals, objectives and scope. The field sampling team will review the site-specific health and safety plan (HASP) (provided by the contractor); Havana Power Station site safety requirements, SAP summary and field standard operating procedures (SOPs). If necessary, field activity area(s) reconnaissance may be performed to familiarize field staff with field conditions, identify access points, and locate monitoring wells.

3.1 Site Access

The Site point of contact (owner, operator, or designated representative) should be notified at least 24 hours before the sampling team arrives at the Site. If not part of the sampling kit, arrangements should be made to obtain the keys for the monitoring devices, and inquiries should be made as to the conditions at the Site (access, weather, operations that may affect sampling, etc.).

Upon arrival at the Site, the sampling team must check in with Site security before entering the facility. An appropriate government-issued form of identification (e.g., Driver's License) will be needed for security clearance and Site access. Personnel must check-in with the site manager or sampling team leader before being allowed into the field activity area. Visitor information (e.g., affiliation, reason for visit, etc.) will be documented in the sign-in/out form maintained at the facility. Unauthorized visitors will not be allowed in field activity areas. Personnel entering the field activity area will review and act in accordance with the site-specific HASP.

3.2 Mobilization Activities

Mobilization activities include:

- Prepare a Site contact list, including the names of field team personnel and subcontractors, affiliation, and contact numbers for distribution to all field team members.
- Receive permission to access privately and/or publicly owned properties, if required, to perform off-property investigations. Where feasible, off-property access will be coordinated within schedule constraints, such as limiting activities during school hours, peak business hours, etc.
- Evaluate access for accessibility to sampling locations with proposed equipment.

- Coordinate subcontractors which may include drillers, laboratories, surveyors, etc. and review scope of work, schedule, and discuss special equipment needs.
- Acquire proper personal protective equipment (PPE).
- Review analytical requirements, request appropriate sample containers from the analytical laboratories, and discuss delivery/pickup of coolers, including weekend deliveries.
- Secure and verify working conditions of field instruments in accordance with their respective SOPs.
- Load appropriate equipment and supplies to perform the field activities.
- Coordinate the management/disposal of investigative waste.
- Prepare equipment staging areas.
- Locate survey information or identifying the need to survey previous and/or proposed initial sampling locations.

3.3 Site Safety

Field activities will be conducted in accordance with a Site-Specific HASP in conjunction with the Facility site-specific safety plan(s). The HASP is not part of this SAP and the personnel performing the groundwater sampling have the responsibility to provide the HASP to their staff and are responsible for knowing the HASP requirements.

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4 SAMPLE COLLECTION PROCEDURES

4.1 Groundwater Sampling

4.1.1 Overview

This section describes groundwater sampling collection methods and requirements. Groundwater sampling is performed to determine if the CCR unit (or multi-unit) is adversely impacting the upper-most aquifer (as defined in 40 CFR 257.53). The methods listed here are consistent with requirements of the CCR Rule. Groundwater will be sampled by low-flow methods and sampling activity details will be recorded on field forms (Appendix B). NRT SOP 07-07-13 (Appendix C) will be followed for low-flow sampling.

4.1.2 Water Level Elevation Readings

Groundwater elevation readings will be collected prior to the start of sample collection. Water level measurements at a CCR unit (or multi-unit) will be collected within the same day. Dedicated sampling equipment (pumps and tubing) will be stored within the water column in a manner that allows water levels to be measured without removing this dedicated equipment. The equipment will remain in place during water level measurements. Groundwater elevation readings will be collected to the hundredth of a foot in accordance with the NRT SOP 07-07-05 (Appendix C) and will be recorded on in the field logbook and/or on the appropriate field form.

4.1.3 Monitoring Well Groundwater Sampling

Groundwater samples will be collected using low-flow sampling techniques in accordance with USEPA and ASTM guidelines. For assessment or corrective action monitoring, water level measurements and well sampling will generally be conducted beginning with wells containing the lowest concentration to wells with highest concentration to limit the possibility of cross-contamination. However, equipment which comes into contact with well water will be cleaned according to NRT SOP 07-04-09.

4.1.3.1 Well Integrity

Well integrity will be evaluated and appropriately noted on a field form in accordance with NRT SOP 07-07-01 Well Integrity Evaluation and Maintenance, provided in Appendix C prior to collection of field data.

Significantly compromised monitoring wells should not be sampled and the issues will be immediately discussed with the project manager for further well evaluation, repair and/or abandonment. An example monitoring well evaluation form is included in Appendix B.

4.1.3.2 Low-Flow Sampling Equipment and Process

Low-flow sampling is synonymous with low-stress sampling; personnel conducting low-flow sampling must consider this and should be familiar with this sampling technique. The purpose of low-flow sampling is to collect a representative formation sample. This is accomplished through use of low discharge pumping rates which equates to the groundwater infiltration into the well. Pump discharge rates between 100 and 500 milliliters per minute (mL/min) are typical. Higher rates are possible in highly permeable formations. Low-flow sampling conditions have not been reached until the following conditions have been met:

- The water level within the well has stabilized during pumping
- The water being removed is from the screened interval
- The measurements of water quality indicators have stabilized

The following equipment is required to perform low-flow sampling:

- Dedicated positive displacement bladder pumps capable of withdrawal at a constant rate between 100 and 500 mL/min and can meet the designed lift requirements.
- Multiprobe water quality meter equipped with a flow-through cell
- All necessary tubing required to connect the pump to the flow-through cell
- Electric water level indicator(s) capable of measurement to the hundredth of a foot
- A calibrated pail to collect purge water
- Low-flow sampling field forms (Appendix B), pens and field book

Low-flow groundwater sampling will be conducted in accordance with NRT SOP 07-07-13 Low Flow Groundwater Sampling (Appendix C). During well purging and throughout sample collection, field parameters are continually monitored and recorded using probes in a flow-through cell. The groundwater quality meter will be calibrated, operated and maintained according to NRT SOP 07-11-01 Field Instrument Calibration, Operation, and Maintenance, provided in Appendix C. Measurements will be recorded at a rate equivalent to the time required to fill the flow-through cell volume. For example, if the volume of the flow through cell is 500 mL and the pumping rate is 250 mL/min; one reading should be taken every 2 minutes. Stabilization criteria measurement time intervals are dependent on the flow rate. Stabilization is achieved when three consecutive readings have fallen within the ranges of the parameters in the table below. Exceptions for one or more stabilization parameters are allowable under some sampling conditions (i.e., extreme heat or cold, very high turbidity, etc.)

Field Parameter	Stabilization Criterion
Specific Conductance	± 3% micro Siemens per centimeter (µS/cm) @ 25 degrees centigrade (°C)
pH	±0.1 Standard Units (S.U.)
Temperature	±0.1 ºC or ±0.2 ºF
Dissolved Oxygen	±10% or ± 0.2 milligrams per liter (mg/L) whichever is greater
Eh or ORP	± 20 millivolt (mV)
Turbidity	<10 nephelometric turbidity units (NTUs) or ± 10% when turbidity is greater than 10 NTUs

When stabilization is achieved and prior to sample collection, the flow-through cell is disconnected and laboratory containers are filled from the system tubing. The flow rate should not be adjusted following parameter stabilization or during sample collection.

4.1.3.3 Sample Collection

Once low-flow sampling conditions are met, sample collection may begin. The flow-through cell is removed and the samples collected directly from the pump discharge tubing at the same flow rate that was used during well purge stabilization. Samples will be placed in appropriate laboratory supplied containers and preserved in accordance with the analytical method requirements listed in Table 1. Samples will be collected in order of analyte stability, as summarized below.

- Non-filtered, non-preserved samples (sulfate, total dissolved solids, fluoride, chloride)
- Non-filtered, preserved samples (combined radium 226 and 228 and total metals)

During each sampling event, a duplicate sample may be collected from a randomly selected groundwater monitoring well. Field duplicate quality control samples will be collected by sequentially alternating filling between containers. Procedures for collecting groundwater samples are described in NRT SOPs 07-07-07 Groundwater Sampling (Appendix C) and 07-07-13 Low-Flow Groundwater Sampling, (Appendix C).

In the event that sample turbidity is not below 10 NTUs a sample filtered through a 0.45 micron filter may be collected (at the discretion of the project manager) for metals analysis in addition to the unfiltered sample. Both filtered and unfiltered samples will be submitted for metals analyses.

In cases where a well has been purged dry during stabilization (low yield wells), it will be necessary to let the water in the well recover (up to one or more days) before collecting the sample. If possible, let the well recover with enough volume to collect all analytical parameters. However, low-yield wells may not recover sufficiently within one day to collect all the necessary analytes. Several days may be needed to collect all the necessary samples.

4.2 Field Documentation

4.2.1.1 Field Data Recording

Field activities will be documented in accordance with this SAP and NRT SOP 07-02-01 Field Documentation, provided in Appendix C. Documentation will be completed through the use of the following field forms provided in Appendix B and/or a field notebook.

- Monitoring Well Evaluation Checklist
- Well Development and Groundwater Sampling Field Form
- Chain of Custody
- MANAGES Tracker Table Form
- Field Calibration Form

The MANAGES Tracker Table includes examples for proper documentation of primary samples, duplicate samples, dry wells, equipment blanks, and trip blanks.

Data generated in the field will be reduced and validated, as appropriate, before reporting. Field entries into the MANAGES Tracker Table Form will be entered into the MANAGES Tracker Table spreadsheet and verified against the collected field data. Data collected in the field will be scanned following completion of the sampling event (typically within 10 days) and transmitted to the project manager.

Data flow will follow the NRT MANAGES Data Flow SOP 01-03-01B (Appendix C) which describes the steps and responsibility associated with collecting, storing and checking data collected in the field and provided by the laboratory.

4.2.1.2 Data Tracking, Storage, and Retrieval

Field data forms and notes will be scanned and stored electronically in the project file and retrieved as described in NRT SOP 01-03-01B. Samples sent to the laboratory for analysis will be tracked using the CoC and the MANAGES Tracker Table.

4.2.1.3 Final Documentation Files

All final data, field notes, and other pertinent documents produced or delivered will be tracked and stored as required by NRT SOP 01-03-01B.

5 DECONTAMINATION

5.1 Overview

Decontamination procedures will be performed to remove chemical constituents from non-dedicated sampling equipment used during groundwater monitoring activities. Proper decontamination procedures prevent chemical constituents from being transferred between sampling location and being transported out of controlled areas. However, the use of dedicated or disposable sampling equipment significantly reduces the chances of sample impacts from re-use of equipment.

5.2 Decontamination of Equipment

Cleaning and decontamination of equipment shall occur at a designated field activity area, downgradient, and downwind from the clean equipment drying and storage areas. Decontamination procedures will be performed and documented in accordance with NRT SOP 07-04-09 (Appendix C).

5.2.1 Sampling Equipment

Non-dedicated sampling equipment will be washed with a solution of Alconox and potable water, and then triple rinsed with distilled water or ultrapure/de-ionized (DI) water and allowed to air dry. Equipment decontamination procedures will be minimized through the use of either dedicated or disposable sampling equipment. However, some sampling equipment may require decontamination, and these include at a minimum:

- Water level meter
- Flow through cell

Equipment decontamination procedures are described in NRT SOP 07-04-09 (Appendix C).

5.2.2 Sample Container Decontamination

Sample container decontamination is not required; the analytical laboratory will provide pre-cleaned and preserved (as applicable) containers for samples to be submitted for laboratory analysis. Sample containers will not be used if the container integrity is compromised in any manner, and arrangements will be made with the laboratory to get replacement container(s).

6 SAMPLE PRESERVATION, SHIPMENT, CHAIN OF CUSTODY AND FIELD QUALITY ASSURANCE/QUALITY CONTROL

Sample labeling, handling and chain of custody (CoC) requirements are described in NRT SOPs 07-03-01 Sample Labeling, Logging, and Storage and 07-03-03 Chain-of-Custody, provided in Appendix C. Alternate sample labeling methods are acceptable upon approval by NRT and the owner/operator.

6.1 CCR Unit (or Multi-Unit) Identification

Each CCR unit (or multi-unit) will be identified with a 3-digit CCR unit (or multi-unit) identification code (Unit ID or Multi-Unit ID). The Havana East Ash Pond Cells 1, 2, 3, and 4 Multi-Unit ID is 701.

6.2 Sample Identification

CCR unit (or multi-unit) identification (Unit ID or Multi-Unit ID) and monitoring well identification (Well ID) will be according to owner/operator guidelines. Samples collected in the field will be identified on the CoC by the Well ID. Reports from the laboratories will include the Unit ID (or Multi-Unit ID) and the Well ID. If a well is associated with more than one CCR unit (or multi-unit) the analytical results for that well will be included on the laboratory reports for all applicable CCR units (or multi-units).

6.3 Sample Container, Volume, Preservation and Holding Times

Groundwater will be containerized, preserved, and stored in accordance with this SAP and NRT SOP 07-04-05. Sample containers, volumes, preservatives, and holding times for groundwater samples are summarized on Table 1. Prior to initiating sampling activities, the analytical laboratory will verify sample container, volume, preservation, and holding times. The laboratory will provide the appropriate sample containers with preservatives.

6.4 Field Sampling Quality Control

Field quality control (QC) samples to be collected as described in the NRT SOP 07-04-07 Quality Control Samples provided in Appendix C. Field QC collected samples are:

- Field duplicates
- Field blanks (if required by project manager)
- Equipment blanks (if non-dedicated sampling equipment used)
- Matrix Spike/Matrix Spike Duplicates (MS/MSDs)

6.4.1 Field Duplicates

Field duplicate samples are collected to evaluate the precision of the whole method, from field sampling to laboratory analysis. Field duplicate samples shall be collected at the same time, using the same procedures and equipment, and in the same types of containers as the parent samples. They shall also be preserved in the same manner and submitted for the same analyses as the parent samples. Field duplicates will be collected at the ratio of one duplicate for every 10 parent samples.

6.4.2 Field Blanks

Field blanks are used to identify potential contamination of a sample by site contaminants from a source not associated with the sample collected (e.g. air-borne dust from a source not related to the samples). Field blanks shall be collected by pouring distilled or DI water directly into the appropriate sample containers at pre-designated locations at the site. They shall also be preserved in the same manner and submitted for the same analyses as investigative samples. After collection, field blanks are handled and treated in the same manner as investigative samples. If required, one field blank will be collected per sampling event.

6.4.3 Equipment Blanks

Equipment blanks are also referred to as rinsate blanks or equipment rinsates. Equipment blanks are used to determine if non-dedicated equipment decontamination procedures are sufficient and there is no cross-contamination from one sample to another, and may be used to determine if dedicated equipment is free of measurable concentrations of constituents of potential concern. Equipment blanks shall be collected by pouring distilled or DI water onto or into the sampling equipment and directly filling the appropriate sample containers with the water that has contacted the sampling equipment. Equipment blanks are always collected after sampling equipment has been decontaminated and may be performed prior to collecting the first sample, after collecting highly impacted samples, and/or at the conclusion of sampling. After collection, equipment blanks are handled and treated in the same manner as investigative samples, unless noted otherwise in site-specific documents. If required, one equipment blank may be collected per sampling event.

6.4.4 Matrix Spike/Matrix Spike Duplicates

MS/MSD samples are collected to evaluate the effect of sample matrix on analytical results and the precision and accuracy of laboratory procedures. As with field duplicate samples, MS/MSD samples should be collected at the same time, using the same procedures and equipment, and in the same types of containers as the parent samples. They shall also be preserved in the same manner and submitted for the same analyses as the parent samples. MS/MSD samples will be collected at a ratio of one MS/MSD sample per twenty parent samples collected.

6.5 Sample Custody

Chain of custody procedures are required by USEPA guidance and will be conducted in accordance with the NRT SOP 07-03-03 (Appendix C). Samples collected must be maintained under secure conditions and documented through CoC procedures. A sample is under a person's custody if the following requirements are met:

- The sample is in the person's possession
- The sample is in the person's view after being in the person's possession
- The sample is in a secured location after being in the person's possession

Field personnel are responsible for the custody of samples until custody is transferred. Sample containers will be properly identified, labeled, handled and transported in accordance with the NRT SOP 07-03-05 (Appendix C). All samples must be accompanied by a CoC form at all times and a separate CoC will be completed for each sampling event and site.

When transferring the possession of samples, the individual relinquishing the sample will sign the "relinquished from" line on the CoC. If a team is involved in the sample collection, only one team member is required to sign the CoC. The receiving individual will then sign the CoC, noting the date and time the samples were received. This record documents the transfer of sample custody from the sampler to another person. The original CoC will accompany the sample shipment. A copy of the CoC will be retained to document the transfer of custody. The hard copy will be scanned and saved in the project file.

6.6 Sample Shipping

Transportation and shipping requirements are detailed in the NRT SOP 07-03-09 Packing and Shipment of Environmental Samples and Equipment, provided in Appendix C. Deviations from the packing and shipment SOP are allowable if the samplers deliver the samples to the laboratory themselves; however, alternate packing and shipment methods must preserve sample integrity and CoC, as well as follow applicable United States Department of Transportation (USDOT), International Air Transport Association (IATA) and carrier-specific regulations and requirements. Samples collected during field investigations must be classified prior to shipment, as either environmental or dangerous goods samples.

As it pertains to groundwater sampling the shipment of the following preserved samples is also not regulated provided the amount of preservative used does not exceed the amounts specified in 40 CFR 136.3. Specifically, 40 CFR 136.3(e) Table II, note 3, states: "For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials:"

- "Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater)"

Pre-preserved sample containers received from a laboratory do not exceed this amount of preservative. As related to this groundwater monitoring, the aforementioned preservative (HNO_3) pertain to metals in groundwater samples.

7 LABORATORY ANALYTICAL PROCEDURES AND QUALITY ASSURANCE/QUALITY CONTROL

Groundwater will be analyzed by a NELAP certified laboratory using methods that provide the required reporting limits for the requested analytes. The CCR Rule defines the parameters to be analyzed and include the following:

Appendix III analytes:

- Metals: Boron and calcium
- Chloride
- Fluoride
- Sulfate
- Total dissolved solids
- pH (field analysis)

Appendix IV analytes include:

- Metals: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, lithium, lead, molybdenum, selenium and thallium
- Mercury
- Fluoride
- Combined radium 226 and 228

The CCR Rule stipulates different phases of groundwater monitoring and including:

- Initial Sampling - Appendix III and IV parameters including 8 independent samples.
- Detection Monitoring - Appendix III parameters
- Assessment Monitoring - Appendix III and IV parameters sampled annually and Appendix III and detected Appendix IV parameters samples semi-annually
- Correction Action Monitoring - As specified in the corrective action plan

The Sampling and Analysis Summary is provided on Table 1. Table 3, Summary of Groundwater Analytical Methods, provides the full Appendix III and IV analyte list with method detection limits (MDLs) and reporting limits (RLs) as well as the USEPA Maximum Contaminant Levels (MCLs). Analytical methods were selected based on providing RLs which are at or below the USEPA MCL. Laboratories are required to analyze quality control samples which (depending on the analysis) may include:

- Initial calibration
- Initial calibration verification
- Continuing calibration verification
- Method blanks
- Serial dilution
- Interference check samples
- Initial and continuing calibration blanks
- Matrix spike and matrix spike duplicates
- Laboratory control samples

Refer to Tables 4, 5, 6 and 7 for laboratory quality control requirements including measurement performance criteria for the inorganics, metals, mercury and radium 226 and 228 analyses, respectively.

The analytical laboratory will conduct level 2 data verification (see NRT SOP 01-03-01B) and will provide Havana Power Station and NRT a level 2 electronic data deliverable (EDD) in an agreed upon format which is compatible with the NRT and the owner's/operator's databases. Laboratory EDDs and PDF reports will be sent to the NRT data group (gdsdata@obg.com) within 10 business days or as agreed upon with the laboratory. Once the Lab EDDs and PDF reports are received a quality assurance and quality control (QA/QC) assessment will be completed. The QA/QC assessment will include reviewing incoming laboratory data to ensure requirements of this report, CCR Rule, and the site-specific requirements are met. Once the QA/QC assessment is complete appropriate parties will be notified that the data results are ready for data storage and analysis or communicate if adjustments are needed as well as a timetable for completing needed corrections in accordance with the CCR Rule and site specific schedule.

8 DATA MANAGEMENT

Field and analytical groundwater analytical data will be managed and stored by NRT according to the NRT MANAGES Data Flow SOP 01-03-01B.

8.1 Field Data Exchange

Field data including field forms, MANAGES Tracker Table, CoCs and shipping information will be electronically scanned into a PDF for each sampling event. The compiled PDF will be distributed to the NRT data group either by uploading to the NRT Sharefile FTP site or by email (gdsdata@obg.com) within 10 business days of the completion of the sampling event. The sampling team will review all data for accuracy prior to submitting to NRT.

8.2 MANAGES Database

Groundwater data will be stored in the Electrical Power Research Institute (EPRI) MANAGES™ database which will be maintained at NRT by the NRT data group.

8.3 Protocol for Data Exchange

NRT will import and maintain the field and analytical data in the MANAGES database. NRT will ensure that the version of MANAGES used is consistent with the version used by the owner/operator.

8.4 Data for Public Review

Groundwater data collected to satisfy requirements of the CCR Rule will be included in an Annual Groundwater Monitoring Report (Annual Report). In accordance with the CCR Rule, the Annual Report will be posted to a public website for public review. If the facility enters assessment monitoring or corrective action monitoring, that data will be posted separately to the public website as required by the CCR Rule.

9 MANAGEMENT OF INVESTIGATIVE DERIVED WASTES (IDW)

Investigative Derived Wastes (IDW) (purgewater and decontamination solutions) will be produced during sampling activities. The methodology for the management, storage, and disposal of the wastes is described below. Groundwater (purge water) handling, storage and disposal procedures will ensure that potential adverse environmental impacts associated with the waste do not occur, and that all wastes are transported, and disposed in accordance with local, state and/or federal regulations and in coordination with the facility.

9.1 Water and Decontamination Solutions

Water and decontamination solutions likely to be produced during monitoring activities include the following:

- Water from monitoring well development, low-flow sampling well purging, and sampling activities
- Decontamination solutions from field equipment, sampling equipment, and personal protective equipment

Disposal of water generated during well installation, development and sampling will be coordinated with the facility.

9.2 Personal Protective Equipment

Waste PPE will be stored in plastic garbage bags and disposed of in a dumpster with general refuse, unless otherwise specified by the facility.

10 REFERENCES

ASTM International. 2004d. D5092-04e1 Standard Practice for Design and Installation of Ground Water Monitoring Wells. ASTM Book of Standards Volume 4.08.

ASTM International. 2005c. D5521-05 Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers. ASTM Book of Standards Volume 4.08.

Code of Federal Regulations, Title 40 Volume 25, Title 40 – Protection of Environment, Chapter I Environmental Protection Agency, Part 300 – National Oil and Hazardous Substances Pollution Contingency Plan, Subpart E – Hazardous Substance Response, Section 300.400, Procedures for Planning and Implementing Off-Site Response Actions, Revised July 1, 2003.

USDOE, 2002, *Adaptive Sampling and Analysis Program (ASAP)*, Environmental Assessment Division (EAD), http://www.ead.anl.gov/project/dsp_topicdetail.cfm?topicid=23.

USEPA, 1987, A Compendium of Superfund Field Operation Methods, Office of Emergency and Remedial Response, EPA/540/P-87/001, December 1987.

USEPA, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Office of Solid Waste and Emergency Response, EPA/540/G-89/004, October 1988.

USEPA, 1992a, Monitoring Well Development Guidelines for Superfund Project Managers, Office of Solid Waste and Emergency Response. April 1992

USEPA, 1992b, Guide to Management of Investigative- Derived Waste (IDW). Office of Solid Waste and Emergency Response. Publication 9345.3-03FS, January 1992.

USEPA, 1992c, “Specifications and Guidance for Contaminant-Free Sample Containers”. Office of Solid Waste and Emergency Response. December 1992. Publication 9240.0-05A, EPA540/R-93/051, Washington, D.C. 28 pp.

USEPA, 1997b, Field Analytical and Site Characterization Technologies Summary of Applications, EPA-542-R-97-011, Office of Solid Waste and Emergency Response, Washington, DC, November 1997.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, USEPA Region IV, November 2001.

USEPA, 2002b, On-line field analytical technologies encyclopedia (FATE), http://fate.clu-in.org/.

USEPA, 2002c, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, OSWER, EPA 542-S-02-001.

USEPA, 2003a, Improving Decision Quality: Making the Case for Adopting Next-Generation Site Characterization Practices, Wiley Periodicals, Inc.

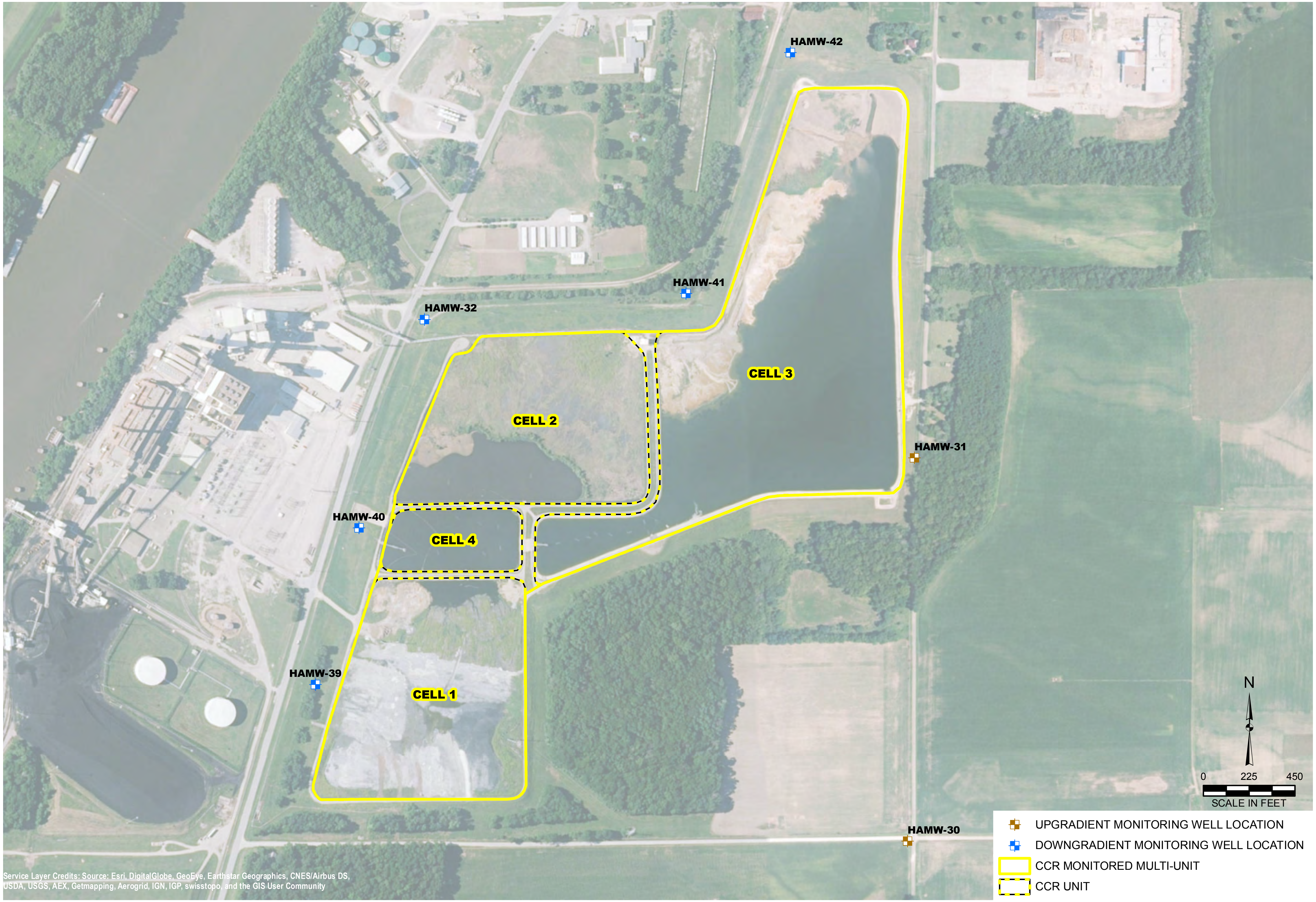
USEPA, 2003c, Using Dynamic Field Activities for On-Site Decision Making: A Guide for Project Managers, EPA/540/R-03/002, OSWER No. 9200.1-40, -600-R-02-013, Office of Solid Waste and Emergency Response, Washington, D.C., May 2003.

