UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NEW ENGLAND REGION
FIVE POST OFFICE SQUARE, SUITE 100, BOSTON, MA 02109

September 15, 2020

Bruce Thompson
de maximis, inc.
200 Day Hill Road, Suite 200
Windsor, CT 06095

Re: Approval of de maximis inc. report titled *Remedial Design Work Plan – Appendix I Field Sampling Plan* (the "FSP"), dated September 2020.

Nuclear Metals, Inc. Superfund Site

Dear Mr. Thompson:

EPA, in consultation with the Massachusetts Department of Environmental Protection, has completed its review of the FSP, dated September 2020. The FSP was revised in response to EPA comments dated July 2, 2020 and August 31, 2020. The FSP is subject to the terms and conditions specified in the Consent Decree (CD) for Remedial Design / Remedial Action (RD/RA) for the Nuclear Metals, Inc. Site, which has an effective Date of December 6, 2019.

EPA has reviewed the revisions to the FSP and finds that they are acceptable. Therefore, EPA approves the FSP.

If there is any conflict between the Performance Standards as stated in the FSP and the Performance Standards as stated in the CD and statement of work (SOW), the CD and SOW shall control.

Please do not hesitate to contact me at (617) 918-1339 or at smith.christopher@epa.gov should you have any questions in this regard.

Sincerely,

Christopher Smith
Project Manager

NUCLEAR METALS, INC. SUPERFUND SITE

CONCORD, MASSACHUSETTS

Remedial Design Work Plan - Appendix I

Field Sampling Plan (FSP)

de maximis, inc.
200 Day Hill Road, Suite 200
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September 2020

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1.0 INTRODUCTION

This Field Sampling Plan (FSP) supports the implementation of the Remedial Design/Remedial Action (RD/RA) at the Nuclear Metals, Inc. Superfund Site (NMI) and downgradient properties (together, the Site) located in Concord and Acton, Massachusetts (Figure 1).

This FSP has been prepared on behalf of the Respondents performing work at the Site pursuant to the Consent Decree (CD) lodged by the United States Environmental Protection Agency (USEPA) with the United States District Court for the District of Massachusetts Eastern Division in connection with Civil Action No. 1:19-cv-12097-RGS. The CD was entered by the Court on December 6, 2019. The CD and the Statement of Work (SOW), provided as Appendix B to the CD, describe the RD/RA activities to be undertaken by the Settling Defendants (SDs) to the CD, with funding contributions from the Settling Federal Agencies (SFAs).

The RD/RA activities will be divided into five RA projects in order to efficiently implement the overall remedy. RA projects #1 through #4 are outlined in Section 1.4 of the SOW. The need for RA project #5 was identified during the Groundwater Non-Time-Critical Removal Action (NTCRA). The five RA projects include:

#1. Excavation and off-site disposal of contaminated sediments, underground drain lines and debris, and non-Holding Basin (HB) soils, or “Site-wide Soils and Sediments”;

#2. In-Situ Sequestration (ISS) of depleted uranium (DU) in HB soils and of DU and natural uranium (U) in overburden and bedrock groundwater, or “ISS”;

#3. Containment of HB soils with a low-permeability vertical wall and horizontal sub-grade cover, or “HB Containment”;

#4. Hydraulic containment and ex-situ treatment of volatile organic compounds (VOCs) and 1,4-dioxane in groundwater; and

#5. 1,4-dioxane and VOCs in bedrock groundwater.

1.1 Background

The NMI Site includes the 46-acre NMI Property located at 2229 Main Street in Concord, MA and downgradient properties where groundwater contamination has migrated (see Figure 1). The NMI property is surrounded by residential and woodland areas to the east and south, light commercial and industrial areas to the west, and Main Street (Route 62) and the Assabet River to the north. The remaining portions of the Site include the Downgradient Properties, where impacted groundwater is present, and include commercial offices, a former gravel pit and an ice rink located to the north and west of the NMI Property.

1.2 Remedial Design Work Plan Overview

Section 3.1 of the SOW requires submittal of a Remedial Design Work Plan (RDWP) to summarize pertinent Site information, identify and describe the scopes and procedures for various pre-design investigations, describe the anticipated RD process, and discuss the RD-related deliverables and schedule.

As required by Section 3.3(a) of the SOW, Pre-Design Investigation (PDI) Work Plans (WP) have been prepared for four of the anticipated remedial components (Site-wide Soils and Sediments (RA project #1), ISS (RA project #2), HB Containment (RA project #3), and 1,4-dioxane and VOCs in Bedrock Groundwater (RA projects #5)). Note that the hydraulic containment and ex-situ treatment of VOCs and 1,4-dioxane in groundwater was initiated by the Groundwater NTCRA and is currently operating, as such, a further PDI WP is not needed for RA project #4. PDI WPs were prepared for each remedial component, and are attached to the RDWP as follows:

- Site-wide Soils and Sediment PDI WP (Appendix A)
- ISS PDI WP (Appendix B)
- HB Containment PDI WP (Appendix C)
- 1,4-dioxane and VOCs in Bedrock Groundwater PDI WP (Appendix D)

Section 3.4(a) of the SOW requires performance of Treatability Studies (TS) to support the ISS component of the remedy. Separate studies are needed to evaluate and select treatment materials/reagents, for high concentration DU within the HB, low concentration DU outside the HB, and isotopically natural U in bedrock, respectively. In addition to reagent selection, each media will require evaluation to determine the best means to apply the selected reagent. The overall Treatability Study Work Plan (TS WP) is included as Appendix E.

The RDWP also includes the following "Supporting Deliverables":

- To continue the Post-Removal Site Control (PRSC) requirements established pursuant to the Building NTCRA, a "Post Removal Site Control Plan" (PRSCP) is provided as Appendix F.
- Health and Safety Plan (HASP) – Appendix G
- Emergency Response Plan (ERP) – Appendix H
- Field Sampling Plan (FSP) – Appendix I
- Quality Assurance Project Plan (QAPP) – Appendix J
- Site Wide Monitoring Plan (SWMP) – Appendix K, and
- Community Relations Support Plan (CRSP) – Appendix L.

1.3 Purpose

This FSP establishes sample collection and field monitoring methods and procedures to be followed to ensure that sampling and investigatory activities at the Site are conducted in a consistent

manner and in accordance with technically acceptable protocols. Sample collection and field monitoring methods and procedures presented in this FSP are consistent with prior work conducted at the NMI Site. The objective of the FSP is to facilitate the collection of environmental monitoring data that meets Data Quality Objectives (DQOs) established in the individual PDI WPs and summarized in the Quality Assurance Project Plan (QAPP) (Appendix J of the RDWP). Additionally, specific handling and analytical methods for each sample medium, indicating appropriate sample containers, preservation, and holding times are provided in the QAPP.

The RDWP includes several work plans that describe the scope of planned field investigations to support the RD phase of the project. In consideration of the nature of the planned investigation activities, this FSP provides Standard Operating Procedures (SOPs) for environmental monitoring activities expected or likely to be conducted during the RD phase of the work (see Attachment I-1).

1.4 Document Organization

The remainder of the report is organized into three sections, each of which is identified and briefly described as follows:

- **Section 2 – Pre-Design Investigation Scope of Work:** Provides the context for and the intent of the anticipated PDIs; and
- **Section 3 – Technical Methodology:** Specifies the procedures to be followed throughout the duration of the RD activities.

2.0 PRE-DESIGN INVESTIGATION SCOPE OF WORK

As described above, PDI WPs have been developed for the four anticipated remedial components (Site-wide Soils and Sediments (RA project #1), ISS (RA project #2), HB Containment (RA project #3), and 1,4-dioxane and VOCs in Bedrock Groundwater (RA project #5)). The following Section provides the intent of the five PDIs as follows:

- Section 2.1 - Site-wide Soils and Sediment
- Section 2.2 - ISS
- Section 2.3 - HB Containment
- Section 2.4 - 1,4-dioxane and VOCs in Bedrock Groundwater

A detailed summary of the various tasks included as part of each PDI is included as Table 2-1. Several of the PDIs described below may be seasonally dependent or have a particular timeframe when the work should be completed to facilitate the schedule and deadlines outlined in the SOW. Additionally, due to the complex nature of the overall remedy, each RA project is anticipated to proceeded independently of other, non-relevant, RA projects.

2.1 Site-wide Soils and Sediments

A total of five PDIs will be performed to further characterize the limits of soil and sediment excavation, and to refine the means and methods for the Site-wide Soil and Sediment remedy.

PDIs include:

PDI-SSS-1: Refine delineation of PCBs and other COCs at the northeast outfall area (Site Area A4), the sweepings pile (Site Area A5) and within the Cooling Pond (Site Area B2);

PDI-SSS-2: Mapping of DU metal fragments and the areal extent of anticipated removal actions;

PDI-SSS-3: Refine delineation of DU within sub-slab soil beneath former building footprints based on the sub-slab soil investigation performed as part of the Building NTCRA;

PDI-SSS-4: Refine delineation of ecological COCs within the bog lag zone, evaluate Cooling Pond sediment removal methods and perform Gabion Wall stability analysis; and

PDI-SSS-5: Evaluate volume, gradation and chemical testing of existing soils available from potential on-Site borrow source area.

2.2 In-situ Sequestration

A total of four PDIs and three TS will be performed to further refine the means and methods for the ISS remedy in order to achieve Applicable or Relevant and Appropriate Requirements (ARARs) for the groundwater plume by reducing overburden and bedrock uranium concentrations to, at, or below, the remediation goal of 30 µg/L within an acceptable timeframe.

PDIs include:

PDI-ISS-1: Perform baseline Site-wide groundwater sampling;

TS-ISS-1: Perform column testing of ISS amendments for DU-impacted overburden soils beneath the HB;

TS-ISS-2: Perform batch and column testing of ISS amendments for DU-impacted overburden groundwater downgradient of the HB;

PDI-ISS-2: Perform pumping and rebound analysis for U in bedrock groundwater; and

PDI-ISS-3: Perform pilot testing of injection methods throughout the saturated overburden soils in the DU-plume area downgradient of the HB based on selected reagent(s).

The following PDIs are proposed as contingency based on the results of PDI-ISS-2:

TS-ISS-3: Perform batch and column testing of ISS amendments for U-impacted bedrock groundwater downgradient of the HB; and

PDI-ISS-4: Pilot testing of injection methods in bedrock throughout the U-plume area downgradient of the HB based on selected reagent(s).

2.3 Holding Basin Containment

A total of five PDIs will be performed to further refine the means and methods of construction for the HB containment remedy in order to achieve ARARs by preventing DU from migrating downgradient.

PDIs include:

PDI-HB-1: Collect geotechnical, seismic and hydrogeologic data necessary from within HB footprint for HB wall design;

PDI-HB-2: Perform seismic evaluation for HB wall design;

PDI-HB-3: Perform bench scale testing of slurry and concrete mix possibilities for HB wall design;

PDI-HB-4: Perform cover design and slope stability analysis for HB cap design; and

PDI-HB-5: Perform seepage analysis to evaluate the hydraulic properties of the containment wall and to evaluate the necessary depth of the wall.

2.4 1,4-Dioxane and VOCs in Bedrock

This PDI will be performed to further refine the means and methods of the 1,4 dioxane and VOC in bedrock remedy. The PDI includes refining the delineation of 1,4-dioxane and VOC concentrations

in shallow bedrock and assessing the effect pumping groundwater from shallow bedrock wells will have on the 1,4-dioxane and VOC concentrations in bedrock.

3.0 TECHNICAL METHODOLOGY

The various field methods relevant to the work associated with the PDIs described in the RDWP and in Section 2 of this FSP are summarized in the following Sections. A summary of the anticipated SOPs based on the PDI tasks is included in Table 3-1. The SOPs are included as Attachment I-1.

3.1 Soil Investigation

Several PDIs require surface and subsurface soil samples as summarized in Tables 2-1 and 3-1. Several sampling techniques will be used, such as geotechnical drilling, direct-push boreholes (i.e., sonic boreholes, etc.), test pits, and hand sampling techniques (e.g., hand auger, trowel, slide hammer). These methods will be selected based on their relevance and field conditions present at the time of sampling. Procedures relevant to soil monitoring/sampling are summarized below.

Relevant Field SOPs:

- NMI-S-001: Surface and Subsurface Soil Sampling using Manual Methods;
- NMI-S-002: Sediment Sampling;
- NMI-S-003: Jar Headspace Sampling Procedure;
- NMI-S-004: Soil and Rock Drilling and Soil Sampling;
- NMI-S-005: Test Pitting and Sampling;
- NMI-S-006: Soil Description; and
- NMI-S-007: Extraction/Preservation of Soil/Sediment VOCs.

3.2 Groundwater Investigation

Several PDIs require groundwater sampling as summarized in Tables 2-1 and 3-1. Groundwater will be monitored on the site by sampling existing monitoring wells, and/or installing and sampling new monitoring wells, piezometers, and temporary well points. Several sampling techniques will be used, such as the EPA Low Flow/Minimal Drawdown method, as well as other situation-specific techniques to gather geotechnical and hydrogeologic data such as pump testing, slug testing and packer testing. Procedures relevant to groundwater monitoring/sampling are summarized below.

Relevant Field SOPs:

- NMI-GW-001: Monitoring Well Integrity Survey;
- NMI-GW-002: Monitoring Well Development;
- NMI-GW-003: Monitoring Well Installation;
- NMI-GW-004: Well Abandonment;

- NMI-GW-005: Groundwater Sampling Using HydroPunch™;
- NMI-GW-006: Groundwater Profiling;
- NMI-GW-007: Down-Hole Groundwater Field Parameter Measurement;
- NMI-GW-008: Direct Push Drive-Point Piezometers;
- NMI-GW-009: Water-Level Measurement Procedures;
- NMI-GW-010: Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells;
- NMI-GW-011: Groundwater Sampling for PFAS;
- NMI-GW-012: Groundwater Sampling with HydroSleeves™;
- NMI-GW-013: Groundwater Sampling with Snap Samplers:
- NMI-GW-014: BarCad Well Sampling;
- NMI-GW-015: Assabet Municipal Well Sampling;
- NMI-GW-016: Packer Testing Procedures;
- NMI-GW-017: Specific Capacity Testing and Data Reduction;
- NMI-GW-018: Pump Testing;
- NMI-GW-019: Slug Testing; and
- NMI-GW-020: Field Analysis of Fluorescent Tracer Dye in Groundwater.

3.3 Surface Water Investigation

PDIs associated with the Site-wide Soil and Sediment remedy may require surface water sampling as summarized in Tables 2-1. These samples will be collected using several situation-specific procedures, including grab sampling and peristaltic pumping. Procedures relevant to surface water monitoring and sampling are summarized below.

Relevant Field SOPs:

- NMI-SW-001: Surface Water Sampling; and
- NMI-SW-002: Operations Over, Near, or on Water.

3.4 Air Investigation

Procedures relevant to air monitoring/sampling are summarized below.

Relevant Field SOPs:

- NMI-A-001: Sub-slab Soil Gas Sampling; and
- NMI-A-002: Indoor-Air Sampling.

3.5 General Field Procedures

Procedures relevant to the overall sampling plan are summarized below.

Relevant Field SOPs:

- NMI-001: Chain of Custody, Handling, Packing and Shipping;

- NMI-002: Submersible Pump Operation;
- NMI-003: Calibration of Field Instruments – Multiparameter (ORP, NTU, DO, Etc.) Meters;
- NMI-004: Calibration of Field Instruments – FID/PID/O2-LEL Meters;
- NMI-005: Investigation-Derived Waste Handling and Storage;
- NMI-006: Drum Sampling;
- NMI-007: Field and Heavy Equipment Decontamination;
- NMI-008: Field Activity Forms; and
- NMI-009: General Survey Procedures.

3.6 Radiological Health Physics Procedures

Due to the potential for work activities to occur in, or adjacent to, areas with ionizing radiation or radioactive material, a Radiation Protection Program (RPP) has been established for the Site and is included as Appendix A of the HASP. Specific health physics procedures have been established to provide detail so that each critical element of the RPP can be implemented in the field. The use of these health physics procedures should be used in conjunction with applicable field SOPs as directed by the designated Site Radiation Safety Officer (RSO).

Relevant Health Physics Procedures:

- SOP 2.4: Calibration of Radiation Survey Meters
- SOP 2.7.4: Operation of Radiological Instrumentation
- SOP 2.7.18: Gamma Walkover Survey with the Ludlum 2241-2 Survey Meter and 44-10 Detector
- SOP 2.7.21: Operation of the Thermo Scientific RadEye SX
- SOP 3.4.1: Performance and Documentation of Radiological Surveys
- HP-NMI-01: Conduct of Radiological Work;
- HP-NMI-02: Health Physics Definitions;
- HP-NMI-03: Radiological Worker Training Manual;
- HP-NMI-05: Radiological Surveys;
- HP-NMI-06: Radiological Monitoring and Decontamination;
- HP-NMI-07: Radiological Posting and Labeling;
- HP-NMI-08: Radiation Exposure Limits and Monitoring;
- HP-NMI-09: Sealed Source Accountability and Leak Check;
- HP-NMI-10: Radiological Air Sampling;
- HP-NMI-11: Radiological Work Permits;
- HP-NMI-12: Radiological Material Receipt and Shipment;
- HP-NMI-13: Environmental Monitoring;
- HP-NMI-14: Exposure Investigation;
- HP-NMI-15: Instrument Response Check;
- HP-NMI-16: Ludlum 3 Operation;
- HP-NMI-17: Employee In – Out Processing;
- HP-NMI-18: Ludlum 2929 Operation;

- HP-NMI-19: Radioactive Waste Classification and Packaging;
- HP-NMI-20; Ludlum 2350-1 Operation;
- HP-NMI-21: Ludlum 2224-1 Operation;
- HP-NMI-22: Tennelec Series 5 Operation;
- HP-NMI-23: Operation Ludlum Model 3 with 44-10 Probe;
- HP-NMI-24: Operation of the Falcon 5000 HPGe Spectrometer;
- HP-NMI-25: Heavy Equipment Decontamination and Free Release;
- HP-NMI-26: Ludlum Model 19 Operation;
- HP-NMI-27: Waste Conveyance Handling and Shipping; and
- HP-NMI-28: Exterior Perimeter High Volume Air Sampling.