USEPA, 2004b, Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup, Office of Solid Waste, EPA-542-F-04-001a, www.epa.gov/tio, www.cluin.org, April 2004

U.S. EPA, 2007. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, EPA/530/SW-846, 3rd Edition (Revision 0); November 1986; Revision 6, as amended: I (July 1992), II (September 1994), IIA (August 1993), IIB (January 1995), III (December 1996), IIIA (April 1998), IIIB (November 2004), IV (February 2007), U.S. Environmental Protection Agency, Washington D.C., 3500 pp.

USEPA, 2015, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule, 40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, April 2015

FIGURES



Y:\Mapping\Projects\22\2285_Havana\MXD\SAP\Figure 1_Site and Well Location Map - Havana East Ash Pond.mxd Author: mmejac; Date/Time: 5/18/2016, 9:24:35 AM

DRAWN BY/DATE:
MDM 5/18/16
REVIEWED BY/DATE:
YAD 5/18/16
APPROVED BY/DATE:
SJC 5/18/16

SITE AND WELL LOCATION MAP
HAVANA EAST ASH POND CELLS 1, 2, 3, AND 4
MULTI-UNIT ID: 701

SAMPLING AND ANALYSIS PLAN
DYNEGY CCR RULE GROUNDWATER MONITORING
HAVANA POWER STATION
HAVANA, ILLINOIS

PROJECT NO: 2285/2.3

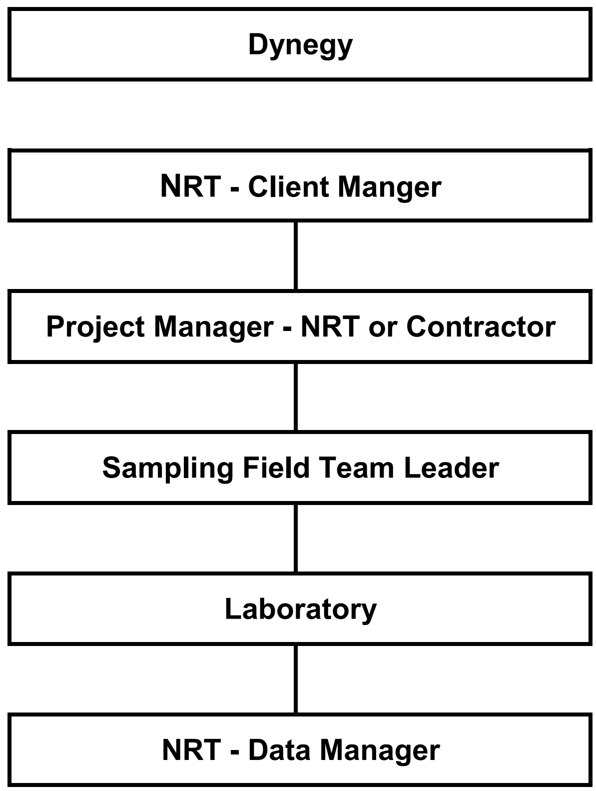
FIGURE NO: 1

NATURAL RESOURCE TECHNOLOGY

Figure 2 – Communication Flow Chart

Sampling and Analysis Plan

Dynegy Groundwater Sampling



TABLES

Table 1. Sampling and Analysis Summary
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring
CCR Multi-Unit Name: Havana East Ash Pond Cells 1, 2, 3, and 4
Multi-Unit ID: 701

Parameter	Analytical Method[5]	Number of Samples	Field Duplicates[1]	Field Blanks[2]	Equipment Blanks[2]	MS/MSD[3]	Total	Container Type	Minimum Volume[4]	Preservation (Cool to 4 °C for all samples)	Sample Hold Time from Collection Date
Metals - Appendix III (1)											
Boron and Calcium	6020	7	1	0	0	1	9	plastic	600 mL	HNO_3 to pH<2	6 months
Metals - Appendix IV (2)											
Other Metals (3)	6020	7	1	0	0	1	9	plastic	600 mL	HNO3 to pH<2	6 months
Mercury	7470A or 6020	7	1	0	0	1	9	plastic	400 mL	HNO_3 to pH<2	28 days
Inorganic Parameters - Appendix III (1)											
Fluoride	9214	7	1	0	0	1	9	plastic	300 mL	Cool to 4 °C	28 days
Chloride	9251	7	1	0	0	1	9	plastic	100 mL	Cool to 4 °C	28 days
Sulfate	9036	7	1	0	0	1	9	plastic	50 mL	Cool to 4 °C	28 days
Total Dissolved Solids	SM 2540 C	7	1	0	0	1	9	plastic	200 mL	Cool to 4 °C	7 days
Radium - Appendix IV (2)											
Radium 226	9315 or EPA 903	7	0	0	0	0	7	plastic	1000 mL	HNO3 to pH<2	6 months
Radium 228	9320 or EPA 904	7	0	0	0	0	7	plastic	1000 mL	HNO_3 to pH<2	6 months
Field Parameters											
pH (1)	SM 4500-H+ B	7	NA	NA	NA	NA	7	flow-through cell	NA	none	immediately
Dissolved Oxygen	SM 4500-O/405.1	7	NA	NA	NA	NA	7	flow-through cell	NA	none	immediately
Temperature	SM 2550	7	NA	NA	NA	NA	7	flow-through cell	NA	none	immediately
Oxidation/Reduction Potential	SM 258O B	7	NA	NA	NA	NA	7	flow-through cell	NA	none	immediately
Specific Conductivity	SM 2510 B	7	NA	NA	NA	NA	7	flow-through cell	NA	none	immediately
Turbidity (4)	SM 2130 B	7	NA	NA	NA	NA	7	flow-through cell or hand-held turbidity meter	NA	none	immediately

Notes:

(1) USEPA Appendix III Parameters: collected during Background, Detection and Assessment Monitoring phases (boron, calcium, chloride, fluoride, pH, sulfate, total dissolved solids (TDS))

(2) USEPA Appendix IV Parameters: collected during Background and Assessment Monitoring phases
(antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and 228 combined)

(3) Other Metals = antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, lead, lithium, molybdenum, selenium, thallium

(4) If turbidity exceeds 10 NTUs, a duplicate sample filtered through a .45 micron filter may be collected for metals analysis in addition to the unfiltered sample. Both samples would be submitted for analysis.

NA = not applicable
HNO_3 = nitric acid
°C = degrees Celsius
mL = milliliter

1. Field duplicates will be collected at a frequency of one per group of 10 or fewer investigative water sample. Field duplicates will not be collected for radium analysis.
2. Field blanks will be collected at the discretion of the project manager; Equipment blanks will be collected at a rate of 1 per sampling event if non-dedicated equipment is used.
3. Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples will be collected at a frequency of one per group of 20 or fewer investigative water samples per CCR unit/multi-unit. Additional volume to be determined by laboratory.
4. Sample volume is estimated and will be determined by the laboratory.
5. Analytical method numbers are from SW-846 unless otherwise indicated. Analytical methods may be updated with more recent versions as apropriate.

Table 2. Sample Location Summary
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring
CCR Multi-Unit Name: Havana East Ash Pond (Cells 1, 2, 3, and 4)
Multi-Unit ID: 701

Well ID	HAMW-31	HAMW-30	HAMW-32	HAMW-39	HAMW-40	HAMW-41	HAMW-42
Well Location Latitude	40°16'47.71"	40°16'29.10"	40°16'54.47"	40°16'36.74"	40°16'44.34"	40°16'55.72"	40°17'7.41"
Well Location Longitude	-90°3'58.23"	-90°3'58.68"	-90°4'29.28"	-90°4'36.22"	-90°4'33.43"	-90°4'12.69"	-90°4'6.07"
Well Construction Material	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Well Diameter (inches)	2	2	2	2	2	2	2
Top of Casing Well Elevation (ft) (1)	493.39	472.91	455.50	468.59	470.23	467.95	481.95
Well Depth Below Ground Surface (ft) (2)	44.8	29.1	26.2	35.0	34.5	35.0	44.0
Screen Length (ft)	10.0	9.0	10.0	10.0	10.0	10.0	10.0
Top of Screen Elevation (ft) (3)	455.6	449.9	435.7	441.2	445.7	440.1	445.2
Bottom of Screen Elevation (ft) (3)	445.6	440.9	425.7	431.2	435.7	430.1	435.2
Well Stick-up Above Ground Surface (ft) (4)	3.19	2.60	1.80	2.39	0.03	2.85	2.75
Hydraulic Position of Well (5)	U	U	D	D	D	D	D

[U:KJS 4/18/16; CB: JJW 4/22/16][U:KLT 5/4/16, C:PMH 5/11/16]

Notes:
PVC = polyvinyl chloride
ft = feet
1. Top of Casing Elevations are referenced to NAVD88.
2. Well Depth Below Ground Surface referenced to ground surface at time of well construction.
3. Top and Bottom of Screen Elevations reported as listed on well construction forms.
HAMW-39, HAMW-40, HAMW-41, and HAMW-42 Screen Elevations are referenced to NAVD88.
The vertical datum for wells HAMW-31, HAMW-30, and HAMW-32 was not specified.
4. Well Stick-up Above Ground Surface calculated from Top of Casing Well Elevation and Ground Surface Elevation collected on June 17, 2015 by Chastain & Associates LLC.
5. Upgradient (U) or downgradient (D)

Table 3. Summary of Groundwater Analytical Methods
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring
CCR Multi-Unit Name: Havana East Ash Pond Cells 1, 2, 3, and 4
Multi-Unit ID: 701

Constituent	CAS	Unit	Analytical Methods [1]	USEPA MCL [2]	RL [4]	MDL [4]
Metals						
Antimony	7440-36-0	µg/L	6020	6	1	0.25
Arsenic	7440-38-2	µg/L	6020	10	1	0.25
Barium	7440-39-3	µg/L	6020	2000	1	0.4
Beryllium	7440-41-7	µg/L	6020	4	1	0.5
Boron	7440-42-8	µg/L	6020	NS	25	10
Cadmium	7440-43-9	µg/L	6020	5	1	0.25
Calcium	7440-70-2	µg/L	6020	NS	125	100
Chromium	7440-47-3	µg/L	6020	100	1	0.3
Cobalt	7440-48-4	µg/L	6020	NS	1	0.25
Lead	7439-92-1	µg/L	6020	15	1	0.25
Lithium	7439-93-2	µg/L	6020	NS	1	0.5
Mercury	7439-97-6	µg/L	6020 or 7470A	2	0.2	0.051
Molybdenum	7439-98-7	µg/L	6020	NS	1	0.25
Selenium	7782-49-2	µg/L	6020	50	1	0.9
Thallium	7440-28-0	µg/L	6020	2	1	0.25
Inorganics						
Fluoride	7681	mg/L	9214	4	0.1	0.05
Chloride	16887-00-6	mg/L	9251	250 [3]	5	1
Sulfate	18785-72-3	mg/L	9036	250 [3]	10	5
Total Dissolved Solids	10052	mg/L	SM 2540 C	500 [3]	20	10
Other						
Combined Radium 226/228	7440-14-4	pCi/L	9315/9320 or EPA 903/904	5	-- [5]	-- [6]
Field						
pH	NA	SU	SM 4500-H+ B	NS	NA	NA
Oxidation/Reduction Potential	NA	mV	SM 2580 B	NS	NA	NA
Dissolved Oxygen	NA	mg/L	SM 4500-O/405.1	NS	NA	NA
Temperature	NA	^{o}C	SM 2550	NS	NA	NA
Specific Conductivity	NA	µS/cm	SM 2510 B	NS	NA	NA
Turbidity	NA	NTU	SM 2130 B	NS	NA	NA

Notes:
NS = No standard
RL = Reporting limit as established by the laboratory
MDL = Method detection limit as established by the laboratory
SM = Standard Methods for the Examination of Water and Wastewater
ug/L = micrograms per liter
mg/L = milligrams per liter
pCi/L = picoCuries per liter
µS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit
CAS = Chemical Abstract Number

1. Analytical method numbers are from SW-846 unless otherwise indicated.
2. USEPA MCL = United States Environmental Protection Agency Maximum Contaminant Level.
3. USEPA SMCL = United States Environmental Protection Agency Secondary Maximum Contaminant Level.
4. Reporting limits and method detection limits will vary depending on the laboratory performing the work.
5. All radium results will be reported (values may be positive or negative) and will include uncertainty and the calculated MDC.
6. Laboratories calculate a minimum detectable concentration (MDC) based on the sample.

Table 4 - Summary of Laboratory Quality Control Requirements - Inorganics (Fluoride, Chloride, Sulfate and Total Dissolved Solids)
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring

Sampling Procedure	Analytical Methods	Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance
Low-flow groundwater	F - 9214, Cl - 9251, SO_4 - 9036, and TDS - SM 2540C	Precision	RPD < 25% (or +/- 2 X RL if sample or duplicate is < 5 X RL)	Field Duplicate
	Cl - 9251, SO_4 - 9036	Accuracy and Precision	90-110%, RPD < 20%	Matrix Spike Matrix Spike Duplicate
	F - 9214, TDS - SM 2540C	Accuracy and Precision	85-115%, RPD < 20%	Matrix Spike Matrix Spike Duplicate
		Accuracy	No detections exceeding the RL	Method Blank
		Accuracy	90 to 110%	Laboratory Control Sample
		Accuracy/Bias	r > 0.995	Initial Calibration
		Accuracy/Bias	%D = +/- 10%	ICV and CCV
		Accuracy/Bias	< reporting limit	ICB/CCB
		Field Completeness	100%	Data Completeness Check
		Analytical Completeness	95%	Data Completeness Check

Notes:
CCB = Continuing Calibration Blank
CCV = Continuing Calibration Verification
ICB = Initial Calibration Blank
ICV = Initial Calibration Verification
RL = reporting limit
RPD = relative percent difference
%D = percent difference

Table 5 - Summary of Laboratory Quality Control Requirements - Metals
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring

Sampling Procedure	Analytical Method	Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance
Low-flow groundwater	6020	Precision	RPD < 25% (or +/- 2 X RL if sample or duplicate is < 5 X RL)	Field Duplicate
		Accuracy and Precision	75-125%, RPD < 20%	Matrix Spike Matrix Spike Duplicate
		Accuracy	No detections exceeding the RL	Method Blank
		Accuracy	80-120%	Interference Check Sample
		Precision	+/- 10 %D	Serial Dilution
		Accuracy	80 to 120%	Laboratory Control Sample
		Accuracy/Bias	r > 0.995	Initial Calibration
		Accuracy/Bias	%D = +/- 10%	ICV and CCV
		Accuracy/Bias	< reporting limit	ICB/CCB
		Field Completeness	100%	Data Completeness Check
		Analytical Completeness	95%	Data Completeness Check

Notes:
CCB = Continuing Calibration Blank
CCV = Continuing Calibration Verification
ICB = Initial Calibration Blank
ICV = Initial Calibration Verification
RL = reporting limit
RPD = relative percent difference
%D = percent difference

Table 6 - Summary of Laboratory Quality Control Requirements - Mercury
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring

Sampling Procedure	Analytical Method	Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance
Low-flow groundwater	7470A	Precision	RPD < 25% (or +/- 2 X RL if sample or duplicate is < 5 X RL)	Field Duplicate
		Accuracy and Precision	75-125%, RPD < 20%	Matrix Spike Matrix Spike Duplicate
		Accuracy	No detections exceeding the RL	Method Blank
		Accuracy	85 to 115%	Laboratory Control Sample
		Sensitivity	RLs , ½ the action level	RL adequacy check
		Accuracy/Bias	r > 0.995	Initial Calibration
		Accuracy/Bias	%D = +/- 10%	ICV and CCV
		Accuracy/Bias	< reporting limit	ICB/CCB
		Field Completeness	100%	Data Completeness Check
		Analytical Completeness	95%	Data Completeness Check

Notes:
CCB = Continuing Calibration Blank
CCV = Continuing Calibration Verification
ICB = Initial Calibration Blank
ICV = Initial Calibration Verification
RL = reporting limit
RPD = relative percent difference
%D = percent difference

Table 7 - Summary of Laboratory Quality Control Requirements - Radium 226 and 228
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring

Sampling Procedure	Analytical Method	Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance
Low-flow groundwater	9315 and 9320; or EPA 903 and 904	Accuracy	70 to 130%	Laboratory Control Sample
		Accuracy	< RL	Method Blank
		Accuracy	40 to 110%	Carrier % Yield
		Field Completeness	100%	Data Completeness Check
		Analytical Completeness	95%	Data Completeness Check

Notes:
RPD = relative percent difference
< RL = less than reporting limit

Table 8. Goals for Precision, Accuracy, and Completion of Field Measurements
Sampling and Analysis Plan
Dynegy CCR Rule Groundwater Monitoring

Field Parameter	Precision Goal	Accuracy Goal	Completion Goal
Water Level	± 0.01 foot	± 0.01 foot	90%
pH	± 0.1 s.u.	± 0.1 s.u.	90%
Specific Conductance	± 100 µS/cm	± 100 µS/cm	90%
Temperature	± 10%	± 10%	90%
Oxidation/Reduction Potential	± 1.0 mV	± 1.0 mV	90%
Dissolved Oxygen	± 0.3 mg/L	± 0.3 mg/L	90%
Turbidity	± 0.1 NTU	± 5% of reading ± 1 NTU	90%

Notes:
mg/L = Milligrams per liter
mV = Millivolt
s.u. = standard pH units
µS/cm = Micro Siemens per centimeter
NTU = nephelometric turbidity unit

APPENDIX A

MONITORING WELL SYSTEM CERTIFICATION

40 CFR Part 257.91(f) Groundwater Monitoring System Certification
CCR Multi-Unit: Dynegy Midwest Generation, LLC; Havana Power Station; Havana East Ash Pond (Cells 1, 2, 3, and 4)

In accordance with Title 40 Code of Federal Regulations (40 CFR) Part 257, Subpart D, Section 257.91(f), the owner or operator of a coal combustion residual (CCR) unit (or multi-unit) must obtain a certification from a qualified professional engineer stating that the groundwater monitoring system at the CCR unit (or multi-unit) has been designed and constructed to meet the requirements of 40 CFR § 257.91. If the groundwater monitoring system includes the minimum number of monitoring wells specified in 40 CFR § 257.91(c)(1), the certification must document the basis supporting use of the minimum number of monitoring wells. Further, in accordance with 40 CFR § 257.91(e)(1), when completing the groundwater monitoring system certification, the qualified professional engineer must be given access to documentation regarding the design, installation, development, and decommissioning of any monitoring wells, piezometers and other measurement, sampling, and analytical devices.

The groundwater monitoring system designed and constructed for the Havana East Ash Pond (Cells 1, 2, 3, and 4) includes more than the minimum number of monitoring wells specified in 40 CFR § 257.91(c)(1). The undersigned has been given access to documentation regarding the design, installation, development, and decommissioning of monitoring wells, piezometers and other measurement, sampling, and analytical devices concerning the Havana East Ash Pond (Cells 1, 2, 3, and 4).

I, Eric Tlachac, a qualified professional engineer in good standing in the State of Illinois, certify that the groundwater monitoring system at the Havana East Ash Pond (Cells 1, 2, 3, and 4) has been designed and constructed to meet the requirements of 40 CFR § 257.91.

Eric J. Tlachac
Qualified Professional Engineer
062-063091
Illinois
October 17, 2017

LICENSED PROFESSIONAL ENGINEER
ERIC J. TLACHAC
062-063091
STATE OF ILLINOIS

I, Stuart Cravens, a licensed professional geologist in good standing in the State of Illinois, certify that the groundwater monitoring system at the Havana East Ash Pond (Cells 1, 2, 3, and 4) has been designed and constructed to meet the requirements of 40 CFR § 257.91.

Stuart J. Cravens
Licensed Professional Geologist
196-000108
Illinois
October 17, 2017

LICENSED PROFESSIONAL GEOLOGIST
Stuart J. Cravens
196-000108
ILLINOIS

APPENDIX B

FIELD AND DATA FORMS

Monitoring Well Evaluation Checklist

Site ______________________

Inspection Date __________

Well Number __________

Major wells repairs* required to maintain well integrity?	Yes	No	NA

Stick-up Monitoring Wells	Yes	No	NA	**Comments**
1. Outer protective Casing				
Not corroded				
Not dented				
Not cracked				
Not loose				

	Yes	No	NA	
2. Inner casing				
Not corroded				
Not dented				
Not cracked				
Not loose				

	Yes	No	NA	
3. Are there weep holes in outer casing?				
4. Weep holes able to drain?				
5. Is there a lockable cap present?				
6. Is there a lock present?				
7. Bumper posts in good condition?				

Flushmount Monitoring Wells	Yes	No	NA	
8. Can the lid be secured tightly?				
9. Does the lid have a gasket that seals?				
10. No water in the flushmount?				
11. Is the well cap lockable?				
12. Is there a lock present?				

All Monitoring Wells	Yes	No	NA	
Downhole Condition				
12. Water level measuring point clearly marked?				
13. No obstructions in well?				
14. No plant roots or vegetation in well?				
15. No sediment in bottom of well?				
If present, how much sediment?	ft			
16. Installed as total depth.	ft			
17. Measured total depth of well.	ft			

General Condition	Yes	No	NA	
18. Concrete pad installed?				
19 . Concrete pad				
Slope away form casing?				
Not deteriorated?				
Not heaved or below surrounding grade?				
20. No surface seal settling?				
21. Well clearly visible and labeled?				

Comments:

* Major well repair are those that require a subcontractor or separate mobilization to complete

WELL DEVELOPMENT AND GROUNDWATER SAMPLING FIELD FORM

PROJECT INFORMATION

Site: ____________________ Client: ____________________

Project Number: ____________ Task #: ________ Start Date: ____________ Time: ________

Field Personnel: ____________________ Finish Date: ____________ Time: ________

WELL INFORMATION

Well ID: ____________

Casing ID: ________ inches

EVENT TYPE

☐ Well Development
☐ Low-Flow / Low Stress Sampling
☐ Well Volume Approach Sampling
☐ Other (Specify):

WATER QUALITY INDICATOR PARAMETERS (continued)

Sampling Stage	Time (military)	Volume Removed (gallons)	Depth to Water (Feet)	Drawdown (Feet)	Temp. (°C)	pH (SU)	SEC or Cond. (µs/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	ORP (mV)	Visual Clarity

NOTES (continued)

ABBREVIATIONS

Cond. - Actual Conductivity
FT BTOC - Feet Below Top of Casing
na - Not Applicable
nm - Not Measured
ORP - Oxidation-Reduction Potential
SEC - Specific Electrical Conductance
SU - Standard Units
Temp - Temperature
°C - Degrees Celcius

WELL DEVELOPMENT AND GROUNDWATER SAMPLING FIELD FORM

PROJECT INFORMATION

Site: ______________________ Client: ______________________

Project Number: ______________ Task #: __________ Start Date: ______________ Time: ________

Field Personnel: ______________________ Finish Date: ______________ Time: ________

WELL INFORMATION

Well ID: ______________

Casing ID: __________ Inches

Screen Interval: ______________

Borehole Diameter: __________ Inches

Filter Pack Interval: ______________

EVENT TYPE

- ☐ Well Development
- ☐ Low-Flow / Low-Stress Sampling
- ☐ Well Volume Approach Sampling
- ☐ Other (Specify below)

____

PURGE INFORMATION

Purge Method: ☐ Bailer ☐ Pump

Bailer Type: n/a

Pump Type and Serial #: ______________

Tube/Pump Intake Depth: ______________

Stabilized Pumping Rate: ______________

DEPTH MEASUREMENTS

	INITIAL		FINAL	
	Depth FT BTOC	Time (24-Hour)	Depth FT BTOC	Time (24-Hour)
LNAPL				
Groundwater				
DNAPL				
Casing Base				

VOLUME CALCULATION AND PRODUCTION INFORMATION

Volume Calculation Type: ☐ Well Casing ☐ Borehole

Volume Per Foot: ______________

Standing Water Column: __________ feet

1 Well Volume: __________ Gallons 3 Well Volumes: __________ Gallons

5 Well Volumes: __________ Gallons 10 Well Volumes: __________ Gallons

Total Volumes Produced: __________ Gallons

Well Purged Dry? ☐ Yes ☐ No

Water Level Serial #: ______________ Water Quality Probe Type and Serial # ______________

WATER QUALITY INDICATOR PARAMETERS

Sampling Stage	Time (military)	Volume Removed (gallons)	Depth to Water (Feet)	Drawdown (Feet)	Temp (°C)	pH (SU)	SEC or Cond. (µs/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	ORP (mV)	Visual Clarity
initial											
purge											

NOTES

ABBREVIATIONS

Cond. - Actual Conductivity
FT BTOC - Feet Below Top of Casing
na - Not Applicable
nm - Not Measured
ORP - Oxidation-Reduction Potential
SEC - Specific Electrical Conductance
SU - Standard Units
Temp - Temperature
°C - Degrees Celcius

NATURAL RESOURCE TECHNOLOGY, INC.
234 W. FLORIDA STREET, 5th FLOOR
MILWAUKEE, WI 53204
TEL: 414.837.3607

CHAIN OF CUSTODY #________

DATE: ____________

PAGE: ________ OF ________

LABORATORY SAMPLES SUBMITTED TO:	CLIENT PROJECT NAME / PROJECT NUMBER / TASK NUMBER:
ADDRESS:	PROJECT CONTACT: / QUOTE NO.:
CITY:	SAMPLER(S): (SIGNATURE)
TEL: / FAX: / E-MAIL	

TURNAROUND TIME

☐ STANDARD ☐ 24 HR 48 ☐ ☐ 72 HR ☐ 5 DAYS

Data Package: Level 2 Level 4

Preservatives: A = none, B= HCL, C = H_2S0_4, D = $HN0_3$, E = methanol, F = Sodium Bisulfate, G = zinc acetate, H = other

Preservation Code (pick letter)

Filtered (Yor N)

REQUESTED ANALYSIS

Method Number and Analytes

SPECIAL REQUIREMENTS

LAB USE ONLY	SAMPLE ID	QC SAMPLE	FIELD COMMENTS	SAMPLE DATE	SAMPLE TIME	MATRIX	SAMPLE TYPE	SAMPLE INTERVAL (ft) TOP	SAMPLE INTERVAL (ft) BOTTOM	#Cont

Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:

MANAGES Tracker Table

Example Type	Site Name	Unit ID	Unit Name	Well	CCR Program Well (Yes/No)	If not CCR Well, List Program (e.g, IEPA)	SampleDate (mm/dd/yyyy)	SampleTime (hh:mm 24hr)	Sample Name Unit ID_Well_Date (mmddyy)	Duplicate Information	Initial (pre-sample collection) Depth to Groundwater (feet)	Stabilized Dissolved Oxygen (mg/l)
Primary Sample	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*18D*	*Yes*		*10/1/2015*	*18:15*	*999_18D_100115*		*4.80*	*5.28*
Duplicate Sample	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*18D*	*Yes*		*10/1/2015*	*18:15*	*999_18D_100115_dup*	*Dup of sample 999_18D_100115*	*4.80*	*5.28*
Dry Well	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*02S*	*Yes*		*10/15/2015*	*7:40*	*NA*			
Equipment Blank	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*Equipment Blank*	*Yes*		*10/2/2015*		*999_EB_100215*			
Trip Blank	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*Trip Blank*	*Yes*		*10/2/2015*		*999_TB_100215*			

MANAGES Tracker Table

Stabilized Oxidation Reduction Potential (millivolts)	Stabilized PH, Field (Standard Units)	Stabilized Specific Conductance, Field (mmhos/cm)	Stabilized Temperature, Water (Degrees Celsius)	Stabilized Turbidity, Quantitative (NTU)	Groundwater Filtered (Yes OR No)?	Laboratory	Sampler Initials	Sampling Company	Comments
212	*7.49*	*0.151*	*10.12*	*7.9*	*Yes*	*Teklab*	*MCW*	*NRT*	
212	*7.49*	*0.151*	*10.12*	*7.9*	*Yes*	*Teklab*	*MCW*	*NRT*	
							MCW	*NRT*	*Well dry, no sample*
					No	*PDC*	*MCW*	*NRT*	*Rinse of bucket*
					No	*TestAmerica*	*MCW*	*NRT*	

Field Calibration Form
Groundwater Quality Meter

Groundwater Quality Meter Manufacturer/Model ______________
Serial Number ____________________
oxidation/reduction potential, dissolved oxygen, pH, tubidity _____

Date of Calibration Check	Calibration Standard Concentration	Calibration Reading	Within +/_ 10% (yes or no)	Comments

APPENDIX C

STANDARD OPERATING PROCEDURES

Prepared By:	MDM/AJS	Date Prepared:	10/29/2015
Corporate Officer:	DPK	Date Approved:	10/30/2015

EPRI MANAGES^{TM} DATABASE DATA FLOW

1.1 Scope and Application

Natural Resource Technology, Inc. (NRT) is committed to continually improving the data flow process to make it efficient and consistent. This Standard Practice establishes policies and procedures specifically concerning streamlining the flow, dissemination, and storage of field and laboratory analytical data tracked and maintained using Electric Power Research Institute's (EPRI) MANAGES groundwater data management software (MANAGES database), and outlines the roles and responsibilities of NRT staff.

MANAGES is only available to clients that contribute to EPRI and the specific program that gives the client access and permission to use MANAGES. It is also important to note that there are various versions of MANAGES available and specific clients may only have access to some versions of MANAGES. **Prior to starting work, it is critical that NRT confirm with the client that they have access to MANAGES and specifically which Version they are allowed to use. NRT will ensure that the version of MANAGES NRT uses is consistent with the version being used by the client.**

1.2 Data Flow System

The Data Flow System was established for streamlining the process of receiving and filing field and analytical data and producing data deliverables. The benefit of this process is the ability to perform quality control checks at several steps during data processing, as well as standardization of electronic and hard copy filing. The data team is in part responsible for the quality control checks, electronic and hard copy filing, data import and production of data tables. The data team is responsible for the implementation of new standards as they apply to data management.

1.3 Definitions

Several terms used in this Standard Practice may not be familiar to all staff that will use this document. The following terms are defined as follows:

- MANAGES Tracker Table – Project-specific table of field and laboratory data compiled by the project team to be used by data group for tracking and importing data.
- Project–specific sampling documents – Documents compiled by the project team used to complete specific tasks. These may include but are not limited to the site-specific work plan, quality assurance project plan (QAPP), construction quality assurance project plan (CQAPP), and sampling summary.
- Import Summary – Report generated by the data group and includes a summary of the laboratory data sample designation groups that were brought into the EPRI MANAGES database.
- Quality Control – Set of procedures to ensure the quality of a service or product. It is a means of checking that samples were collected, analyzed and reported correctly.
- Quality Assurance - Maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production.
- Level 2 Data Verification – Review of analytical data that includes holding times, analytical methods, surrogate recoveries, laboratory control sample recoveries, matrix spike and matrix spike duplicate recoveries and relative percent differences, method blank concentrations and reporting limits.

1.4 Roles and Responsibilities

Numerous individuals have roles and responsibilities in the collection and management of field, analytical and geotechnical data. No roles are more or less important than others and each contribute to the accurate and seamless approach to data management. Quality control is an especially important aspect of the data flow process and each staff member is responsible for some form of quality control. Staff and their responsibilities are described below.

1.4.1 Project Manager (PM)

PMs (or their designee) have responsibilities during all phases of data management which include the following:

- Generate a sampling summary form with a sampling summary matrix for the project-specific sampling documents prior to the sampling event.
- Provide sample summary and anticipated level of QC necessary to Data Team.
- Review updated MANAGES Tracker table (Attachment A) for conformance with the project-specific sampling documents:
  - Within 10 days of the completion of sample collection
  - Again when all analytical data is in-house
- Review import summary report from the data team.
- Define data quality objectives during kick-off meeting to explain roles/responsibilities, data schedules and sampling requirements.

1.4.2 Field Staff

The field staff members for a given sampling event have the following responsibilities:

- Achieve a thorough and complete understanding of sampling and data requirements for the given project prior to mobilizing.
- Collect samples according to the sample summary provided by the PM, project-specific sampling documents, and the approved standard field operating procedures.
- Complete field forms including the chain of custody (COC) and MANAGES Tracker Table.
- Create and maintain a MANAGES Tracker table spreadsheet (Attachment A) according to project-specific sampling documents.
- Send samples and completed COC to the laboratory according to approved field SOPs.
- Complete field documentation of the PDF formats (i.e. field forms, field notes, copy of COC) and of the electronic version of the MANAGES Tracker Table.
- Provide completed documents to PM and Data Team within 10 days of the end of the field sampling event

1.4.3 Data Team

The data team members have the following responsibilities:

- Review the MANAGES Tracker Table when the sample acknowledgment form is received from the laboratory and/or when field documentation is received. The MANAGES Tracker Table is intended to capture all the information required to store data in the MANAGES database.
- Receive electronic data deliverable (EDD) and report from laboratory, review MANAGES Tracker Table, save files on server, and communicate the status of the data to the PM.
- Perform initial QC check on field data (e.g., compare field notes to MANAGES Tracker Table) and notify project manager and field staff via e-mail of initial quality control check results.
- Perform Level 2 data verification (if requested) and communicate results to PM.
- Perform 10% check of EDD against the laboratory report. If errors are found, additional checking will be performed until the Data Team is confident the data is correct.
- Import data from the lab EDD and MANAGES Tracker table to the MANAGES database.
- Send import summary report to the PM.
- Generate requested data deliverables (if necessary).

1.4.4 Quality Control

Quality control is very important in the data flow process and:

- Is not the responsibility of any one person or group
- Is required of all staff members in some form
- Begins at the planning stages of the project and continues until a final report is issued

The Data Team will perform quality control on all field documentation and laboratory analytical results with the following steps:

- Reconcile the laboratory analytical report, the field data, with the provided project-specific sampling documents. Any discrepancies with field documentation or scope of work will be brought to the attention of the appropriate project level (i.e. field staff, project manager) for clarification.

- Perform Level 2 data verification (if requested by PM) of laboratory data integrity and its usability for its intended purpose. Issues regarding laboratory analysis and reporting will be brought to the attention of the project manager and the data team will work directly with the laboratory to resolve the issues.

- Notify NRT project manager regarding data discrepancies (i.e. missing field documentation, missing or late analytical data).

- Complete quality control on the data before import into the analytical database to assure all NRT and project-specific standards are being met.

ATTACHMENT A

MANAGES TRACKER TABLE SPREADSHEET

MANAGES Tracker Table

Example Type	**Site Name**	**Unit ID**	**Unit Name**	**Well**	**CCR Program Well (Yes/No)**	**If not CCR Well, List Program (e.g, IEPA)**	**SampleDate (mm/dd/yyyy)**	**SampleTime (hh:mm 24hr)**	**Sample Name Unit ID_Well_Date (mmddyy)**	**Duplicate Information**	**Initial (pre-sample collection) Depth to Groundwater (feet)**	**Stabilized Dissolved Oxygen (mg/l)**
Primary Sample	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*18D*	*Yes*		*10/1/2015*	*18:15*	*999_18D_100115*		*4.80*	*5.28*
Duplicate Sample	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*18D*	*Yes*		*10/1/2015*	*18:15*	*999_18D_100115_dup*	*Dup of sample 999_18D_100115*	*4.80*	*5.28*
Dry Well	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*02S*	*Yes*		*10/15/2015*	*7:40*	*NA*			
Equipment Blank	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*Equipment Blank*	*Yes*		*10/2/2015*		*999_EB_100215*			
Trip Blank	*Dynegy Power Station*	*999*	*Dynegy Ash Pond No.2*	*Trip Blank*	*Yes*		*10/2/2015*		*999_TB_100215*			

MANAGES Tracker Table

Stabilized Oxidation Reduction Potential (millivolts)	Stabilized PH, Field (Standard Units)	Stabilized Specific Conductance, Field (mmhos/cm)	Stabilized Temperature, Water (Degrees Celsius)	Stabilized Turbidity, Quantitative (NTU)	Groundwater Filtered (Yes OR No)?	Laboratory	Sampler Initials	Sampling Company	Comments
212	*7.49*	*0.151*	*10.12*	*7.9*	*Yes*	*Teklab*	*MCW*	*NRT*	
212	*7.49*	*0.151*	*10.12*	*7.9*	*Yes*	*Teklab*	*MCW*	*NRT*	
							MCW	*NRT*	*Well dry, no sample*
					No	*PDC*	*MCW*	*NRT*	*Rinse of bucket*
					No	*TestAmerica*	*MCW*	*NRT*	

Revised By:	DJV	Date Revised:	01-28-2013
Corporate Officer:	BRH	Date Approved:	05-29-2014

GENERAL FIELD DOCUMENTATION

1.1. Scope and Application

This field procedure is applicable to documentation of data obtained during field activities. Field data are recorded in field notebooks, field forms, and/or field electronic data recorders, providing means for recording all data collecting activities. Field representatives will use concise language for descriptive and detailed field entries to enable field activity reconstruction without reliance on the collector's memory. Refer to the project-specific documents for variances to this SOP.

1.2. Notebooks

Field notebooks are bound books permanently assigned to field personnel. The cover of each notebook will contain the following information:

- Person to whom the book is assigned
- Person’s contact information (phone number and email address)
- Office address and phone number
- Project name
- Project location
- Project number and task (if applicable)
- Book number

If a notebook is transferred to another staff person, notation should be made of the transfer with the date and appropriate signatures. To maintain integrity of the data collection process, bound notebooks must retain all pages; no pages are to be removed.

1.3. Field Forms

Hardcopy or electronic field forms may be used for data collection during field activities. All lines requiring information on the field forms are to be filled out completely. If information cannot be provided for a certain line, notes should be provided on why the information cannot be provided. It is not necessary to duplicate information recorded on field forms in field notebooks. Field notebooks should identify forms that were completed each day, as the forms constitute supplemental records to field notebook.

1.4. Daily Entries

Field measurements, observations, and information pertinent to a field activity is recorded legibly with non-erasable black ink. When weather prohibits using ink, a non-smear lead pencil may be used. Strive for objective, factual entries written in the field while fresh in the memory. The end of each entry and unfilled pages are identified by drawing a diagonal line through unused space on the page with the author's signature.

At the beginning of each daily entry, the following information is recorded:

- Date
- Page number
- Start and end time
- Weather
- Field personnel present
- Level of personal protection equipment required and used
- Signature of the person making the entry
- Any instrument calibration details

At the completion of field activities, scan hardcopy pages and copy electronic information to the appropriate project folder.

1.4.1. Entry Changes

When necessary, make changes to hardcopy entries by crossing a single line through the error in a manner that avoids obscuring the original entry and entering the new information. Initial and date the entry change. If appropriate, note the reason for the change. Do not erase the original entry, and do not obscure so it cannot be read.

1.5. Form and Notebook Management

Scan and/or save field notes, whether hardcopy or electronic, to the project folder **at least** weekly and upon task completion. This step will minimize data loss should forms or notebooks be lost or destroyed.

1.6. References

ASTM D6089Standard Guide for Documenting a Groundwater Sampling Event

USEPA, 2010, Field Branches Quality System and Technical Procedures, Region 4, Science and Ecosystem Support Division, Athens, Georgia, http://www.epa.gov/region4/sesd/fbqstp/

Prepared By:	SGW	Date Prepared:	12-20-2012
Corporate Officer:	BRH	Date Approved:	12-23-2013

SAMPLE LABELING, LOGGING AND STORAGE

0.1. Scope and Application

This standard is applicable to labeling, logging, and storing of analytical environmental media samples including soil, groundwater, surface water, sediment, and air. Proper label procedures are essential to preserve sample identity and tracking. Storage and shipment methods must preserve sample integrity and chain of custody (COC), as well as follow applicable United States Department of Transportation (USDOT), International Air Transport Association (IATA), and carrier-specific regulations and requirements. Shipping samples and equipment is covered in standard operating procedure (SOP) 07-03-09. COC procedures are established to provide sample integrity and are covered in SOP 07-03-03. Refer to the project-specific documents for variances to this SOP.

0.2. Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety procedures when working with potentially hazardous material, preservatives, or with material of unknown origin. Project Health and Safety Plans contain additional practices, if required, to mitigate site-specific hazards.

0.3. Sample Identification

0.3.1. Unique Sample Identification

A unique 9-digit identification code will be assigned to each sample retained for analysis on all United States Environmental Protection Agency (USEPA) sites and on a site-specific basis for other projects as determined by the project manager. This code will be formatted as a number series with the sample month (2-digit), date (2-digit), year (2-digit) followed by a consecutive sample number (3-digit). Example: The first sample collected on December 25, 2012 would be identified as 122512001, as detailed below:

12	25	12	001
Month	**Date**	**Year**	**Consecutive Sample Number**

Consecutive sample numbers will indicate the individual sample sequence in the total set of samples collected during that phase of investigation.

0.3.2. Sample Media

Sample media will be noted on field notes and logs with 2-letter media codes as summarized below:

Air	AS	Air Sparging Point
	GP	Gas Probe
	GM	Gas Monitoring Well
	SV	Soil Vapor Probe
	SS	Sub-Slab Vapor Probe
	IA	Indoor Air Sample
	AM	Ambient Air Sample
	VE	Soil Vapor Extraction Well
Material	AC	Asbestos Containing Material
	LS	Lead Wipe Samples
Sediment	SD	Sediment Sample
Soil	SB	Soil Boring (no monitoring well installed)
	HA	Hand Auger (shallow soil sample)
	TP	Test Pit
	EB	Excavation Base Sample
	EW	Excavation Wall Sample
Water	MW	Monitoring Well
	PZ	Piezometer
	PW	Potable Well
	RW	Recovery Well
	TW	Temporary Monitoring Well
	SW	Surface Water Sampling
	SG	Surface Water Staff Gauge

0.4. Sample Labeling

Affix a non-removable, water-resistant label to the body of each container. The label will stick to a clean dry sample container much easier than a dirty wet container. Place the label on the sample container before sampling. The following information will be written on the label with indelible ink that will not smudge when wet:

- Project Number
- Sample ID
- Date of sample collection
- Time of sample collection (military time)
- Sampler initials
- Preservative (if applicable) or None
- Requested laboratory analyte(s)

0.5. Sample Logging

Thorough and accurate record keeping is achieved by completing field note and/or logbook entries during the sample process as data are collected. If possible, one person should be responsible for logging samples for consistency.

0.5.1. Sample Control Log

When using unique sample identification (Section 1.3.1), all samples will be logged daily on a sample control log (Attachment A), which will be stored in the project data files. Sample control logs will provide data entry columns and space for each sample for the following information:

- Sample ID
- Sample media (see Section 1.3.2)
- Sample location

- Sample depth or sample interval
- Analyte(s) requested
- COC number
- Analytical laboratory
- Miscellaneous notes (low sample volume, sample not submitted, etc.)

0.5.2. Sample Chain of Custody

Sample chain-of-custody will be in accordance with SOP 07-03-03. Chain of Custody records will be kept with the analytical laboratory reports in the project files.

0.6. Sample Storage

- Collect samples in the appropriate container with labels then place samples to be retained for chemical analysis into re-sealable plastic bags.
- Place bagged samples in coolers with bagged ice or other cooler devices (e.g., refrigerator) to reach and maintain required analytical preservation temperatures (typically 4 degrees Centigrade (^{o}C) +/- 2 °C).
- Complete a COC for all samples and keep with the samples in the specific cooler.
- Maintain coolers with fresh ice and periodically drain excessive melt water.
- Use signed and dated COC seals on the cooler lid when shipping the samples and when the samples are no longer in the sampler’s possession.
- Ship samples daily (if possible) or have the laboratory courier pick samples up daily. Ship samples in accordance with SOP 07-03-09.
- Maintain appropriate COC on coolers and other sample storage containers in accordance with SOP 07-03-03.

0.7. References

ASTM Standard D3694, 1996 (2004), “Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents,” ASTM International, West Conshohocken, PA, 2004, DOI: 10.1520/D3694-96R11, www.astm.org

ASTM Standard D4220, 1995 (2007), “Standard Practices for Preserving and Transporting Soil Samples,” ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/D4220-95R07, www.astm.org

ASTM Standard D4840, 1999 (2010), “Standard Guide for Sampling Chain of Custody Procedures,” ASTM International, West Conshohocken, PA, 2010, DOI: 10.1520/D4840-99R10, www.astm.org

ATTACHMENT A

SAMPLE CONTROL LOG

Project Name: ____________________ Analytical Laboratory: ____________________

Project ID: ____________________ Geotechnical Laboratory: ____________________

Task ID: ____________________ Field Staff ID(s): ____________________

Month (2-digit)	Date (2-digit)	Year (2-digit)	Sample Number (3-digit)	Unique Sample ID	Sample Media	Sample Location	Sample Depth (feet)	QC Sample Information (duplicate, blank, etc...)	COC Number	Notes (turnaround time, handling notes

Reviewed By:	KJB	Date Reviewed:	10-29-2012
Corporate Officer:	BRH	Date Approved:	06-25-13

CHAIN-OF-CUSTODY

1.1. Scope and Application

This field procedure outlines chain-of-custody procedures to record sample data and maintain sample integrity. A chain-of-custody (COC) form is a legal document used to track sample custody from sample collection to sample delivery at the laboratory. The procedures ensure the integrity of the sample from collection to data reporting. Refer to the project-specific documents for variances to this SOP.

1.2. Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3. Sample Custody

Samples collected must be maintained under secure conditions and documented through COC procedures. As few people as possible should be part of the COC. A sample is under a person's custody if the following requirements are met:

- The sample is in the person's possession.
- The sample is in the person's view after being in the person's possession.
- The sample is in a secured location after being in the person's possession.

1.4. Chain-of-Custody Procedures

Field staff are responsible for the custody of samples until custody is transferred. Sample containers will be identified, tagged, handled, and transported in accordance with SOP 07-03-05. All samples must be accompanied by a COC form at all times and a separate COC will be generated for each sampling event and site.

When transferring the possession of samples, the individual relinquishing the sample will sign the "relinquished from" line on the COC. If a team is involved in the sample collection, only one team member is required to sign the COC. The receiving individual will then sign the COC, noting the date and time the samples were received. This record documents the transfer of sample custody from the sampler to another person.

The original record must accompany the sample shipment. A copy of the COC will be retained to document the transfer of custody. The hard copy will be scanned and saved in the master project file under Electronic Data Submittals (e.g., P:/1549/Electronic Data Submittals/October 2112).

1.4.1. Chain-of-Custody Errors

Erroneous information may not be erased on the COC. Errors will be lined out and initialed, and the correction written in a manner to not obscure the error.

1.5. Commercial Shipping

The COC will be maintained when using a commercial shipper (e.g., Fedex, UPS) without the carrier signing the COC. The COC will be signed for release custody, sealed in a plastic bag (e.g., one-gallon freezer Ziploc® bag), taped to the inside of the cooler lid, and seal inside. Note that nothing is written in the "received by" section of the COC at this time. The carrier's established custody documentation procedure is used to verify custody during transportation. Shipping receipts, including tracking numbers, should be scanned and saved in the project file.

A minimum of two custody seals on the outside of the coolers are required. Custody seals shall be affixed to the top and side of the cooler and contain the following information: date, signature, and unique ID number. The unique ID numbers are recorded on the COC associated with the same container. The custody seal should be secured beneath the shipping tape so the container cannot be opened without breaking the seals. The shipping containers should be marked "THIS END UP," and arrow labels indicating the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and receiving laboratory shall be placed on the outside of the container.

1.5.1. Multiple Cooler Shipments

If the samples are shipped in more than one container, a separate COC is required for each container. The COC must only list the samples that are within the associated container.

1.6. References

ASTM D4840-99(2010) Standard Guide for Sampling Chain-of-Custody Procedures.

ASTM D6911-03(2010) Standard Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

USEPA, Field Branches Quality System and Technical Procedures, Region 4, Science and Ecosystem Support Division, Athens, Georgia, http://www.epa.gov/region4/sesd/fbqstp/

Reviewed By:	RJG	Date Reviewed:	05-24-2012
Corporate Officer:	BRH	Date Approved:	12-23-2013

SAMPLE LOCATION IDENTIFICATION AND CONTROL

1.1. Scope and Application

This field procedure describes identification of sample locations for water levels, geological samples, and physical dimensions frequently required during field activities. Samples collected from each location will have a unique sample identifier in accordance with SOP 07-03-01. Refer to the project-specific documents for variances to this SOP.

All sampling locations shall be uniquely identified and depicted on an accurate drawing, topographic map, or other type of site illustration. Sampling locations should be referenced so their location(s) are established and reproducible. A sample location must be identified by a coordinate system or other appropriate procedures outlined in SOP-07-03-07 that would enable an independent investigator to reproduce sample collection from the same location(s).

1.2. Sample Location Identification

Sample locations are assigned alphanumeric codes, which are used to coordinate laboratory data tracking and graphic depiction of sample locations on drawings and figures. Each sample location is issued a unique numeric code that corresponds to a specific map location on a plan view of a site. An alpha-code (letter) is used to describe the type of sampling activity performed at the specific numeric location.

The following 2-letter media codes will be used:

Air	AS	Air Sparging Point
	GP	Gas Probe
	GM	Gas Monitoring Well
	SV	Soil Vapor Probe
	SS	Sub-Slab Vapor Probe
	IA	Indoor Air Sample
	AM	Ambient Air Sample
	VE	Soil Vapor Extraction Well
Material	AC	Asbestos Containing Material
	LS	Lead Wipe Samples
Sediment	SD	Sediment Sample
Soil	SB	Soil Boring (no monitoring well installed)
	HA	Hand Auger (shallow soil sample)
	TP	Test Pit
	EB	Excavation Base Sample
	EW	Excavation Wall Sample
Water	MW	Monitoring Well
	PZ	Piezometer
	PW	Potable Well
	RW	Recovery Well
	TW	Temporary Monitoring Well
	SW	Surface Water Sampling
	SG	Surface Water Staff Gauge

A typical series of alphanumeric codes for a site might include test pit locations TP01 through TP12; borings SB01, SB02, SB03; and monitoring wells MW01, MW02, MW03.

Each sample location will have only one alphanumeric code. A borehole drilled for installing a monitoring well will be identified as MW. There should not be both an SB identifier for a soil sample and an MW identifier for a groundwater sample.

Note that soil borings performed for collecting a groundwater grab sample (e.g., through screened auger, open borehole, Geoprobe®, or Hydro-Punch®) are identified as soil borings, not monitoring wells. These types of sampling locations may be further identified on site figures with a clarifying suffix (GW), such as SB01 (GW). The site map legend will explain the meaning of all symbols used to identify sampling points.

If previous work has been performed at a site, the alphanumeric code should continue with previous successive numbers. If there is any potential for conflict with existing sample number identifiers, the proposed sample number should begin with series 101, 1001, or other appropriate system. Dashes should be eliminated from sample number identifiers. For example, SB101 should be used instead of SB-101.

When applicable, sample location identifications must be identical to sample locations entered into a database of analytical results. A sample control log, if completed (SOP 07-03-01), is a good place to track sample location identification information that can be used for entering analytical results into the database and/or post-processing GPS location information.

1.3. References

USEPA, 2007, Field Branches Quality System and Technical Procedures, Region 4, Science and Ecosystem Support Division, Athens, Georgia, http://www.epa.gov/region4/sesd/fbqstp/

Prepared By:	SGW	Date Prepared:	11-29-2012
Corporate Officer:	BRH	Date Approved:	11-22-2013

PACKING AND SHIPMENT OF ENVIRONMENTAL SAMPLES AND EQUIPMENT

1.1. Scope and Application

This field procedure outlines standard methods for packing (and labeling of the package) and shipping of environmental samples (e.g., soil, groundwater, surface water, sediment, and air) and field equipment. Packing and shipment methods must preserve sample integrity and chain of custody (COC), as well as follow applicable United States Department of Transportation (USDOT), International Air Transport Association (IATA) and carrier-specific regulations and requirements.

The procedures contained in this document are to be used by field personnel when packing and shipping environmental samples and dangerous goods by ground or air transport via UPS or FedEx or similar carrier. However, most packing procedures will also pertain to samples shipped by a lab courier. Samples collected during field investigations must be classified prior to shipment, as either environmental or dangerous goods samples. This standard operating procedure (SOP) cannot cover all packaging and shipping circumstances. Please refer to DOT and IATA references for comprehensive packing and shipping instructions for packing and shipping requirements not covered by this SOP.