FIGURES

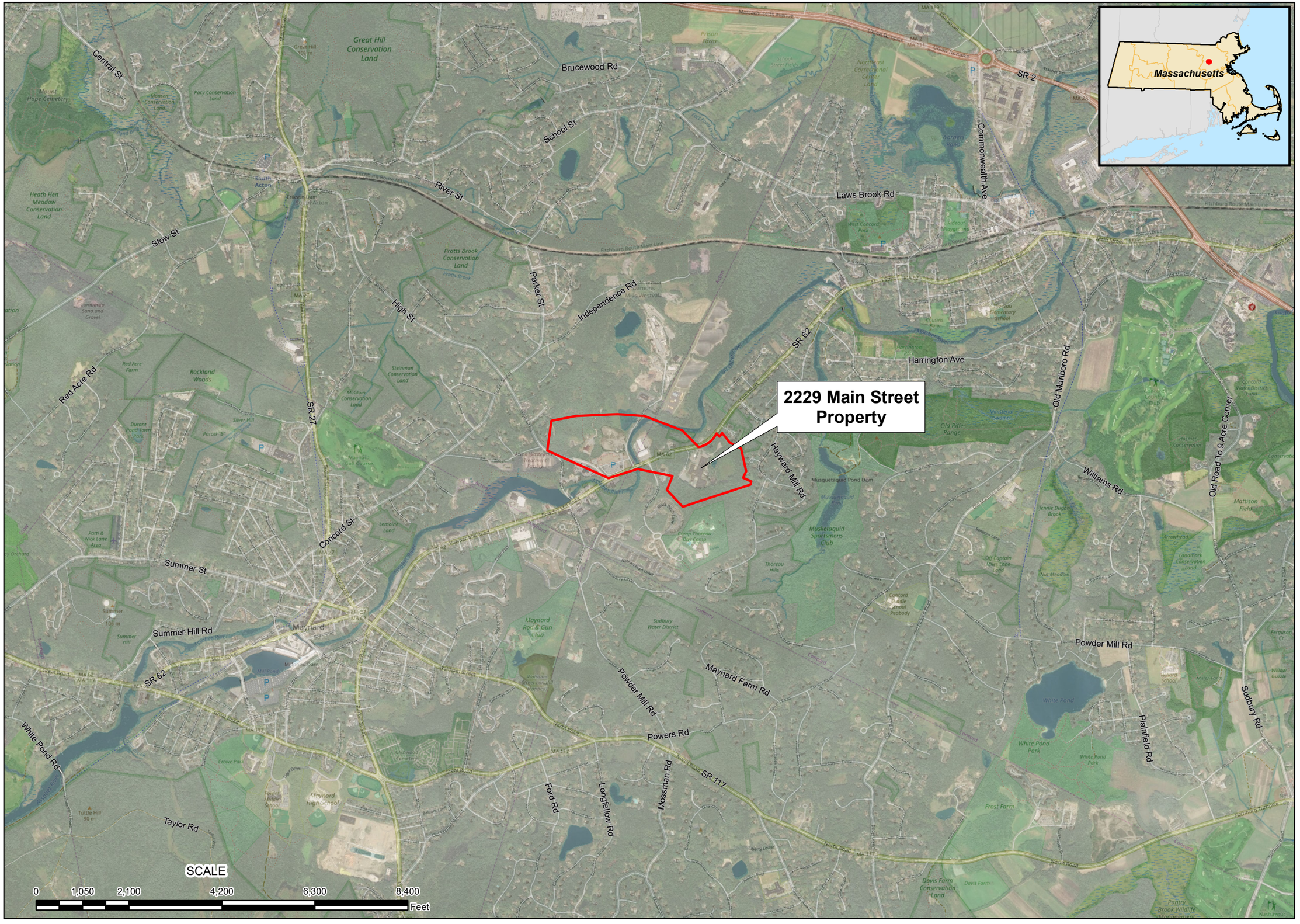

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Figure 1

Site Location Map

Nuclear Metals, Inc. Site
Remedial Design Work Plan

Concord, Massachusetts

Description:

2229 Main Street Property

Map Legend:

Site Boundary

Spatial Projection:

Coordinate System:
MA State Plane Mainland
FIPS Zone: 2001
Units: US Survey Feet
Datum: NAD83

Plot Info:

File: Fig01_SiteLoc.mxd
Project No.: 3252
Plot Date: 11/19/2019
Arc Operator: LS
Reviewed by: HG

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de maximis, inc.

TABLES

Table 2-1
Summary of Tasks by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

PDI Investigation	PDI Objective	PDI Scope
Site-wide Soil and Sediment		
PDI-SSS-1	PCBs and other COC delineation at northeast outfall area	Collect surface and shallow subsurface soil samples to refine delineation of COCs.
	PCBs and other COC delineation at sweepings pile	Conduct borings to refine delineation of COCs.
	PCBs and other COC delineation within Cooling Pond Area	Collect surface and shallow subsurface samples to refine delineation of COCs.
PDI-SSS-2	Mapping of DU metal fragments and areal extent of removal actions	Collect surface and shallow subsurface samples at locations of DU penetrators identified during NTCRA to confirm removal of penetrators; perform field radiation scanning of shallow soil in fence line survey units established during NTCRA.
PDI-SSS-3	Delineate uranium (based on sub-slab soil investigation performed as part of NTCRA)	Conduct borings through the existing floor slab to further evaluate the presence of COCs and to refine delineation of COCs for future excavation.
PDI-SSS-4	Bog sediment removal, landfill limits and Define subsurface conditions above Gabion Wall	Define wetland boundary, habitat types and species inventory to develop a restoration plan for the bog. EM and GPR Survey of Landfill and area above Gabion Wall to evaluate methods of landfill excavation, including support along the toe of slope of landfill and bog interface, and potential limits of excavation above Gabion Wall to reduce lateral loads on the wall.
	Cooling Pond sediment removal methods and Gabion Wall stability analysis	Define surface water and groundwater interactions within the Cooling Pond by installing piezometers along toe of slope and within the Cooling Pond footprint. Collect data on sediment, groundwater and surface water chemistry to confirm that excavation and replacement of sediment will not result in recontamination of new sediment. Means and methods of excavation for removal of Cooling Pond sediments will be evaluated based on sediment gradation, consistency, and strength as well as Gabion Wall Stability.
PDI-SSS-5	Evaluate soil type and volume, and chemical testing of soil available from on-site borrow source	Conduct borings to characterize the soil gradation, volume of potential soil that could be used as backfill on-site. Chemical testing of the soil for reuse will be conducted to meet risk-based criteria for future site use of the on-site borrow material.

Table 2-1
Summary of Tasks by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

PDI Investigation	PDI Objective	PDI Scope
In-Situ Sequestration		
PDI-ISS-1	Baseline groundwater sampling	Collect water levels and groundwater samples from monitoring wells throughout the Site to obtain a snapshot of current groundwater conditions at the beginning of the RD process.
PDI-ISS-2	Pumping and Rebound Analysis for Uranium in Bedrock Groundwater	Open bedrock wells will be installed throughout the isotopically natural U plume for testing the viability of pumping as a remedy for U in bedrock; water with be extracted from the bedrock wells for several days to evaluate the ability of pumping alone to reduce U concentrations in the long term. Periodic sampling will be conducetd of extracted groundwater to evaluate U concentrations over time and to evaluate potential rebound (if concentrations go down during pumping).
PDI-ISS-3	ISS Pilot Testing in Overburden Formation (Based on the results of the TS-ISS-1)	Two reagents will be selected for overburden injectability testing outside of the HB. Injection methods will be chosen to match the selected reagents and tested to evaluate the effectiveness of each injection method, including ROI, reagent distribution with depth, predictability of reagent distribution, injectate concentration (i.e., mass loading), and target injection volume per location. Results from this PDI will be used to select the final reagent and concentration, injection location spacing, injection depth intervals and design of a suitable monitoring program to evaluate the full-scale effectiveness in overburden groundwater.
PDI-ISS-4	(**IF DEEMED NECESSARY**) ISS Pilot Testing in Bedrock Groundwater (Based on the results of PDI-ISS-2 and TS-ISS-3)	Two reagents will be selected for bedrock injectability testing outside of the HB. Injection methods will be chosen to match the selected reagents and tested to evaluate the effectiveness of each injection method, including ROI, reagent distribution with depth, predictability of reagent distribution, injectate concentration (i.e., mass loading), and target injection volume per location. Results of this PDI will be used to estimate how many injection locations are needed in bedrock, the likely injection pressures and volumes, reagent mass loading and the need for recirculation to distribute amendment.

Table 2-1
Summary of Tasks by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

PDI Investigation	PDI Objective	PDI Scope
Treatability Study - In-Situ Sequestration		
TS-ISS-1	Reagent Selection Testing for Overburden Soils Within Holding Basin	Three column studies will be performed using soils collected from beneath the HB and Site groundwater to test ISS amendments (Apatite II® and zero valent iron). At the end of the test, the oxidation-reduction (redox) state of the groundwater pumped through the columns will be changed to determine if uranium remains sequestered under changing redox.
TS-ISS-2	Reagent Selection Testing for Overburden Groundwater Downgradient of Holding Basin	Batch testing will be performed using soil from downgradient of the HB and Site groundwater with lower uranium concentration to test ISS amendments (Apatite II®, zero valent iron and soluble phosphate). The most effective dose for each amendment will be carried forward to column testing. Column testing will be performed using soils from downgradient of the HB and Site groundwater with lower uranium concentrations to test the most effective dose of ISS amendments (Apatite II®, zero valent iron and soluble phosphate) identified through the batch testing. Alkalinity of influent groundwater will be adjusted during the last week of column testing to determine stability of sequestered uranium under changing geochemistry. Columns will be dismantled at the conclusion of testing and samples of soil from columns will undergo solid phase testing to evaluate sequestration mechanism and possible formation of uranyl phosphate precipitates.
TS-ISS-3	(**IF DEEMED NECESSARY**) Reagent Selection Testing for Bedrock Groundwater (Based on the results of PDI-ISS-2)	Batch testing will be performed using bedrock from downgradient of the HB and Site bedrock groundwater to test ISS amendments. The most effective dose for each amendment will be carried forward to pilot testing (PDI-ISS-4).

Table 2-1
Summary of Tasks by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

PDI Investigation	PDI Objective	PDI Scope
Holding Basin Containment		
PDI-HB-1	Collect geotechnical, seismic, and hydrogeologic data necessary to design a containment wall that prevents DU from migrating downgradient and meets ARAR	Six borings along the alignment of the cutoff wall into bedrock to evaluate soil density and bedrock characteristics by conducting SPTs throughout the overburden of each of these borings, and coring bedrock for laboratory testing to aid in the design of the containment wall and construction methods
		Borehole geophysics to evaluate water bearing zones and bedrock fracture orientation within the six borings and two of the geophysical cross-hole borings.
		CMTs will be installed in six of the bedrock borings to gain multi-level piezometric head and GW quality information to support hydraulic design of the containment wall and evaluating ARARs.
		Observation wells (OWs) will be installed within 3 bedrock boreholes located adjacent to the deep CMTs to allow for slug testing and short duration pumping to observe response in CMTs and other OWs.
		Geotechnical Laboratory testing: up to 15 grain size tests on overburden soils, up to 15 compression strength tests on rock core, and up to 8 Cerchar Abrasivity tests on rock core.
		Conduct research on pump house foundation and utility alignments into pump house, and conduct test pits to confirm utilities and structures (i.e. pump house slabs) that need to be removed for wall construction.
PDI-HB-2	Seismic Evaluation for Holding Basin Wall Design	Drill six bedrock boreholes for cross-hole geophysics, forming two sets of 3-hole arrays for the geophysics.
		Field shear wave measurements using cross-hole geophysical methods to characterize soil and bedrock to support the probabilistic seismic analysis to meet seismic design ARARs.
		Conduct seismic analysis, determine design loads for containment wall in accordance with ASCE-7 design standards, and perform structural design of wall to resist design earthquake.
PDI-HB-3	Bench Scale Testing of Slurry and Wall Mix Designs	Testing up to five containment wall mix designs for compressive strength and hydraulic conductivity.to identify a design that will meet the ARAR. Conduct a preliminary evaluation of pH impacts to surrounding groundwater.
		Test bentonite slurry mixed with on-site municipal water source for swell index and fluid loss to evaluate potential bentonite products to be used for temporary support of excavated panels during barrier wall construction.
PDI-HB-4	Cover Design and Slope Stability Analysis	Up to four borings into Holding Basin to collect geotechnical data necessary for cover system design.
		Hand Probes to determine organics thickness within bog, and soft sediment thickness of sediments in Cooling Pond.
		Hand Probes along slopes adjacent to the Holding Basin and Cooling Pond to evaluate near surface soil conditions.
		Field vane shear measurements will be conducted on organics located within the bog.
		Two test pits behind the gabion wall south of the Cooling Pond to evaluate the wall cross-section.
		Plumbness survey of the gabion wall face at up to two transects.
		Slope Stability analysis for proposed finished grades of Holding Basin Cap and adjacent side slopes, and side slopes adjacent to bog and Cooling Pond.
PDI-HB-5	Seepage Analysis to evaluate hydraulic properties of wall and depth of wall	Setup SEEP/w model with overburden and bedrock aquifer geometry with hydraulic conductivity values from Geosyntec calibrated groundwater flow model and CMTs and OWs tested in PDI HB-1.
		Conduct parametric seepage modelling on wall depth and wall hydraulic conductivity to evaluate design parameters of containment wall

Table 2-1
Summary of Tasks by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

PDI Investigation	PDI Objective	PDI Scope
1,4-Dioxane and VOCs in Bedrock Groundwater		
PDI-14D-1	Delineation, Pumping and Rebound Analysis of 1,4-Dioxane and VOCs in Bedrock Groundwater	Sevearl bedrock monitoring wells will be installed to refine delineation of the 1,4-dioxane plume in bedrock above the remedial goal of 0.46 ug/L and pumped to assess the effectiveness of groundwater extraction as a remedy. The general scope for the groundwater extraction testing is the same as that described above for PDI-ISS-2.

Table 3-1
Summary of Standard Operating Procedures Required by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

SOP No.	Procedures / Tasks	Site-wide Soil and Sediment Remedy	In-Situ Sequestration Remedy	Holding Basin Physical Containment	1,4 Dioxane and VOC in Bedrock	Contingency
	Soil Procedures					
NMI-S-001	Surface and Subsurface Soil Sampling using Manual Methods	X		X		
NMI-S-002	Sediment Sampling	X		X		
NMI-S-003	Jar Headspace Sampling Procedures	X		X		
NMI-S-004	Soil and Rock Drilling and Sample Collection	X	X	X	X	
NMI-S-005	Test Pitting and Sampling	X		X		
NMI-S-006	Soil Description	X	X	X	X	
NMI-S-007	Extraction/Preservation of Soil/Sediment for VOCs	X		X		
	Groundwater Procedures					
NMI-GW-001	Monitoring Well Integrity Survey					X
NMI-GW-002	Monitoring Well Development	X	X	X	X	
NMI-GW-003	Monitoring Well Installation	X	X	X	X	
NMI-GW-004	Well Abandonment					
NMI-GW-005	Groundwater Sampling Using HydroPunch™					X
NMI-GW-006	Groundwater Profiling			X		
NMI-GW-007	Down-Hole Groundwater Field Parameter Measurement			X		
NMI-GW-008	Direct Push Drive-Point Piezometers	X		X		
NMI-GW-009	Water-Level Measurement Procedures	X	X	X	X	
NMI-GW-010	Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells	X	X	X	X	
NMI-GW-011	Groundwater Sampling for PFAS		X		X	
NMI-GW-012	Groundwater Sampling with HydraSleeves™					X
NMI-GW-013	Groundwater Sampling with Snap Samplers					X
NMI-GW-014	BarCad Well Sampling		X		X	
NMI-GW-015	Assabet Municipal Well Sampling		X			
NMI-GW-016	Packer Testing Procedures		X	X	X	
NMI-GW-017	Specific Capacity Testing and Data Reduction		X	X	X	
NMI-GW-018	Pump Testing Procedures		X	X	X	
NMI-GW-019	Slug Testing			X	X	
NMI-GW-020	Field Analysis of Flourescent Tracer Dye in Groundwater		X			
	Surface Water Procedures					
NMI-SW-001	Surface Water Sampling	X				
NMI-SW-002	Operations Over, Near, or on Water	X				
	Air Procedures					
NMI-A-001	Sub-slab Soil Gas Sampling					X
NMI-A-002	Indoor Air Sampling					X

Table 3-1
Summary of Standard Operating Procedures Required by Pre-Design Investigation
Remedial Design Work Plan - Appendix I, Field Sampling Plan
Nuclear Metals, Inc. Superfund Site, Concord MA

	Misc. Procedures					
NMI-001	Chain of Custody, Handling, Packing, and Shipping	X	X	X	X	
NMI-002	Submersible Pump Operation	X	X	X	X	
NMI-003	Calibration of Field Instruments - Multiparameter (ORP, NTU, DO, Etc.) Meters	X	X	X	X	
NMI-004	Calibration of Field Instruments - FID/PID/ O2-LEL Meters	X		X		
NMI-005	Investigation-Derived Waste Handling and Storage	X	X	X	X	
NMI-006	Drum Sampling	X		X		
NMI-007	Field and Heavy Equipment Decontamination	X	X	X	X	
NMI-008	Field Activity Forms	X	X	X		
NMI-009	General Survey Procedures	X	X	X	X	
	Health Physic Procedures					
SOP 2.4	Calibration of Radiation Survey Meters	X				
SOP 2.7.4	Operation of Radiological Instrumentation	X				
SOP 2.7.18	Gamma Walkover Survey with the Ludlum 2241-2 Survey Meter and 44-10 Detector	X				
SOP 2.7.21	Operation of the Thermo Scientific RadEye SX	X				
SOP 3.4.1	Performance and Documentation of Radiological Surveys	X				
HP-NMI-01	Conduct of Radiological Work	Health Physic Procedures are to be used in conjunction with applicable field procedures when deemed necessary by Radiologic Safety Officer				
HP-NMI-02	HP Definitions					
HP-NMI-03	Radiological Worker Training Manual					
HP-NMI-04	*TBD (Open Procedure)*					
HP-NMI-05	Radiological Surveys					
HP-NMI-06	Radiological Monitoring and Decontamination					
HP-NMI-07	Radiological Posting and Labeling					
HP-NMI-08	Radiation Exposure Limits and Monitoring					
HP-NMI-09	Sealed Source Accountability and Leak Checks					
HP-NMI-10	Radiological Air Sampling					
HP-NMI-11	Radiological Work Permits					
HP-NMI-12	Radioactive Material Receipt and Shipment					
HP-NMI-13	Environmental Monitoring					
HP-NMI-14	Exposure Investigation					
HP-NMI-15	Instrument Response Checks					
HP-NMI-16	Ludlum 3 Operation					
HP-NMI-17	Employee In - Out Processing					
HP-NMI-18	Ludlum 2929 Operation					
HP-NMI-19	Radioactive Waste Classification and Packaging					
HP-NMI-20	Ludlum 2350-1 Operation					
HP-NMI-21	Ludlum 2224-1 Operation					
HP-NMI-22	Tennelec Series 5 Operation					
HP-NMI-23	Operation Ludlum Model 3 with 44-10 Probe					
HP-NMI-24	Operation of the Falcon 5000 HPGe Spectrometer					
HP-NMI-25	Heavy Equipment Decontamination and Free Release					
HP-NMI-26	Ludlum Model 19 Operation					
HP-NMI-27	Waste Conveyance Handling and Shipping					
HP-NMI-28	Exterior Perimeter High Volume Air Sampling					

STANDARD OPERATING PROCEDURES (SOPs)

STANDARD OPERATING PROCEDURE NMI-S-001

SURFACE AND SUBSURFACE SOIL SAMPLING USING MANUAL METHODS

1.0 INTRODUCTION

The purpose of this operating procedure is to describe the procedures for the collection of surface and shallow subsurface soil samples. The procedures are intended specifically to minimize alteration of sampled during collection. Surficial soil samples as referenced herein mean soils or soil-like material located less than 6 feet below ground surface which may contain quantities of contaminants.

1.1 Objective

The objective of this procedure is for the collection of representative samples of surficial soil. These operating procedures may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

1.2 Equipment

The following equipment is needed for surface and shallow subsurface soil sampling:

- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan;
- Site map(s)/plan(s)
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or disposable aluminum pan
- Plastic or stainless-steel spoons and/or wooden tongue depressors
- Appropriate size sample containers
- Plastic zip lock bags
- Sample Labels
- Chain of Custody records and custody seals
- Sampling Record Form
- Cooler(s)
- Ice
- Decontamination supplies/equipment

Sampling devices and equipment may include one or more of the following:

- Stainless steel trowel(s) or scoop(s)
- Stainless steel spade or shovel
- Bucket auger
- Bit auger
- Continuous flight (screw) auger
- Post-hole auger
- Extension/drill rods
- T-handle
- Core sampler

- Sampling trier
- Thin wall tube sampler
- Split spoons
- Vehimeyer soil sampler outfit
- Tubes
- Points
- Drive head
- Drop hammer
- Puller jack and grip
- Backhoe
- Telescopic mechanical sampling arm (aluminum poles)
- Stainless steel sampling beaker
- Russian Peat Corer
- Peat Probe/Rod

2.0 PROCEDURES

The following steps will be followed for surface and shallow subsurface soil sampling. Any deviations from these steps should be discussed with the project manager and documented in the field notes.