1.2. Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards. In addition to handling sampling media, great care should be exercised when handling sample preservatives because they are typically concentrated acids or bases and may cause harm if accidentally ingested, inhaled, or if they come in contact with the skin.

1.3. Sample Transportation

This field procedure does not address transportation of hazardous waste. Samples of hazardous waste are exempt from hazardous waste regulations, however samples may still be considered as a dangerous good and subject to appropriate regulations when transported by air. NRT staff shall avoid the shipment of samples by air transport whenever possible. To the extent feasible, arrangements should be made with laboratories for sample pick-up on site by the laboratory's courier service or a service contracted by NRT. The need for such services should be considered and budgeted for at the project proposal stage.

Environmental samples collected by NRT will not be transported on public transportation systems (e.g., buses, ferries, and passenger aircraft) or by the United States Postal Service unless authorized by the project manager and a person with up to date training. Sample media collected during field activities may meet regulatory definitions for hazardous materials and/or dangerous goods. Staff shall strictly comply with all regulations involving the shipment of hazardous and/or dangerous goods. Both USDOT and IATA regulations require that personnel receive training if they are involved in packaging, labeling, and/or shipping hazardous materials and dangerous goods. Therefore, shipment of hazardous materials and dangerous goods must be performed by individuals with up to date training. Training is required by IATA every 24 months.

The shipment of the following unpreserved samples is typically not regulated:

- Drinking water
- Groundwater
- Soil
- Sediments
- Treated effluent
- Biological samples
- Surface water

The shipment of the following preserved samples is also not regulated provided the amount of preservative used does not exceed the amounts found in 40 Code of Federal Regulation (CFR) 136.3 which states:

"For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials:

- Hydrochloric acid (HCL) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater)
- Nitric acid (HNO3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater)
- Sulfuric acid (H2SO4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater)
- Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less)

Typical pre-preserved sample containers received from a laboratory do not exceed the aforementioned amounts of preservatives. As related to typical NRT work, the aforementioned preservatives pertain to but are not limited to samples collected for volatile organic compounds (VOCs) (HCL), metals (HNO_3), nitrite + nitrate nitrogen, oil and grease, total kjeldahl nitrogen (H_2SO_4), sulfide (zinc acetate/NaOH) and cyanide (NaOH).

- Drinking water
- Groundwater
- Treated effluent
- Surface water

The shipment of soil and sediment samples preserved by USEPA Method 5035 methanol or sodium bisulfate are subject to varying degrees of shipping regulations. Three levels of regulations apply depending on type and quantity of preservative used and method of sample packaging. These regulations are summarized as follows:

- Small quantity exception - (< 30 milliliters (mL) inner containers [VOC vials]), *not subject* to Hazardous Material Regulations (HMR) provided the package is in accordance with 49 CFR 173.4 (small quantity exceptions)

- Limited quantity DOT hazardous material--must meet regulatory requirements minus UN specification containers (49 CFR 172.700 training applies)

- Fully regulated DOT hazardous material—Limited Quantity exception not taken, package must be in *full* compliance with HMRs (49 CFR 172.700 training applies)

Note: DOT regulations associated with the use of preservatives in the field may be avoided by using Encore™ or Terracore samplers when collecting soil samples (these methods do not require preservation with methanol or sodium bisulfate).

1.3.1. Shipment as a Small Quantity Exception (49 CFR 173.4)

The DOT small quantity exception described in 49 CFR 173.4(a)(1)(i) states that the maximum quantity of material per inner container is limited to 30 mL for authorized liquids, other than Division 6.1,Packing Group I materials (i.e., poisons). As applied to the preservatives of Method 5035, if there is less than or equal to 30 mL of methanol or aqueous sodium bisulfate solution per inner container (VOC vials), this material is not subject to any other requirements of the hazardous materials regulations except those presented in 49 CFR 173.4. Typically, soils are preserved with 10 mLs of methanol or sodium bisulfate. However, aside from the 30 mL receptacle limit, there are additional restrictions:

- Each inner receptacle with a removable closure (cap), has its closure held securely in place (tape the cap).

- Unless equivalent cushioning and absorbent material surrounds the inside packaging, each inner receptacle is securely packed in an inside packaging with cushioning (bubble wrap) and absorbent material that will not chemically react with other material and is capable of absorbing the entire contents (if liquid) of the receptacle (sorbent pads placed in the bottom of the cooler).

- The inside packaging is securely packed in a strong outside packaging (typical plastic cooler).
- The completed package, as demonstrated by prototype testing, is capable of sustaining each of the following free drops made from a height of 1.8 meters (5.9 feet) directly onto a solid unyielding surface without breakage or leakage from any inner receptacle and without a substantial reduction in the effectiveness of the package.

The gross mass of the completed package must not exceed 29 kg (64 pounds). The package must not be opened or otherwise altered until it is no longer in commerce (chain of custody seals). The shipper must indicate on the airway bill under nature and quantity of goods: *Dangerous Goods in Excepted Quantities.* IATA also requires the application of an ***excepted quantities label****.* Refer to Attachment A of this SOP for an example of the excepted quantities label. This label should contain the certification language identified above.

Label entries include shipper signature, title, date, address, and indication of the hazard class and associated UN number. The United Nations (UN) number for methanol is 1230, Class or Division 3, sub risk 6.1 and is a flammable liquid. The UN number for sodium bisulphate is 2837, Class or Division 8, and is a corrosive.

While 49 CFR 173.4 does not have a total net quantity limitation, IATA Dangerous Goods Regulations (DGR Section 2.7.4.2) *does.* For packing group II materials (e.g., methanol and sodium bisulfate), the total net quantity limit is one (1) L. This equates to 100 inner containers (VOC vials) containing approximately 10 mL of material per outer package (i.e., sample cooler).

When discussing the shipment of DOT hazardous materials in the air mode, shippers have additional restrictions that are identified in Columns 9A/9B of the 49 CFR 172.101 hazardous materials table. Net quantity limits for methanol for passenger and cargo aircraft are one (1) liter and sixty (60) liters, respectively. The net quantity limits for aqueous sodium bisulfate solutions are one (1) liter and thirty (30) liters, respectively. Shippers should note that these quantities exceed the IATA small quantity exception. **Therefore, if preservative volume (methanol or sodium bisulfate solution) is less than 30 mL per VOC vial (inner container) and the total net quantity per cooler (outer package) is limited to one (1) L, DOT HMRs or IATA DGR's quantity limits are not an issue provided packaging conforms with 49 CFR 173.4.**

NRT samplers should strive to ship methanol or aqueous sodium bisulfate preserved samples by laboratory courier and not by air. NRT samplers should without exception package methanol and aqueous sodium bisulfate preserved samples to take advantage of the small quantity exception if shipment by air is unavoidable. NRT personnel must follow all applicable packaging, labeling, and shipping conditions as described above. Limited quantity and fully regulated DOT hazardous material shipping are not included in this SOP. For shipping quantities, samples, or materials not discussed above, or if there is any question regarding a shipment, refer to IATA, Dangerous Goods Regulations. Copies are located in the NRT office.

1.3.2. Other Dangerous Goods

Listed below are a few common dangerous goods used in environmental sampling that requiring special handling/shipping. Note this is **NOT** a complete list.

- Dry ice
- Lithium batteries
- Isobutylene compressed gas (PID calibration gas)

If any of these items are to be shipped, refer to the following:

Dry ice – Dry ice is sometimes used to freeze samples during shipment to the laboratory. Dry ice is forbidden for shipment on passenger aircraft. The following permanent markings are required on the outer packaging of all IATA dry ice shipments:

- Dry Ice or Carbon Dioxide Solid
- UN 1845
- Net weight of dry ice in kilograms
- Name and address of the shipper
- Name and address of the recipient

- Class or Division 9
  - Hazard – Miscellaneous

An IATA Class 9 Miscellaneous label must appear on all dry ice shipments. Refer to Attachment B of this SOP for an example Dry Ice label.

Lithium batteries – Lithium batteries are commonly used in devices like mobile phones, laptops, PDAs, cameras, photoionization detectors, and landfill gas meters. The two main types of lithium batteries are lithium metal (primary non-rechargeable) and lithium ion (rechargeable). They are Class or Division 9, Hazard–Miscellaneous and Packing Group II. UN numbers are as follows:

- UN 3480, Lithium ion batteries
- UN 3481, Lithium ion batteries packed with equipment
- UN 3481, Lithium ion batteries contained in equipment
- UN 3090, Lithium metal batteries
- UN 3091, Lithium metal batteries packed with equipment

To comply with Section II IATA shipping requirements, shipments containing lithium batteries and cells must comply with specific packaging guidelines.

- Ensure that lithium batteries are individually packaged in fully enclosed inner packaging such as a plastic bubble wrap or pasteboard to provide protection for each battery.
- Shield and protect lithium batteries to prevent short circuits or contact with conductive materials within the packaging that could cause short circuits.
- Ensure that packaging is proven (i.e., tested) to meet the requirements of each test in the UN Manual of Tests and Criteria, Part III, Sub-Section 38.3.
- Make sure that lithium batteries are completely enclosed (such as in equipment or surrounded by plastic with void space filled to prevent movement), except when the proper shipping names end with “contained in equipment.”

- Place contents in a sturdy outer container (hard shell pelican case, plastic cooler or heavy-duty cardboard box).
- Provide correct labeling and documentation. Refer to Attachment C for example labels.

Isobutylene compressed gas (PID calibration gas) - Isobutylene is UN number 1055, Class or Division 2.1, Hazard – Flammable gas. Isobutylene compressed gas is forbidden for transport by air. It is **not permitted** as an excepted quantity. Compressed gas needs to be transported by ground transport, only. Refer to Attachment D for an example label.

1.3.3. Packaging for Shipment

All samples shipped via commercial carrier will meet the minimum requirements listed below whether or not they are regulated by USDOT or IATA. The objectives of basic sample packaging are to ensure sample containers do not break and to prevent liquid leaking from the outer packaging from sample container breakage, condensation, or melted ice. **(If you ship a cooler and it leaks anything, it will sit where it leaked until we pick it up!)**

- Maintain COC procedures and documentation in accordance with SOP 07-03-03. Write the carrier's name in the received column and any associated tracking number used by the carrier (e.g., FedEx or UPS air bill numbers).
- Select a sturdy cooler in good condition. Cooler size should be chosen to allow sufficient volume for packing material, samples, and ice without exceeding a weight the average person is capable of lifting and the standard weight limits for commercial carriers. Multiple coolers may be used for sample shipments.
- Close and secure the drain plug (inside and outside of cooler) with duct tape or similar material.
- Place a water absorbent pad on the bottom of the cooler and place a layer of inert cushioning material, such as bubble pack, on top of the absorbent pad.
- Line the cooler with two large heavy-duty plastic bags of sufficient size so that the full depth of the cooler may be used without exceeding the capacity of the bags.
- Place samples inside the liner bags so that at least ½ of the cooler volume is available for the placement of ice. Recommended practices for packing are summarized below:

- Place all glass containers in separate and appropriately sized bubble bags/wrap or foam blocks. Pack samples with sufficient inner packaging to ensure containers do not bump each other or move freely during transportation.
- To prevent labels from getting saturated during transportation, place sample container in a single sealable plastic bag (e.g., a one-gallon freezer Ziploc® bag). Multiple sealable bags may be used if all containers from a sample location will not fit in a single bag. The exception is VOA vials for VOC analysis. If more than one cooler is used for storage and/or shipping, all VOA vials must remain in a single cooler with the trip blank vials or the project must maintain separate cooler trip blanks. **(To limit the cost of analysis of multiple trip blanks always put all the VOCs as in one cooler, if possible without exceeding limitations above. Thus requiring only one trip blank analysis.)**
- Place bottles inside the plastic bags lining the cooler with those for volatile organic analysis towards the center of the cooler. Sample containers should not exceed 50 percent of the cooler volume.
- As a courtesy to the laboratory please ensure the sample containers have been decontaminated (if necessary) before shipment. Try not to send grossly contaminated bottles and jars to the laboratory.

- Place loose ice (do not use "blue ice") in re-sealable heavy-duty plastic bags (e.g., a one-gallon freezer Ziploc® bags). Place bagged ice in between and on top of the samples. At packing completion, cooler should be approximately 50% ice, by volume. Coolers should be completely filled so that samples do not move excessively during shipping; Twist and tie the large plastic bags used to line the coolers.

- Place COC records in a clear sealable plastic bag (e.g., one-gallon freezer Ziploc® bag) and either tape the bag to the inside of the cooler lid or lay it on top of the sealed liner bags. If the samples are shipped in more than one cooler, place a copy of the COC records in each cooler. Label the COC record copies in the coolers to reflect the total number of coolers.

- Affix at least two COC seals to the top and sides of the cooler so that the cooler cannot be opened without breaking the COC seals. Sign the custody seal with an indelible marker and cover the seal with transparent tape.

- Securely tape the top of the cooler shut with packing tape.

- Place laboratory label address on the cooler. Commercial carrier insurance for recollection of all samples will be taken on all carrier waybills.

- Wrap the cooler with strapping tape in two or more locations to secure lid.

- Place “Fragile” and “This Side Up” labels (or similar) on at least two sides of the cooler.

- **Labels used in the shipment of hazardous materials** (e.g., Cargo Only Air Craft or Flammable Solids) **are not permitted** on the outside of the container used to transport environmental samples, unless the material is classified and handled as a hazardous material for shipping.

- Retain a copy of the shipping waybill and attach the copy to the master file COC documentation.

1.4. References

ASTM International, D3694-96(2004) Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents

ASTM International, D4220-95R00 Practices for Preserving and Transporting Soil Samples

ASTM International, D6911-03 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

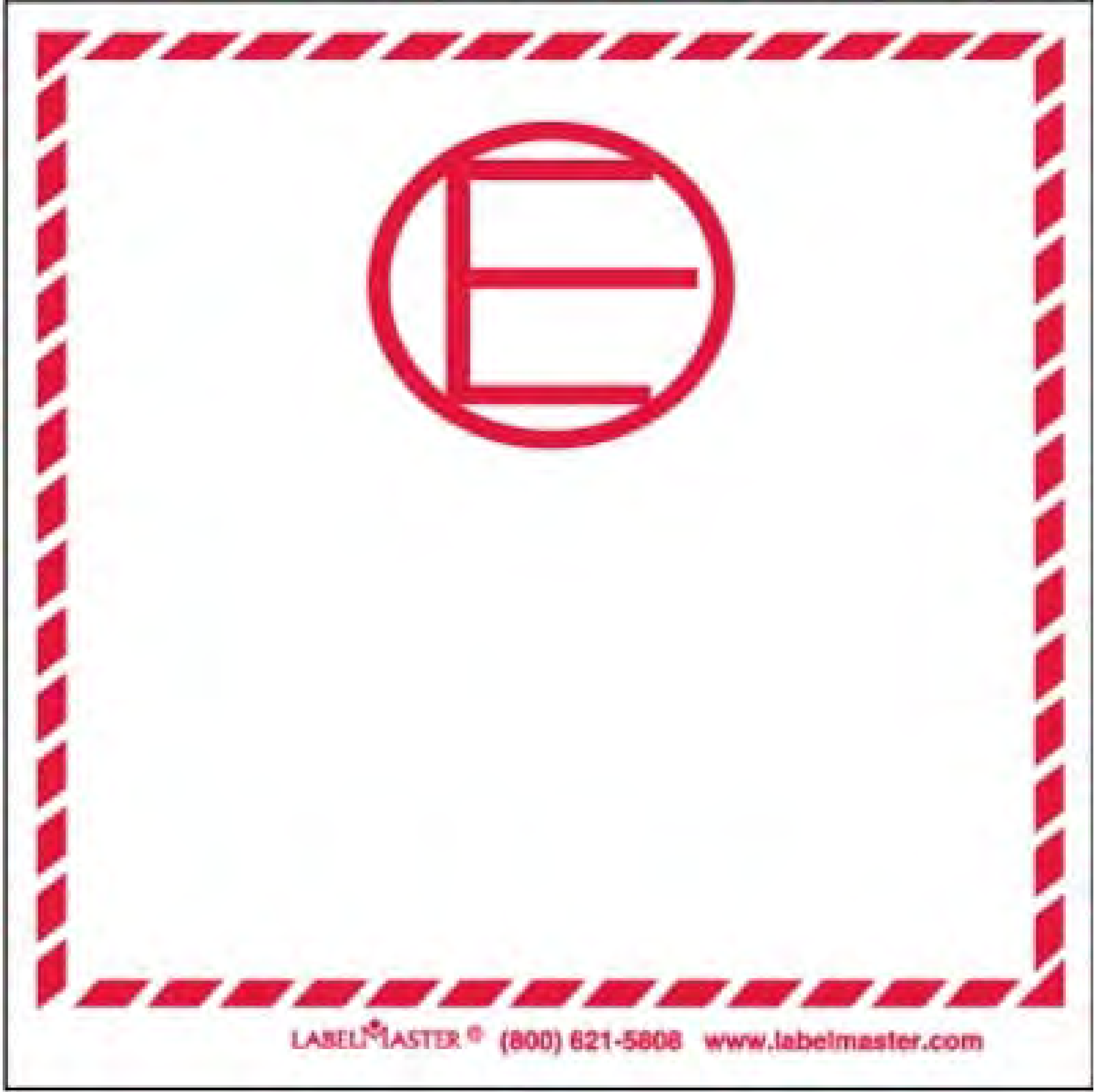
International Air Transport Association (IATA), 2012, Dangerous Goods Regulations.

USDOT, 49 CFR Parts 100 to 185

USEPA, 1981, Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples, Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

ATTACHMENT A

EXCEPTED QUANTITY LABEL


LABELMASTER ® (800) 621-5808 www.labelmaster.com

ATTACHMENT B

DRY ICE LABEL

Shipper's Declaration not Required

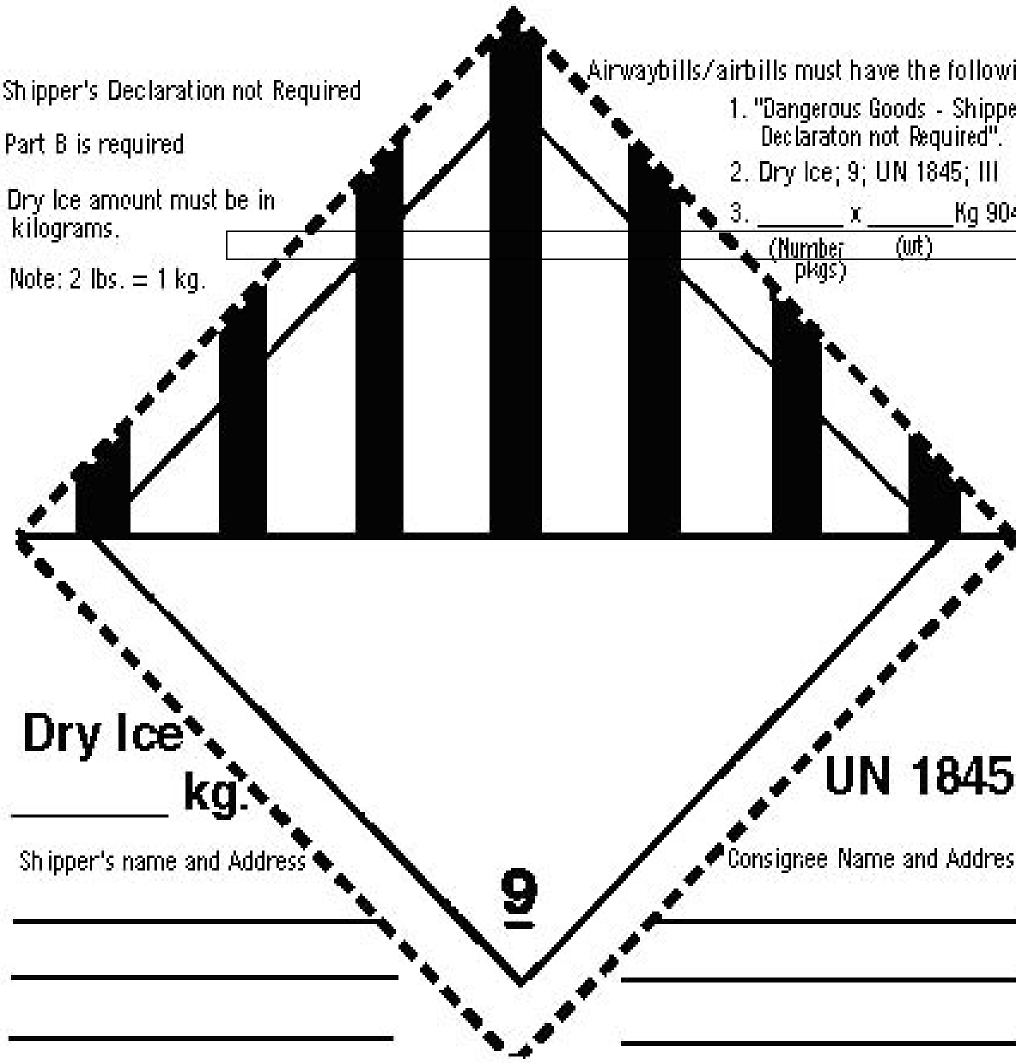
Part B is required

Dry Ice amount must be in kilograms.

Note: 2 lbs. = 1 kg.

Airwaybills/airbills must have the following:

1. "Dangerous Goods - Shipper's Declaraton not Required".
2. Dry Ice; 9; UN 1845; III
3. _______ x _______Kg 904
   (Number pkgs) (wt)



Dry Ice

________ **kg.**

UN 1845

Shipper's name and Address

____

____

____

Consignee Name and Address

____

____

____

ATTACHMENT C

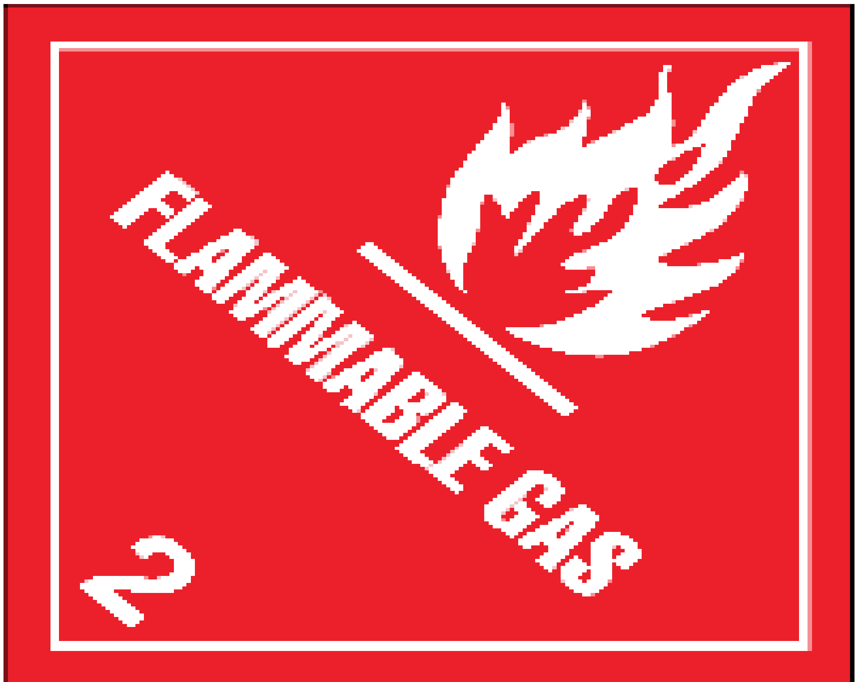
LITHIUM ION SHIPPING LABELS


CAUTION !
IF DAMAGED
Lithium Ion battery
DO NOT LOAD OR TRANSPORT
PACKAGE IF DAMAGED
For more information, call


CAUTION!
IF DAMAGED
LITHIUM ________ BATTERY
DO NOT LOAD OR TRANSPORT
PACKAGE IF DAMAGED
For more information, call

ATTACHMENT D

COMPRESSED GAS LABEL



COMPRESSED GAS N.O.S.
UN 1954

Reviewed By:	JJW/SLM	Date Reviewed:	08/20/2012
Corporate Officer:	BRH	Date Approved:	06/25/2013

SAMPLE VOLUMES, CONTAINERS, PRESERVATION, AND HOLDING TIMES

1.1 Scope and Application

This standard is applicable to the use of sampling containers and preservatives provided by a contracted analytical laboratory in quality-controlled containers. The general requirements forample containers, preservatives, and analytical holding times are discussed below. Refer to the project-specific documents for variances to this SOP.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3 Sample Volumes

Sample volume requirements are determined by the laboratory based on the required analysis. Field staff should prepare for the possibility of collecting additional samples by ordering several spare sample containers for each analysis. The number of spare sample containers to bring to the site is dependent on the task and is at the discretion of the project manager. Field staff should carry a minimum of 1 extra container for every 10 samples to be collected.

In the event that there are no available laboratory-prepared sample containers on site and additional sampling is necessary, the project manager shall be contacted to determine whether it is appropriate to collect a sample. In such instances, the volume of sample obtained should be sufficient to perform all required analyses with an additional amount collected to provide for quality control needs, split samples, or repeat examinations. The laboratory receiving the sample should be consulted to determine specific volume requirements. Sample volumes collected from waste sources at hazardous waste sites or samples from sources known to be toxic should be kept to a minimum.

The sample volume required for each analysis is the volume of the standard container provided by the laboratory less empty space required for sample mixing by laboratory personnel and safe shipment of samples to the laboratory. Allow a minimum of ten percent empty space in every sample container with the exception of samples collected for purgeable organic analyses (volatile organic compounds [VOCs]) or dissolved gases such as sulfides for which sample containers must be completely filled.

1.4 Selection and Proper Preparation of Sample Containers

The type of sample container is dictated by the analyses required. Selection and preparation of sample containers will be performed by the analytical laboratory. All sample containers provided by the laboratory will be shipped with chain-of-custody records. Field personnel shall inspect all sample containers prior to commencing field activities to ensure container seals, labels, and preservatives meet COC, sample labeling, packing, and shipping requirements.

1.5 Sample Preservation

Samples for some analyses must be preserved and the preservatives will be supplied by the laboratory. In most instances, containers will be provided with preservatives already pre-measured inside the bottle. In such cases, labels will indicate preservative and likely be sealed; these containers are not rinsed prior to filling with sample.

All samples requiring preservation should be preserved immediately upon collection in the field. However, exceptions may be made when addition of a preservative may have an unknown or potentially dangerous effect, for example:

- Samples collected within a hazardous waste site that are known or thought to be highly contaminated with toxic materials. Barrel, drum, closed container, spillage, or other source samples from hazardous waste sites are not to be preserved with any chemical. These samples may be preserved by placing the sample container on ice, if necessary.

- Samples that have extremely low or high pH or samples that may generate potentially dangerous gases when preservatives are added.

All samples preserved with chemicals shall be clearly identified by indicating on the sample tag that the sample is preserved. If samples normally requiring preservation were not preserved, field records shall indicate why.

1.6 Sample Holding Times

The elapsed time between sample collection and initiation of laboratory analyses must be within the prescribed "holding time" for each analysis to be performed as defined by the analytical method, USEPA, ASTM International, and/or laboratories. Holding times for each analytical method must be confirmed with the contracted laboratory prior to sample collection.

1.7 References

ASTM Standard D3694, 1996 (2011), "Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents," ASTM International, West Conshohocken, PA, 2011, DOI: 10.1520/D3694-96R11, www.astm.org.

ASTM Standard D4841, 1988 (2008), "Standard Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents," ASTM International, West Conshohocken, PA, 2008, DOI: 10.1520/D4841-88R08, www.astm.org.

ASTM Standard D5903, 1996 (2006), "Standard Guide for Planning and Preparing for a Groundwater Sampling Event," ASTM International, West Conshohocken, PA, 2006, DOI: 10.1520/D5903-96R12, www.astm.org.

ASTM Standard D6517, 2000 (2012)e1, "Standard Guide for Field Preservation of Ground-Water Samples," ASTM International, West Conshohocken, PA, 2012, DOI: 10.1520/D6517-00R12E01, www.astm.org.

Reviewed By:	JJW/SLM	Date Reviewed:	08/21/2012
Corporate Officer:	BRH	Date Approved:	06/25/2013

QUALITY CONTROL SAMPLES

1.1 Scope and Application

This procedure describes the collection of quality control (QC) samples. QC samples are used to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness, and comparability of data obtained during investigative activities. Refer to the project-specific documents for variances to this SOP.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3 Equipment and Materials

Equipment and materials for the collection and analysis of quality control samples shall be identical to those used for the collection and analysis of the investigative samples of the same medium and collection method.

1.4 Types of Quality Control Samples

QC samples include field duplicate samples, matrix spike (MS) and matrix spike duplicate (MSD) samples, trip blanks, field blanks, and equipment blanks.

1.4.1 Field Duplicate Samples

Field duplicate samples are collected from various media to evaluate the representativeness and comparability of data obtained during investigative activities. Field duplicate samples shall be collected at the same time, using the same procedures and equipment, and in the same types of containers as the original samples. They shall also be preserved in the same manner and submitted for the same analyses as the original samples. The minimum/required frequency of field duplicate sample collection for each sample media shall be specified in the Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and/or other site-specific documents.

1.4.2 Matrix Spike and Matrix Spike Duplicate Samples

Matrix Spike and Matrix Spike Duplicate (MS/MSD) samples are collected to evaluate the effect of sample matrix on analytical results and the precision and accuracy of laboratory procedures. As with field duplicate samples, MS/MSD samples shall be collected at the same time, using the same procedures and equipment, and in the same types of containers as the original samples. They shall also be preserved in the same manner and submitted for the same analyses as the original samples. The minimum/required frequency of MS/MSD sample collection for each sample media shall be specified in the QAPP, FSP, and/or other site-specific documents.

1.4.3 Trip Blanks

Trip blanks are used to detect contamination that may be introduced in the field or during transit, bottle preparation, sample log-in, or sample storage within the laboratory. Trip blanks also reflect contamination that may occur during the analytical process. Trip blanks are samples of reagent-free water, properly preserved, which are prepared by the analytical laboratory in a controlled environment prior to field mobilization. Trip blanks are kept with the laboratory-provided containers through the sampling process and returned to the laboratory with the other samples being submitted for volatile organic compound (VOC) analysis. Trip blanks must be used for samples intended for VOC analysis and are preserved and analyzed for VOCs. One trip blank will accompany each cooler containing samples for VOC analysis or as specified in the QAPP, FSP, and/or other site-specific documents.

1.4.4 Equipment Blanks

Equipment blanks are also referred to as rinsate blanks or equipment rinsates. Equipment blanks are used to determine if non-dedicated equipment decontamination procedures are sufficient and there is no "carryover" from one sample to another, and may be used to determine if dedicated equipment is free of measurable concentrations of constituents of potential concern. Equipment blanks shall be collected by pouring distilled or deionized (DI) water onto or into the sampling equipment and directly filling the appropriate sample containers with the water that has contacted the sampling equipment. Equipment blanks are always collected after sampling equipment has been decontaminated and may be performed prior to collecting the first sample, after collecting highly impacted samples, and/or at the conclusion of sampling. After collection, equipment blanks are handled and treated in the same manner as investigative samples, unless noted otherwise in site-specific documents. The minimum/required frequency of equipment blanks for each sample media shall be specified in the QAPP, FSP, and/or other site-specific documents.

1.4.5 Field Blanks

Field blanks are used to determine potential for contamination of a sample by site contaminants from a source not associated with the sample collected (e.g. air-borne dust or high concentration volatiles in air from a source not related to the samples). Field blanks shall be collected by pouring distilled or ultrapure/DI water directly into the appropriate sample containers at pre-designated locations at the site. They shall also be preserved in the same manner and submitted for the same analyses as investigative samples. After collection, equipment blanks are handled and treated in the same manner as investigative samples, unless otherwise noted in the site-specific documents. The minimum/required frequency of equipment blanks for each sample media shall be specified in the QAPP, FSP, and/or other site-specific documents.

1.5 Evaluation of Quality Control Samples

Data generated by quality control samples and how they relate to the precision, accuracy, representativeness, and comparability of other data obtained during an investigation will be evaluated by the project team according to procedures defined in the QAPP, FSP, and/or other site-specific documents.

1.6 References

USEPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QC Plan and Data Validation Procedures, Interim Final, EPA/540/G-90/004.

USEPA, 2002a, Quality Management Plan for the Superfund Division, Region 5, Chicago, Illinois.

USEPA, 2002b, Guidance for Quality Assurance Project Plans, EPA QA/G-5/ EPA/240/R-02/009.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

USEPA, October 2010, Field Sampling Quality Control, Region 4, Operating Procedure, SESDPROC-011-R3, SESD, Athens, Georgia, http://www.epa.gov/region4/sesd/fbqstp/Field-Sampling-Quality-Control.pdf

USEPA, August 2011, Field-based Analytical Methods, Summary of Quality Control Samples and the Information They Provide, http://www.epa.gov/superfund/programs/dfa/download/qctable.pdf

Reviewed By:	JJW/SLM	Date Reviewed:	07/23/2013
Corporate Officer:	BRH	Date Approved:	07/24/2013

EQUIPMENT DECONTAMINATION

1.1 Scope and Application

This standard describes the decontamination of field equipment prior to field use. Decontamination procedures to be executed prior to field mobilization and while in the field both follow this standard operating procedure (SOP).

Sampling and field equipment decontaminated in accordance with these procedures meet the requirements for achieving standard data quality objectives. Site-specific field decontamination procedures may be substituted for the procedures described in this SOP when samples are to be analyzed for data uses with lower level data quality objectives. Refer to the project-specific documents for variances to this SOP.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety SOPs when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3 Cleaning Materials

Specific cleaning materials to be used for your project will depend on the type and level of contaminants anticipated at a site and should be identified in site-specific documents. Typical cleaning materials used in equipment decontamination include:

- Detergent such as a standard brand of laboratory detergent (e.g., Alconox® or Liquinox®). The use of any other detergent must be justified and documented in project files. Note that some projects may require the use of phosphate-free detergent.
- Nitric acid solution (10%). This cleaning agent is prepared from reagent-grade nitric acid and deionized water.

- Pesticide-grade isopropanol cleaning solvent. Other solvents may be substituted for a particular investigation if needed (e.g., hexane). Pesticide-grade acetone or methanol is acceptable; however, if pesticide-grade acetone is used, the detection of acetone in samples collected with acetone-rinsed equipment is suspect. Pesticide-grade methanol is much more hazardous to use than either pesticide-grade isopropanol or acetone, and its use is discouraged. The use of any solvent other than pesticide-grade isopropanol for equipment decontamination purposes must be justified and documented in site documents.

- Deionized water, or tap water that has been treated by passing through a standard deionizing resin column. Deionized water should contain no detectible heavy metals or other inorganic compounds.

- Commercially available distilled tap water. Although deionized water is preferred, distilled water can be substituted for deionized water, as appropriate, on a project-specific basis. If commercially available distilled water is used, the purity of the water should be checked by submitting a sample for laboratory analysis.

- Organic-free tap water that has been treated with activated carbon and deionizing units. Organic-free water should contain no pesticides, herbicides, or extractable organic compounds, and less than 5 µg/L of purgeable organic compounds.

- Tap water from municipal water treatment systems. Untreated potable water supply is not an acceptable substitute for tap water.

During cleaning, the substitution of high-grade water (e.g., deionized, distilled, or organic-free water) for tap water is permitted and need not be noted as a variation of this SOP, provided the deionized and organic-free water meets the specific quality control procedures as outlined above. Throughout the remainder of this procedure, high-grade water refers to deionized, distilled, or organic-free water, unless otherwise specified.

1.4 Decontamination Procedure for Standard Equipment

General decontamination procedure is summarized as follows:

1. Physical removal of particles

2. Detergent wash[1]

3. Tap water rinse

4. High-grade water rinse

5. Air dry

After final decontamination and prior to storage, equipment will be wrapped in one layer of clean aluminum foil. Foil edges will be rolled into a "tab" to allow for easy removal. Then, the piece of equipment will be sealed in plastic and dated. In addition, if there was a deviation from the decontamination SOP, this will be noted on the label.

If particular contaminants are present, decontamination steps may need to be added for site specificity, including:

- Nitric acid rinse if metals are of concern at a site
- Solvent rinse if particular organics are of concern

Use of any additional decontamination steps will be identified in the site-specific documents.

1.4.1 Decontamination Procedure for Equipment Used to Collect Samples of Toxic or Hazardous Waste

Equipment that is used to collect samples of hazardous materials or toxic wastes or materials from hazardous waste sites, RCRA facilities, or in-process waste streams shall be decontaminated before it is returned from the field. At a minimum, this decontamination procedure shall consist of procedures described in Section 1.4.2. More stringent decontamination procedures may be required, depending on the waste sampled. Alternative decontamination procedures will be provided in site-specific documents.

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[1] When sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade solvent to remove residue before proceeding with Step 3. In extreme cases, it may be necessary to steam clean the field equipment before proceeding with Step 3. If the field equipment cannot be cleaned utilizing these procedures, it should be discarded.

1.4.2 Equipment-Specific Decontamination Procedures

Submersible Pumps and Non-Dedicated Hoses/Tubing Used to Purge Ground Water Wells

Submersible pumps and non-dedicated hoses/tubing used to purge ground water wells will be decontaminated using the following procedure:

1. Pump a sufficient amount of detergent water through the hose/tubing to flush residual purge water
2. Pump a sufficient amount of high grade water through the hose/tubing to flush detergent water
3. Rinse the outside of the pump housing with detergent water
4. Rinse the outside of the pump housing with tap water or higher grade water
5. Rinse the outside of the pump housing with high-grade water
6. Hoses/tubing used only for purging wells shall be cleaned prior to reuse. Hoses/tubing used for sampling shall be discarded after use, with new hose/tubing being used every sampling event
7. Equipment will be placed in a polyethylene bag or wrapped with polyethylene film to prevent contamination during storage or transit. Insure that a set of rotors, fuses, and cables are attached to each cleaned pump

1.4.2.2 Subcontractor Equipment

Subcontractor equipment that is not directly used to collect sample material (e.g. auger flights) must be decontaminated prior to arrival on site and during site work in a manner approved by NRT that mitigates the potential for cross contamination. Subcontractor equipment that is directly used to collect sample material (e.g. split spoon) must be decontaminated per Section 1.4 of this SOP or a site-specific method identified in site-specific documents. The subcontractor will collect all investigation-derived waste (IDW) generated from decontamination of their equipment in a manner that will allow it to be handled and disposed of properly.

1.4.2.3 Sample Coolers and Shipping Containers

All ice chests and reusable containers shall be washed with detergent (interior and exterior), rinsed with tap water and air dried before storage. In the event that an ice chest becomes severely contaminated with concentrated waste or other toxic material, it shall be cleaned as thoroughly as possible, rendered unusable, and properly disposed.

1.4.2.4 High-Grade Water Storage Containers

High-grade water storage containers will only be used only for transporting high-grade water. To decontaminate the container, use the following procedure:

New containers shall be rinsed thoroughly with high-grade water, filled with high-grade water and capped with one layer of Teflon® paper; and one layer of aluminum foil immediately after using.

For used containers:

- Wash the exterior of the container with detergent and rinse with deionized water.
- Rinse the interior of the container twice with solvent.
- Rinse the interior of the container thoroughly with high-grade water. The container shall be filled with high-grade water and capped with one layer of Teflon® paper, and one layer of aluminum foil. High-grade water will not be stored in the containers longer than three days.
- Cap with one layer of Teflon® paper, and one layer of aluminum foil immediately after using in the field.

1.4.2.5 Vehicles

Vehicles should be washed at the conclusion of each field trip. This routine maintenance should minimize any chance of contamination of equipment or samples due to contamination of vehicles. When vehicles are used in conjunction with hazardous waste site inspections, or on projects where pesticides, herbicides, organic compounds, or other toxic materials are known or suspected to be present, a thorough interior and exterior decontamination is mandatory at the conclusion of such investigations.

All vehicles shall be equipped with trash bags and/or trash containers to facilitate vehicle decontamination. All personnel are responsible for keeping field vehicles clean by removing all trash and other debris. All contaminated trash and equipment must be kept separate from ordinary trash and must be properly disposed on-site.

1.5 Segregating Used Field Equipment

Field equipment or reusable sample containers needing decontamination will not be stored with clean equipment or materials.

1.6 Restocking Decontaminated Equipment

All decontaminated, plastic-wrapped equipment, containers, and tubing not used in the field may be placed back in stock after the following precautions are taken:

- Soap and water rinse the outer plastic wrap on the equipment, sample tubing, or sample containers. Allow to air dry.
- If plastic wrap leaks during soap/water rinse, remove equipment and decontaminate it again.

1.7 Storage of Field Equipment and Sample Containers

All decontaminated field equipment and sample containers shall be stored in a contaminant free environment.

1.8 Disposal of Cleaning Materials

If solvents or nitric acid are used during the decontamination process for sampling equipment and containers, the solvent or acid shall be collected and disposed through an approved hazardous waste disposal contract.

1.9 References

ASTM Standard D5088, 2002 (2008), "Standard Practice for Decontamination of Field Equipment Used at Waste Sites," ASTM International, West Conshohocken, PA, 2008, DOI: 10.1520/D5088-02R08, www.astm.org.

USEPA, Region IV, 2011, Field Equipment Cleaning and Decontamination, SESDPROC-205-R2, SESD, Athens, Georgia.

Prepared By:	TBN	Date Prepared:	12/31/12
Corporate Officer:	BRH	Date Approved:	1/3/14

WELL INTEGRITY EVALUATION AND MAINTENANCE

1.1. Scope and Application

This standard is applicable to evaluation of well integrity and maintenance. A well integrity evaluation identifies wells that are not suitable for obtaining hydraulic and/or groundwater quality information because of their physical condition. The evaluation may involve both visual inspection and hydraulic testing. Results of the evaluation are used to determine whether or not a well is functional or requires rehabilitation (Section 1.6) or abandonment (SOP 07-05-07). Well integrity evaluations shall be completed on an "as needed" basis or may be scheduled as part of a project work plan or groundwater monitoring plan. Refer to project-specific documents for variances from this SOP.

1.2. Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3. Equipment

- Site map with well locations
- Notebook, well inspection form, hydraulic test form, well construction logs, other field forms
- Digital camera
- Shovel
- Tape measure
- Electronic water level probe, pressure transducer, and automatic data logger

- Bailer with rope, suction pump, down-hole pump, or solid PVC or steel slug
- Personal protective equipment
- Calibrated bucket
- Differential Global Positioning System (DGPS) unit or equivalent GPS unit with sub-meter accuracy
- Groundwater elevation table, if available
- Monitoring Well Evaluation Checklist (Attachment A)

1.4. Physical Inspection

Each well location must be compared to the location shown on the site map. If necessary, resurvey and adjust the location on the map. The physical condition of the well is determined by visually inspecting the well and completing the monitoring well inspection form (attached). Specific items of concern are the visible well construction materials, the use of any substances in the well construction that may result in contamination of the well, the condition of surface seals, drainage from the well, and well security. Any damage that could permit surface water infiltration to the well will be noted. A photograph of each well may be taken, with a clearly visible well identification number, to document the inspection.

Depth to water and total well depth will be measured and compared with the well depth in the well construction log and depth to groundwater on the Groundwater Elevation Table. A bailer or slug will be lowered into the well to identify obstructions or damage to the well screen or casing that requires well maintenance or rehabilitation. Any sediment present at the bottom of the well will be noted.

If hydraulic conductivity testing was previously performed on the well, a single well aquifer test (SOP-07-07-11) may be performed to determine if silt has decreased the well hydraulic conductivity, indicating that well maintenance or rehabilitation may be necessary for collection of representative data. The results of the single well aquifer test will be compared to previous aquifer tests to determine if hydraulic conductivity has decreased.

1.5. Data Evaluation

The visual inspection and available aquifer test data will be used to identify any defects, inconsistencies, or other problems with the well. The boring/well construction logs will also be reviewed to assess the appropriateness of the installation relative to the intended use of the well.

Additionally, the construction log should be carefully reviewed for compliance with code requirements, such as state regulations. Any deviations should be noted and their significance evaluated with respect to the well's ability to achieve the desired data quality objective.

1.6. Well Maintenance and Rehabilitation

Deficiencies or damage will be evaluated on a case-by-case basis. Well maintenance or rehabilitation that cannot be implemented at the time of inspection will be implemented within a reasonable period of time. Well maintenance or rehabilitation may include, but is not limited to:

- Replacement of aboveground components
- Silt/sediment removal
- Well surging and redevelopment
- Biomass removal and/or cleaning with an approved biocide (well shock)
- Repair or replace well equipment (e.g., pumps)

If deficiency or damage cannot be corrected through well maintenance or rehabilitation, the well may be abandoned in accordance with SOP 07-05-07 and applicable federal, state, and local regulations. Abandoned wells critical to site activities and/or operations will be replaced.

1.7. Documentation

Inspection, maintenance, and rehabilitation activities will be recorded in a field log book and/or on the appropriate field forms.

1.8. References

ASTM Standard D6089, 1997 (2010), "Standard Guide for Documenting a Groundwater Sampling Event," ASTM International, West Conshohocken, PA, 2010, DOI: 10.1520/D6089-97R10, www.astm.org

ASTM Standard D4448, 2001 (2007), "Standard Guide for Sampling Groundwater Monitoring Wells," ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/D4448-01R07, www.astm.org

USEPA, Field Branches Quality System and Technical Procedures, Region 4, Science and Ecosystem Support Division, Athens, Georgia, http://www.epa.gov/region4/sesd/fbqstp/

ATTACHMENT A

MONITORING WELL EVALUATION CHECKLIST

Monitoring Well Evaluation Checklist

Site ____________	Major wells repairs* required to maintain well integrity?		Yes	No	NA
Inspection Date ______					
Well Number ______					

Stick-up Monitoring Wells				**Comments**
1. Outer protective Casing	Yes	No	NA	
Not corroded				
Not dented				
Not cracked				
Not loose				
2. Inner casing	Yes	No	NA	
Not corroded				
Not dented				
Not cracked				
Not loose				
	Yes	No	NA	
3. Are there weep holes in outer casing?				
4. Weep holes able to drain?				
5. Is there a lockable cap present?				
6. Is there a lock present?				
7. Bumper posts in good condition?				
Flushmount Monitoring Wells	Yes	No	NA	
8. Can the lid be secured tightly?				
9. Does the lid have a gasket that seals?				
10. No water in the flushmount?				
11. Is the well cap lockable?				
12. Is there a lock present?				
All Monitoring Wells	Yes	No	NA	
Downhole Condition				
12. Water level measuring point clearly marked?				
13. No obstructions in well?				
14. No plant roots or vegetation in well?				
15. No sediment in bottom of well?				
If present, how much sediment?	ft			
16. Installed as total depth.	ft			
17. Measured total depth of well.	ft			
General Condition	Yes	No	NA	
18. Concrete pad installed?				
19 . Concrete pad				
Slope away form casing?				
Not deteriorated?				
Not heaved or below surrounding grade?				
20. No surface seal settling?				
21. Well clearly visible and labeled?				

Comments:

* Major well repair are those that require a subcontractor or separate mobilization to complete

Prepared By:	TBN	Date Prepared:	10/21/13
Corporate Officer:	BRH	Date Approved:	11/22/13

GROUNDWATER and NAPL ELEVATION MEASUREMENTS

1.1 Scope and Application

This standard is applicable to the collection of groundwater and non-aqueous phase liquid (NAPL) elevation measurements. Refer to project-specific documents (workplans) for variances to this SOP.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3 Preliminary Procedures

Specific measurements during a sampling event, such as water level and depth of well, and observations of well condition should be documented in a field book or field form. The well shall be visually inspected and any damage that could permit surface water infiltration into the well must be noted and documented in accordance with Well Integrity Evaluation and Maintenance SOP 07-07-01.

1.4 Groundwater Level Measurements

Measurement of the static water level is taken prior to well purging and sample withdrawal. The elevation of the groundwater is determined by the following equation:

Groundwater Elevation = Top of Casing Elevation - Depth to Water

Measurements will be in units consistent with the units and datum used to survey the measurement point on the well.

All well measurements must be made from the point at which the elevation was measured (e.g., top of well casing). This point must be noted in the comments section of field notes or forms. Measurements shall not be made relative to protective casings, which are subject to frost heave.

1.4.1 Groundwater and NAPL Elevation Measurements

If wells have not been equipped with dedicated systems containing static head sensors (pressure transducers) or similar devices, then a water level indicator or oil/water interface probe shall be used to determine the static level of water in the well and to measure the total depth of the well. An oil/water interface probe should not be used to collect water level readings from wells that do not contain NAPL. Lead weight water level indicators should not be used.

When the indicator probe contacts the water, dependent upon the model, a series of beeps or a continuous beep will sound. If using an oil water interface probe a different sound will indicate the presence of NAPL. The following steps are for measuring groundwater and NAPL:

1. When groundwater elevation contour maps are to be prepared, collect synoptic depth to groundwater measurements (e.g. collect measurements consecutively at every site well in the shortest period of time possible and prior to any sampling activities).

2. Done PPE as required by the HASP.

3. Clean the water level indicator or oil/water interface probe and cable in accordance with SOP 07-04-09. As with other activities it is preferred to start collecting readings from the cleanest wells and end with the most contaminated wells to reduce the risk of cross-contamination. Decontaminate the water level indicator (probe) with laboratory-grade soap and potable or deionized water between each well location.

4. If NAPL is known to be present in the well, it is recommended to place a piece of plastic sheeting and absorbent pads adjacent to the well to use as a clean work area. Cut a hole in the center of sheeting and place the sheet around the well.

5. If light or dense non-aqueous phase liquid (LNAPL or DNAPL) and/or an absorbent sock is present in the well (based on a review historical data, if available), place enough absorbent pads on the plastic sheet beside the well to absorb oil that may be present when the absorbent sock and oil/water interface probe is removed from the well.

6. Unlock and open the well cover while standing upwind of the well. Remove well cap. If PID readings are required by the workplan, insert the PID probe approximately 4 to 6 inches into the casing of the well headspace and cover with gloved hand. Record the PID reading on the field log.

7. Locate the measuring reference point on the well casing. If one is not found, initiate a reference point by notching the inner and outer casings with a hacksaw or by using a waterproof marker. All down-hole measurements will be taken from the reference points.

8. Take time to monitor whether the measured depth to groundwater represents static groundwater elevation. If the well is not vented, then pressure caps may prevent some water columns from equilibrating with atmospheric pressure; be alert for this condition (sometimes indicated by an audible popping or hissing noise when the cap is removed) in non-vented wells. Record these observations in field notes and return to the well as needed to make additional measurements to determine whether or not the water level has equilibrated.

9. If an absorbent sock is already in the well, note the presence of the sock on the log, remove the absorbent sock, and make a qualitative estimate of the volume of LNAPL present in the absorbent sock. Proceed to Step 12 after the well has equilibrated (wait up to 1 hour before measuring LNAPL thickness and water level).

10. Record the inside diameter of the well casing on the field log.

11. For wells that do not contain NAPL, measure the depth to water to the nearest 0.01 foot using a water level indicator. Confirm the measurement by gently raising and lowering the water level indicator to collect several readings, record the confirmed depth to water in the field notes.

12. At all locations containing LNAPL, except those monitoring wells containing highly viscous LNAPL (see note below), lower the oil/water interface probe into the well to determine the existence of any light immiscible layer. Carefully record the depths of the air/light-phase and light-phase/water interfaces (to the nearest 0.01 foot) to determine the thickness of the light-phase immiscible layer (if present). If no light-phase immiscible layer is present, record the depth of the air/water interface and inspect the probe for NAPL residue and note the presence/absence of the residue on the probe in the field notes. In the absence of an oil/water interface probe, NAPL thickness can also be estimated using a bailer (glass or plastic). Slowly lower the bailer into the top of the water column. For LNAPL measurements, do not allow the bailer to fill completely. For dense non-aqueous phase liquid (DNAPL) measurements allow the bailer to drop to the bottom of the well. Retrieve the bailer, place on a bailer stand, and measure the thickness of product in the bailer. Record the measurement as an estimate.

    Note: Use extreme caution when gauging monitoring wells with highly viscous LNAPL. Highly viscous LNAPL is difficult to remove from sampling equipment. To gauge viscous LNAPL depths, mark a section of PVC pipe at 1-foot intervals to estimate location of the pipe within the well and slowly lower pipe into the well until reaching the fluid/air interface. Mark the PVC pipe at the top of casing (TOC) and slowly remove. Measure difference between the uppermost limit of

LNAPL on the pipe (if present) and the mark made at the TOC. The difference is the top of LNAPL. To get depth to water, use two sections of PVC pipe that when put one inside the other will also fit down the 2-inch diameter well (e.g., ¾" diameter pipe inside a 1½" diameter pipe). Make sure that the ¾" pipe is at least 6 inches longer than the 1½" pipe). Tape the bottom of the two pipes such that the tape can be easily removed–but not lost into the bottom of the well, and can be lowered through the LNAPL/water interface. Slowly lower the two pipes into the well until reaching the bottom of the well. Push the ¾" pipe through the 1½" pipe to remove the tape and allow groundwater to enter pipes. Remove the ¾" diameter pipe and allow the water level to equilibrate inside the 1½" pipe (wait up to 1 hour before measuring). After allowing the well to equilibrate, gauge the water level in the well as detailed above.