2.1 Entries Preparation

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
- Obtain necessary sampling and monitoring equipment.
- Decontaminate or pre-clean equipment and ensure that it is in working order.
- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
- Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan.
- Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator prior to soil sampling, and utility clearance should always be confirmed before beginning work.

2.2 Pre-Sampling Observations, Notes and Required Entries

The information listed below will be recorded in a project Field Logbook and a Sampling Record Form. The following list of measurements and observations represent a minimum requirement for soil samples:

- Sampling Location Number
- Time
- Date Collected
- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory) to receive samples
- Description of Sample Location with Sketch or Map
- Sample Depth (i.e., distance in feet from ground surface)
- Photograph Number and Roll Used (if applicable).
- Observable Physical Characteristics
- Odor
- Color
- Density, Consistency, etc.
- Layering
- Other
- Evidence of Stressed Vegetation or Wild Life in Area where Sample was taken
- Ambient Weather Conditions during Sampling
- Air Temperature
- Sky Condition
- Recent Precipitation or Drought
- Samples Collected (enter all sample numbers collected at this location)

2.3 Sampling Device Instructions

The specific procedures and equipment for surficial soil sampling will be defined in a Site work plan or related document. The following presents a description of sampling devices commonly used to collect surficial soil samples within 6 feet of ground surface. The split spoon sampler, when used with drilling equipment, can also collect subsurface soil samples to much greater depths. The most appropriate device for a specific sampling program as described in a Site work plan or related document has been selected based on site conditions (accessibility, type of soil, desired depth of samples, etc.) and on climate conditions (e.g. frozen ground in winter).

The selected devices for each sampling task are described in detail in a Site work plan or related document. Any changes to procedures outlined in a Site work plan or related document will be specified by the Site Manager.

2.3.1 Hand Scoops, Trowels, Spades and Shovels

This method is probably the simplest, most expeditious, direct method for making soil samples accessible. Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. These devices are easy to operate, decontaminate and work well for sampling most surficial soils. Surface material is removed to the required depth and a stainless steel or plastic scoop is then used to collect the sample. This method can be used in most soil types but is limited to sampling at or near the ground surface. Accurate, representative

samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member.

Hand scoops and trowels consist of the usual garden type trowel or scoop usually constructed of stainless steel. A stainless-steel laboratory scoop is a preferred scoop device due to its non-corrosive nature. Scoops or trowels work well in collecting grab samples of surficial soils or sludges. A flat, pointed mason trowel is helpful to cut a block of the desired soil when undisturbed profiles are required. A typical shovel or spade constructed of stainless steel can be used to collect representative soil samples near the surface. Devices plated with chrome or other exterior coatings that may chemically alter the sample should not be used. Plating is particularly common with garden implements such as potting trowels.

Procedures for Use

- Carefully remove the top layer of soil to the desired sample depth with a cleaned, stainless steel spade, shovel, trowel, or scoop. In the case of sludges exposed to air, it may be desirable to remove the first 1-2 centimeters of material prior to collecting the sample.
- Using a cleaned, stainless steel scoop or trowel, collect the desired quantity of soil.
- If volatile organic analysis is to be performed, refer to sample methods described in NMI-S-007.
- Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Note that disposable aluminum pans shall not be used if analysis of aluminum is required. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

2.3.2 Bucket and Bit Augers with Thin-Wall Tube Attachment

This system consists of a bucket or bit auger, or a thin-wall tube sampler, a series of extensions/drill rods, and a "T" handle (Figure 1). A cleaned bucket or bit auger is used to bore a hole to the desired sampling depth and then is withdrawn. When using the bucket auger, the soil sample must be removed from the bucket with a cleaned, stainless steel spoon or trowel. The bucket auger can collect a large soil sample (up to 24 ounces) but is limited in penetrating depth to approximately 2 feet under ideal conditions. Bucket augers are useful for direct sample recovery, because they provide a large volume of sample in a short time. The bit auger has greater penetrating depth (up to 6 feet) but collects a small soil sample. The bit auger tip is removed from the auger when the desired sampling depth is reached and replaced with the thin wall tube attachment. The system is then lowered down the cored hole and driven into the soil to the completion depth. The system is withdrawn, and the core is collected from the thin wall tube sampler.

Other types of augers include continuous flight (screw) and post-hole augers. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

This equipment can be used in a wide variety of soil conditions. The presence of rock layers and collapsing of the borehole usually prohibit sampling at depths greater than 3 to 6 feet. The equipment is inexpensive, easy to operate, and generally works well to sample most surficial soils.

Procedures for Use

- Attach the cleaned auger bucket or bit to a drill rod extension and further attach the "T" handle to the drill rod.
- Clear the area to be sampled of any surface debris (twigs, rocks, litter). It may be advisable to remove the first 3 to 6 inches of surface soil for an area approximately 6 inches in radius around the drilling location.
- Begin augering by rotation of the "T" handle, periodically removing accumulated soils onto a plastic sheet spread near the hole. This prevents accidentally brushing loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole and avoids possible contamination of the surrounding area.
- After reaching the desired depth, slowly and carefully remove the auger from the hole.
- If a bucket auger is used, remove the soil sample with a cleaned, stainless steel spoon or trowel.
- If a bit auger is used, remove the auger tip from the extension rods and replace with a cleaned, thin-wall tube sampler. Install the proper cutting tip.
- Carefully lower the tube sampler down the borehole. Gradually press the tube sampler into the soil. Take care to avoid scraping the borehole sides. Avoid hammering the drill rods to facilitate coring, as the vibrations may cause the boring walls to collapse.
- Remove the tube sampler and unscrew the drill rods.
- Remove the cutting tip and remove the core from the device.
- Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.
- If volatile organic analysis is to be performed, refer to sample methods described in NMI-S-007.
- Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.
- If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and repeat previous steps, making sure to decontaminate the auger and tube sampler between samples.

- Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

2.3.3 Hand Held Corer

The device consists of a "T" handle and cylindrical core tube (Figure 2). The device is equipped with a check valve at the top to prevent washout during retrieval through an overlying water layer, if applicable, and a nosepiece at the bottom to help contain the sample. This device can be used in a wide variety of soil conditions. Hand corers can also be fitted with brass or polycarbonate plastic liners.

Procedures for Use

- Inspect the corer for proper pre-cleaning.
- Press the corer in with a smooth continuous motion.
- Twist the corer, and then withdraw the corer in a single smooth motion.
- Remove the nosepiece and withdraw the sample into a stainless steel, plastic or other appropriate homogenization container.
- Transfer the sample into an appropriate sample container with a stainless-steel spoon, wooden tongue depressor or equivalent.

2.3.4 Thin Tube Handheld Sampling Trier

The system consists of a trier, a long hollow cylindrical tube with a slot trending almost its entire vertical length, and a "T" handle (Figure 3). The trier is driven into the soil to be sampled and used to extract a core sample from the appropriate depth. The tip and edges of the tube are sharp to allow the trier to cut a core by rotation of the "T" handle once it is completely pushed-down or manually driven to the depth of collection. Triers range from approximately 20 to 60 inches in length and from approximately 0.5 to 1 inch in diameter.

Procedures for Use

- Insert the cleaned trier into the soil or sludge material at a 0 to 45° angle from horizontal. This orientation minimizes the spillage of sample from the sampler. Extraction of samples might require tilting of the containers.
- Rotate the trier once or twice to cut a core of material.
- Slowly withdraw the trier, making sure the slot is facing upward.
- If volatile organic analysis is to be performed, refer to sample methods described in NMI-S-007.
- Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Note that disposable aluminum pans shall not be used if analysis of aluminum is required.
- Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When

compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

2.3.5 Split Spoon Sampler

Split spoon sampling is generally used to collect undisturbed soil cores of 18 or 24 inches in length. A split spoon sampler consists of a cylindrical hollow steel or stainless-steel sampler usually 24 inches long and 2 or 3 inches in outside diameter. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted. Split spoon samplers collect in-situ soil samples that permit stratigraphic logging. To remove the split spoon sampler and collect a soil sample, remove the sampler from the driving rods and unscrew the tapered nosepiece and top piece from the sampler. The spoon will then split into two longitudinal sections. It may be necessary to use a pipe wrench to unlock the threaded nosepieces. This sampling device is almost always used in conjunction with a drilling rig and as such is an equipment intensive effort. However, the split spoon may be used with a hand-held drop hammer for collection of shallow soil samples (less than 6 feet below ground surface).

Procedures for Use

- Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.
- Place the sampler in a position perpendicular to the sample material.
- Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.
- Record in the Field Logbook or test boring log the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.
- Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler is typically available in 2 and 3 ½-inch diameters. A larger barrel may be necessary to obtain the required sample volume.
- Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

2.3.6 Test Pit/Trench Excavation

A backhoe can be used to remove sections of soil, when detailed examination of soil characteristics is required. This is a relatively expensive sampling method because of the cost of backhoe operation. Refer to the appropriate operation procedure for more information on test pit excavations.

Procedures for Use

- Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities.
- Review the site-specific Health & Safety plan and ensure that all safety precautions including appropriate monitoring equipment are installed as required.
- Using the backhoe, excavate a trench approximately three feet wide and approximately one foot deep below the cleared sampling location, or as specified in a Site work plan or related document. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.
- A shovel may be used to remove a one to two-inch layer of soil from the vertical face of the pit where sampling is to be done.
- Record in the Field Logbook or test pit log the depth intervals from which the samples are being collected.
- Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket. A telescopic mechanical arm (see next sampling device) and stainless-steel sampling beaker may be used to collect samples.
- If volatile organic analysis is to be performed, refer to sample methods described in NMI-S-007.
- Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Note that disposable aluminum pans shall not be used if analysis of aluminum is required. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.
- Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material. The test pit/excavation should be backfilled in accordance with a Site work plan or related document.

2.3.7 Telescopic Mechanical Sampling Arm

The device consists of an aluminum pole approximately 1 to 2 inches in diameter divided into three, 4-foot sections. Attached to the end of the pole is a stainless-steel sampling beaker (usually with an 18-ounce capacity). The pole is capable of telescoping from 4 to 12 feet. This mechanical sampling arm is used to collect soil samples from test pits or other excavations. It allows a sample to be collected from a location that would otherwise be difficult to access.

Procedures for Use

- Attach the cleaned, stainless steel beaker to the end of the pole either by tightening a clamp or wing nuts.
- Make sure your feet are safely and securely positioned.
- Telescope the pole to the required length.

- Lower the pole end into the test pit or other excavation.
- Collect the sample.
- Remove the sample from the beaker with a cleaned, stainless steel scoop, trowel or new wooden tongue depressor.

2.3.8 Soil/Peat Sampling in Wetlands by Russian Peat Corer

The Russian peat corer is an open chambered instrument used to collect undisturbed soil samples. The side-filling corer is inserted into the sediment in the closed position to the desired depth. Once at the desired depth, the corer is rotated, and the sample stored within the core. The following steps outline the procedure for using the Russian peat corer.

- Manually insert the bottom point of the Russian peat corer with the blunt edge of the core tube turned against the cover plate to prevent sediment from entering the tube during advancement. If the soil is highly consolidated or otherwise hard to penetrate, a slide hammer can be used to aid in driving the sampler.
- When the Russian peat corer is driven to the required depth, turn the core tube clockwise 180 degrees allowing to tube to rotate and allowing the sharp edge to cut through the sediment longitudinally.
- Pull up the corer and retrieve the sample by turning the core tube counterclockwise. The sample will be exposed on the core cover plate.
- Describe physical characteristics of the soil in accordance with the appropriate operation procedures.
- Collect soil sub-samples from extracted cores and process as described in accordance with the appropriate operation procedures.

2.3.9 Soil Penetration Test (SPT) by Peat Probe/Rod

The Standard Penetration Test (SPT) is a measure of the penetrative resistance of soils. This test (ASTM D4544) investigates the resistance of a peat layer to penetration by a driven rod. The thickness of the peat layer will be determined by abrupt increase in the resistance which marks the rod hitting the underlying soil layer. The standard graduated steel rod has a diameter of 9.5 +/- 1.0-mm diameter and 1.0 or 1.2-m in length with the option of adding on additional lengths of rod to extend the testing depth. The standard procedure for SPT by peat probe is as follows:

- Align the rod vertically
- Penetrate the peat with the rod by pushing or diving. Add sections to the rod with increasing depth
- Measure the thickness of the peat when the resistant to penetration of the rod increases sharply owing to the resistance of the material underlying the peat. It may be possible to hear the scraping of the rod in the underlying soil
- Pull up the rod and inspect the rod for evidence that mineral material was encountered
- Record the lateral position of the sounding

2.4 Sampling Procedures

- After entries are completed, label and number required sample bottles. Fill out the label in indelible ink and carefully and clearly address all categories and parameters.
- Sample analyses will be specified by the Project Coordinator and Site Manager. A list of these analyses and required containers and handling procedures is presented in a Site work plan or related document.
- Sampling instructions have been provided for several sampling devices most often used to collect surficial soil samples. Select the appropriate sampling device.
- Record observations and describe soil per appropriate operating procedure.
- Decontaminate sampling device and/or container prior to use according to per appropriate operating procedure.
- Sample containers (glass jars and vials) should be filled to the top. Refer to a Site work plan or related document for sample volume size and appropriate containers for given analyses. Sample containers should contain laboratory-provided preservatives, if necessary. Care should be taken to prevent the presence of air bubbles in VOA vials. All container caps will include an inner teflon septa or lining and must be tightly secured to contain the sample. All samples will be stored and shipped at 4°C. Refer to the appropriate operating procedure for operating procedures on sample handling and preservatives.
- Check for appropriate liner in cap and secure cap tightly. Store the samples with ice in a cooler, following these sealing and packing procedures:
- Ice will be placed in plastic zip-lock bags to contain ice water. Sample containers will be adequately layered in bubble wrap to prevent breakage. Samples will be positioned upright in the cooler to prevent breakage, and samples will be stored and shipped at 4oC.
- All 40-milliliter VOA vials will be sealed in thick or heavy-duty plastic zip lock bags.
- Check to make sure all appropriate information is in Field Logbook or Sampling Record form and Chain-of-Custody form using indelible ink.
- If samples are to be shipped to a laboratory for analysis, a Chain-of-Custody record, custody seals, fragile markers, and reinforced nylon tape will all be properly affixed to or on the sample cooler.
- Chain-of-Custody Form - enclose in large plastic zip lock bag and tape to inside top of cooler lid.
- Custody Seals - place custody seal over cooler gasket separating the cooler lid from the cooler bottom at all sides except hinged location.
- Nylon Tape - tape completely around cooler at two locations. Tape reinforcing will prevent cooler from opening if the lid locking mechanism fails.
- Fragile Markers - fragile markers and upright stickers will be affixed to each side of the cooler.
- Refer to SOP HP-NMI-12 for transfer of radioactive samples to the laboratory.

2.5 Sample Containers

The samples for each analysis will be collected in the appropriate containers and handled in accordance with the procedures described in a Site work plan or related document.

2.6 Chain-of-Custody Forms

All samples submitted to the contract analytical laboratory for analyses, will be accompanied by a Chain-of-Custody form. Appropriate Chain-of-Custody procedures will be followed at all times during a sampling event and subsequent transport to the contract analytical laboratory. Refer to the appropriate operation procedures on completing a Chain-of-Custody form and Chain-of-Custody procedures. Refer to SOP HP-NMI-12 for transfer of radioactive samples to the laboratory.

2.7 Decontamination

Soil sampling equipment will be cleaned prior to and between each use according to the appropriate operating procedure. After decontamination, the equipment will be wrapped in aluminum foil and placed on clean racks off the ground until it is used.

2.8 Quality Assurance/Quality Control

There are no specific quality assurance (QA) activities that apply to the implementation of these operating procedures. However, the following QA procedures apply:

- All data must be documented on field data sheets or within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in a Site work plan or related document. Equipment calibration activities must occur prior to sampling/operation, and they must be documented.

2.4 Documentation

Field documentation sampling shall be recorded in daily field logs, it is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel.

STANDARD OPERATING PROCEDURE NMI-S-002

SEDIMENT SAMPLING

1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to describe the procedures for the collection of representative sediment and wetland soils samples. Sediment and wetland sediment/soil as referenced herein mean deposited sediment or soil-like material below both flowing and standing surface water. Wetlands are lands transitional between terrestrial and aquatic systems where the water table is typically at or near the surface, or the land is covered by shallow water. Wetland sediment/soils exhibit features characteristic of the wetland conditions of saturation, flooding, or ponding, which must occur long enough during the growing season to develop anaerobic and reducing conditions in the upper horizons of the soils. Hydric soil indicators are currently termed "redoximorphic" features of the soils, a term used to replace descriptions of "soil mottling" due to wetness. Wetland sediment/soils include organic and mineral soils ranging from poorly drained to well drained.

Sediment and wetland sediment/soil samples may contain contaminants that are insoluble in water, persistent in the environment, relatively immobile in the soil, and/or exhibit low volatility. Accordingly, the procedures are intended specifically to minimize the alteration of samples.

1.1 Objective

The object of this procedure is for the collection of representative samples of sediment and wetland soil. These operating procedures may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

1.2 Equipment

The following equipment is needed for sediment sampling:

Required:

- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan;
- Project specific notes, plans, figures, reports, etc., including Work Plan (WP), Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), or other applicable project planning document
- Field book, field data forms and sampling sheets included in SOP NMI-008 with writing utensils
- Tape measure
- Appropriate sampler and associated equipment
- Digital camera
- Stainless steel, plastic, or other appropriate composition bucket, bowl or pan
- Plastic or stainless-steel spoons and/or wooden tongue depressors
- Appropriate environmental sample containers

- Appropriate transport containers and packing (chain of custody, custody seals); labeling, and shipping materials (coolers, bags) with ice as outlined in SOP NMI-001;
- Plastic Zip-lock® bags
- Decontamination supplies/equipment

Sampling equipment may include one or more of the following:

- Stainless steel spade or shovel
- Stainless steel trowel(s) or scoop(s)
- Bucket auger with thin-wall tube attachment (stainless steel)
- Bit auger with thin-wall tube attachment (stainless steel)
- Thin-wall tube sampler
- Split-spoon sampler
- Gravity corer
- Ponar grab sampler
- Ekman dredge
- Lexan® tubes
- Peristaltic pump
- Russian peat corer
- Piston corer

Optional:

- Survey equipment, compass or global positioning system (GPS) to locate sampling points
- Survey stakes w/ hammer, flags or buoys and anchors
- Nylon rope
- Plastic sheeting or tarp

2.0 PROCEDURES

The following steps will be followed for surface and shallow subsurface soil sampling. Any deviations from these steps should be discussed with the project manager and documented in the field notes.

2.1 Field Preparation

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
- Obtain necessary sampling and monitoring equipment.
- Contact the laboratory and order the appropriate number and types of sample jars; include extra jars in case of breakage or mislabeling in the field. Sample glassware should be *prelabelled by the lab* prior to sampling; if using blank labels, use indelible ink (black Sharpie) to write sample IDs *before the sample is taken* (once the label is wet, a Sharpie will not work).
- Decontaminate or pre-clean equipment and ensure that it is in working order.

- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
- Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan.
- Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator prior to soil sampling, and utility clearance should always be confirmed before beginning work.