13. At locations known to contain DNAPL it may not be appropriate to use an oil/water interface probe because DNAPL tends to be difficult to remove from equipment. It is recommended to use dedicated or disposable equipment for recording DNAPL thickness to reduce decontamination time and reduce the risk of cross contamination. DNAPL measurements should be collected after a groundwater sample is collected, if any. It is recommended to collect DNAPL measurements using the following method:

    a. Purchase a stainless steel hex nut from the hardware store.

    b. Tie the nut to the end of some white nylon rope.

    c. Carefully lower the rope and nut into the well stop as soon as the nut reaches the bottom of the well. Mark the rope at the top of the casing and carefully remove the rope and nut.

    d. Record the thickness of DNAPL staining on the white rope (this is DNAPL thickness). The measurement from the mark at the top of the casing to the top of the DNAPL staining is the depth to DNAPL measurement. <u>Note that DNAPL may enter the well from any portion of the screened interval and accumulate in the bottom of the well, so this depth and thickness reading should not be used to make statements about the thickness and elevation of DNAPL in the formation around the well.</u>

    e. <u>The stainless steel nut and nylon rope should be disposed of as investigative derived waste along with gloves, paper towels, and oil absorbent materials in accordance with the HASP and/or workplan.</u>

1.4.2 Depth of Well Measurements

This measurement is required at well construction to determine purge volumes and at least annually to evaluate well integrity. If sampling is conducted less frequently than once a year, well depth will be measured during each sampling event. Wells with dedicated pumps are exempt from this measurement. The depth of well, when not field measured, should be obtained from the Well Construction Log and noted on the Well Purge form and also noted in the comments section, as being "from the Well Construction Log".

Measurement of depth to well bottom is made with a water level meter or with a measuring tape with a weighted bottom. Measure the depth to well bottom to nearest 0.01-ft relative to the reference point. Adjust measurements to account for the length of the water meter probe housing which extends below the water level sensor or for the length of weight below the bottom of the tape, if any. Depth to bottom measurements should be avoided in situations when performing the measurement stirs up sediment settled in the well sump. If possible, wait to take depth to well bottom measurement until after sampling is completed, and/or rely on past measurement of depth to well bottom to calculate well volumes.

1. After recording the static water level and collecting groundwater samples (if any), unroll the cable or tape until it hits the bottom of the well
2. Slowly pull up the slack until slight tension is felt on the cable
3. Slowly raise and lower until a feel for the bottom is obtained
4. Record the total well depth measurement in field notebook or forms
5. Decontaminate the indicator and length of measuring tape used to collect the reading in accordance with SOP 07-04-09

1.6 References

ASTM Standard D3415, 1998 (2011), “Standard Practice for Identification of Waterborne Oils,” ASTM International, West Conshohocken, PA, 2011, DOI: 10.1520/D3415-98R11, www.astm.org

USEPA, Field Branches Quality System and Technical Procedures, Region 4, Science and Ecosystem Support Division, Athens, Georgia, http://www.epa.gov/region4/sesd/fbqstp/

Prepared By:	THC	Date Reviewed:	7/31/2013
Corporate Officer:	BRH	Date Approved:	1/3/2014

GROUNDWATER SAMPLING

1.1 Scope and Application

This Standard Operating Procedure (SOP) describes commonly-used groundwater sampling methods and identifies routines to follow when collecting samples from monitoring wells. Guidance documents and SOPs published by the United States Environmental Protection Agency (USEPA) and ASTM International provide the foundation for this SOP. Procedures outlined below are intended to ensure that representative samples are collected in ways that are safe, technically defensible, easily replicated, appropriate for the selected analytical methods, and sensitive to site-specific conditions and hydrogeology. Refer to project-specific documents for variances from this SOP.

1.2 Summary of Methods

This SOP describes two methods that are most-commonly used to purge and sample groundwater from monitoring wells: 1) well volume method, and 2) low-flow (low-stress or micro-purge) method.

1.2.1 Well Volume Method

Using the well volume method, a pre-determined volume of groundwater is purged from the monitoring well to remove stagnant water from the well's casing (riser pipe). Typically a minimum of 3 well volumes of groundwater is removed; however, modification (reduction) of the minimum number of purge volumes is acceptable when water quality parameters (field parameters) are monitored at regular intervals during purging. Samples are collected when the minimum purge volume has been removed and/or when water quality parameters stabilize within acceptable limits.

1.2.2 Low-flow Method

Using the low-flow method, groundwater is purged (pumped) from a monitoring well at low flow rates that result in minimal drawdown. Depth to groundwater and groundwater quality parameters (field parameters) are monitored throughout the purging process. Pumping rates are adjusted to ensure groundwater entering the pump is from the screened formation and not from stagnant water in the well casing above the pump inlet. Samples are collected when drawdown and groundwater quality parameters stabilize within pre-determined criteria.

1.3 SOPs for Related Tasks

This SOP applies only to sampling groundwater from monitoring wells. Sampling methods for drinking water wells, surface water, pore water, leachate, and other liquid wastes are not described in this SOP.

However, this groundwater sampling SOP requires adherence to other SOPs for closely-related tasks, some of which are referenced herein:

- SOP 07-07-01 Well Integrity Evaluation
- SOP 07-07-05 Groundwater and Non-Aqueous Phase Liquid Elevation Measurement
- SOP 07-11-01 Equipment Calibration, Operation, and Maintenance
- SOP 07-04-09 Equipment Decontamination
- SOP 07-04-07 Quality Control Samples
- SOP 07-03-01 Sample Labeling and Storage
- SOP 07-03-03 Chain of Custody
- SOP 07-03-09 Shipping

2.1 Pre-mobilization Planning

Successful groundwater sampling requires planning for health and safety considerations, selecting and preparing sampling equipment, knowledge of laboratory analytical methods, field-sampling procedures, and attention to record-keeping requirements.

Planning for a groundwater sampling event includes the following basic components:

- Identify scope of work and project objectives
- Prepare a health and safety plan
- Coordinate laboratory analytical services
- Select purging and sampling methods and equipment
- Prepare field equipment
- Prepare necessary field documentation forms
- Coordinate disposal of investigative-derived waste (purge water)

2.1.1 Site-Specific Considerations

Knowledge of site conditions and previous sampling records/field notes is helpful. Select equipment and sampling methods to match the scope of work and site-specific data quality objectives.

When planning a sampling event, it is also important to understand the following site-specific information:

- Site access, security, and health and safety issues
- Known or unknown concentrations of compounds of concern
- Anticipated depth to water at individual wells
- Presence or absence of NAPLs and/or DNAPLs
- Purging methods (e.g. well volume, low flow, modified, other)
- Equipment selection (e.g. pumps, bailers, or a combination of both)
- Criteria for monitoring of field parameters
- Sampling order (typically from least to most contaminated wells)
- Requirements for field-filtering and field-preservation of samples

- Requirements for field and/or laboratory QA/QC samples
- Decontamination procedures
- Identification of short hold times or special sample handling requirements
- List of analytes and analytical methods
- Site-specific SOPs, methods, and/or record-keeping requirements

2.1.2 Health & Safety Plan, Personal Protective Equipment

Use of a site-specific Health and Safety Plan (HASP) and personal protection equipment (PPE) is mandatory for all sampling activities. NRT's Health & Safety Coordinator must approve the HASP and appropriate PPE prior to any on-site activities.

Level D protection, at minimum, is required for field activities involving groundwater sampling; however, PPE will vary according to possible levels of risk and exposure pathways. Additional protection, such as Tyvek® suits, splash guards, and/or respirators may be necessary. Use of field-screening devices, such as a photoionization detector (PID), for monitoring breathing zones and/or decontamination zones may also be appropriate.

Attention to proper use of PPE and thorough decontamination of equipment that comes in contact with groundwater and/or the ground surface is also essential to preventing personal exposures and sample cross-contamination. Site-specific requirements may also necessitate the use of plastic sheeting and/or other work-area precautions to prevent releases, exposures, and cross-contamination during sampling.

When working in roadways, parking lots, and other high-traffic areas, wear high visibility clothing and use safety cones, signage, flashing signals, flaggers, or other safety precautions. Properly establish traffic control according to detailed instructions contained in Department of Transportation (DOT) traffic control handbooks/manuals. Obtain permits for work in right-of-ways, including permission to dispose of investigation derived waste (purge water) to public sanitary sewer or wastewater treatment facilities if called for in the site-specific sampling plan.

2.1.3 Laboratory Coordination

Provide the analytical laboratory with enough lead time to manage the project. Order sample containers, communicate billing, reporting information (e.g., level IV QC reporting), and field sampling dates prior to field work. Requests for quick turnaround require advanced notice.

Be sure to complete the following checklist when ordering and receiving sample containers:

- Confirm list of analytes
- Confirm methods of analysis and minimum required sample volume
- Determine whether samples are to be field-filtered and/or field-preserved
- Order extra containers as a contingency
- Count the number and type of containers received
- Discuss hold times and shipping and receiving procedures
- Determine whether special instructions are needed in writing on the chain of custody (COC)

Once the groundwater samples have been collected and shipped, make practice of calling the laboratory as a courtesy to provide anticipated arrival dates and numbers of samples. Identify samples with short hold times or that may contain exceptionally high concentrations of compounds of concern. Keep a copy of the signed COC that was shipped with the samples, and also keep any documentation of the laboratory's receipt of COCs. Include a specific list of the analytes requested on the COC as this is used by the lab to confirm the appropriate analyses have been completed and/or reported.

2.1.4 Field Equipment

Select sampling equipment necessary to achieve the data quality objectives for the project. Inspect, calibrate, and decontaminate all equipment prior to use in the field according to SOP 07-11-01 (Equipment Calibration, Operation, and Maintenance), and SOP 07-04-09 (Equipment Decontamination).

The following list provides an overview of some of the items typically needed in the field:

- Health and Safety Plan (HASP)
- First Aid Kit
- PPE (minimum Level D)
- Scope of Work
- Site Maps
- Well Keys/Site Access Keys
- Mobile Phone
- Camera
- Calculator
- Field Log Book/Field Forms
- Tools
- Chain of Custody Forms
- Custody Seals
- Sample Containers
- Cooler and Ice
- Strapping Tape
- Permanent Markers/Pens
- Ziploc® Baggies
- Paper Towels
- Plastic Sheeting
- Garbage Bags
- Water Level Meter
- Weighted Steel Tape
- Oil-Water Meter
- Calibrated Buckets
- Alconox® Soap
- Brushes
- De-ionized (DI)/Potable Water
- Water Quality Meters
- Calibration Solutions
- Calibration Standards
- Meter Operation Manuals

- Flow-Through Cell
- Calibrated Beakers/Cups
- Tubing (HDPE, Tygon®, silicon)
- Disposable Filters (barrel filters)
- Bladder Pump
- Bladder Pump Control Box
- Safety Line for Bladder Pump
- Disposable Bladders
- Check Valves, Catch Plates
- Air Compressor
- Peristaltic Pump
- Submersible Pump (Whaler®, other)
- Extension Cords
- Hose Clamps
- Portable Battery (automotive/marine)
- Alligator Clips
- Electric Tape
- Generator and Gasoline

2.1.5 Field Forms

Field-records of all purging and sampling procedures are kept either in field notebooks or on site-specific field forms. Field notes for groundwater sampling may include observations and documentation of well inspection, water level, equipment calibration, purging and sampling information, sample control logs, and chain of custody. Record-keeping requirements are described Section 4.1.

2.1.6 Waste Disposal

Contaminated purge water will be discharged as directed in the site-specific sample plan. If disposal is required, it should be arranged prior to the sampling event. A waste profile and permission from regulatory authority and wastewater operator may be needed to dispose purge water to a sanitary sewer, wastewater treatment facility, landfill, or on-site disposal facility.

3.1 Groundwater Sampling Procedure

This SOP describes steps to follow when performing the well volume method using bailers or submersible pumps, and the low-flow method using bladder or peristaltic pumps.

Sampling generally proceeds in the following fashion:

- Establish a safe working zone
- Assess well condition
- Measure depth to groundwater
- Measure depth to well bottom (except in some cases)
- Measure thickness of any non-aqueous phase liquids (NAPLs or DNAPLs), if present
- Calculate well volumes
- Purge the well, using either the well volume or low flow (low-stress/ micro-purge) method
- Collect samples
- Label and pack samples on ice for shipping
- Decontaminate equipment
- Complete all record-keeping requirements, including COC
- Ship samples

3.1.1 Well Integrity

Assess the condition of monitoring wells and protective casings prior to sampling activities. Measure depth to well bottom and compare measurement to previous measurements. The presence of obstructions and bent or broken casing (risers) must be considered before lowering pumps or other equipment into the well. Make note of, photograph, and repair, if possible, any damage to the monitoring well. Replace any missing locks or pressure caps prior to leaving the site. Include a well condition report as a part of the groundwater sampling field notes. Refer to SOP 07-07-01 (Well Integrity) for additional instructions.

3.1.2 Depth to Groundwater

Record the depth to groundwater to the nearest 0.01 ft, relative to the reference point at the top of well casing. A notch or permanent marking at the top of well casings (typically PVC) commonly marks the reference point. Measure depth to groundwater beginning at the least contaminated well and proceed to the most contaminated well. Decontaminate the water level meter (probe) with laboratory-grade soap and potable or deionized water between each well location. Refer to SOP 07-07-05 (Groundwater and Non-Aqueous Phase Liquid Elevation Measurement) and SOP 07-04-09 (Equipment Decontamination) for additional instructions.

Take time to monitor whether the measured depth to groundwater represents static groundwater elevation. Pressure caps may prevent some water columns from equilibrating with atmospheric pressure; be alert for this condition when pressure caps are very tight or produce an audible popping or hissing noise when removed. Record these observations in field notes and return to the well several times to make additional measurements to determine whether the water level has equilibrated.

Groundwater with elevated specific conductance (conductivity) may also interfere with the accuracy of water level measurement due to meter sensitivity. Adjust the sensitivity of the water level meter to make an accurate measurement, however, try to use a consistent sensitivity setting from well to well.

When groundwater elevation contour maps are to be prepared, collect synoptic depth to groundwater measurements (e.g. collect measurements consecutively at every site well in the shortest period of time possible and prior to any sampling activities).

3.1.3 Depth to Bottom

Measurement of depth to well bottom is also made with a water level meter or with a measuring tape with a weighted bottom. Measure the depth to well bottom to nearest 0.01 ft relative to the reference point. Adjust measurements to account for the length of the water meter probe housing which extends below the water level sensor or for the length of weight below the bottom of the tape, if any. Decontaminate measuring tapes and water level probes and the full length of measuring tape that entered the well casing with laboratory grade soap and potable or de-ionized (DI) water according to SOP 07-04-09 (Equipment Decontamination), prior to use at other wells.

Depth to bottom measurements should be avoided in situations when performing the measurement stirs up sediment settled in the well sump. If possible, wait to take depth to well bottom measurement until after sampling is completed, and/or rely on past measurement of depth to well bottom to calculate well volumes. Note on field forms when historical depth to bottom measurements are used.

3.1.4 Thickness of NAPLs

Where immiscible liquids, such as petroleum non-aqueous phase liquid (NAPL), is present on the surface of the water column, an oil-interface probe (oil-water meter) is used to measure NAPL thickness. Differing patterns of audible alarms indicate “oil” as opposed to water. Record the depth to NAPL and depth to water relative to the reference point at the top of well casing. Decontaminate the probe and length of measuring tape that entered the well casing with laboratory grade soap and potable or DI water before use at another well. Refer to SOP 07-04-09 (Equipment Decontamination) for more instructions.

NAPL thickness can also be estimated using a bailer (glass or plastic). Slowly lower the bailer into the top of the water column. Do not allow the bailer to fill completely. Retrieve the bailer, place on a bailer stand, and measure the thickness of product in the bailer. Record the measurement as an estimate.

3.1.5 Purging and Pumping Equipment

Purging for the well volume method can be accomplished with bailers and a variety of submersible pumps (e.g., Grundfos®, Whaler®, Proactive®), inertia (e.g., WaTerra®). Bladder pumps (e.g., Well Wizard®), and suction (peristaltic) pumps are preferred when performing the low-flow method. In some cases, use of a combination of equipment is appropriate, because the type of bailer or pump selected for purging may not be appropriate for sampling.

The material construction of bailers and pumps should also be considered with respect to potential interferences. For example, the use of polyvinyl chloride (PVC) and polyethylene is discouraged when the detected concentrations of organic compounds is anticipated to be at or near laboratory detection limits, because organics may leach in and out of these materials. Teflon® and Teflon®-lined sampling devices are preferred in these cases.

3.2 Purging and Sampling Using the Well Volume Method

Using the well volume method, a pre-determined volume of water is evacuated from the well using a pump or bailer. Typically a minimum of 3 to 5 well volumes of water is removed to evacuate stagnant water from the monitoring well casing (riser pipe) and filter pack. Minimum purge volume requirements vary based on project-specific and regulatory requirements. Modification (reduction) of the minimum number of purge volumes is acceptable when groundwater quality parameters (field parameters) are monitored at regular intervals during purging. Samples can be collected when parameters stabilize within acceptable limits or when minimum purge volumes have been achieved.

3.2.1 Well Volume Estimation

Purge volumes are calculated in the field and depend on the measured depth to groundwater, measured or historical depth to well bottom, and well casing diameter.

The following calculation is used to estimate one well volume:

$$\text{Volume} = \pi(r^2)(h)$$

Where: r = inside radius of well casing (ft.)
h = height of standing water column in well casing (ft.)
$\pi \approx 3.14$; and $1\ ft^3 \approx 7.48$ gal)

Estimating Common Well Volumes

Groundwater monitoring wells are commonly constructed of 2-inch diameter, Schedule 40 or Schedule 80 polyvinyl chloride (PVC) risers and screens. The conversion chart below can be also be used to estimate well volumes for PVC monitoring wells. The volume of water (gallons) per foot of water column is shown in the far right column of the chart. Commonly used conversions for 2-inch diameter Schedule 40 and Schedule 80 PVC are highlighted.

Wells other than monitoring wells, such as injection and extraction wells, wells with multiple casings, production wells, and drinking water wells are constructed with larger diameter PVC, stainless steel, or iron casing. Measure and use the inside diameter of casing material to estimate the well volume according to the calculations above.

Conversion Table for Common PVC Well Diameters

Nominal Casing Diameter (inch)	Casing Inside Diameter (inches)	Casing Inside Radius (inches)	Casing Inside Radius (feet)	Volume per Foot of Water Column (gal)
Schedule 40				
1	1.05	0.53	0.04	0.04
1.25	1.38	0.69	0.06	0.08
1.5	1.61	0.81	0.07	0.11
2	**2.07**	1.04	0.09	**0.163**
3	3.07	1.54	0.13	0.38
4	4.03	2.02	0.17	0.66
6	6.065	3.03	0.25	1.50
8	7.981	3.99	0.33	2.60
12	11.938	5.97	0.50	5.81
Schedule 80				
1	0.96	0.48	0.04	0.04
1.25	1.28	0.64	0.05	0.07
1.5	1.5	0.75	0.06	0.09
2	**1.94**	0.97	0.08	**0.153**
3	2.9	1.45	0.12	0.34
4	3.83	1.92	0.16	0.60

Borehole Volume Calculations

Borehole volume accounts for the volume of standing water in the well casing and the volume of water contained in the well's filter pack material. Calculations of borehole volume require knowledge of well construction – borehole diameter, height of filter pack and filter pack seal, inside and outside diameter of well casing, and assumed effective porosity of the filter pack material. Borehole volumes are most often used when drilling and developing wells, but in some instances it is useful to compare the number of well volumes removed during purging to an equivalent number of borehole volumes.

Several methods are commonly used to estimate borehole volume. The following calculations are one example of estimation of one borehole volume:

Borehole volume = well volume + volume of water in filter pack

Well volume = $\pi(r^2)(h)$
where: r = inside radius of well casing (ft)
h = height of standing water column in well casing (ft)

Volume of water in filter pack = $n[\pi(r_1)^2 - \pi(r_2)^2]\, h_{fp}$
where: n = effective porosity of filter pack material
r_1 = radius of borehole (ft)
r_2 = outside radius of well casing (ft)
h_{fp} = height of standing water in filter pack (ft)

3.2.2 Groundwater Quality Parameters

Water quality parameters (field parameters) are monitored periodically when performing a modified well volume method. Stagnant water in the well casing is determined to be completely purged from the well when water quality parameters stabilize. Often, parameters stabilize before 3 well volumes have been removed. However, purging more than one well volume may be necessary for water quality parameters to stabilize. If parameters do not stabilize after 3 well volumes have been removed, additional well volumes should be removed. If water quality parameters do not stabilize within 5 volumes, it is at the discretion of the project leader whether to collect a sample or to continue purging.

Record all water quality parameter data, at a minimum, beginning with the first well volume, and every well volume after. In cases where a pump is used, water quality data are recorded at regular intervals along with the time, pumping rate, and total purge volume. When purging water with a pump, an in-line flow-through cell should be used to collect water quality parameter data. When using a bailer, parameters should be checked periodically by placing the water quality instruments (probes/meters) in a beaker or cup containing each sample of purged water. When measuring in a beaker, atmospheric exposure may affect readings for oxidation reduction potential [ORP] and dissolved oxygen.

Samples are collected after a minimum of one well volume of groundwater has been purged from the well and parameters have stabilized. Alternatively, samples are collected after 3 to 5 well volumes are purged.

Stability for water quality parameters is achieved when parameter readings fall within the following criteria for three consecutive time intervals.

Field-Measured Parameter Stabilization Criteria for Groundwater[1]

Parameter	Stabilization Criteria
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Dissolved Oxygen	+/- 10% of reading or +/- 0.2 mg/L, whichever is greater
Oxidation-Reduction Potential	+/- 20 mV
pH	+/- 0.2 standard units
Temperature	+/- 0.1°C
Turbidity*	<10 NTUs or ± 10% when turbidity is greater than 10 NTUs

Notes: µS/cm = micro Siemens per centimeter
°C = degrees Celsius
mg/L = milligrams per liter
mV = millivolts
NTUs = nephelometric turbidity units

* *Turbidity is an optional field parameter*

3.2.3 Purging Using a Bailer

Disposable or dedicated bailers are preferred when bailers are used for most purging and sampling scenarios, because they eliminate time needed to clean bailers and the possibility of cross contamination. However, if a non-dedicated, re-usable, bailer is used, the bailer must be washed with laboratory-grade soap and triple rinsed inside and out with DI water before purging or sampling according to SOP 07-04-09 (Equipment Decontamination).To minimize purge time, select the largest diameter bailer that will fit into the well and a length and weight of bailer that you can easily handle.

1 Stabilization criteria referenced here are consistent with ASTM D6771-02 *Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations*

Prior to deploying the bailer in the well, fasten nylon rope, preferably braided to the top of the bailer, and fasten the other end of the rope to the protective casing or some other object at the ground surface to prevent the loss of the rope and bailer down the well. Check the rope knots periodically during the bailing process, and re-tighten or re-fasten as needed.

Disposable Nitrile®, PVC, or latex gloves must be worn during bailing. Change gloves frequently when gloves become dirty or torn. At a minimum, wear new gloves when sampling, after decontaminating equipment, and when beginning work at a new well location.

Use the following procedure to manually deploy and retrieve the bailer to and from the water column:

- Slowly lower the bailer into the well until it contacts the water column
- Allow the bailer to fill with water until it becomes submerged
- Pull the bailer out of the well and coil the rope into a clean bucket or onto clean plastic sheeting
- Do not allow the bailer to come into contact with any surface other than your gloves, the inside of the well, clean plastic sheeting, or a dedicated bucket
- Pour water from the bailer into a calibrated bucket to keep track of the volume purged, and periodically pour water into a cup or beaker to monitor water quality parameters
- Continue bailing until the required volume of water is purged from the well or until water quality parameters stabilize
- Contain purged water, as necessary, for proper disposal
- Collect samples (see Section 3.4)
- Decontaminate equipment

3.2.4 Purging Using Submersible Pumps

Non-dedicated pumps and any non-dedicated tubing must be decontaminated using laboratory-grade soap and water according to SOP 07-04-09 (Equipment Decontamination) prior to lowering the pump and tubing into a well. Place gasoline-powered electrical generating equipment downwind of the well location to minimize the possibility for cross contamination. Disposable Nitrile®, PVC, or powderless latex gloves must be worn when handling down-hole equipment. At a minimum, wear new gloves when sampling, after decontaminating equipment, and when beginning work at a new well location.

Purging of the well involves the correct placement of the pump and turning it on:

- Slowly lower the equipment (pump, electrical cords, discharge tubing, safety line) into the well; use zip ties to bundle tubing and cords together to prevent it from tangling in the well or becoming stuck in a well joint
- Lower the pump to the depth of the well screen, if possible; for deep wells, lower the pump as deep as practical, depending on pump capacity
- Do not place the pump on the well bottom, to avoid stirring up sediment settled at the well bottom, and to avoid clogging the well with sediment
- Turn on the pump and record the pumping rate using a calibrated bucket and stopwatch
- When monitoring water quality parameters, use a flow through cell and water quality probes (sensors) to periodically collect parameter data; if not using a flow-through cell, periodically collect samples of purge water in a cup or beaker; note when parameter data are collected for samples exposed to the atmosphere
- Continue pumping until the required volume of water has been purged or water quality parameters stabilize
- Contain purge water, as necessary, for proper disposal
- Collect samples (see Section 3.4)
- Decontaminate equipme

3.2.4 Sampling

When purging and sampling with bailers, fill laboratory containers directly from the bailer using a bailer stand and bottom dischargers. Samples collected for VOC analysis are collected via VOC dischargers, which restrict the flow rate to prevent aeration. Samples that require field-filtering are first contained in a disposable carboy and then pumped through a barrel filter using a peristaltic pump.

When using submersible pumps, collect samples directly from the discharge tubing using a pumping rate not greater than the purging rate. If using a flow-through cell, disconnect it prior to sampling. Samples that require field-filtering can be filtered in-line using a filter connected directly to discharge tubing, or a disposable carboy may be used, as described above.

Use tubing appropriate for the compounds of concern. Collect samples for analysis of the most sensitive parameters first, and collect samples requiring field filtration last. Sampling protocol is described in detail in Section 3.4.

3.3 Purging and Sampling Using the Low-flow Method

Using the low-flow (low-stress, micro-purge) method, groundwater is purged at rates affecting minimal to no drawdown which effectively isolates stagnant water in the well casing (riser) above the pump inlet. Depth to groundwater and water quality parameters (field parameters) should be monitored throughout the purging process. Pumping rates are adjusted to ensure that flow of groundwater to the pump is from the saturated formation and not from stagnant water in the well casing. Samples are collected once drawdown and water quality parameters stabilize.

Purging for the low-flow method is performed using either a peristaltic (suction) pump, or a bladder pump. Tubing and bladders should be Teflon® or Teflon®-lined, although non-lined high-density polyethylene (HDPE) tubing is appropriate for many compounds of concern. In some situations, low-flow methods may be performed using other submersible pumps (e.g. Grundfos®, Whaler®, Proactive®) and inertia pumps (e.g. WaTerra®); see Section 3.3.3 for potential data quality implications.

3.3.1 Using a Peristaltic Pump

A peristaltic pump is used at the ground surface to apply a suction force to lift water from the well through small diameter tubing. Maximum lift for peristaltic pumps is in the range of 15 to 29 feet; and, pumping rates range from less than 50 milliliters per minute (mL/min) to several gallons per minute (gal/min). Peristaltic pumps exert reduced pressure on the pumped water which can result in degassing and volatilization of the sample. Changes in pressure can affect pH, oxidation reduction potential (ORP), and other gas-sensitive parameters (ASTM D6634-01[2006]). As a result, USEPA recommends that peristaltic pumps not be used for low-flow groundwater sampling when depth to water exceeds 15 feet, especially when collecting samples for analysis of volatile organic compounds (VOCs).

3.3.2 Using a Bladder Pump

A bladder pump uses compressed air to squeeze a flexible membrane (bladder) that is contained in a rigid housing. Groundwater enters the bladder under hydrostatic pressure through a check valve, and compressed air supplied via small diameter airline compresses the bladder which forces water from the bladder to the surface through a small diameter water return line (the compressed air does not contact the water). Flow rate and airline pressure are regulated via an electronic control box. Pressure is applied in timed cycles, allowing the bladder to refill and compress at intervals appropriate for the depth, hydraulic conductivity of the saturated formation, and desired flow rate. Lift capacity of the pump is directly related to the pressure of the drive gas source.

Representative groundwater samples can be obtained for all analytes in nearly all field conditions using a bladder pump. Low-flow sampling with a bladder pump reduces the possibility for degassing, agitation, and volatilization of the sample, as compared to peristaltic or submersible pumps.

3.3.3 Using Other Pumps

Other submersible pumps (e.g. Grundfos®, Whaler®, ProActive®) are commonly used to purge groundwater from monitoring wells (i.e. for the well volume method) or to accomplish well development. However, they are not always appropriate for low-flow sampling. Some studies show that using submersible pumps to collect groundwater samples for analysis of VOCs generates analytical data similar to that for bladder pumps; however, the valves used to restrict the flow of submersible pumps reduce pressure potentially resulting in degassing of the sample. Submersible pump impellers also cause heat and turbulent flow which can also result in changes in water chemistry. Pump failures may also release contaminants (oiled parts, plastics, etc) into a monitoring well. Due to these limitations, bladder pumps are recommended over submersible pumps for low flow sampling, particularly for VOCs.

3.3.4 Field Procedure

The objective of the low-flow method is to perform low-stress pumping of a monitoring well to clearly document that samples represent groundwater entering the well from the screened formation at the depth of the pump inlet. To do so, the sampler must place the pump inlet at the appropriate depth, pump in a manner that minimizes stress to the formation, and monitor drawdown and groundwater quality parameters at regular intervals.

The low-flow field method is performed according to the following steps:

- Assemble equipment, (e.g. pumps, tubing, flow through cell, water quality instruments)
- Clean (decontaminate) all down-hole equipment
- Calibrate water quality instruments
- Measure initial depth to groundwater
- Place pump/pump inlet tubing at appropriate depth in the screened interval
- Begin pumping at an initial rate (typically 100 mL/min or less)
- Calculate minimum purge volume (time intervals) for parameter readings
- Monitor water level drawdown and water quality parameters
- Adjust pumping rate to minimize/stabilize drawdown
- Continue pumping until drawdown and water quality parameters stabilize
- Collect samples

Preparation

Clean all non-dedicated down-hole equipment according to SOP 07-04-09 (Equipment Decontamination) prior to measuring initial depth to water or lowering a pump or inlet tubing into the well. Non-dedicated bladder pumps should be disassembled, cleaned, and re-assembled; also remove and clean pump gaskets, check valves, and inlet screens. Clean, calibrate, and test water quality instruments (probes) according to the manufacturer's instruction manuals. Document calibration results at the beginning of the day and periodically throughout the day, according to the site-specific work plan. Flow through cells and containers for purge water should be assembled prior to the start of pumping. Lengths of tubing should be measured to match the depth at which the pump or pump inlet will be deployed in the well. If dedicated tubing is used (i.e. tubing that is left hanging inside a well casing), inspect and replace tubing, if compromised.

Depth of Pump Inlet

The appropriate depth of pump or pump inlet tubing depends on the hydrogeology of the screened formation and well construction details:

- In cases where the screen intersects a single soil/rock material, the pump inlet should be placed at the midpoint of the well screen.
- In cases where the screen intersects multiple layers of soil/rock material or fractured rock, the pump inlet should be placed at a depth intersecting the layer expected to have the highest hydraulic conductivity.
- Where zones of contamination are known or assumed to occur at specific depths, the depth of pump inlet should match the depth of contamination. For example, petroleum compounds often accumulate in smear zones near the water table interface – pump inlets placed at the midpoint or near the bottom of well screen may not provide a representative sample in this instance.
- Do not place the pump inlet at or near the well bottom, because pumping near the well bottom can mobilize solids settled in the well sump.
- Do not place the pump inlet at or above the top of the well screen, because low-stress pumping would capture stagnant water in the well casing rather than formation water.

Pumping Rate

The initial pumping rate should be 100 mL/min or less. Lower hydraulic conductivity units (i.e. clay) should be pumped at lower initial flow rates; higher hydraulic conductivity units (i.e. sand) can be pumped at higher initial flow rates. Adjust the pumping rate to be as low as practicable, to achieve stabilization of water quality parameters without inducing significant drawdown (e.g. without pumping stagnant water from the well casing). Do not induce continuous drawdown. Pumping rates at which water level stabilization can be achieved range generally from 100 to 500 mL/min. Samples must not be collected using a pumping rate that exceeds the pumping rate at which stabilization was achieved. Conceptually, once flow rate and water quality parameters have stabilized, a direct connection to the aquifer has been established, and any changes or disruptions to flow rate could break that connection and result in stagnant water being included in the samples.

The optimal pumping rate that will achieve stabilization for drawdown and water quality parameters will be specific to each well. Do not attempt to pump every well at a site at the same pumping rate. Use historical sampling information to replicate pumping rates for specific wells, as appropriate.

Monitoring Drawdown

Depth to water in the monitoring well should be monitored at 1 to 2 minute intervals until water level stabilization occurs and periodically afterwards. Drawdown during the course of pumping and sampling should not exceed 25% of the distance between the top of screen and pump inlet. Also, the volume of water pumped that is attributable to drawdown (stagnant water pumped from the well casing) should not exceed 10% of the total volume of water pumped. Some wells, especially those screened in clay, may not achieve water level stabilization (i.e., the water level continues to drop even at flow rates less than 50 ml/min). If this occurs, contact the field leader and Project Manager to discuss alternative methods for sample collection such as completely purging the well and returning to collect the sample once the well has recovered, or using a passive sampling method.

Monitoring Water Quality Parameters

Water quality parameters that provide evidence that formation-quality water is being pumped include pH, temperature, conductivity (specific conductance), dissolved oxygen, and oxidation-reduction potential (redox, or ORP, also measured as Eh). Turbidity, discussed below, may also be a useful field parameter. Record these parameters continuously (if possible) or at regular time intervals using a closed flow through cell or similar instrumentation. Use a small volume flow through cell and monitor the cell for air bubbles (leakage).

The frequency of water quality parameter measurements should be not less than the time needed to evacuate the volume of the in-line flow through cell. Also determine the volume of water contained in the pump (i.e. bladder volume) and discharge tubing. Consider increasing time intervals to account for these volumes, especially when pumping rates are slow and/or the depth to pump inlet is significant. In instances where water quality parameter stabilization occurs quickly, be sure to also allow enough time for individual water quality instruments to stabilize (check manufacturer's recommendations). Dissolved oxygen sensors, for example, typically take longer to stabilize than pH, temperature, conductivity, and ORP sensors.

Stabilization of water quality parameters is achieved when three consecutive readings, several minutes apart, fall within the criteria listed below. These criteria are consistent with ASTM D6771-02: however, they may not apply to all sites. Site-specific parameters and criteria may be established to account for variations in aquifer properties, groundwater chemistry, well hydraulics, and contaminant distribution.

Field-Measured Parameter Stabilization Criteria for Groundwater

Parameter	Stabilization Criteria
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Dissolved Oxygen	+/- 10% of reading or +/- 0.2 mg/L, whichever is greater
Oxidation-Reduction Potential	+/- 20 mV
pH	+/- 0.2 standard units
Temperature	+/- 0.1°C
Turbidity	<10 NTUs or ± 10% when turbidity is greater than 10 NTUs

Notes: µS/cm = micro Siemens per centimeter
°C = degrees Celsius
mg/L = milligrams per liter
mV = millivolts
NTUs = nephelometric turbidity units

Turbidity

Turbidity is indicative of the stress pumping places on the screened formation. Measure turbidity with the same frequency (time intervals) as other water quality parameters or, at a minimum, at the beginning of pumping and again prior to collecting a sample. Ideally, low-flow purging should proceed until turbidity is less than 10 NTU, however, turbidity greater than 10 NTU can be natural and unavoidable. Analytical bias can occur for samples collected with turbidity greater than natural conditions.

When turbidity increases during pumping, too much stress is being placed on the well – lower the pumping rate. If the turbidity remains high, stop pumping and allow the well to rest without removing the pump. Resume pumping at a low rate and monitor turbidity for stabilization. As noted above, natural turbidity may remain higher than targeted stabilization criteria.

To minimize initial turbidity, carefully lower pumps and tubing into the monitoring well to avoid stirring sediment that has settled at the well bottom. Turbidity and other water quality parameters will typically stabilize more quickly when using dedicated pumps.

3.3.5 Sampling

When using the low-flow method, disconnect the flow cell without shutting off the pump and collect samples directly from the discharge tubing using the same pumping rate as was used to achieve stabilization. Use tubing appropriate for the compounds of concern. Collect samples for analysis of the most sensitive parameters first, and collect samples requiring field filtration last. Sampling protocol is described in detail in Section 3.4.

Be aware of potential quality control issues when collecting samples using the low-flow method:

- Samples should not be collected using a pumping rate greater than the purging/stabilization rate
- Once stabilization has been achieved do not disrupt the connection to the groundwater in the formation by shutting off the pump or changing the flow rate
- When collecting samples for analysis of VOCs, pump at a rate less than 250 mL/min, and avoid aerating groundwater in pump tubing or flow through cell
- Some chemical constituents may leach to tubing
  - Teflon® or Teflon®-lined tubing is preferred for samples that will be analyzed for VOCs, SVOCs, pesticides, and PCBs
  - HDPE or polypropylene tubing may be used for metals and other organics
  - Siliclastic (silicon) tubing should be less than 1 foot in length (when used with peristaltic pumps and when used with barrel filters)
- Shade equipment and tubing to avoid direct sunlight and warm ambient air temperatures

Field Forms

Field forms or field notes should record the following information, in addition to site and well information, to document water level and water quality parameter stabilization during low-flow pumping and sampling:

- Type, make, and model of pumping and water quality instruments
- Equipment calibration (include copies of calibration certificates as appropriate)
- Decontamination procedures
- Depth of pump or pump inlet
- Volumes of flow through cell, discharge tubing, and pump (bladder)
- Initial pumping rate and time intervals
- Drawdown, stabilized water level, and pumping rate at stabilization
- Field-measured water quality data at regular time intervals during purging
- Time and pumping rates for all measurements
- Rate of pumping at time of sample collection

Section 4.1 describes in detail the record keeping requirements to follow when groundwater sampling.

Instrument Error

Instruments suspected of producing erroneous readings should be recalibrated. If the values obtained continue to be outside normal ranges, troubleshoot or replace the instrument. If the instrument cannot be replaced and provides data critical to performing and documenting the purging procedure, notify the Project Manager. Do not discard the samples, if collected. Flag any out of range data recorded in field notes using an asterisk and a written description of the occurrence. Deviation from standard field procedure, use of alternate equipment, or re-sampling may be required to determine whether anomalous readings were the result of mechanical or human error and to ensure documentation of the collection of a representative sample.

3.4 Collecting Samples

This section describes sampling protocol to follow when using either the well volume method or low-flow method. Representative samples are collected when the monitoring well is purged according to the requirements of the standard procedure and when the sample is appropriately collected, preserved, handled, shipped, and analyzed. Groundwater samples must be collected in the appropriate order, field-filtered and field-preserved according to analytical methods, accompanied with quality assurance/quality control (QA/QC) samples, immediately preserved on ice, and shipped with the appropriate chain-of-custody documentation.

3.4.1 Sampling Order

Collect samples according to analyte stability, as summarized below, unless otherwise specified in a site-specific work plan or field sampling plan:

- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)
- Non-filtered, non-preserved samples (e.g. PCBs, pesticides, sulfate)
- Non-filtered, preserved samples (e.g. phenols, nitrogen, total metals, organic carbon)
- Available cyanide (follow lab provide cyanide kit direction for collection of sample)
- Filtered, non-preserved samples (e.g. chromium IV)
- Filtered, preserved samples (e.g. dissolved metals)
- Miscellaneous parameters

In addition, collect samples for sulfate analysis before collecting sulfuric-acid preserved samples (e.g. nitrogen), and collect samples for nitrogen compound analysis before nitric-preserve samples (e.g. dissolved metals).

3.4.2 Filling Sample Containers

Observe the procedures and cautions below when filling sample containers:

- Take precautions when handling acid preservatives or opening containers pre-filled with acid preservatives, according to the site-specific Health & Safety Plan (HASP).
- Remove sample container lids carefully. Do not touch the inside of the lid or the Teflon® lid septum, and do not place the lid on the ground.
- If containers, lids, or Teflon® septum come in contact with the ground or any other contaminated surface, carefully rinse the object with sample water; replace septum facing the sample.
- Fill sample containers with the appropriate preservative, volume, and headspace.
- Do not allow discharge tubing to come in contact with the inside of the sample container.
- Minimize sample contact with the atmosphere and collect samples away from possible sources of cross-contamination such as vehicle or equipment exhaust.
- Overfill containers used for VOC analysis (40 ml HCL-preserved glass vials) to eliminate air bubbles. Slowly fill the vial until surface tension (convex water surface) is maintained at the top of the vial. Replace the cap gently and invert the vial to check for air bubbles. Open the vial and add more water to the existing sample, if necessary, to eliminate air bubbles. Do not empty the bottle and refill.

3.4.3 Field Filtering

Use an in-line disposable 0.45 micron (µm) filter, or equivalent, to filter groundwater samples for which the analytical method requires field-filtering. When using a pump, connect the filter directly to the pump discharge tubing, and pump a small volume of sample volume through the filter before beginning to fill the sample container. When using a bailer, water is often transferred from the bailer to a disposable carboy, and then pumped through a barrel filter using a pump, as described above. Collect a field/equipment blank whenever collecting field-filtered samples.

Follow these procedures when field-filtering groundwater samples:

- Filter samples immediately in the field; if field conditions prevent field-filtering, filter samples as soon as possible or instruct the analytical laboratory to filter samples upon receipt
- Use disposable filters (i.e. Geotech® barrel filters) to eliminate cross-contamination
- Do not re-use disposable filters
- Do not re-use temporary containers/pre-filtration containers
- Note the size and material (i.e. 500 mL polyethylene carboy) of pre-filtration containers

3.4.4 Sample Preservatives and Hold Times

Samples are to be field-preserved, if necessary, immediately after filtering or immediately after sample collection if not filtered. Pre-measured volumes of preservatives should be added to the sample bottle prior to sampling. In most cases, laboratory-supplied containers are provided with pre-measured preservatives already placed in the containers. Arrange for timely shipment of samples with short hold times.

3.4.5 QA/QC Samples

SOP 07-04-07 (Quality Control Samples) describes the intended use and collection methods for quality control samples that should be used to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness, and comparability of data obtained from groundwater samples. Deviation from the Quality Control SOP should be clearly identified in site-specific Workplan, Field Sampling Plan (FSP), or Quality Assurance Project Plan (QAPP).

The following QA/QC samples should be considered and collected, as necessary:

QA/QC Sample Type	Application
Field Duplicate	Compares differences in analytical results for identical (duplicate) samples
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	Evaluates effect of sample matrix on analytical results
Trip Blank	Identifies contribution/introduction of contaminants

	during shipment/transport
Temperature Blank	Verifies proper sample transport temperature
Equipment Blank	Determines effectiveness of in-field decontamination procedures (also known as Rinseate Blank)
Field Blank	Identifies possible environmental cross-contamination

4.1 Record Keeping/Field Forms

Field-records of all purging and sampling procedures are kept either in NRT notebooks or on site-specific field forms. Electronic copies of field notes and should be made and saved to the project directory on NRT's electronic server (typically these notes are stored in the same folder as the laboratory analytical results). Sample control logs and sample identification numbers are to be completed and assigned according to SOP 07-03-01 (Sample Labeling and Storage) and SOP 07-03-05 (Sample Location, Identification, and Control).

4.1.1 Field Notebook

At a minimum, the following information should be recorded in a field notebook, on groundwater sampling forms, or on a site/project-specific groundwater sampling forms:

- Weather conditions
- Well condition
- Size, diameter, and well casing material
- Water level, relative to top of well casing
- Depth to bottom, or historical depth to bottom, relative to top of well casing
- Thickness and/or presence of any NAPLs
- Calculation of well volumes
- Time when purging begins
- Purge method (e.g. bailed, pumped)
- Initial color, odor, and clarity of purge water
- Initial water quality parameter data (e.g. pH, temperature, conductivity, ORP, turbidity)
- Time intervals, water levels, water quality parameters, pumping rate, and cumulative purge volumes (if low-flow sampling)

- Sample collection time
- Water quality parameters at the time of sample collection
- Number and type of sample containers
- Method and type of field-filtration and/or field-preservation
- Sample identification number and lab identification/chain of custody number
- Name and manufacturer of any equipment used
- Calibration results
- Description of decontamination procedures
- Total purge volume
- Location where purge water is disposed (e.g. discharge to ground or contained in drum)
- If drums are used, note the location and number of drums stored on site

4.1.2 Chain of Custody

The parameters to be analyzed are to be listed for each sample on the Chain-of-Custody (COC) as is described in SOP 07-03-03 (Chain of Custody). The COC should also clearly identify the specific USEPA-approved method of analysis to be performed on each sample, provide the specific list of analytes to be reported (e.g., list specific metals or aroclors to be reported), and provide any special instructions. For example, samples that require laboratory filtering, samples that contain known interferences with the analytical method, samples expected to contain unusually elevated concentrations of compounds, and samples with short hold times, should be clearly identified.

4.1.3 Packing and Shipping

Samples are to be placed on ice immediately after sample collection, and packed and shipped according to SOP 07-03-09 (Shipping). Samples are always shipped to the laboratory or any other facility under COC-procedure and using custody seals. When using a courier, obtain driver signatures on the COC. Ship groundwater samples in compliance with all applicable requirements for shipping hazardous and/or dangerous materials.

References

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

ASTM International, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM International, D6089-97(2003)e1 Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D6301-03 Practice for the Collection of Samples of Filterable and Nonfilterable Matter in Water

ASTM International, D6452-99(2005) Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

ASTM International, D6564-00(2005) Standard Guide for Field Filtration of Ground-Water Samples

ASTM International, D6634-01 Guide for the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells

ASTM International, D6771-02 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

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LOW-FLOW GROUNDWATER SAMPLING

1.1 Scope and Application

This Standard Operating Procedure (SOP) describes low-flow groundwater sampling methods and identifies routines to follow when collecting samples from monitoring wells. Guidance documents and SOPs published by the United States Environmental Protection Agency (USEPA) and ASTM International provide the foundation for this SOP. The procedure outlined below is intended to ensure that representative samples are collected in ways that are safe, technically defensible, easily replicated, appropriate for the selected analytical methods, and sensitive to site-specific conditions and hydrogeology. Refer to project specific documents for variances from this SOP.

1.2 Summary of Methods

This SOP describes the low-flow (low-stress or micro-purge) method used to purge and sample groundwater from monitoring wells.

1.2.1 Low-flow Method

Using the low-flow method, groundwater is purged (pumped) from a monitoring well at low flow rates that result in minimal drawdown. Depth to groundwater and groundwater quality parameters (field parameters) are monitored throughout the purging process. Pumping rates are adjusted to ensure groundwater entering the pump is from the screened formation and not from stagnant water in the well casing above the pump inlet. Samples are collected when drawdown and groundwater quality parameters stabilize within pre-determined criteria.

1.3 SOPs for Related Tasks

This SOP applies only to sampling groundwater from monitoring wells. Sampling methods for drinking water wells, surface water, pore water, leachate, and other liquid wastes are not described in this SOP.

However, this groundwater sampling SOP requires adherence to other SOPs for closely-related tasks, some of which are referenced herein:

- SOP 07-07-01 Well Integrity Evaluation
- SOP 07-07-05 Groundwater and Non-Aqueous Phase Liquid Elevation Measurement
- SOP 07-11-01 Equipment Calibration, Operation, and Maintenance
- SOP 07-04-09 Equipment Decontamination
- SOP 07-04-07 Quality Control Samples
- SOP 07-03-01 Sample Labeling and Storage
- SOP 07-03-03 Chain of Custody
- SOP 07-03-09 Shipping

2.1 Pre-mobilization Planning

Successful groundwater sampling requires planning for health and safety considerations, selecting and preparing sampling equipment, knowledge of laboratory analytical methods, field-sampling procedures, and attention to record-keeping requirements.

Planning for a groundwater sampling event includes the following basic components:

- Identify scope of work and project objectives
- Prepare a health and safety plan
- Coordinate laboratory analytical services
- Select purging and sampling methods and equipment
- Prepare field equipment
- Prepare necessary field documentation forms
- Coordinate disposal of investigative-derived waste (purge water)

2.1.1 Site-Specific Considerations

Knowledge of site conditions and previous sampling records/field notes is helpful. Select equipment and sampling methods to match the scope of work and site-specific data quality objectives.

When planning a sampling event, it is also important to understand the following site-specific information:

- Site access, security, and health and safety issues
- Known or unknown concentrations of compounds of concern
- Anticipated depth to water at individual wells
- Presence or absence of NAPLs and/or DNAPLs
- Purging methods (e.g. low flow, modified, other)
- Equipment selection (e.g. pumps, bailers, or a combination of both)
- Criteria for monitoring of field parameters
- Sampling order (typically from least to most contaminated wells)
- Requirements for field-filtering and field-preservation of samples
- Requirements for field and/or laboratory QA/QC samples
- Decontamination procedures
- Identification of short hold times or special sample handling requirements
- List of analytes and analytical methods
- Site-specific SOPs, methods, and/or record-keeping requirements

2.1.2 Health & Safety Plan, Personal Protective Equipment

Use of a site-specific Health and Safety Plan (HASP) and personal protection equipment (PPE) is mandatory for all sampling activities. NRT's Health & Safety Coordinator must approve the HASP and appropriate PPE prior to any on-site activities.

Level D protection, at minimum, is required for field activities involving groundwater sampling; however, PPE will vary according to possible levels of risk and exposure pathways. Additional protection, such as Tyvek® suits, splash guards, and/or respirators may be necessary. Use of field-screening devices, such as a photoionization detector (PID), for monitoring breathing zones and/or decontamination zones may also be appropriate. Attention to proper use of PPE and thorough decontamination of equipment that comes in contact with groundwater and/or the ground surface is also essential to preventing personal exposures and sample cross-contamination. Site-specific requirements may also necessitate the use of plastic sheeting and/or other work-area precautions to prevent releases, exposures, and cross-contamination during sampling.

When working in roadways, parking lots, and other high-traffic areas, wear high visibility clothing and use safety cones, signage, flashing signals, flaggers, or other safety precautions. Properly establish traffic control according to detailed instructions contained in Department of Transportation (DOT) traffic control handbooks/manuals. Obtain permits for work in right-of-ways, including permission to dispose of investigation derived waste (purge water) to public sanitary sewer or wastewater treatment facilities if called for in the site-specific sampling plan.

2.1.3 Laboratory Coordination

Provide the analytical laboratory with enough lead time to manage the project. Order sample containers, communicate billing, reporting information (e.g., level IV QC reporting), and field sampling dates prior to field work. Requests for quick turnaround require advanced notice.

Be sure to complete the following checklist when ordering and receiving sample containers:

- Confirm list of analytes
- Confirm methods of analysis and minimum required sample volume

- Determine whether samples are to be field-filtered and/or field-preserved
- Order extra containers as a contingency
- Count the number and type of containers received
- Discuss hold times and shipping and receiving procedures
- Determine whether special instructions are needed in writing on the chain of custody (COC)

Once the groundwater samples have been collected and shipped, make practice of calling the laboratory as a courtesy to provide anticipated arrival dates and numbers of samples. Identify samples with short hold times or that may contain exceptionally high concentrations of compounds of concern. Keep a copy of the signed COC that was shipped with the samples, and also keep any documentation of the laboratory's receipt of COCs. Include a specific list of the analytes requested on the COC as this is used by the lab to confirm the appropriate analyses have been completed and/or reported.

2.1.4 Field Equipment

Select sampling equipment necessary to achieve the data quality objectives for the project. Inspect, calibrate, and decontaminate all equipment prior to use in the field according to SOP 07-11-01 (Equipment Calibration, Operation, and Maintenance), and SOP 07-04-09 (Equipment Decontamination). The following list provides an overview of some of the items typically needed in the field:

- Health and Safety Plan (HASP)
- First Aid Kit
- PPE (minimum Level D)
- Scope of Work
- Site Maps
- Well Keys/Site Access Keys
- Mobile Phone
- Camera
- Calculator
- Field Log Book/Field Forms
- Tools
- Chain of Custody Forms

- Custody Seals
- Sample Containers
- Cooler and Ice
- Strapping Tape
- Permanent Markers/Pens
- Ziploc® Baggies
- Paper Towels
- Plastic Sheeting
- Garbage Bags
- Water Level Meter
- Weighted Steel Tape
- Oil-Water Meter
- Calibrated Buckets
- Alconox® Soap
- Brushes
- De-ionized (DI)/Potable Water
- Water Quality Meters
- Calibration Solutions
- Calibration Standards
- Meter Operation Manuals
- Flow-Through Cell
- Calibrated Beakers/Cups
- Tubing (HDPE, Tygon®, silicon)
- Disposable Filters (barrel filters)
- Bladder Pump
- Bladder Pump Control Box
- Safety Line for Bladder Pump
- Disposable Bladders
- Check Valves, Catch Plates
- Air Compressor
- Peristaltic Pump
- Submersible Pump (Whaler®, other)
- Extension Cords
- Hose Clamps
- Portable Battery (automotive/marine)
- Alligator Clips
- Electric Tape
- Generator and Gasoline

2.1.5 Field Forms

Field-records of all purging and sampling procedures are kept either in field notebooks or on site-specific field forms. Field notes for groundwater sampling may include observations and documentation of well inspection, water level, equipment calibration, purging and sampling information, sample control logs, and chain of custody. Record-keeping requirements are described Section 4.1.

2.1.6 Waste Disposal

Contaminated purge water will be discharged as directed in the site-specific sample plan. If disposal is required, it should be arranged prior to the sampling event. A waste profile and permission from regulatory authority and wastewater operator may be needed to dispose purge water to a sanitary sewer, wastewater treatment facility, landfill, or on-site disposal facility.

3.1 Groundwater Sampling Procedure

This SOP describes steps to follow when performing the low-flow method using bladder or peristaltic pumps.