During the first site reconnaissance, use stakes, flagging, or buoys to identify and mark all sampling locations within wetlands. Verify and/or document locations using calibrated GPS unit. Use GPS to locate sediment stations and deploy anchor(s) alongside or downstream of intended sampling locations. Occupy river stations in an upstream sequence whenever possible. All wetland staked locations and in-water sampling areas should be utility-cleared by the property owner or the On-Scene-Coordinator prior to sampling. Utility clearance should always be confirmed prior to beginning work.

2.2 Presampling Observations, Notes and Required Entries

The information listed below will be recorded in a project Field Logbook and a Sampling Record Form. The following list of measurements and observations represent a minimum requirement for soil samples:

- Sampling Location Number
- Time
- Date Collected
- Samplers (names of individuals who actually collected samples)
- Sample Destination (Analytical Laboratory) to receive samples
- Description of Sample Location with Sketch or Map
- GPS coordinates of sampled locations (often logged electronically on GPS unit)
- Sample Depth (i.e., distance in feet from ground surface)
- Number of Samples/Volume collected
- Depth of water above sample (distance in feet from top of water surface to top of sediment)
- Photograph Number (if applicable).
- Observable Physical Characteristics - odor, color, texture, layers, precipitates, proximity to erosional/depositional features
- Evidence of Stressed Vegetation or Wild Life in Area where Sample was taken
- Ambient Weather Conditions during Sampling - Air Temperature
- Sky Condition, Recent Precipitation or Drought
- Description of the sample location, including *approximate* dimensions of stream or waterbody at Sampling Point (measured after sampling)

2.3 Sampling Device Instructions

The sampling devices presented below may be used to collect sediment and wetland sediment/soil samples within several feet of the ground surface. The specific procedures and equipment for sediment and wetland sediment/soil sampling may be specified in the project WP, FSP, QAPP or related document. The most appropriate device for a specific sampling program may be based on the depth of water at a sampling location, the physical characteristics of the sediment to be sampled, and/or site conditions (accessibility, type of soil or sediment, desired depth of samples, etc.).

2.3.1 Hand Scoops, Trowels, Spades and Shovels

This method is probably the simplest, most expeditious, direct method for sampling accessible sediment. These devices are easy to operate, decontaminate, and work well for sampling low moisture, exposed (e.g., intertidal or wetland surface) locations. Stainless steel or rigid non-contaminating plastic are the preferred material for these tools.

Surface material is sampled to the specified depth using a stainless steel or plastic scoop, trowel, spade or shovel. In wetlands, vegetation may or may not be considered part of the sediment/soil sample; any such distinction must be discussed and cleared with an authorized project team leader, unless addressed in the project WP, FSP, or QAPP. For the purpose of this method, surface sediment or wetland sediment/soil is considered to range from 0 to 6 inches in depth and a shallow aqueous layer is considered to range from 0 to 12 inches in depth. Scoops or trowels can be disruptive to the liquid/sediment interface and may cause substantial alteration of the sample. Thus, these methods are limited in application to bulk surface "grab" sampling.

Procedures for Use

- Carefully remove the top layer of vegetation/debris to the desired sample depth with a cleaned, stainless steel spade, shovel, trowel or scoop. In the case of sludges exposed to air, it may be desirable to remove the first 1-2 centimeters of material prior to collecting the sample.
- Using a cleaned, stainless steel scoop or trowel, collect the desired quantity of sediment.
- If compositing a series of grab samples, use a disposable aluminum pan, plastic bin or a properly decontaminated stainless-steel mixing bowl or Teflon tray for mixing. Consider what contaminants could be inadvertently introduced depending on the tray composition (e.g. phthalates if using plastic trays and the laboratory suite calls for organic compounds).
- Surface water should be decanted from the sample or the composition mixing bowl prior to sealing or transfer to the sample container. Care should be taken to retain the fine sediment fraction during this procedure.
- If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a laboratory-supplied cut-off syringe or Encore® sampler. Place the remainder of the sample into a stainless steel, plastic, or other appropriate compositing container, and mix thoroughly to obtain a homogenous

sample representative of the entire sampling interval. Then, place the sample into the appropriate labeled containers.
- Check that a Teflon liner is present in cap if required. Secure cap tightly.
- Refer to the project specific documentation and operating procedures related to sample preservation information.

2.3.2 Bucket and Bit Augers with Thin-Wall Tube Attachment

This method should only be attempted on very consolidated sediment absent overlying surface water, such as within an intertidal zone during low tide, or for wetland sediment/soil. Collection of a sub-surface sediment or wetland sediment/soil sample can be accomplished with a system consisting of a bucket or bit auger, a series of extensions, a "T" handle, and a thin wall tube attachment (Figure 1). The use of additional extensions in conjunction with a bucket auger can increase the sampling depth from which sediment can be collected.

A cleaned bucket or bit auger is used to bore a hole to the desired sample depth and then is withdrawn. When using a bucket auger, the soil sample must be removed from the bucket with a cleaned, stainless steel spoon or trowel. The bucket auger can collect a large sediment sample (up to 24 ounces) but is limited in penetrating depth to approximately two feet under ideal conditions. The bit auger has a greater penetrating depth (up to six feet) but collects a lesser volume of sediment. The bit auger tip is removed from the auger when the desired sampling depth is reached and replaced with the thin wall tube attachment. The system is then lowered back into the cored hole and driven into the sediment at the completion depth. The corer is then withdrawn, and the sample collected from the thin wall tube sampler. The various depths represented by the core are homogenized for the appropriate depth. This equipment can be used in a wide variety of sediment and wetland sediment/soil conditions. This equipment is inexpensive, easy to operate, and generally works well to sample most sediments.

<u>Procedures for Use</u>

- Attach the cleaned auger head to the required length of extensions, then attach the "T" handle to the upper extension.
- Clear the area to be sampled of any surface debris (dead vegetation, twigs, rocks, litter). It may be advisable or necessary to remove the first 8 to 15 cm of surface sediment for an area approximately 15 cm in radius around the sampling location.
- Insert the bucket auger or bit auger into the sediment at a 0o to 20° angle from vertical. This orientation minimizes spillage of the sampler upon extraction from the sediment.
- Begin drilling by rotation of the "T" handle, to cut a core of sediment. If desired sample location is at a depth, periodically remove accumulated sediment in the auger and place on a plastic sheet spread near the hole. This prevents accidentally brushing loose material back down the borehole when removing the auger or adding extensions. It also facilitates refilling the hole and avoids possible contamination of the surrounding area.
- After reaching the desired depth, slowly and carefully remove auger from boring.
- If a bucket auger is being used, remove soil sample with cleaned, stainless steel spoon or trowel.

- If a bit auger is being used, remove auger tip from the extension rods and replace with cleaned thin wall tube sampler. Install proper cutting tip.
- Carefully lower the tube sampler down the borehole. Gradually press the tube sampler into the sediment. Take care to avoid scraping the borehole side. Avoid hammering the drill rods to facilitate coring, as the vibrations may cause the boring walls to collapse.
- Remove the tube sampler and the unscrew drill rods.
- Remove the cutting tip and remove the core from the device.
- Discard the top of the core (approximately 1 inch), as this represents material collected before penetration of the layer of concern. Transfer the remaining sample or a specified aliquot of sample into an appropriate sample container.
- If VOC analysis is to be performed, transfer the sample into an appropriate, labeled container with a stainless-steel spoon, wooden tongue depressor or equivalent, and secure the cap tightly.
- If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and repeat previous steps, making sure to decontaminate the auger and tube sampler between samples.
- Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed sediment or wetland soil material.

2.3.3 Hand Held Corer

The device consists of a "T" handle and cylindrical core tube (Figure 2). The device is equipped with a check valve at the top to prevent washout during retrieval through an overlying water layer, if applicable, and a nosepiece at the bottom to help contain the sample. This device can be used in a wide variety of soil conditions. Hand corers can also be fitted with brass or polycarbonate plastic liners.

Procedures for Use

- Lower the corer through the water column to the top of sediment; push the corer manually through the sediment to the desired depth, or refusal with a smooth, continuous motion.
- Twist the corer, and then withdraw the corer in a single smooth motion.
- Remove the nosepiece and withdraw the sample into a stainless steel, plastic or other appropriate homogenization container.
- Transfer the sample into an appropriate sample container with a stainless-steel spoon, wooden tongue depressor or equivalent.

2.3.4 Gravity Corer (with Stabilizing Fins)

This method consists of a cylindrical metal tube with a detachable tapered nosepiece on the bottom and a ball or check valve located on the top. The device may have stabilizing fins to maintain vertical positioning as the device is moving through the water column. The tapered nosepiece facilitates cutting and reduces core disturbances during penetration. Gravity corers are capable of collecting benthic sediment samples ranging from 15 to 30 inches depending upon the density of the sampled material and weight of the device. This device works well to collect

sediment samples in a marine environment or from a low velocity stream, pond or river. Some gravity corers have attachable weights and may accept plastic or brass liners.

Procedures for Use

- Attach a pre-cleaned corer to the required length of a sample line. Solid braided 5-millimeter (3/16 inch) nylon line is sufficient; 20-millimeter (3/4 inch) nylon, however, is easier to grasp during hand hoisting.
- Secure the free end of the line to a fixed support on the vessel to prevent accidental loss of the corer.
- Lower the corer through the water column to the top of sediment; push the corer manually through the sediment to the desired depth, or refusal.
- Retrieve the corer slowly using a smooth, continuous lifting motion. Do not bump the corer as this may result in some sample loss.
- Remove the nosepiece from the corer and slide the sample out of the corer into a stainless steel, plastic or other appropriate homogenization container. For vertical sub-sampling, the core tube may be cut along its entire length and opened to facilitate observation of lithology.
- When subsampling for homogenization and chemical analysis, scrape the outer layer of sediment in contact with the core tube prior to homogenizing. This outer layer may be used for grain size analysis, which is not compromised by cross-contamination.
- Transfer the homogenized sample into an appropriate sample jar with a stainless-steel spoon, wooden tongue depressor or equivalent.

2.3.5 Petite Ponar Grab Sampler

Collection of surface sediment can be accomplished with a system consisting of a remotely activated Petite Ponar Grab or Petite Ponar Dredge (Figure 3) and a deployment system. The Petite Ponar Grab is a weighted, clamshell-type grab sampling device with levered jaws that are activated by the release of a stainless-steel dowel equipped with a spring. This technique consists of 1) manually opening the sampler 2) latching the stainless steel dowel in place which is held in place by 3) lifting the Ponar assembly and then 4) slowly lowering the grab sampler through the water column to the surface of the sediment using of nylon rope or extended handle. When the tension in the rope is released, the stainless-steel dowel is ejected by the spring. The lifting action applied to rope or cable pulls on the lever arms of the grab sampler, which gently closes the jaws of the clamshell device. When the jaws are fully closed, the sediment is held within the device; stainless steel screen doors on the top of the device allow overlying water to remain on the sediment sample, keeping the surface intact.

This device is used to collect consolidated fine- to coarse-textured sediment. The Petite Ponar sampler is only capable of collecting a shallow surface sediment sample (~ 4 inches).

Procedures for Use

- Attach a sturdy nylon rope or steel cable to the ring provided on top of the pre-cleaned Petite Ponar Grab sampler. Solid braided 5-millimeter (3/16 inch) nylon line is

sufficient; 20-millimeter (3/4 inch) nylon, however, is easier to grasp during hand hoisting. The sample is heavy so a fool proof knot, such as a bowline, should be tied if the operator is not using hardware fasteners.

- Measure and mark the distance to the sediment surface on the sample line. A secondary mark, slightly shallower will indicate proximity, so that the lowering rate can be reduced, this preventing unnecessary bottom disturbance.
- Tie the free end of the sample line to a fixed point to prevent accidental loss of sampler.
- Arrange the Ponar sampler with the jaws latched in the open position, setting the stainless-steel dowel into the lever arms so the sampler remains open when lifted from the top. If the sampler is so equipped, place the spring-loaded pin into the aligned holes in the lever arms. From this point on, support the sampler only by the lift line or the sampler will be tripped, and the jaws will snap closed.
- Begin lowering the sampler until the proximity mark is reached, or to a point approximately 2 inches above the sediment.
- Drop the sampler onto the sediment. Slack on the line (several centimeters) should release the spring-loaded pin; a slight 'tug' on the line will ensure the stainless-steel pin is ejected. In strong currents more slack may be necessary to release mechanism. Pull the line up quickly but smoothly on the line, which will close the sampler.
- Slowly raise the sampler to the surface, not allowing to let the line go slack. Once on board, the sampler can be tilted to allow any free liquid to flow through the screens on the top of the sampler. Care should be taken to retain the fine sediment fraction during this operation. Note: if sampling using a cut-off syringe (e.g. for VOCs or AVS), the top screens can be removed, and a syringe inserted into the sediment.
- Open the sampler and transfer the sediment to a disposable aluminum tray, stainless steel bowl, plastic bin or other appropriate container. Ensure that non-dedicated containers have been adequately decontaminated. If necessary, continue to collect additional sediment samples until sufficient material has been secured to fulfill laboratory requirements. Gently but thoroughly homogenize the sample to a consistent color/texture, then transfer the sediment to sample containers appropriate for the analysis requested. Samples for VOCs should be collected directly from either the top of the Ponar or the bucket before homogenization to minimize volatilization of contaminants.

2.3.6 Thin Tube Handheld Sampling Trier

The system consists of a trier, a long hollow cylindrical tube with a slot trending almost its entire vertical length, and a "T" handle (Figure 3). The trier is driven into the soil to be sampled and used to extract a core sample from the appropriate depth. The tip and edges of the tube are sharp to allow the trier to cut a core by rotation of the "T" handle once it is completely pushed-down or manually driven to the depth of collection. Triers range from approximately 20 to 60 inches in length and from approximately 0.5 to 1 inch in diameter.

Procedures for Use

- Insert the cleaned trier into the soil or sludge material at a 0 to 45° angle from horizontal. This orientation minimizes the spillage of sample from the sampler. Extraction of samples might require tilting of the containers.
- Rotate the trier once or twice to cut a core of material.
- Slowly withdraw the trier, making sure the slot is facing upward.
- If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless-steel lab spoon, wooden tongue depressor or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

2.3.7 Sediment Sampling with Lexan® Coring Tube

This method consists of a coring tube that samples soft sediments to depths of approximately 1-2 meters. Sampling with a Lexan® coring tube extracts an undisturbed sediment sample which allows sampling of discrete core intervals as well as the study of the sediment-water interface. Using a vacuum pump allows the tube to be capped without disturbing the sample. The process described below can be facilitated, if necessary, by filing a sharp beveled edge on the outer side of the coring tube prior to advancing the tube into the sediment. The sharp edge will help advance the coring tube.

Procedures for Use

- If using a boat to access the sampling location, anchor or spud the boat, if necessary, to remain within a radius of approximately 1-5 meters from the originally identified sample location.
- Using a handheld GPS, document the proposed sample location in the field notebook along with other appropriate information collected during sediment sampling activities.
- Measure the total depth of water with a weighted tape. If wading in a wetland, identify an area that has the least amount of vegetation as the roots of plants often interfere with the penetration of the Lexan tube.
- At each sample location, lower a section of Lexan® tube until it reaches the top of the sediment.
- Push the Lexan® tube into the sediment by hand or using a fence post driver or core driver block, to the desired depth, or until refusal. If the procedure is being performed to determine sediment depth (probing), a calibrated rod may be used in place of the Lexan® tube. If the procedure is being performed to collect samples for laboratory analysis, continue with Step 6.

- Drive the tube several more inches using a post driver or core driver block and measure the distance. This procedure is performed to obtain a "plug" at the bottom of the core and prevent the loose sediment from escaping.
- Place a plastic core tube cap on top of the Lexan core tube (to maintain suction), which should prevent the sediments/plug from escaping. Some devices use a vacuum pump on top of the Lexan® tube.
- Rotate the tube at about a 15-degree angle from vertical, first clockwise, then counterclockwise, to help separate the plug at the bottom of the tube from the sediment. Slowly pull the tube from the sediment, twisting it slightly as it is removed (if necessary).
- Before the tube is fully removed from the water, place a soft plastic cap on the bottom end of the tube while it is still submerged.
- Keeping the tube upright, wipe the bottom end dry and seal the cap with duct tape and label. Measure the length of sediment recovered and evaluate the integrity of the core. If the core is not suitably intact, repeat coring procedure within 5 to 10 feet of the first location attempted.
- While still keeping the core upright, use a hacksaw to make a horizontal cut in the tube approximately one inch above the sediment.
- Re-cap the cut end of the tube, seal the cap with duct tape, and mark this end as "top".
- Wipe the tube dry.
- Slice tube open the tube (the use of power 'nibbler' is recommended) or push the sediment from tube onto pre-cleaned aluminum foil; scrape the outer surface of the sediment core that was in contact with the coring tube wall to remove vertical smearing.
- Sediment samples to be analyzed for volatile organic compounds (VOCs) will be transferred directly from the sample core to the sample containers.
- All other surface sediment samples will be transferred to a disposable aluminum basting pan or a stainless-steel mixing bowl for homogenization. Additional samples may be required to collect the volume of sediment specified in the study design. The mixing bowl should be covered with aluminum foil while additional samples are being collected to prevent sample contamination (e.g., from precipitation, splashing water). After a sufficient volume of sediment is transferred to the mixing bowl, homogenize the contents of the bowl using stainless-steel spoons until the texture and color of the sediment appears to be uniform.
- After the sample is homogenized, transfer the sample into an appropriate sample container.

2.3.8 Piston Corer

The method of using a piston corer utilizes the general procedure as described above for using a Lexan® tube. The piston inserted into the core tube aids in maintaining suction to minimize loss of unconsolidated material from the bottom of the tube. Piston corers are typically used when undisturbed sediment samples at significant penetration depths are required.

Procedures for Use

- If using a boat to access the sampling location, anchor or spud the boat, if necessary, to remain within a radius of approximately 1-5 meters from the originally identified sample location.
- As provided in the WP, FSP, or QAPP, determine how deep of a penetration is needed at the specific sampling location. Prepare the appropriate length of tubing to be able to achieve the desired penetration depth plus an additional couple of feet.
- Run the line through the tubing and connect to the piston stopper. Insert the piston stopper approximately 0.5 inches from the end of the tube.
- Attach the tubing to the piston core with provided clamps and/or other mechanism.
- Slowly lower the tube/piston unit through the water column until it reaches the top of sediment. When the tube has reached the sediment, try to minimize movement of the tube to minimize any sediment disturbance. Tie off the line attached to the stopper to a permanent fixture on the vessel.
- Drive the tubing into the sediment to the penetration depth required.
- Remove the line and attach to the piston corer. Bring up tube and core and position horizontally on the boat or ground.
- Immediately cap the open end of the tube. Remove piston corer from the tube and cap the other end.
- After both ends are capped and properly secured, the core should be stored vertically to allow for the sediment to settle. Once settled, cut Lexan® tube where necessary to accommodate the size of the extracted core.
- If the required depth was not reached and or there was not the acceptable retrieval. Redeploy the piston corer prior to capping the ends. There may be debris in the way of the tube and/or other hard objects that impede penetration. In the event that the desired penetration depth is not achieved, slightly change the sample location (within the 1-5 m radius of the original sample location). If the area continues to be problematic, contact an authorized project team leader.
- Once an acceptable core is extracted, capped and left to settle, cut the tube open and describe and sample from the core as described in Section 3.4.8 and transfer the sample into an appropriate sample container

2.3.9 Sediment Sampling in Wetlands with Russian Peat Corer

The Russian peat corer is a chamber-type instrument that collects an unconsolidated sediment/soil sample in wetlands. The side-filling corer is inserted into the sediment in the closed position to the desired depth. Once at the desired depth, the corer is rotated, and the sample stored within the core. The following steps outline the procedure for using the Russian peat corer:

Procedures for Use

- Manually insert the bottom point of the Russian Peat Corer with the blunt edge of the core tube turned against the cover plate to prevent sediment/soil from entering the tube

during advancement. If the sediment is highly consolidated or otherwise hard to penetrate, a slide hammer can be used to aid in driving the sampler.

- When the Russian Peat Corer is driven to the required depth, turn the core tube clockwise 180 degrees allowing to tube to rotate and allowing the sharp edge to cut through the sediment longitudinally.
- Pull up the corer and retrieve the sample by turning the core tube counterclockwise. The sample will be exposed on the core cover plate.
- Describe physical characteristics of the sediment/soil in accordance with the appropriate operating procedure.
- Sub-sample and/or homogenize the sample for chemical analyses as described previously. Transfer the sample into an appropriate sample container.

2.3.10 Sediment Sampling with Peristaltic Pump

The method of sediment sampling with a peristaltic pump consists of lowering tubing to a desired sampling location and using the peristaltic pump to extract the sediment from the bottom of the water body. This method of sediment sampling may be efficient for the collection of flocculent, unconsolidated sediments with very high-water content.

Procedures for Use

- If using a boat to access the sampling location, anchor or spud the boat, if necessary, to remain within a radius of approximately 1-5 meters from the originally identified sample location.
- Document the proposed sample location with a handheld GPS and record the ID in the field notebook along with other appropriate information collected during sediment sampling activities.
- Measure the total depth of water using a weighted tape.
- Lower a new piece of Waterra tubing of sufficient length (potentially with weight added) to a depth 1-2 feet above measurement from Step 3.
- Initiate pump and purge 3 tube volumes. Deactivate pump, but do not allow backflow.
- Lower tubing to a depth 6 inches above measurement from Step 3.
- Initiate pump, wait until 'floc' comes to end of line, then collect floc in a beaker. When sufficient volume is available, fill sample container.
- After the sampling at the sample location is completed and the appropriate sample jars are filled, decontaminate re-useable sampling equipment.

2.3.11 Sediment Sampling with Ekman Dredge

The Ekman dredge (Figure 5) can be used in water of various depths and can be released from a boat or from a pier or bridge. This type of sediment sampler is most efficient in waters with little to no current and is best for sampling consolidated, fine textured sediments as well as soft sediments, such as silt, muck and sludge. The method of sediment sampling with the Ekman dredge consists of slowly lowering the grab sampler (the jaws being held in the open position with two cables under spring tension) through the water column to the sediment surface with a cable or nylon rope. This sampler can also be used in a wetland attached to a pole specifically

designed to trip the dredge once it is in place. Once the sampler has reached the top of sediment, the dredge buckets are released using a messenger device (sent down the rope), collecting a surface grab sample (depth depending on the dimensions of the dredge bucket).

Procedures for Use

- Once at the predetermined sample location, anchor or spud the boat to remain within a radius of approximately 1-5 meters from the originally identified sample location.
- Identify the proposed sample location ID in the field notebook along with other appropriate information collected during sediment sampling activities.
- Measure the total depth of water using a weighted tape.
- Thread a sturdy nylon cable through the top bracket of the sampler.
- Arrange the Ekman dredge sampler so that the jaws are in the open position and trip cables are positioned over the release studs. Take extra precaution to ensure that there is nothing in the way of the jaws during this step in the event of accidental deployment of the spring-loaded jaw. This can best be achieved by cocking the jaws open with the Ekman upright in a plastic bin.
- Slowly lower the sampler over the side of the boat until it rests on the sediment surface. When the sampler hits the surface of the sediment, the field person should be able to see the deployment rope go slightly slack.
- Trigger the jaw release mechanism by lowering a messenger down the line.
- Slowly pull the sampler back up through the water column.
- Once on board, place the Ekman in a clean plastic tub (the surface of the sediment can be accessed by opening the top flaps of the sampler). To release the sediment from the grab, pull the trip cables up and place the eye loops around the release mechanisms. Estimate the sample volume and percent water by volume. Record on sampling sheet.
- Transfer the sample into an appropriate sample container

2.4 Sampling Procedures

- After entries are completed, label and number required sample bottles. Fill out the label in indelible ink and carefully and clearly address all categories and parameters.
- Sampling instructions have been provided for various optional sampling devices which may be used to collect sediment and wetland sediment/soil samples. Select the prescribed sampling device, or an appropriate alternative to meet project objectives. Any change in sampling device should be cleared first with an authorized project team member.
- Sample analyses will be specified by the Project Coordinator and Site Manager. A list of these analyses and required containers and handling procedures is presented in a Site work plan or related document.
- Record observations and describe soil per appropriate operating procedure.
- Decontaminate sampling device and/or container prior to use according to per appropriate operating procedure.
- When collecting sediment samples that may consist of very soft, high water content or flocculent-like sediment (e.g. lacustrine setting, low energy environments), efforts should be made to minimize disturbance during sampling. Appropriate measures should also be

taken during sub-sampling (e.g., keeping sampler upright, carefully draining overlying water by drilling small holes in the coring tubes at the top of the cohesive sediment layer) to minimize loss and/or disturbance of "flocculent" fine-grained particles.)

- Sub-sampled sediment samples must be homogenized or, when called for, composited and homogenized, before placing in containers. Homogenization is appropriate for most chemical analytical parameters, including but not limited to: metals, pesticides/PCBs, herbicides, semi-volatile organic compounds (SVOCs). However, samples for volatile organic compounds (VOCs) should not be homogenized prior to adding to VOC sample containers. Samples for VOCs typically require special sampling devices (e.g. blunt syringes) provided by the laboratory, including special preservatives (e.g. methanol).
- Sample containers (glass jars and vials) should be filled to the top. Refer to a Site work plan or related document for sample volume size and appropriate containers for given analyses. Sample containers should contain laboratory-provided preservatives, if necessary. Care should be taken to prevent the presence of air bubbles in VOA vials. All container caps will include an inner Teflon septa or lining and must be tightly secured to contain the sample. All samples will be stored and shipped at 4°C. Refer to per appropriate operating procedure for operating procedures on sample handling and preservatives.
- Check for appropriate liner in cap and secure cap tightly. Store the samples with ice in a cooler, following these sealing and packing procedures:
- Ice will be placed in plastic zip-lock bags to contain ice water. Sample containers will be adequately layered in bubble wrap to prevent breakage. Samples will be positioned upright in the cooler to prevent breakage, and samples will be stored and shipped at 4oC.
- All 40-milliliter VOA vials will be sealed in thick or heavy-duty plastic zip lock bags.
- Check to make sure all appropriate information is in Field Logbook or Sampling Record Form and Chain-of-Custody form using indelible ink.
- If samples are to be shipped to a laboratory for analysis, a Chain-of-Custody record, custody seals, fragile markers, and reinforced nylon tape will all be properly affixed to or on the sample cooler.
- Chain-of-Custody Form - enclose in large plastic zip lock bag and tape to inside top of cooler lid.
- Custody Seals - place custody seal over cooler gasket separating the cooler lid from the cooler bottom at all sides except hinged location.
- Nylon Tape - tape completely around cooler at two locations. Tape reinforcing will prevent cooler from opening if the lid locking mechanism fails.
- Fragile Markers - fragile markers and upright stickers will be affixed to each side of the cooler.

2.5 Sample Containers

The samples for each analysis will be collected in the appropriate containers and handled in accordance with the procedures described in a Site work plan or related document.

2.6 Chain-of-Custody Forms

All samples submitted to the contract analytical laboratory for analyses, will be accompanied by a Chain-of-Custody form. Appropriate Chain-of-Custody procedures as detailed in SOP NMI-001 will be followed at all times during a sampling event and subsequent transport to the contract analytical laboratory. Refer to the appropriate operation procedures on completing a Chain-of-Custody form and Chain-of-Custody procedures.

2.7 Decontamination

Sediment sampling equipment will be cleaned prior to and between each use according to per appropriate standard operating procedure SOP NMI-007. After decontamination, the equipment will be wrapped in aluminum foil or placed on clean racks or polyethylene sheeting and placed off the ground until it is used.

2.8 Quality Assurance/Quality Control

There are no specific quality assurance (QA) activities that apply to the implementation of these operating procedures. However, the following QA procedures apply:

- All data must be documented on field data sheets or within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in a Site work plan or related document. Equipment calibration activities must occur prior to sampling/operation, and they must be documented.
- Per EPA Region 1 data validation guidelines, analytical data must be rejected if solids content for a sample falls below 30% unless, in the judgement of the validator, sampling and/or analytical preparation steps were employed to address high moisture soil/sediment/solid samples. If solids content for a sediment sample is determined by the Laboratory to be below 30%, the sample will be discarded and flagged. A new sample will then be collected and resubmitted to the laboratory for testing. To meet the data validation guidelines, additional sample volume will be collected when resampling due to low solids is necessary. In some cases, if visual observations indicate the potential for low solids, a larger sample aliquot will be provided to the laboratory.

2.9 Documentation

Field documentation of sampling shall be recorded in daily field logs. It is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel. Field documentation procedures and activity forms are included in SOP NMI-008.

STANDARD OPERATING PROCEDURE NMI-S-003

JAR HEADSPACE SAMPLING PROCEDURES

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for conducting jar headspace measurements during field investigations at hazardous and non-hazardous waste sites.

1.1 Objective

The objective of jar headspace screening is to gain a field measurement of the concentration of organic vapors in the gas emanating from a soil or groundwater sample collected during boring, soil sampling, or water sampling. The procedure involves collecting soil or water samples, sealing them in airtight containers, and then analyzing the Total Organic Vapors (TOVs) in gasses above the sample (i.e., the gas concentrations in the head space of the sealed sample container) using a portable vapor/gas detector.

Jar headspace data can be used as part of a health and safety program, to pre-screen analytical samples, or as a guide during sub-surface investigations. Data collected using these methods are considered qualitative and specific compounds cannot be distinguished. However, the data is frequently sufficient for determining "hot spots" and general levels of contamination.

1.2 Equipment

The following list of equipment may be utilized when conducting jar headspace measurements. Site-specific conditions may warrant the use of additional or deletion of items from this list.

- Photo ionization detector (PID) or flame ionization detector (FID)
- Aluminum foil
- Clean jars (approximately 500 ml or larger for soil – jars less than 8 oz. capacity should not be used; approximately 40 ml to 1000 ml for water). If jars are unavailable, a back-up, but not the preferred, approach is to use one-gallon resealable plastic bags (soil only)
- Field logbook
- Decontaminated stainless steel sampling equipment
- Charcoal methane filter (for FID only)

1.3 Cautions and Potential Problems

Environmental factors may influence the performance of these methods. These factors include:

1. High moisture in headspace.
2. High organic and clay levels in soil.

3. Dissolved organics in water.
4. Age or degree of weathering of the contaminant.
5. Temperature variations.

High soil moisture and high organic and clay levels in soil can limit the volatilization of contaminants into the container headspace. High ambient humidity levels may also disrupt the PID operation and result in the ambient air readings other than 0.0 ppm. The presence of dissolved organics in water can also reduce volatilization of contaminants. High levels of organics in soil and water may also produce methane, a natural gas that conflicts with TOV readings in FIDs. Contaminants that are weathered tend to contain a larger fraction of low volatility constituents that the virgin material because more volatile constituents have already volatilized over time. This can bias the measured contaminant concentrations to be lower than would be expected with a fresh product. Temperature variations during VOC volatilizations could affect the amount of vapors that form in the jar headspace.

Before beginning a jar headspace program, calibrate the probe per the manufacturer's specification. Also, obtain a measurement of background levels of organic vapors at the Site. Taking these levels into account when interpreting jar headspace measurements will prevent false readings and/or bias.

It is important to note that measurements obtained using portable vapor/gas detectors such as a PID or FID are considered qualitative and not quantitative data. This type of data is sufficient for stating the general presence of contamination in basic levels (low/medium/high) and for assessing site health and safety. This type of data should not be used to identify specific contaminants or to determine whether a sample is "clean". Specifics for data quality levels of jar headspace field screening methods are provided in *Expedited Site Assessment Tools For Underground Storage Tank Sites* (EPA 510/B-97/001 March 1997).

2.0 PROCEDURES

2.1 Jar Headspace for Soil Samples

The following procedures should be followed for jar headspace measurements of soil samples. Note that a re-sealable plastic bag may be substituted for clean jars. Headspace sample collection should occur immediately after the soil is exposed to air to prevent volatilization. Headspace analysis should be completed on the same working day that the sample is collected

1. Put on latex or other sterile gloves.
2. Fill two clean glass containers half-full with the sample to be analyzed. Quickly cover each open top with one sheet of clean aluminum foil (shiny side up) and subsequently apply screw caps to tightly seal the jars. The type and size of the jar or plastic bag, as well as the amount of sample collected, should be consistent for all samples collected at a site.
3. **Allow at least 10 minutes for the sample and headspace to reach pseudo-equilibrium (i.e., headspace development). Vigorously shake jars for 15 seconds both at the beginning and end of the headspace development period.** Where ambient

temperatures are below 32 F (0 C), headspace samples should be warmed such as in a heated vehicle or building. Samples should not be allowed to sit so long that condensate forms in the container.

4. Subsequently to headspace development, remove screw lid to expose (but no remove) the foil seal. Quickly puncture foil seal with instrument sampling probe, to a point about one-half of the headspace depth. Exercise care to avoid uptake of water droplets or soil particulates.
5. As an alternative, withdraw headspace gas using a syringe and then inject this gas into the instrument probe or septum-fitted inlet (use this method only if the instrument can accept an injection such as for a test gas standard).
6. Following probe insertion through foil seal and/or sample injection to the probe, record highest meter response as the jar headspace concentration. Using foil seal/probe insertion method, maximum response should occur between 2 and 5 seconds. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case headspace data should be discounted.
7. The headspace screening data from both jar samples should be recorded and compared. If replicates are performed, headspace readings should be consistent to plus or minus 20 percent.
8. PID and FID field instruments shall be operated and calibrated to yield total organic vapors in ppm (v/v). PID instruments must be operated with an appropriate electron volt (eV) (+/-) lamp source. Operation, maintenance, and calibration shall be performed in accordance with the site's Quality Assurance Project Plan.
9. Deviations, departures and/or additions to the above procedures should be consistent with 310 CMR 40.0017. In such cases, compelling technical justification must be presented and documented by the methodology proponent.

2.2 Jar Headspace for Water Samples

The following procedures should be followed for jar headspace measurements of water samples. Headspace analysis should be completed on the same working day that the sample is collected.

1. Put on latex or other sterile gloves.
2. Fill two clean glass containers one-half to two-thirds full with the sample to be analyzed. Quickly cover each open top with one sheet of clean aluminum foil (shiny side up) and subsequently apply screw caps to tightly seal the jars. The type and size of the jar, as well as the amount of sample collected, should be consistent for all samples collected at a site.
3. **Allow at least 10 minutes for the sample and headspace to reach pseudo-equilibrium (i.e., headspace development).** Where ambient temperatures are below 32 F (0 C), headspace samples should be warmed such as in a vehicle or building. Samples should not be allowed to sit so long that condensation forms in the container. **Prior to analysis, the sample should be gently shaken for 15 to 20 seconds.**

4. Subsequently to headspace development, remove screw lid to expose (but not remove) the foil seal. Quickly puncture foil seal with instrument sampling probe, to a point about one-half of the headspace depth. Exercise care to avoid uptake of water.
5. Following probe insertion through foil seal and/or sample injection to the probe, record highest meter response as the jar headspace concentration. Using foil seal/probe insertion method, maximum response should occur between 2 and 5 seconds. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case headspace data should be discounted.
6. The headspace screening data from both jar samples should be recorded and compared. If replicates are performed, headspace readings should be consistent to plus or minus 20 percent.
7. PID and FID field instruments shall be operated and calibrated to yield total organic vapors in ppm (v/v). PID instruments must be operated with an appropriate eV (+/-) lamp source. Operation, maintenance, and calibration shall be performed in accordance with the site's Quality Assurance Project Plan.
8. Deviations, departures and/or additions to the above procedures should be consistent with guidance provided in the Massachusetts Contingency Plan (310 CMR 40.0017).

3.0 REFERENCES

Guidance for Preparing Standard Operating Procedures. EPA/240/B-01/004. March 2001.

Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

Expedited Site Assessment Tools For Underground Storage Tank Sites. EPA 510/B-97/001 March 1997

METER CALIBRATION

Geosyntec consultants
geosyntec.com

Project Name: _____ **Date:** _____ **Recorded By:** _____ **Page** ____ **of** ____

Project Number: _____ **Weather:** _____ **PrimaryActivities:** _____

PIDs

Serial Number		Ambient Air (ppm)	100ppm Isobutylene (ppm)
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		

GEMs

Serial Number		Ambient Air			Calibration Gas			Ambient Air		
		CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									

NOTES:

Personnel Signature: _____ **Date:** _____

Meter Calibration.xl

SOIL HEADSPACE MEASUREMENTS

Geosyntec consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Borehole ID _____ PID Model Number _____

Project Name _____ PID Serial Number _____

Project Number _____ Date Analyzed _____

Site Location _____ Calibration _____

Field Personnel _____ _____

Recorded By _____ _____

Sample Number	Sample Media	PID Measurements (ppmV)					
		First Reading	Time	10.6/11.7 (eV)	Second Reading	Time	10.6/11.7 (eV)

STANDARD OPERATING PROCEDURE NMI-S-004

SOIL AND ROCK DRILLING

1.0 INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for recording subsurface conditions in soil borings during site hydrogeological and geotechnical investigations. The SOP conforms to "A Compendium of Superfund Field Operations Methods (EPA/540/P-87/001)" and other pertinent technical publications.

1.2 Objective

The objective of soil and rock borings is to provide samples for description and characterization of subsurface conditions, and obtain samples for geotechnical and/or chemical analyses, often prior to installation of a monitoring well. This objective requires the use of consistent procedures for documenting observations and collecting samples.

2.0 PROCEDURES

2.1 Equipment and Supplies

The following equipment may be used during soil and rock borings. Site-specific conditions may warrant addition to, or deletion of items from this list.

- Appropriate health and safety gear (e.g., PPE) per the Health and Safety Plan;
- Field activity forms
- Appropriate field screening device (e.g. Photoionization detector [PID])
- Water level indicator
- Field portable folding table;
- Alconox, liquinox, or other non-phosphate concentrated laboratory grade soap;
- Deionized Water (for decontamination);
- Portable table for core logging
- Polyethylene sheeting
- Boring logs for borings/wells completed in the area

- Investigative Derived Waste (IDW) drums, roll-off container, or similar
- Sample containers and permanent makers for labeling (if samples are collected)

2.2 Predrilling Requirements

Dig-safe must be contacted prior to drilling in public areas. Drilling locations shall be no closer than 25 ft to overhead utilities. The appropriate utility companies will be contacted to provide insulation of utility lines as needed prior to commencement of drilling activities.

When conducting borings in an industrial facility, the project or field engineer/geologist should contact facility personnel necessary to receive clearance to drill at specified locations based on plant utility drawings. The names of the personnel authorizing clearance will be documented in the field log book. The exact location of each boring shall also be reviewed by responsible site personnel to confirm that the area is free of the facility-owned buried utilities. It is preferred that the drilling locations are also inspected by the driller for access and logistics prior to the drilling. In some cases, soft digging techniques such as air knifing, vacuum clearing and/or hand augering to a depth beyond utilities (e.g., 5-feet below the ground surface) is performed at drilling locations to confirm utilities are absent from the boring location.

Personal Protective Equipment (PPE) and air quality and noise monitoring equipment may be prudent depending on the surrounding. Such equipment, when needed, shall be set up prior to the commencement of drilling.