Sampling generally proceeds in the following fashion:

- Establish a safe working zone
- Assess well condition
- Measure depth to groundwater
- Measure depth to well bottom (except in some cases)
- Measure thickness of any non-aqueous phase liquids (NAPLs or DNAPLs), if present
- Calculate well volumes
- Purge the well
- Collect samples

- Label and pack samples on ice for shipping
- Decontaminate equipment
- Complete all record-keeping requirements, including COC
- Ship samples

3.1.1 Well Integrity

Assess the condition of monitoring wells and protective casings prior to sampling activities. Measure depth to well bottom and compare measurement to previous measurements. The presence of obstructions and bent or broken casing (risers) must be considered before lowering pumps or other equipment into the well. Make note of, photograph, and repair, if possible, any damage to the monitoring well. Replace any missing locks or pressure caps prior to leaving the site. Include a well condition report as a part of the groundwater sampling field notes. Refer to SOP 07-07-01 (Well Integrity) for additional instructions.

3.1.2 Depth to Groundwater

Record the depth to groundwater to the nearest 0.01 ft, relative to the reference point at the top of well casing. A notch or permanent marking at the top of well casings (typically PVC) commonly marks the reference point. Measure depth to groundwater beginning at the least contaminated well and proceed to the most contaminated well. Decontaminate the water level meter (probe) with laboratory-grade soap and potable or deionized water between each well location. Refer to SOP 07-07-05 (Groundwater Elevation Measurements) and SOP 07-04-09 (Equipment Decontamination) for additional instructions.

Take time to monitor whether the measured depth to groundwater represents static groundwater elevation. Pressure caps may prevent some water columns from equilibrating with atmospheric pressure; be alert for this condition when pressure caps are very tight or produce an audible popping or hissing noise when removed. Record these observations in field notes and return to the well several times to make additional measurements to determine whether the water level has equilibrated.

Groundwater with elevated specific conductance (conductivity) may also interfere with the accuracy of water level measurement due to meter sensitivity. Adjust the sensitivity of the water level meter to make an accurate measurement, however, try to use a consistent sensitivity setting from well to well. When groundwater elevation contour maps are to be prepared, collect synoptic depth to groundwater measurements (e.g. collect measurements consecutively at every site well in the shortest period of time possible and prior to any sampling activities).

3.1.3 Depth to Bottom

Measurement of depth to well bottom is also made with a water level meter or with a measuring tape with a weighted bottom. Measure the depth to well bottom to nearest 0.01 ft relative to the reference point. Adjust measurements to account for the length of the water meter probe housing which extends below the water level sensor or for the length of weight below the bottom of the tape, if any. Decontaminate measuring tapes and water level probes and the full length of measuring tape that entered the well casing with laboratory grade soap and potable or de-ionized (DI) water according to SOP 07-04-09 (Equipment Decontamination), prior to use at other wells.

Depth to bottom measurements should be avoided in situations when performing the measurement stirs up sediment settled in the well sump. If possible, wait to take depth to well bottom measurement until after sampling is completed, and/or rely on past measurement of depth to well bottom to calculate well volumes. Note on field forms when historical depth to bottom measurements are used.

3.1.4 Thickness of NAPLs

Where immiscible liquids, such as petroleum non-aqueous phase liquid (NAPL), is present on the surface of the water column, an oil-interface probe (oil-water meter) is used to measure NAPL thickness. Differing patterns of audible alarms indicate “oil” as opposed to water. Record the depth to NAPL and depth to water relative to the reference point at the top of well casing. Decontaminate the probe and length of measuring tape that entered the well casing with laboratory grade soap and potable or DI water before use at another well. Refer to SOP 07-04-09 (Equipment Decontamination) for more instructions.

NAPL thickness can also be estimated using a bailer (glass or plastic). Slowly lower the bailer into the top of the water column. Do not allow the bailer to fill completely. Retrieve the bailer, place on a bailer stand, and measure the thickness of product in the bailer. Record the measurement as an estimate.

3.1.5 Purging and Pumping Equipment

Bladder pumps (e.g. Well Wizard®), and suction (peristaltic) pumps are preferred when performing the low-flow method. In some cases, use of a combination of equipment is appropriate, because the type of pump selected for purging may not be appropriate for sampling.

The material construction of pumps should also be considered with respect to potential interferences. For example, the use of polyvinyl chloride (PVC) and polyethylene is discouraged when the detected concentrations of organic compounds is anticipated to be at or near laboratory detection limits, because organics may leach in and out of these materials. Teflon® and Teflon®-lined sampling devices are preferred in these cases.

3.2 Purging and Sampling Using the Low-flow Method

Using the low-flow (low-stress, micro-purge) method, groundwater is purged at rates affecting minimal to no drawdown which effectively isolates stagnant water in the well casing (riser) above the pump inlet. Depth to groundwater and water quality parameters (field parameters) should be monitored throughout the purging process. Pumping rates are adjusted to ensure that flow of groundwater to the pump is from the saturated formation and not from stagnant water in the well casing. Samples are collected once drawdown and water quality parameters stabilize.

Purging for the low-flow method is performed using either a peristaltic (suction) pump, or a bladder pump. Tubing and bladders should be Teflon® or Teflon®-lined, although non-lined high-density polyethylene (HDPE) tubing is appropriate for many compounds of concern. In some situations, low-flow methods may be performed using other submersible pumps (e.g. Grundfos®, Whaler®, Proactive®) and inertia pumps (e.g. WaTerra®); see Section 3.2.3 for potential data quality implications.

3.2.1 Using a Peristaltic Pump

A peristaltic pump is used at the ground surface to apply a suction force to lift water from the well through small diameter tubing. Maximum lift for peristaltic pumps is in the range of 15 to 29 feet; and, pumping rates range from less than 50 milliliters per minute (mL/min) to several gallons per minute (gal/min). Peristaltic pumps exert reduced pressure on the pumped water which can result in degassing and volatilization of the sample. Changes in pressure can affect pH, oxidation reduction potential (ORP), and other gas-sensitive parameters (ASTM D6634-01[2006]). As a result, USEPA recommends that peristaltic pumps not be used for low-flow groundwater sampling when depth to water exceeds 15 feet, especially when collecting samples for analysis of volatile organic compounds (VOCs).

3.2.2 Using a Bladder Pump

A bladder pump uses compressed air to squeeze a flexible membrane (bladder) that is contained in a rigid housing. Groundwater enters the bladder under hydrostatic pressure through a check valve, and compressed air supplied via small diameter air line compresses the bladder which forces water from the bladder to the surface through a small diameter water return line (the compressed air does not contact the water). Flow rate and air line pressure are regulated via an electronic control box. Pressure is applied in timed cycles, allowing the bladder to refill and compress at intervals appropriate for the depth, hydraulic conductivity of the saturated formation, and desired flow rate. Lift capacity of the pump is directly related to the pressure of the drive gas source.

Representative groundwater samples can be obtained for all analytes in nearly all field conditions using a bladder pump. Low-flow sampling with a bladder pump reduces the possibility for degassing, agitation, and volatilization of the sample, as compared to peristaltic or submersible pumps.

3.2.3 Using Other Pumps

Other submersible pumps (e.g. Grundfos®, Whaler®, ProActive®) are commonly used to purge groundwater from monitoring wells (i.e. for the well volume method) or to accomplish well development. However, they are not always appropriate for low-flow sampling. Some studies show that using submersible pumps to collect groundwater samples for analysis of VOCs generates analytical data similar to that for bladder pumps; however, the valves used to restrict the flow of submersible pumps reduce pressure potentially resulting in degassing of the sample. Submersible pump impellers also cause heat and turbulent flow which can also result in changes in water chemistry. Pump failures may also release contaminants (oiled parts, plastics, etc) into a monitoring well. Due to these limitations, bladder pumps are recommended over submersible pumps for low flow sampling, particularly for VOCs.

3.2.4 Field Procedure

The objective of the low-flow method is to perform low-stress pumping of a monitoring well to clearly document that samples represent groundwater entering the well from the screened formation at the depth of the pump inlet. To do so, the sampler must place the pump inlet at the appropriate depth, pump in a manner that minimizes stress to the formation, and monitor drawdown and groundwater quality parameters at regular intervals.

The low-flow field method is performed according to the following steps:

- Assemble equipment, (e.g. pumps, tubing, flow through cell, water quality instruments)
- Clean (decontaminate) all down-hole equipment
- Calibrate water quality instruments
- Measure initial depth to groundwater
- Place pump/pump inlet tubing at appropriate depth in the screened interval
- Begin pumping at an initial rate (typically 100 mL/min or less)
- Calculate minimum purge volume (time intervals) for parameter readings
- Monitor water level drawdown and water quality parameters
- Adjust pumping rate to minimize/stabilize drawdown
- Continue pumping until drawdown and water quality parameters stabilize
- Collect samples

Preparation

Clean all non-dedicated down-hole equipment according to SOP 07-04-09 (Equipment Decontamination) prior to measuring initial depth to water or lowering a pump or inlet tubing into the well. Non-dedicated bladder pumps should be disassembled, cleaned, and re-assembled; also remove and clean pump gaskets, check valves, and inlet screens. Clean, calibrate, and test water quality instruments (probes) according to the manufacturer's instruction manuals. Document calibration results at the beginning of the day and periodically throughout the day, according to the site-specific work plan. Flow through cells and containers for purge water should be assembled prior to the start of pumping. Lengths of tubing should be measured to match the depth at which the pump or pump inlet will be deployed in the well. If dedicated tubing is used (i.e. tubing that is left hanging inside a well casing), inspect and replace tubing, if compromised.

Depth of Pump Inlet

The appropriate depth of pump or pump inlet tubing depends on the hydrogeology of the screened formation and well construction details:

- In cases where the screen intersects a single soil/rock material, the pump inlet should be placed at the midpoint of the well screen
- In cases where the screen intersects multiple layers of soil/rock material or fractured rock, the pump inlet should be placed at a depth intersecting the layer expected to have the highest hydraulic conductivity
- Where zones of contamination are known or assumed to occur at specific depths, the depth of pump inlet should match the depth of contamination. For example, petroleum compounds often accumulate in smear zones near the water table interface – pump inlets placed at the midpoint or near the bottom of well screen may not provide a representative sample in this instance.
- Do not place the pump inlet at or near the well bottom, because pumping near the well bottom can mobilize solids settled in the well sump.
- Do not place the pump inlet at or above the top of the well screen, because low-stress pumping would capture stagnant water in the well casing rather than formation water.

Pumping Rate

The initial pumping rate should be 100 mL/min or less. Lower hydraulic conductivity units (i.e. clay) should be pumped at lower initial flow rates; higher hydraulic conductivity units (i.e. sand) can be pumped at higher initial flow rates. Adjust the pumping rate to be as low as practicable, to achieve stabilization of water quality parameters without inducing significant drawdown (e.g. without pumping stagnant water from the well casing). Do not induce continuous drawdown. Pumping rates at which water level stabilization can be achieved range generally from 100 to 500 mL/min. <u>Samples must not be collected using a pumping rate that exceeds the pumping rate at which stabilization was achieved.</u> Conceptually, once flow rate and water quality parameters have stabilized, a direct connection to the aquifer has been established, and any changes or disruptions to flow rate could break that connection and result in stagnant water being included in the samples.

The optimal pumping rate that will achieve stabilization for drawdown and water quality parameters will be specific to each well. Do not attempt to pump every well at a site at the same pumping rate. Use historical sampling information to replicate pumping rates for specific wells, as appropriate.

Monitoring Drawdown

Depth to water in the monitoring well should be monitored at 1 to 2 minute intervals until water level stabilization occurs and periodically afterwards. Drawdown during the course of pumping and sampling should not exceed 25% of the distance between the top of screen and pump inlet. Also, the volume of water pumped that is attributable to drawdown (stagnant water pumped from the well casing) should not exceed 10% of the total volume of water pumped. Some wells, especially those screened in clay, may not achieve water level stabilization (i.e., the water level continues to drop even at flow rates less than 50 ml/min). If this occurs, contact the field leader and Project Manager to discuss alternative methods for sample collection such as completely purging the well and returning to collect the sample once the well has recovered, or using a passive sampling method.

Monitoring Water Quality Parameters

Water quality parameters that provide evidence that formation-quality water is being pumped include pH, temperature, conductivity (specific conductance), dissolved oxygen, and oxidation-reduction potential (redox, or ORP, also measured as Eh). Turbidity, discussed below, may also be a useful field parameter.

Record these parameters continuously (if possible) or at regular time intervals using a closed flow through cell or similar instrumentation. Use a small volume flow through cell and monitor the cell for air bubbles (leakage).

The frequency of water quality parameter measurements should be not less than the time needed to evacuate the volume of the in-line flow through cell. Also determine the volume of water contained in the pump (i.e. bladder volume) and discharge tubing. Consider increasing time intervals to account for these volumes, especially when pumping rates are slow and/or the depth to pump inlet is significant. In instances where water quality parameter stabilization occurs quickly, be sure to also allow enough time for individual water quality instruments to stabilize (check manufacturer's recommendations). Dissolved oxygen sensors, for example, typically take longer to stabilize than pH, temperature, conductivity, and ORP sensors.

Stabilization of water quality parameters is achieved when three consecutive readings, several minutes apart, fall within the criteria listed below. These criteria are consistent with ASTM D6771-02: however, they may not apply to all sites. Site-specific parameters and criteria may be established to account for variations in aquifer properties, groundwater chemistry, well hydraulics, and contaminant distribution.

Field-Measured Parameter Stabilization Criteria for Groundwater

Parameter	Stabilization Criteria
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Dissolved Oxygen	+/- 10% of reading or +/- 0.2 mg/L, whichever is greater
Oxidation-Reduction Potential	+/- 20 mV
pH	+/- 0.2 standard units
Temperature	+/- 0.1°C
Turbidity	<10 NTUs or ± 10% when turbidity is greater than 10 NTUs

Notes: µS/cm = micro Siemens per centimeter
°C = degrees Celsius
mg/L = milligrams per liter
mV = millivolts
NTUs = nephelometric turbidity units

Turbidity

Turbidity is indicative of the stress pumping places on the screened formation. Measure turbidity with the same frequency (time intervals) as other water quality parameters or, at a minimum, at the beginning of pumping and again prior to collecting a sample. Ideally, low-flow purging should proceed until turbidity is less than 10 NTU, however, turbidity greater than 10 NTU can be natural and unavoidable. Analytical bias can occur for samples collected with turbidity greater than natural conditions.

When turbidity increases during pumping, too much stress is being placed on the well – lower the pumping rate. If the turbidity remains high, stop pumping and allow the well to rest without removing the pump. Resume pumping at a low rate and monitor turbidity for stabilization. As noted above, natural turbidity may remain higher than targeted stabilization criteria.

To minimize initial turbidity, carefully lower pumps and tubing into the monitoring well to avoid stirring sediment that has settled at the well bottom. Turbidity and other water quality parameters will typically stabilize more quickly when using dedicated pumps.

3.2.5 Sampling

When using the low-flow method, disconnect the flow cell without shutting off the pump and collect samples directly from the discharge tubing using the same pumping rate as was used to achieve stabilization. Use tubing appropriate for the compounds of concern. Collect samples for analysis of the most sensitive parameters first, and collect samples requiring field filtration last. Sampling protocol is described in detail in Section 3.3.

Be aware of potential quality control issues when collecting samples using the low-flow method:

- Samples should not be collected using a pumping rate greater than the purging/stabilization rate
- Once stabilization has been achieved do not disrupt the connection to the groundwater in the formation by shutting off the pump or changing the flow rate

- When collecting samples for analysis of VOCs, pump at a rate less than 250 mL/min, and avoid aerating groundwater in pump tubing or flow through cell
- Some chemical constituents may leach to tubing
  - Teflon® or Teflon®-lined tubing is preferred for samples that will be analyzed for VOCs, SVOCs, pesticides, and PCBs
  - HDPE or polypropylene tubing may be used for metals and other organics
  - Siliclastic (silicon) tubing should be less than 1 foot in length (when used with peristaltic pumps and when used with barrel filters)
- Shade equipment and tubing to avoid direct sunlight and warm ambient air temperatures

Field Forms

Field forms or field notes should record the following information, in addition to site and well information, to document water level and water quality parameter stabilization during low-flow pumping and sampling:

- Type, make, and model of pumping and water quality instruments
- Equipment calibration (include copies of calibration certificates as appropriate)
- Decontamination procedures
- Depth of pump or pump inlet
- Volumes of flow through cell, discharge tubing, and pump (bladder)
- Initial pumping rate and time intervals
- Drawdown, stabilized water level, and pumping rate at stabilization
- Field-measured water quality data at regular time intervals during purging
- Time and pumping rates for all measurements
- Rate of pumping at time of sample collection

Section 4.1 describes in detail the record keeping requirements to follow when groundwater sampling.

Instrument Error

Instruments suspected of producing erroneous readings should be recalibrated. If the values obtained continue to be outside normal ranges, troubleshoot or replace the instrument. If the instrument cannot be replaced and provides data critical to performing and documenting the purging procedure, notify the Project Manager. Do not discard the samples, if collected. Flag any out of range data recorded in field notes using an asterisk and a written description of the occurrence. Deviation from standard field procedure, use of alternate equipment, or re-sampling may be required to determine whether anomalous readings were the result of mechanical or human error and to ensure documentation of the collection of an epresentative sample.

3.3 Collecting Samples

Representative samples are collected when the monitoring well is purged according to the requirements of the standard procedure and when the sample is appropriately collected, preserved, handled, shipped, and analyzed. Groundwater samples must be collected in the appropriate order, field-filtered and field-preserved according to analytical methods, accompanied with quality assurance/quality control (QA/QC) samples, immediately preserved on ice, and shipped with the appropriate chain-of-custody documentation.

3.3.1 Sampling Order

Collect samples according to analyte stability, as summarized below, unless otherwise specified in a site-specific work plan or field sampling plan:

- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)
- Non-filtered, non-preserved samples (e.g. PCBs, pesticides, sulfate)
- Non-filtered, preserved samples (e.g. phenols, nitrogen, total metals, organic carbon)
- Available cyanide (follow lab provide cyanide kit direction for collection of sample)

- Filtered, non-preserved samples (e.g. chromium IV)
- Filtered, preserved samples (e.g. dissolved metals)
- Miscellaneous parameters

In addition, collect samples for sulfate analysis before collecting sulfuric-acid preserved samples (e.g. nitrogen), and collect samples for nitrogen compound analysis before nitric-preserve samples (e.g. dissolved metals).

3.3.2 Filling Sample Containers

Observe the procedures and cautions below when filling sample containers:

- Take precautions when handling acid preservatives or opening containers pre-filled with acid preservatives, according to the site-specific Health & Safety Plan (HASP).
- Remove sample container lids carefully. Do not touch the inside of the lid or the Teflon® lid septum, and do not place the lid on the ground.
- If containers, lids, or Teflon® septum come in contact with the ground or any other contaminated surface, carefully rinse the object with sample water; replace septum facing the sample.
- Fill sample containers with the appropriate preservative, volume, and headspace.
- Do not allow discharge tubing to come in contact with the inside of the sample container.
- Minimize sample contact with the atmosphere and collect samples away from possible sources of cross-contamination such as vehicle or equipment exhaust.
- Overfill containers used for VOC analysis (40 ml HCL-preserved glass vials) to eliminate air bubbles. Slowly fill the vial until surface tension (convex water surface) is maintained at the top of the vial. Replace the cap gently and invert the vial to check for air bubbles. Open the vial and add more water to the existing sample, if necessary, to eliminate air bubbles. Do not empty the bottle and refill.

3.3.3 Field Filtering

Use an in-line disposable 0.45 micron (μm) filter, or equivalent, to filter groundwater samples for which the analytical method requires field-filtering. When using a pump, connect the filter directly to the pump discharge tubing, and pump a small volume of sample volume through the filter before beginning to fill the sample container. Collect a field/equipment blank whenever collecting field-filtered samples.

Follow these procedures when field-filtering groundwater samples:

- Filter samples immediately in the field; if field conditions prevent field-filtering, filter samples as soon as possible or instruct the analytical laboratory to filter samples upon receipt
- Use disposable filters (i.e. Geotech® barrel filters) to eliminate cross-contamination
- Do not re-use disposable filters
- Do not re-use temporary containers/pre-filtration containers.
- Note the size and material (i.e. 500 mL polyethylene carboy) of pre-filtration containers

3.3.4 Sample Preservatives and Hold Times

Samples are to be field-preserved, if necessary, immediately after filtering or immediately after sample collection if not filtered. Pre-measured volumes of preservatives should be added to the sample bottle prior to sampling. In most cases, laboratory-supplied containers are provided with pre-measured preservatives already placed in the containers. Arrange for timely shipment of samples with short hold times.

3.3.5 QA/QC Samples

SOP 07-04-07 (Quality Control Samples) describes the intended use and collection methods for quality control samples that should be used to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness, and comparability of data obtained from groundwater samples. Deviation from the Quality Control SOP should be clearly identified in site-specific Workplan, Field Sampling Plan (FSP), or Quality Assurance Project Plan (QAPP).

The following QA/QC samples should be considered and collected, as necessary:

QA/QC Sample Type	Application
Field Duplicate	Compares differences in analytical results for identical (duplicate) samples
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	Evaluates effect of sample matrix on analytical results
Trip Blank	Identifies contribution/introduction of contaminants during shipment/transport
Temperature Blank	Verifies proper sample transport temperature
Equipment Blank	Determines effectiveness of in-field decontamination procedures (also known as Rinseate Blank)
Field Blank	Identifies possible environmental cross-contamination

4.1 Record Keeping/Field Forms

Field-records of all purging and sampling procedures are kept either in NRT notebooks or on site-specific field forms. Electronic copies of field notes and should be made and saved to the project directory on NRT's electronic server (typically these notes are stored in the same folder as the laboratory analytical results). Sample control logs and sample identification numbers are to be completed and assigned according to SOP 07-03-01 (Sample Labeling and Storage) and SOP 07-03-05 (Sample Location, Identification, and Control).

4.1.1 Field Notebook

At a minimum, the following information should be recorded in a field notebook, on groundwater sampling forms, or on a site/project-specific groundwater sampling forms:

- Weather conditions
- Well condition
- Size, diameter, and well casing material
- Water level, relative to top of well casing
- Depth to bottom, or historical depth to bottom, relative to top of well casing
- Thickness and/or presence of any NAPLs

- Calculation of well volumes
- Time when purging begins
- Purge method (e.g. bailed, pumped)
- Initial color, odor, and clarity of purge water
- Initial water quality parameter data (e.g. pH, temperature, conductivity, ORP, turbidity)
- Time intervals, water levels, water quality parameters, pumping rate, and cumulative purge volumes (if low-flow sampling)
- Sample collection time
- Water quality parameters at the time of sample collection
- Number and type of sample containers
- Method and type of field-filtration and/or field-preservation
- Sample identification number and lab identification/chain of custody number
- Name and manufacturer of any equipment used
- Calibration results
- Description of decontamination procedures
- Total purge volume
- Location where purge water is disposed (e.g. discharge to ground or contained in drum)
- If drums are used, note the location and number of drums stored on site

4.1.2 Chain of Custody

The parameters to be analyzed are to be listed for each sample on the Chain-of-Custody (COC) as is described in SOP 07-03-03 (Chain of Custody). The COC should also clearly identify the specific USEPA-approved method of analysis to be performed on each sample, provide the specific list of analytes to be reported (e.g., list specific metals or aroclors to be reported), and provide any special instructions. For example, samples that require laboratory filtering, samples that contain known interferences with the analytical method, samples expected to contain unusually elevated concentrations of compounds, and samples with short hold times, should be clearly identified.

4.1.3 Packing and Shipping

Samples are to be placed on ice immediately after sample collection, and packed and shipped according to SOP 07-03-09 (Shipping). Samples are always shipped to the laboratory or any other facility under COC-procedure and using custody seals. When using a courier, obtain driver signatures on the COC. Ship groundwater samples in compliance with all applicable requirements for shipping hazardous and/or dangerous materials.

References

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

ASTM International, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM International, D6089-97(2003)e1 Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D6301-03 Practice for the Collection of Samples of Filterable and Nonfilterable Matter in Water

ASTM International, D6452-99(2005) Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

ASTM International, D6564-00(2005) Standard Guide for Field Filtration of Ground-Water Samples

ASTM International, D6634-01 Guide for the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells

ASTM International, D6771-02 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Reviewed By:	JJW	Date Reviewed:	08-20-2012
Corporate Officer:	RHW	Date Approved:	12-02-2013

FIELD INSTRUMENT CALIBRATION, OPERATION, AND MAINTENANCE

1.1 Scope and Application

This procedure describes guidelines for the calibration, operation, and maintenance of field instruments.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards.

1.3 Equipment

- Measurement and testing equipment
- Instrument operation manual
- Instrument case and necessary appurtenances (e.g., battery charger and attachments)
- Calibration standards (e.g., standard gases and pH fluids)

1.4. Background

Instrument operators must be familiar with the operation of the field instrument being used. Operators will obtain appropriate training before using the instrument in the field. If user certification is required for an instrument, it must be obtained prior to using the instrument in the field.

Instruments must be uniquely identified, such as with a serial number, and that identifier will be recorded in the field notes. Manufacturer’s guides and/or operation manuals will be kept with the instruments for reference at all times.

1.5. Calibration

Field instruments must be calibrated according to the manufacturer's specifications prior to initial use. The instrument shall be recalibrated according to the following:

- The manufacturer's recommended calibration frequency
- After long periods of inactivity between uses
- When readings are observed above/below the instrument range
- If signs or evidence of equipment malfunction are observed

Daily calibration and recalibration activities will be recorded in the field logbook or on appropriate field forms. At a minimum, the following information will be recorded:

- Date and time of calibration
- Instrument make, model, and manufacturer
- Instrument identifier (e.g., serial number or unique inventory number)
- Calibration method
- Calibration standards used
- Any deviation from the manufacturer's recommended procedures or calibration frequency

1.6. Operation

Instruments will be operated in accordance with the manufacturer's instructions. Readings, malfunctions, and deviations from standard operating methods will be documented in the field logbook or on appropriate field forms.

1.7. Maintenance

Instruments will be maintained in accordance with the manufacturer's recommendations. Malfunctioning instruments, or those scheduled for routine maintenance, will be clearly labeled to prevent further use until maintenance is completed. Rentals instruments are not to be maintained by NRT and it will be returned to the supplier if repair or maintenance is required. A replacement instrument will be requested if needed. Supporting calibration and maintenance documentation from the supplier will be scanned and saved in the project folder with associated field notes from the sampling event.

Maintenance for instruments owned by NRT will be tracked and recorded on a dedicated log that will contain the following information:

- Instrument make, model, and manufacturer
- Instrument identification (e.g., serial number or unique inventory number)
- Recommended maintenance and frequency
- Status (e.g., operational, out of service for repair/maintenance, not operational)
- Dates of status change
- Dates of inspection, maintenance, or repairs

Documentation of maintenance for NRT-owned equipment will be stored in a file in the warehouse which is maintained by the warehouse manager.