The supervising geologist/engineer shall record, on field activity forms, the name of the drilling firm and the names of the driller and his assistant(s) as well as the date, project location, project number, and weather conditions.

An accurate time documentation of the drilling activities shall be kept on field activity forms as outlined in SOP NMI-008. The field notes shall include at a minimum, the following:

- time driller and rig arrive on site;
- time drilling begins;
- any delays in the drilling activities and the cause of such delays;
- time drillers go off site; and
- down time (those periods when drilling activities cease due to equipment malfunctions, weather, and ordered stoppages).

In addition, soil or rock boring logs, as appropriate (included in SOP), will be used to document detailed drilling observations.

IDW containers, such as drums or roll off, should be mobilized to the drilling location prior to the start of drilling. The procedures for IDW accumulation, storage and disposal are outlined in SOP NMI-005.

2.3 Soil Sample Collection

Sample collection methods for laboratory analyses are briefly summarized under each relevant drilling method below. Soil samples will be collected into laboratory-provided glassware immediately after their retrieval from the subsurface and necessary screening (e.g. PID) and filled sample containers will be placed on ice. Sample handling, chain of custody, packing, and shipping procedures are detailed in SOP NMI-001.

2.4 Well Installation

Well installation methods are beyond the scope of this SOP. If wells are to be installed in the borings, the well installation methods outlined in SOP NMI-GW-003 should be used.

3.0 BORING METHODS

Borings can be conducted by a variety of drilling methods. The more commonly employed boring techniques may be classified into eight groups, based on the method used in displacing or removing subsurface material during the advancement of the borehole. The eight drilling techniques are: displacement boring, wash boring, sonic drilling, direct push, percussion drilling, rotary drilling, auger boring, and continuous sampling. The quality of the information obtained from the various boring methods varies greatly with the character of the subsurface geologic conditions, and some methods are more appropriate for one soil/rock type than another. As such, careful consideration should be given in selecting the desired method based on site geology, site setting and objective for the boring. It may be necessary to employ more than one boring method to advance a particular borehole. The drilling techniques used on any particular project will be selected by the project manager and/or project geologist and detailed in the work plan(s) supporting the task.

3.1 Wash Boring

This method involves advancing a casing and washing-out the soil to the bottom of the casing with a chopping bit combined with flow of drilling mud to the desired sampling depth. The casing can be advanced by either spinning or hammering (pounding) the casing with a large hammer (typically 300-pound). The borehole is stabilized by the casing, water, or drilling mud. Open samplers, such as the split-or solid-spoon type are driven into the undisturbed soil below the bottom of the borehole to collect soils for sampling and logging of the soil or lithological classification.

This method is most commonly used in soils which do not contain large cobbles and boulders, or cemented horizons. The wash boring method uses drilling water or, more often, drilling mud to flush cuttings from the bit, up the casing and to the ground surface. Because this method involved circulating (and reusing) drilling mud, it is not recommended for environmental borings where the mud can become contaminated. The introduction of drilling fluids can also alter the

chemical composition of the groundwater adjacent to the borehole, and may have an adverse effect on groundwater quality analyses on groundwater samples from monitoring wells installed in the completed borehole.

If it is necessary to use this technique to advance a borehole, the field geologist should determine the source and quality of the drilling fluid to be used in the boring process. The field geologist should not authorize the use of on-site or nearby groundwater or surface water bodies as the source of the drilling water, unless the proposed source has been sampled and analyzed for potential contaminants. In all cases where drilling water or drilling mud are used to advance a borehole, the field geologist should consider obtaining a sample of the drilling fluid for potential analysis, at the discretion of the project manager and quality assurance/quality control (QA/QC) officer.

Wash boring methods are not typically used in conjunction with the collection of soil samples because the soils are broken up and washed with drilling fluid.

3.2 Sonic Drilling

This method involves the use of high frequency, resonant energy generated by the sonic head that is transferred down the core barrel to the drill bit. This vibrating energy allows the bit on the end of the core barrel to cut through subsurface materials. The driller can adjust the sonic frequency to advance the core barrel to allow the bit to cut more effectively through a variety of formations. Override casing is advanced closely behind the sonic core barrel. Upon reaching the desired penetration depth the casing is advanced to the same depth as the core barrel, allowing the core barrel to be removed to retrieve a sample (e.g. after the core barrel is advanced from 5 to 10 feet below ground surface, a section of casing is advanced to 5 to 10 feet below ground surface and the core barrel is retrieved). The barrel is then unloaded into polyethylene bags marked with the boring depths for sampling and logging of the soil or lithological classification.

The polyethylene bags are cut open with a knife to expose the soil cores for logging, screening and sample collection. Soil samples are collected following field screening. Advantages of sonic drilling are that it collects a continuous core from the boring allowing excellent lithologic logging. Sonic methods are also capable of penetrating a variety of materials from soft sand to some rock

3.3 Direct Push

This method involves using a dual tube methodology which allows the collection of subsurface soil samples. The dual tube consists of a steel outer casing with a drive shoe that cuts through soil as the sampler is pushed (with vibration) into the soil and an inner tube (or sleeve) into which the soil sample goes as the sampler is advanced. One of the most common direct push technologies (DPT) sampling methods is the Macro-Core® system developed by Geoprobe. Using the DPT rig, borings are advanced by simultaneously driving an outer stainless-steel

casing containing a disposable inner core tube (i.e., sleeve). Upon reaching the desired penetration, frequently 4 feet as that is the length of the sampler, the sampler is withdraw, the outer sleeve opened and the inner tube which contains the soil sample is removed. The sleeve is then cut to expose soils for logging, screening and sampling. To sample the next interval of soil, a new length of acrylic or PVC tubing is then inserted into the sampler attached to a length of drive pipe, and advanced another sampling interval. In some cases, an outer casing is also advanced after each Macro-Core is driven; the outer casing provides stability for the borehole.

3.4 Rotary Drilling

This method is a variation of the wash boring technique, utilizing a rotary drill bit, rather than a chopping bit. It is employed primarily in advancing and cleaning the borehole to the required sampling depth, and is used in conjunction with air, water, or mud to bring the cuttings to the ground surface. This is the method generally preferred for exploratory test borings in the geo-technical consulting industry. This method is commonly used in environmental investigations when test borings are expected to encounter dense tills and coarse granular deposits (such as gravels) or are expected to terminate at depths exceeding 30 feet below the ground surface. Soils for sampling and logging, such as those needed for lithological classification, are generally collected as cutting come to the surface with the air, water or mud. These samples are collected from the return stream of cuttings, typically using a strainer. Samples collected during rotary drilling are heavily disturbed and may represent a mixture of soils from the intervals intercepted by the drill bit a few minutes prior to collection. Soil sampled collected from the return stream also represent cuttings so rocks may be cut into chips and mixed with surrounding soil. Because the accurate depth and time of collection of rotary samples are not precisely known and they are heavily disturbed/mixed, the samples are typically collected at larger intervals (e.g. every 5 feet) and are representative of general lithology. These samples are not routinely used for laboratory analysis associated with vertical delineation of contamination due the loss of sample integrity, mixing and loss of volatiles associated with rotary drilling. Another alternative for collecting samples with rotary drilling is to advance a sampling tool into the casing. When this is done, tooling is first withdrawn from the casing/boring and a split spoon (or other sampling device) lowered to the bottom of the boring to collect a sample of undisturbed soil from below the drill bit. After the sample is collected, then the bit is inserted back into the casing/boring and drilling advanced.

The primary disadvantage of this technique for environmental investigations is the introduction of drilling water or drilling mud. While mud is avoided with air rotary drilling, the use of air rotary drilling rigs is usually not appropriate for environmental investigations unless filters are used because the cuttings brought to the ground surface are ejected into the air adjacent to the drilling rig. Airborne contaminated soil could pose a health risk to workers at the site and nearby residents.

3.5 Dual Rotary Drilling

This method uses an upper and lower rotary drive which allows the drilling stem and casing to be advanced at the same time. The lower rotary drive rotates and advances the casing while the upper rotary drive advances and controls the drilling stem inside of the casing. The casing and drill stem can be off-set or used independently depending on the objective and geological formation. The cuttings are evacuated from the borehole using pressurized water and discharged into a cyclone. This method is effective when drilling deep open boreholes through thick unconsolidated formations because it prevents sloughing and collapsing within the borehole. Since the drilling stem and casing can be advanced to different depths, specific geological formations can be targeted.

The cutting for sampling and characterization purposes can be collected from the cyclone discharge using a strainer. Samples collected from dual rotary drilling are a general representation of the geology for a specific depth interval due the cutting, mixing and separation of cuttings as they are evacuated from the borehole using pressurized water or air.

3.6 Auger Borings

This method involves advancing helical solid-flight or hollow-stem augers with large mobile equipment. This can be a fast method for advancing the borehole without the use of drilling fluid, and augering can be particularly effective for boring through partially saturated or unsaturated material above the groundwater table. Some disturbance of the natural soil is caused by the advancing augers. Auger borings are primarily used for environmental investigations because they are cost-effective and do not involve the introduction of drilling fluids and muds to the subsurface environment.

Soil samples lithological classification or laboratory analysis are obtained from cuttings brought to the ground by the auger or by advancing a sampling tool (e.g., split-spoon sampler) below the end of the augers. This can only be done, however, when hollow-step augers are used. In some cases, a bit is needed with hollow-stem augers to plug the hole at the bottom of the augers. If a bit is used, then the bit must be removed to deploy the sampler.

Auger borings can be difficult to advance below the groundwater table in granular soils because the soils can liquefy and move up the auger stem and/or collapse against the auger flights and cause excessive friction. This condition is commonly referred to as “running sands” or “blowing sands” in the drilling industry. Running sands can be counteracted with limited success by maintaining a constant hydraulic head in hollow-stem augers during the sampling operations. However, the constant head technique is not effective when drilling more than approximately ten feet below the water table in granular soils.

Augers are difficult, and sometimes impossible, to advance to depths of greater than thirty feet in dense tills or coarse granular deposits (such as gravel).

Solid stem augers are not recommended for environmental investigations because soil samples cannot be obtained from discrete depth intervals. Soil samples from solid stem auger borings are typically collected from the surface of the auger flights as the cuttings are brought to the ground surface.

Slotted, hollow-stem augers are commonly used in environmental investigations when vertical profiling of a water-bearing unit is desired. The slotted lead auger is advanced to a pre-determined depth below the groundwater table, and water within the auger is purged with a pump to draw formation water into the auger. A sample of the groundwater is obtained for analysis and the auger is advanced to the next groundwater-sampling interval.

Samples for lithological classification can be collected from the cuttings brought to the surface on the outside of the auger. These samples are mixed and accurate depths from which they originated can not be ascertained. If samples for laboratory analysis are required during hollow stem auger, the drilling is suspended and conventional sampling procedures are employed (split-spoon sampler) as described above to collect soils ahead of the augers.

3.7 Borehole Stabilization

3.7.1 Casing

Driving steel pipe or casing provide the most reliable and practical method of stabilizing a borehole as it is advanced to the required depth. The casing is advanced by constant blows of a drive hammer (typically 300 pounds, falling over a distance of 24 inches) upon a drive head, which is attached to the casing. As the blows to drive the casing are constant, supplementary information may be obtained in the soil resistance by counting the blows to drive the casing a specified distance (e.g., 1 foot deeper). Casing blows are typically recorded for each foot of penetration for the casing. The casing can also be spun and pushed to the desired depth.

The casing is often driven/spun in five-foot increments, with representative soil samples being obtained on a continuous basis or at the completion of each five-foot drive (depending upon the project specifications). After the casing is advanced, the borehole must be cleaned-out, often with air or mud, prior to obtaining a soil sample. In soft or loose soils, stability of the borehole is increased by keeping the casing filled with water or drilling fluids.

3.7.2 Drilling Mud

Drilling mud is a fluid used to stabilize an encased borehole, or to improve sample quality and minimize soil disturbance in cased holes. Drilling mud may be prepared from commercially available products, typically water plus bentonite clay. Drilling mud has a specific gravity (i.e., weight) that is greater than water and will form a filter cake (i.e., low-permeability skin) on the borehole wall or bottom. This skin plus the weight of the mud applied hydrostatic pressure against the borehole walls which resist collapse of the borehole. However, using mud in a boring makes identification of the cuttings more difficult and prevents groundwater level observations.

The use of drilling mud is typically avoided when conducting environmental investigations. The use of drilling mud can reduce the permeability of the walls of the borehole, and therefore, lead to erroneous water level measurements. Additionally, the use of drilling mud introduces foreign material to the subsurface environment, which is not entirely removed upon completion of the boring. The results of chemical analyses conducted on soil samples from boreholes advanced with drilling mud may not be representative of the natural (undisturbed) formation because the soils have been washed by mud. Water samples obtained from wells installed in these boreholes may contain contaminants or parameters, which were not originally present in the groundwater prior to the use of the drilling mud. Most importantly, mud is recirculated as the boring is advanced, so it can spread environmental impacts as the boring is advanced.

Under no circumstances, should drilling mud be prepared with local or on-site clays. If the use of drilling mud is required to advance the boring, the mud should be prepared with commercially available clays, and samples of the mud mixture should be collected for potential analysis, if needed.

The basic mud mixture employed in the drilling industry is bentonite and fresh water (approximately 6 percent bentonite by weight: 50 pounds of bentonite per 100 gallons of water). Attapulgite clay is commonly used and will mix with saltwater to prevent flocculation. Weight additives such as pulverized barite, hematite, galena, or other heavy minerals may be added to the mixture to increase the specific gravity in troublesome soils or under artesian conditions. The precise ingredients and their proportions in the mixture must be recorded for future reference, particularly when groundwater from wells installed in their borings is to be tested for dissolved metals and pH. Attention must be given to the particular group of contaminants expected to be present in the groundwater beneath the site to determine if the drilling mud may impact analytical results.

3.7.3 Hollow-Stem Augers

Hollow-stem augers are advanced into the overburden to the required sampling depth by spinning as downward pressure is applied. The auger acts as a casing during the advancement of the borehole. A removable center plug allows passage of the sampling equipment (typically a split-spoon sampler or Shelby tube) to the required depth. Augers are usually in five-foot sections. Some disturbances of the sampling zone may be created during the auger operation.

Drillers commonly dislike using the center plug and often attempt to complete the boring without using one. However, the center plug should always be used to prevent soil from entering the auger. If a center plug is not used, the split-spoon sampler may not be located at the desired sampling depth due to the presence of soil inside the auger.

3.8 Borehole Cleaning

Thorough and careful cleaning of the borehole is mandatory for obtaining representative, undisturbed samples. Careful measurement of tool length is required. The washing operation

should not usually extend below the bottom of the casing (cohesive soils are an exception). Special bits that deflect the wash water outward or upward should be employed, and only enough wash water should be pumped down the hole to bring the cuttings to the surface. Special shielded auger cleanouts should be employed in cohesive soils prior to obtaining undisturbed piston samples.

Where details of subsurface conditions are necessary, soil sampling shall be conducted using a split-spoon sampler, driven with a 140-pound hammer with a free-fall of 30 inches. This is a standard method of soil sampling as described in ASTM Designation D1586. If necessary, the length of the hammer shaft will be measured and marked, to ensure a minimum drop of 30 inches. This technique should be conducted as follows:

1. The split-spoon sampler (spoon) consists of a 2-inch (outside diameter) by 1-3/8 inch (inside diameter), 18-inch to 24-inch length, heat-treated, case-hardened steel head, split-spoon, and shoe assembly. Split-spoon or split-tube samplers are the most generally accepted method for obtaining representative soil samples; however, from a geotechnical perspective, the samples obtained using a split-spoon are disturbed and unsatisfactory for some analyses like triaxial testing. The head is vented to prevent pressure buildup during sampling and must be kept clean. A steel ball check valve is located in the head to prevent downward water pressure from acting on the sample; the check valve also aids in keeping the soil sample in the split spoon as the tool is removed from the boring. Removal of the check frequently causes sample loss.
2. The drive rods, which connect the spoon to the drive head, should have stiffness equal to or greater than that of the A-rod. In order to maintain only minimal rod deflection, on exceptionally deep holes, it may be preferable to use N-rods. The size of the drive rods must be kept constant throughout a specific exploration program, as the energy absorbed by the rods will vary with the size and weight of the rod employed. This is most important in geotechnical investigation
3. The drive head consists of a guide rod to give the drop hammer (140 pounds) free fall in order to strike the anvil attached to the lower end of the assembly. The guide rod must be at least 3.5 ft in length to ensure the correct hammer drop.
4. The drop hammer used in determining standard penetration test (SPT) resistance must weigh 140 pounds and have a 2.5-inch diameter hole through the center, for passage of the drive head guide rod.
5. The hammer is raised with a rope activated by the drill rig cathead; no more than two turns of the rope should be allowed on the cathead. A 30-inch hammer drop is mandatory for proper SPT determination. Extreme care must be exercised to produce consistent results. Automatic trip hammers are commercially available, and preferred, since these ensure the 30-inch free-fall drop. When presentation of the soil structure is

critical (such as in liquefaction studies), the automatic trip hammer should be employed.

6. Attach the split-spoon sampler to the drill rods and lower the assembly to the bottom of the borehole. Measure the drill rod stickup to determine if heave or blow-up of the stratum has occurred. Note any penetration of the sampler into the stratum under the weight of the rods. The 140-pound hammer is raised 30 inches above the drivehead anvil and then allowed to free fall and strike the anvil. This procedure is repeated until the sampler has penetrated the full length of the sampler (18 to 24 inches depending on the sampler) into the stratum at the bottom of the borehole.

7. The number of blows of the hammer required for each 6-inch penetration is counted and recorded on the test boring log. A penetration rate of 100 blows per ft is normally considered refusal; however, this criterion may be varied depending upon the desired information. The penetration resistance (N) is determined by adding the second and third 6-inch resistance blow counts together. When other sizes and types of sampling and drive equipment are employed, ASTM reference tables may be used in converting the obtained blow count to the accepted SPT value.

8. The sampler is then withdrawn from the borehole, preferably by pulling on the rope. If the sampler is difficult to remove from the stratum, it may be necessary to remove it by hitting the drive head upward with short, light hammer strokes. Remove the sampler from the bottom of the borehole slowly to minimize disturbance. Keep the casing full of water during the removal operation.

9. Careful measurement of all drilling tools, samplers, and casing must be exercised during all phases of the test boring operations, to ensure maximum quality and recovery of the sample.

10. The split-spoon is opened and carefully examined, noting all soil characteristics, color seam, disturbance, etc. If necessary, a representative sample is selected and preserved in a screw-top, glass jar and properly labeled. In the event that more than one soil type is encountered in the split-spoon, each soil type can be preserved in separate jars.

11. The supervising geologist/engineer shall record, at a minimum, the weight of the hammer, the length of the split spoon sampler, and the number of hammer blows on the spoon per 6 inches of penetration. Upon removal of the sampler, the earth materials shall be logged in accordance with SOP NMI-S-006, Soil Sample Classification. When the number of blow counts exceeds 50 per 6 inches, the split spoon sampling shall be terminated and the number of blows per tenths of a foot (for the last one-half foot) shall be recorded and noted as sample refusal.

12. If a sample is to be retained, a pre-cleaned stainless steel spoon will be used to take the soil sample and fill the sample containers.

13. After the samples have been collected and if a well is not being installed in the boring, the borehole should be backfilled with cement/bentonite or cement, the approximate location of the boring will be marked with an oak stake colored with highly visible spray paint. The boring number will also be written on the stake to identify the sample location for surveying purposes.

3.9 Logging Bedrock Cores

Rock coring is a method to obtain bedrock samples for geologic classification, facilitate their performance of permeability tests, and install groundwater monitoring wells within bedrock formations.

The supervising geologist/engineer on a drilling program is responsible for logging and recording geologic and geotechnical information from rock cores.

There is no universal core barrel or drilling equipment for rock coring. The geologic and topographic conditions, in addition to the requirements of the project, will dictate the type of equipment to be employed on each project. The following factors lead to good production:

1. Ensure a level and stable drilling platform before commencing boring.
2. Ensure that the drill stem remains as nearly vertical as possible. On deep core holes, true alignment of the casing is critical. The driller may elect to use a heavy drilling mud instead of casing to support the borehole walls; this procedure is not acceptable for environmental investigations (see above).
3. Upon encountering boring refusal at the soil/bedrock interface, the casing should be firmly seated on the rock and thoroughly washed out before inserting the diamond-bit core barrel.
4. Inspect the selected core barrel and bit for wear, general cleanliness, and free movement of all parts. Reject any core barrel or bit that appears unsatisfactory. Upon selecting a satisfactory core barrel and bit, the driller will mount the core barrel and bit assembly on the drilling rods and lower it into the borehole until the bit touches the bedrock surface.
5. Pump drill fluid down the drill rods and observe a return flow before commencing drilling operations.
6. Carefully measure all length of rods, core barrel, and stick-up through all phases of the drilling to ensure accurate depth determination.
7. The diamond-bit core barrel should be started in the hole and the rock drilled in continuous five-foot length intervals (runs) until the required depth is reached.
8. Drill with minimal vertical pressure and rotation. Most rigs are equipped with a selection of gear ratios and a variable hydraulically-controlled feed mechanism. Driller expertise in selecting the correct combination of speed and feed rate is invaluable.

9. Water return should be no more than what is sufficient to bring the borehole cuttings to the surface.

10. Record the drilling time per foot, type of bit, estimate of bit wear, drill rig rotations per minute (rpm), and feed pressure.

11. After completing each 5 ft core run, the core barrel is spun and lifted to break the core at the bottom of the run. After the core is broken off it should be withdrawn, labeled, and stored in an approved core box. Cores should be carefully handled to ensure their proper identification and placement in correct order. Care should also be taken to recover as large a percentage of unbroken core as possible.

12. Carefully place the rock core in the core box with wooden partitions so that the cores from each boring will be kept separate. The core should always be placed in the core box in book fashion with the top of the run at the upper left corner and the remaining core placed sequentially from left to right and from the top left corner to the lower right corner. Place a wooden partition at the beginning and end of each core run. The core should fit snugly in the box so that it will not roll or slide because this can break cores. The wooden blocks should be labeled with the Run Number and depths of the beginning and end if each run.

    Each core box should only contain cores from a single boring. Never place the core from more than one test boring in a core box. In addition, wherever core is lost due to the presence of a cavity or large discontinuity (open or filled), a spacer should be placed in the proper position in the core box. The spacer should be labeled with the depth range and thickness of the missing core, and the reason for the missing core (e.g., cavity, large joint, etc.).

13. Carefully examine and classify the rock, and then measure the recovery and rock quality designation (RQD) in percent (described more in section 3.4.4). Record all information on the core boring report.

14. If 100% recovery was not obtained, measure the depth of the borehole versus core length to determine if the missing core remains in the bottom of the borehole.

15. Always terminate each boring with 100% recovery, in order to ensure that appropriate knowledge is available of their materials.

16. The core box should be marked on the top and two ends with the client's name, site identification, boring number, depth range, and box number.

17. The core barrel and drilling tools must be decontaminated upon completion of the borehole to preclude cross contamination between successive boreholes. See SOP NMI-007

18. Wash water used during the core drilling should not be re-circulated to the borehole, if possible.

3.9.1 Wireline Drilling

The procedures for wireline drilling are also the same as for conventional rock coring, with the exception that the core barrel is designed so that the inner core barrel can be raised in a wireline without removing the entire drill string, outer core barrel, and bit. This coring method is more efficient than conventional coring and requires that the drilling rig is equipped with a wireline hoist/winch.

3.9.2 Oriented Core

If precise spatial orientation of rock bedding, foliation, and discontinuities are required, it is recommended that the Christensen Diamond Products Series D-3, NWD-3 core barrel, or equivalent, be employed.

3.9.3 Shotcore Drilling

Shotcore drilling is usually employed to produce large-diameter rock core (2 to 6 ft and larger). The core is cut by the abrasive action of chilled steel shot fed to a rotating steel bit. Shotcoring procedures are as follows:

1. Lower the assembled shotcore barrel to the bedrock surface.
2. Drop one or two handfuls of chilled shot down the center rod. Connect the bit to the drilling spindle and slowly turn by hand with a pipe wrench. A gritty feeling indicates that the shot is beneath the bit.
3. Lift the bit off the bottom and introduce the fresh water supply. When water return appears at the surface, lower the bit to the bedrock surface.
4. Drill feed must be manual with only enough downward pressure to follow the bit. This is an abrasive action and too much shot will wear the core barrel and too little will not core the rock. Driller expertise and careful attention are critical in successful shotcore drilling.
5. Regulate water flow so that it just allows the cuttings and slivers of steel to be carried over the top of the casing. Add additional shot as required.
6. A good flow of muddy slurry to the surface indicates that the rock is being drilled.
7. If water return is clear, but contains fine particles of steel, this is an indication that an excess of shot has been used. Flush the hole and start again.
8. Record the drilling rate and reface the bit shoe after every withdrawal by squaring up the face with a hammer.
9. To recover the core, a hard, uniformly-graded pea gravel is fed into the center rod as it is slowly rotated so the gravel is grouted between the core and the core barrel, and the entire unit is pulled to the surface. On occasion, it may be necessary to remove the core

barrel and drill a small diameter hole in the center of the core while it is still in the hole, and then drive a casing retriever into the core before retrieval is possible.

3.9.4 Preservation of Rockcore

The following information should be included in a rock core run log:

- The depth and length of the core run.
- The coring rate, down pressure, and torque and rotation speed. This information can be obtained from the driller.
- The color of the core wash water. Any changes, loss of return water, or gain of return water will be noted.
- The recovery of the core run recorded as length of rock recovered over the length of the core run.
- The RQD of the run is reported as the sum of inches of all naturally fractured rock core pieces larger than four inches over the total number of inches in the run. The length of the piece will be determined by the distance between naturally occurring fractures.
- The rock type(s) and their location in the core run, rotating color, mineralogy, texture, fossil content, effervescence in hydrochloric acid (HCl), and any other data of geologic significance.
- Any structure in the core, including fractures, clay seams, vugs, bedding, fissility, and any other data of geologic or geotechnical significance.

Rock cores shall be stored in a core box in the sequence in which they were removed from the ground. Core runs will be separated by wooden blocks clearly marked with the depth of the run. The top of the core box shall be marked with the project name, location, project number, boring number, and the depths of the core runs in that box. The front and one end of the core box shall be marked with project name, boring number, and depths of the core runs in that box. All core pieces shall be oriented in the box as they fit together. A black and white stripe shall be drawn down the length of the core, so that core orientation can easily be determined.

3.10 Photographing Soil and Rock Samples from Borings

If soil samples are to be documented with photographs, the photographs should be taken while the soil samples are still in the split spoon. If smearing of the sample has occurred, a fresh exposure can be made by scraping with a pen knife, spatula or other similar object. The split spoon and sample should be placed in a good light, preferably against a solid colored background. A ruler for scale and a tag identifying the sample should be placed in the picture. The identifier tag must have the sample number, depth and project name or number written legibly in the photograph; a marker and white board is convenient. Any photographs taken should be recorded in the field notes.

Rock core samples are photographed in the wooden core box. The rock should be wetted to enhance the color and textural changes in the rock. Due to the relatively large size of most core boxes, the photographer (when possible) should stand up on a chair, tail gate, car bumper or other perch in order to photograph the box from directly above and get the entire box in the camera's field of view. The photograph should include a ruler for scale and an identifier tag indicating the project name and number, the boring number, the date, and the depths of the various core runs.

4.0 DECONTAMINATION

The drilling equipment (e.g. core barrels, rods, drill bits, etc.) and the drilling rig must be decontaminated between boring locations and prior to mobilizing off-site using methods detailed in SOP NMI-007.

ROCK CORE LOGGING FORM

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Geosyntec consultants

Project Name:	Logged By:	Boring Location:
Project Number:	Rig Type:	Depth to Weathered Bedrock: Bedrock:
Drilling Contractor / Name:	Bit Type / Size:	Water Input during Drilling
Drilling Method:	Date / Start: Finish: Time:	Casing Size: ID: OD:

Visual	Depth (ft' bgs)	Sample No. (core interval)	Penetration Rate ft/min	Core Breaks (m if Mechanical)			Rock Quality			Rock Description and Comments on Drilling:
				Depth	Type/Dip	Surface Condition	Recovery	Run Length	RQD (%)	

Hardness:
V hard: no scratch
Hard: difficult to scratch
Med hard: easy scratch

Weathering:
v. slightly……1
slightly……2
moderately……3
severely……4
v. severely……5
completely……6

Fracture Frequency:
Extreme: <1"
Moderate: 1-4"
Slightly: 4-8"
Sound: >8"
Joints: close <->

Discontinuities:
Crack
Joint
Shear (slickensides, striations, polishing)
Fault zone: shears or faults

Texture:
Amorphous/aphanitic
Fine grained: barely seen
Med grained: <1/8th"
Coarse grained: 1/8-1/4"
v coarse grained: >1/4"

Color: gray, dk/lt gray, green gray, etc.

Other: water bearing, altered, fractured, brecciated, decomposed, kaolinized.

Boring and Monitoring Well Construction Log

Sheet ____ of ____

Client :	**Project No.**	**Location:**
Geosyntec Inspector:		**Date :**
Weather:	**Borehole Diameter:**	**Drilling Method:**
Drilling Co.	**Rig Type:**	**Driller**
Depth to water :	**Depth to Refusal:**	**Total Depth :**

Geosyntec consultants

engineers | scientists | innovators

Log of Boring

_____

Well Construction	WL	Depth (feet)	Soil Samples	PID	recovery	Sample Description and Boring Notes
		0				
		5				
		10				
		15				
		20				
		25				
		30				
		35				
		40				
		45				
		50				

Notes:

STANDARD OPERATING PROCEDURE NMI-S-005

TEST PITTING AND SAMPLING

1.0 INTRODUCTION

1.1 Objective

Exploratory test pits are important sources of subsurface information relating to geologic conditions and site suitability fundamental to environmental site assessment and geotechnical design. The following procedure is an introduction to test pit excavation equipment and techniques and an outline of field staff responsibilities while monitoring test pit excavation methods.

The procedures presented herein are intended to be of general use and may be supplemented by a work plan and/or a health and safety plan. As the work progresses and if warranted, appropriate revisions to this standard operating procedure may be made by the project manager. Detailed procedures in this procedure may be superseded by applicable regulatory requirements.

Field staff are responsible for ensuring that the recovered samples are acceptable and that they are properly sub-sampled, sealed, labeled and handled during subsequent site storage and transport.

1.2 Equipment

The field engineer/geologist overseeing the construction of the monitoring well should have the following equipment in the field during well installation:

- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan;
- Field logbook and/or data sheets
- Site map(s)/plan(s)
- Contract with Subcontractor (pay items)
- Exploration Criteria/Specifications
- Engineer's Scale
- 6 ft. Ruler
- Shovel
- Geologist's Pick
- Survey Stakes/Paint/Flagging
- 100 ft. Measuring Tape
- Hand Lens, magnifying
- Camera & Film
- Logs & Forms
- Field Procedures
- Office Supplies (pencils & markers)
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- Plastic or stainless-steel spoons and/or wooden tongue depressors

- Appropriate size sample containers
- Plastic zip lock bags
- Sample Labels
- Chain of Custody records and custody seals
- Cooler(s)
- Ice
- Decontamination supplies/equipment

1.3 Required Environmental Equipment

Test pit excavation programs conducted for environmental purposes will require specific equipment for personal protection, air quality monitoring, headspace screening, sampling, testing and decontamination. A comprehensive list of equipment and materials must be developed for each project in coordination with the Project Manager (PM) and the Health & Safety (H&S) Coordinator prior to the start of the field program.

1.4 Additional Equipment, Specialized Instrumentation, Materials & Company Vehicles

Additional equipment, vehicles and materials may be rented or purchased as needed with the approval of the project manager. Project equipment needs should be addressed proactively so that interoffice allocation can take place. It is recommended that the field staff familiarize themselves with the use, function and availability of all types of equipment standard to the industry.

2.0 PROCEDURES

2.1 Preliminary Preparations

Prior to the beginning of a test pit excavation program field staff must attend a project briefing for the purpose of reviewing the proposal, site and utility plans, contract documents and drawings, applicable regulations, test pit sampling, testing and termination criteria, site restoration, site contacts, phone numbers of team members, and other related documents and references. In addition, certain projects will require the field staff to attend a Health & Safety briefing due to specific occupational safety concerns. The individual nature of these concerns will be addressed by a site-specific Health & Safety Plan.

A file folder for the field activities should be created and maintained such that all relevant documents and log forms likely to be useful for the completion of field activities by others are readily available in the event of personnel changes.

2.2 Duties and Responsibilities

2.2.1 General

The principal reason for providing field representation during test pit excavation is to assure that the field data being collected is accurate and of the type necessary to properly evaluate the site geologic conditions for the subsequent engineering analyses and environmental assessment.

2.2.2 Supervision of Test Pit Excavation Programs

Test pit excavation programs are regularly used for surficial geological mapping activities including routine soil identification and sampling. Test pits are particularly useful for delineating overburden thickness in areas of shallow bedrock and for determining the extent of potentially contaminated zones. In addition, test pits may be used to expose existing underground structures for detailed documentation or as a means to establish the soil profile and to excavate to a particular elevation for the purpose of conducting percolation testing.

Proposed test pit locations and depths may be modified throughout the execution of the excavation program as the accumulated geologic data and any test results are interpreted. For this reason, it is essential that all records are maintained current and complete and that uncertainties are identified for resolution as they occur. Field staff members are responsible for maintaining communication with the project manager and for logistical coordination of the field effort within the work scope and budgetary limits.

Test pit excavation programs are by nature more destructive than other subsurface exploration methods. Field staff should be extremely clear as to the expectations of the client and project manager with regard to site damage and restoration efforts, prior to conducting the test pits.

2.2.3 Verification of Excavation Methods and Services

It is the responsibility of the field staff to verify that test pits and related subsurface sampling and testing methods are in conformance with applicable approved standards and specifications and to document conditions and results. All applicable safety standards must be complied with including establishment of exclusion zones, installation of safety fencing, use of trench boxes, maintenance of proper slopes or benching, and provision of access and egress. The Occupational Safety and Health Administration's (OSHA) Excavation and Trenching standard Title 29 of the Code of Federal Regulation (CFR) Part 1926.650 covers requirements for excavation and trenching standards which may be accessed through their website www.OSHA.gov or from your Health & Safety Administrator. OSHA also provides useful guidance in an easy to read handbook entitled Excavations OSHA 2226.

It is the responsibility of the field staff to verify that proper equipment and techniques are employed and to obtain measurements and make observations independently. Field staff are responsible for complete field logging of groundwater, soil and bedrock conditions, the

maintenance of accurate test records and field exploration location sketches and ensuring proper sample preservation and handling.

Payment for services rendered on behalf of the client is commonly handled by providing an accurate breakdown of the work activities and itemized costs. Excavation subcontractor pay items and method of payment are defined in their contract. Typically test pits are paid for on an hourly basis with a mobilization fee and a utility clearance fee with additional pay items as needed such as laborers, jack hammers and compressors, chainsaws, surface patching with asphalt or reseeding landscaped areas.

2.2.4 Right of Access

Prior to site entry, staff members must ensure that permission has been granted from the property owner to access the property.

2.2.5 Layout and Utility Clearance

Prior to the start of any subsurface exploration all proposed locations must have utility clearance from all appropriate agencies and utility owners. Utility owners typically do not enter private properties. If there are particular concerns regarding utilities on private property, arrangements can be made with a private utility locating service. Prior to contacting any utility agency or service all proposed exploration locations must first be clearly marked in the field either with white paint or staked and white flagged. Additional colors can be used to highlight the location if the ground is snow covered. Alternate locations should be laid out in areas of suspected utilities. The subsurface exploration subcontractor is required to obtain the utility clearance within the terms of the contract or services agreement. Field staff should verify with the driller/test pit contractor that the utilities have been cleared and obtain the clearance number prior to the start of subsurface explorations. Pre-excavation may be necessary in areas of closely spaced utilities either by hand, vacuum, or other means.

2.2.6 Site Briefing

At the start of fieldwork field staff should coordinate a site briefing and review the schedule and work scope with all subcontractors involved with the project. This briefing should include a review of the following:

- Excavation requirements including depths, maximum slopes and shoring
- Test pit lay out, criteria and priority
- Testing and sampling specifics
- Pay items
- Site conditions
- Environmental concerns, known or suspected contamination
- H&S information
- Decontamination requirements
- Site restoration and waste disposal issues
- A site walkover and utility check

While it is the subcontractor's responsibility to obtain the utility clearance, the field representative should pay attention to the utility plans as well as surface manifestations of the utilities including, manholes or catch basin grates, and gate or roadway boxes. Distance to overhead utilities must be verified by the test pit contactor as well.

2.2.7 Test Pit Monitoring

2.2.7.1 General

Test pits are an extremely economical and effective way to rapidly characterize shallow subsurface conditions. Test pits are particularly useful for surficial geologic mapping, determining fill thickness and content, identifying the presence and extent of contamination, contouring shallow bedrock conditions and in determining oversized (cobble and boulder) percentages. Small backhoes with an approximately ¼ cubic yard bucket capacity are capable of excavating test pits up to 12 ft. depth in most materials and can be used with minimal site damage. Larger excavators with an approximately ¾ cubic yard bucket capacity are capable of excavating test pits up to 16 to 20 ft. depth and can be used to construct access for drill rigs on difficult sites. Given sufficient area, excavators can safely enter the excavation and extend the test pit indefinitely. During test pit excavation careful consideration must be given to potential bearing surface disturbance within proposed structures. In addition, care must be taken to minimize other site impacts requiring costly restoration including damage to trees, pavement, curbing, landscaping and utilities.

Field staff members are required to become familiar with the technical details and suitability of all excavation equipment and methods as well as with the regulations governing excavation safety.

2.2.7.2 Excavation Safety

Specific regulations and procedures must be consulted for additional details relating to excavation safety. The Occupational Safety and Health Administration's (OSHA) Excavation and Trenching standard Title 29 of the Code of Federal Regulation (CFR) Part 1926.650 covers requirements for excavation and trenching standards which may be accessed through their website www.OSHA.gov or from your Health & Safety Administrator. OSHA also provides useful guidance in an easy to read handbook entitled Excavations OSHA 2226.

2.2.7.3 Logging

Test pit logging standards require thorough documentation and qualification of all natural and man-made materials and structures encountered. This includes detailed descriptions of any fill materials, overburden soils, bedrock, groundwater, contamination and structures encountered including accurate measurements of the depth and extent of each.

Fill materials and overburden soils are described in accordance with the appropriate operating procedures. While the bedrock may not be penetrated to a great extent in a test pit, effort should be made to qualify the competency of the bedrock through excavation rates and to describe the bedrock hardness, type, weathering and fracturing. Accurate distinction and depths of geologic contacts are a primary objective of test pit excavation programs. Stratigraphic contacts between separate geologic units are drawn with a solid line while variations in texture, density, weathering or color occurring within a unit are distinguished with a dashed line.

Groundwater is of fundamental importance to environmental assessment and geotechnical engineering. Careful observation of the points and rates of groundwater inflow within a test pit may help to make the distinction between perched groundwater and the phreatic surface. The seasonal high-water level may be discernible through mottling or oxidation. A complete record of observations taken throughout the excavation of a test pit must be maintained.

Meaningful terminology to qualify the degree and extent of each type of contamination found on a particular site may be developed on a site-specific basis in conjunction with the project manager. Criteria may be based upon a combination of obvious physical properties and field testing and instrumentation measurements.

Man-made structures must be documented in detailed scale drawings shown in plan and elevation perspective. Every effort should be made to properly identify the type of structure encountered based upon construction, geometry and any other observation. Distinction between a footing and a grade beam or pile cap can only be made by effectively exposing a sufficient area beneath the structure to make a judgement based upon direct observation of the bearing surface. Qualification must be made wherever possible to document the condition of the structure encountered as well. Notes must be taken to clearly describe such details as the integrity of a buried granite block footing, the degree of decomposition of a poured-concrete foundation wall or the spacing and degree of decay observed in a series of timber piles.

2.2.7.4 Sampling

A. Bag Samples – Bulk soil samples are routinely obtained from test pits for the purpose of conducting a number of geotechnical laboratory tests including sieve (gradation), hydrometers, Atterberg limit, unit weight and proctor analysis. It is imperative that a sufficient volume of material is obtained for each sample for the desired test to be performed and for the

results to be valid. Generally speaking, a minimum of 50 lbs. of material must be collected for a standard suite of geotechnical tests. ASTM D2488 defines the minimum amount of soil required for identification and description. The minimum amount required is based on the maximum particle size observed in the soil.

Maximum Particle Size		Minimum Specimen Size (estimated in dry weight)		
No. 4	(5 mm)	coarse sand	100 g	(0.25 lb)
3/8 in.	(10 mm)	fine gravel	200 g	(0.5 lb)
¾ in.	(19 mm)	fine gravel	1.0 kg	(2.2 lb)
1.5 in.	(38 mm)	coarse gravel	8.0 kg	(18 lb)
3 in.	(75 mm)	coarse gravel	60.0 kg	(132 lb)

Bulk samples are retained in clean, unused, heavy-duty sample bags that can contain approximately 0.6 cubic feet (5 gallons) or 80 lbs. of soil. Care must be exercised to obtain a representative sample of material. The coarser fraction in the upper portion of a material stockpile tends to roll to the toe or perimeter of the mound, therefore hand excavation into the stockpile some distance is required in order to obtain a truly representative sample. Grab samples are obtained at a discrete point while composites may be obtained from several points or along a linear trend. Sampling may occur within or across stratification. It is critical to the analysis to recognize the inherent bias in the technique prior to the sampling event. All samples must be thoroughly documented in the field prior to transport off site. Bag sample tags must be affixed to the twist-tie with the following information.

- Project Name
- File Number
- Date
- Sampled By
- Exploration No.
- Sample No.
- Depth
- Remarks (sample source, general description, possible tests to assign, project manager to contact)

B. Jar Samples – Representative soil samples from each stratigraphic unit are routinely obtained from test pits for quick reference by the project manager. These may be retained in clean, unused, 8 oz. glass jars that have been clearly labeled with the following sample information.

- File Number
- Exploration Number
- Sample Number
- Depth
- Stratigraphic unit or geologic interpretation

Soil samples should be carefully selected and placed in sample jars as nearly intact and undisturbed as possible. Original soil structure, including bonding, foliation and stratification, are critical to the geological interpretation and understanding the engineering properties of soils. Careless handling of samples may destroy soil structure making any geologic interpretation of soils during the review process impossible.

Transportation of samples from the site should be addressed by the project manager in advance of the sampling. Commonly samples will be taken at the site by field staff and entered into the sample receiving storage and tracking database. Company owned vehicles may be scheduled for periodic pick-up of contaminated samples or on projects with particularly large sample volume requirements or difficult site access.

2.2.7.5 Percolation Testing

Many state and local agencies require percolation testing to be performed at shallow depths in naturally deposited, undisturbed soils on sites in order to determine infiltration and recharge rates for construction dewatering or for septic system design. Test pits are routinely used to quickly categorize soils for potential siting of such systems by providing broad and easy access to soils at a range of depths for description, percolation testing and determination of the depth to groundwater. Refer to the appropriate operating procedure.

2.2.7.6 Restoration

Test pit excavation programs are by nature more destructive than other subsurface exploration methods. Field staff should be extremely clear as to the expectations of the client and project manager with regard to site damage and restoration efforts. Typically, on undeveloped sites the test pit may be accessed with a minimum of damage to the ground surface and surrounding vegetation and the test pit can be backfilled upon completion with a degree of care to ensure that a relatively smooth surface remains. Limited clearing using a chainsaw is preferable to the vegetation damage resulting from attempting to overrun or sweep vegetation with the excavation equipment. The degree of destruction increases proportionally with the size of the excavation equipment selected,

the number of oversized components or obstructions encountered as well as with the ultimate dimension and depth of the excavation. Landscaped areas may incur widespread damage in traveled zones in addition to the actual areas of excavation. Use of plywood to "raft" the excavation equipment over short distances may not be successful especially during wet conditions and hand grading, raking and reseeding is typically necessary to restore the landscaping. Paved areas should be pre-cut with saws or a jackhammer prior to excavation after which, they should be backfilled and compacted in lifts that have had oversized components segregated and removed. Later a paving crew can place and compact hot-mix asphalt to complete the restoration. Restoration efforts commonly exceed the excavation efforts in time and cost.

2.2.7.7 Environmental Sampling and Monitoring

Environmental sampling combined with discrete field screening of soil for contaminants is routinely conducted during the performance of test pit explorations. In addition, continuous monitoring of air quality within the work zone or at the project site may be required to address H&S concerns. Potential contaminants and sources may be identified in the initial stage of project planning and prior arrangements made for PPE, monitoring, sampling and laboratory analysis.

To minimize the risk of cross-contamination typical environmental sampling programs work from known or suspected clean areas toward areas of known or suspected contamination. Contamination encountered unexpectedly may present serious exposure risks to field personnel without proper PPE and monitoring instrumentation, particularly if the contamination is gross or unidentified. In the event unexpected contamination is encountered, all fieldwork should be suspended and the area evacuated immediately until the Project Manager and the Health & Safety Coordinator can be contacted so that H&S and sampling guidelines can be developed.

A. Decontamination Procedures and Waste Management - Standard equipment decontamination practices may include the establishment of a decontamination area such that decontamination fluids are collected and properly stored for disposal. Typically, a location within the site is chosen away from sensitive or occupied zones and a decontamination pad is created within a bermed area using polyethylene sheeting. A high-pressure steam cleaner is used to wash all equipment prior to each exploration and wastewater is pumped into adjacent drums. Excavation and hand sampling tools are scrubbed between samples at the exploration location using a detergent (water and alconox) solution rinsed with control (tap) water followed by a solvent (methanol) rinse, wiped with a paper towel and rinsed with deionized water before being allowed to air dry. Hexane may be needed for removal of heavy petroleum, grease and coal tar. Decontamination waste, sample residue and excess excavation spoils are typically drummed, labeled and staged onsite for proper disposal.

B. Environmental Soil Sampling - Environmental soil samples obtained for chemical analyses are collected in test pits with special attention given to the rationale behind determining the precise zone to sample, the specifics of the method of soil extraction and the requisite decontamination procedures. Preservation, handling and glassware for environmental soil samples varies considerably depending upon several factors including the type and degree of contamination, the analytical method to be conducted, the analytical laboratory being used and the governing regulations. In addition, the depth and location of samples may be strictly controlled under agency guidelines. Documentation of volatile organic compounds (VOC) in the soil through headspace screening is required in order to provide real-time guidance in the field to direct the sampling. Clean 8 oz. jars are partially filled with newly obtained soils and covered with aluminum foil and allowed to stabilized prior to screening with a photoionization detector (PID). The presence of metals in soils is not associated with odors, while coal tar, fuels and solvents are often easily distinguished. Particular attention is given to discoloration or odors noted, however, it is company policy to avoid fumes and odors at all times. Soils collected from a discrete zone should be homogenized and a representative portion placed into laboratory glassware and labeled. Analytical samples are kept in a cooler with ice blocks and a Chain of Custody form is maintained until transfer to the analytical laboratory. Refer to the appropriate operating procedure for environmental sampling protocols

C. Environmental Water Sampling – Sampling of groundwater encountered in test pits is not a recommended practice due to a variety of potential impacts resulting from the excavation equipment and activity. Visual or olfactory evidence of groundwater contamination should be carefully detailed in order to help direct potential subsequent groundwater sampling through acceptable means.

2.2.7.8 Documentation

Thorough field documentation is the primary responsibility of field staff throughout the execution of any test pit program. Site conditions, soil and rock logging, sample identification and tracking, test and data collection, sketches, photographs, pay item quantities, events, personnel onsite, incidents, discussions and issues must be recorded in the appropriate manner in order to comply with contractual agreements, regulatory requirements and recommended loss prevention practices.

All field documentation must be duplicated, photocopied or reproduced as soon as is practical in order to guard against loss. In no case should originals be mailed, transferred or removed from the author's custody until a backup copy is made. Copies of field documentation should be delivered to the project manager in a timely fashion as the project warrants. Originals may be issued to word processing or data entry personnel directly upon completion of a short-term test pit program or periodically throughout longer term projects.

Documentation related to environmental sampling, testing and chemical analysis is covered in detail in specific procedures developed for the particular sampling practice, medium, compound and applicable regulations.

A. Field Book - The field book is a first line repository of anything observed or discussed onsite without regard to potential use or merit. While the type of information in the field book may in some cases be informal or general in nature, the field book is a legal document. Long after a project is completed and the file is closed the field notes may provide an invaluable record of details that may not have been recorded elsewhere. The standard format of the daily field book entry typically includes the following:

- File Number
- Project & Location
- Date
- Weather
- Personnel Onsite
- Equipment Onsite
- Activities
- Observations
- Conversations
- Data
- Issues
- Incidents
- Other items not recorded elsewhere

B. Photographs - Photographic documentation of site conditions, activities and incidents are very useful for conveying a visual perspective to what may be difficult to describe otherwise. The fundamentals of good photography must be applied for the images to be of use including:

- Lighting (adequate but not excessive)
- Composition (frame the subject properly)
- Perspective (include a scale)

In addition, subject identification within the photograph by means of a white board and use of the camera date/time feature (if so equipped) renders ease to later captioning as does indicating on a site plan during shooting the approximate location and direction of the shot by frame number.

C. Test Pit Logs - Test pit logs must be completed entirely and without omission to stand alone as documentation of the subsurface conditions at a given point. To guard against loss, test pit logs should be proofed in the field and photocopied or faxed as soon as is practical. Protocols for electronic logging using a PDA or laptop computer require periodic file

back-up and memory card replacement as well as daily transmission to the server.

Each test pit log contains a header to identify the project, client and test pit designation and to document the test pit location, the ground surface elevation, contractor and equipment used, Project Manager, Field Representative, date, weather conditions and groundwater entry. Within the body of the test pit log each sampling event is recorded in a column by including sample type, designation and depth. Separate columns are used for USCS group symbol and the USCS identification and description. A column for indicating PID (photoionization detector) readings is included in the Test Pit Log. In the test pit log footer standing groundwater observations noted during the execution of the excavation are carefully recorded in relation to the excavation activity in order to assist in the interpretation of the reading. Boulder counts and test pit dimensions are also recorded in the footer. Guidelines for overburden logging are detailed in the appropriate operating procedure.

D. Special Testing and Instrumentation - Forms for documenting specific field sampling procedures, special testing and instrumentation installations are available for use as appropriate. Specific guidelines for documenting special testing and instrumentation installations may be given within established procedures. In the absence of documentation standards for a particular procedure the general standards of scope, precision, accuracy and completeness from related procedures should be referred to until specific guidelines are developed.

E. Subcontractor Quantities for Test Pits - Test pit pay items are recorded on Subcontractor Quantities for Test Pits which is used to summarize the pay item totals as defined in the contract or agreement with the subcontractor. This form must be reviewed and signed by the subcontractor's representative upon completion of the subsurface exploration program. Carbon copies are distributed to the subcontractor's representative, the project file and the Field Services Manager.

F. As-Built Test Pit Locations and Elevations - An accurate sketch showing the actual (as-built) location of completed test pits must accompany the test pit logs. In addition, the estimated elevation of the ground surface or excavation reference elevation must also be included. Locations and elevations should be measured with 0.1 ft. precision from known or permanent features whenever possible, however, establishment of a temporary baseline and/or series of benchmarks may be necessary in open or virgin sites. An existing site plan with location and elevation data may have been provided for use during the test pit program. In such cases the scale and elevation datum should be verified and the accuracy of the horizontal and vertical data should be checked. All excavation and field

references should be painted or staked in the field as appropriate for future field survey.

G. Geologic Profiles - Simple geologic columns of individual excavations may be quickly sketched in the field and combined as needed in order to produce a two-dimensional stratigraphic cross-section or geologic profile. This exercise may be useful in the development and support of the geologic interpretation of the stratigraphy and in the identification of data gaps during the test pit program.

2.2.7.9 Final Review and Summary

The final complete package of field data must include copies of all first draft field logs, test reports, raw data, field book entries, photographs, plans and sketches, daily field reports, subcontractor quantities and any additional notes. All field data must be reviewed for discrepancies, errors and omissions as well as for the identification of factors of critical importance and any areas of uncertainty.

In addition to the field generated data, all relevant research, correspondence, contracts, drawings, test pit rationale and criteria, sample receiving forms, environmental regulations and health and safety protocols assembled for the test pit program should be included in the final package to the file.

A summary of the test pit program should be prepared including the subcontractor and equipment, dates of execution, the total number of excavations, sampling types and quantities, excavation depths, stratigraphy and depth to bedrock.

The site features and geologic conditions should be described incorporating the synthesized data from the test pit program and all available published literature or research. The geologic summary should present the reasoning behind the interpretation and any supporting documentation including geologic profiles developed for the site and related references.

2.3 Cleaning of Drilling Equipment

Cleaning the test pit rig and associated equipment will follow the appropriate operating procedures.

2.4 Decontamination

Soil sampling equipment will be cleaned prior to and between each use according to per appropriate operating procedure. After decontamination, the equipment will be wrapped in aluminum foil and placed on clean racks off the ground until it is used.

2.5 Quality Assurance/Quality Control

There are no specific quality assurance (QA) activities that apply to the implementation of these operating procedures. However, the following QA procedures apply:

- All data must be documented on field data sheets or within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in a Site work plan or related document. Equipment calibration activities must occur prior to sampling/operation, and they must be documented.

2.6 Documentation

Field documentation shall be recorded in daily field logs. It is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel. A daily field report should be completed for each day of fieldwork. These reports can be scanned and submitted to the project portal.

HALEY ALDRICH

ENVIRONMENTAL TEST PIT LOG

Test Pit No.

Page 1 **of**

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	
EQUIPMENT		**WEATHER**	

Ground El. _____ ft. **Location** _____ **Groundwater depths/entry rates (in./min.):**

El. Datum _____ **PID Make / Model** _____

Depth (ft.)	Sample ID	PID Reading (ppm.)	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (Color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0															

Obstructions:

Remarks:

Bucket Decontamination Metho

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth _____ ft.

measured after _____ hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24		=	
over 24		=	

Test Pit Dimensions (ft.):

Pit Depth _____

Pit Length X Width _____

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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STANDARD OPERATING PROCEDURE NMI-S-006

SOIL DESCRIPTION:

IDENTIFICATION AND DESRCRIPTION OF SOILS IN THE FIELD USING VISUAL-MANUAL METHODS

1.0 INTRODUCTION

The purpose of this operating procedure is to provide the visual-manual procedure outlined in ASTM D2488 for soil identification and description. Soil identification is divided into three broad categories: coarse grained soils, for which the proportion and gradation of the components are most significant; fine grained soils, for which the degree of plasticity and dry strength are the controlling factor; and organic soils.

1.1 Equipment

The field engineer/geologist conducting soil description should have the following equipment during the field investigations:

- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan;
- Field logbook and/or data sheets
- Site map(s)/plan(s)
- Engineer's Scale
- 6 ft. Ruler
- Hand Lens, magnifying
- Camera & Film
- Logs & Forms
- Field Procedures
- Office Supplies (pencils & markers)
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- Plastic or stainless-steel spoons and/or wooden tongue depressors
- Penetrometer, pocket
- Torvane, pocket
- Color chart, Munsell's
- Jars, sample with labels
- Sieves
- HCl (one-part 10N HCl to three parts water)

2.0 PROCEDURE

2.1 Introduction to Soil Identification and Description

The soil identification and description procedures follow the visual-manual procedure outlined in ASTM D2488. Two distinct tasks are required. First the soil is identified based on percentage of grain-size constituents. This process produces a Group Name and Group Symbol for the soil.

Secondly, the soil is described. The additional descriptive information includes properties such as color, density or consistency, odor, structure, and geologic origin.

The Group Names and Group Symbols used to identify soils are determined using the flow charts shown in Figures 1 and 2. The Group Names and Group Symbols generated by this procedure are based on the Unified Soil Classification System. When precise classification of soils is required for engineering purposes, the laboratory procedures outlined in ASTM D2487 must be used.

Soil identification is divided into three broad categories: coarse grained soils, for which the proportion and gradation of the components are most significant; fine grained soils, for which the degree of plasticity and dry strength are the controlling factor; and organic soils. Frequently, coarse grained and fine-grained soils will occur in combination.

Soil identification is limited to soil particles smaller than 3 inches in size.

At the initiation of project planning, the Project Manager, Project Engineer or Scientist, and field personnel determine any project-specific requirements for soil identification and description. Project requirements may dictate the use of a different identification system. Different identification methods are permitted if our client requires them. Although identification systems vary to some degree, the procedural aspects of making the underlying observations and describing the soils encountered generally remain the same.

2.2 Definition of Soil Components

Soil Component		Size Range and Sieve Size
OVERSIZED PARTICLES:		
Boulders	> 12 in.	>305 mm
Cobbles	3 in. to 12 in.	75.0 mm to 305 mm
COARSE GRAINED PARTICLES:		
Gravel:		
coarse Gravel	3 in. to 3/4 in.	75.0 mm to 19.0 mm
fine Gravel	3/4 in. to No. 4 (3/16")	19.0 mm to 4.75 mm
Sand:		
coarse Sand	No. 4 (3/16") to No.10 (1/13")	4.75 mm to 2.00 mm
medium Sand	No. 10 (1/13") to No. 40 (1/60")	2.00 mm to 0.42 mm
fine Sand	No. 40 (1/60") to No. 200	0.42 mm to 0.075 mm
FINE GRAINED PARTICLES:		

Silt:	< No. 200	< 0.075 mm
Nonplastic to very slightly plastic		
Little or no dry strength		
Clay:	< No. 200	< 0.075 mm
Plastic		
Considerable dry strength		

Two other terms are frequently used to broadly describe and define soil behavior:

- Cohesive Soil
  A soil that when unconfined has considerable dry strength when air-dried and that has considerable cohesion when submerged.

- Noncohesive or Cohesionless Soil
  A soil that when unconfined has little or no strength when air-dried and that has little or no cohesion when submerged.

2.3 Sampling

The sample used for soil identification should be representative of the stratum from which it was obtained. All samples should be carefully identified by File No., Exploration No., Sample No., recovery, depth, source, etc.

Soil identification procedures are generally based on a very small quantity of the stratum sampled. Larger particle sizes included in a sample may misrepresent the true proportion of such sizes in a given stratum due to their greater individual weight. Furthermore, in test borings where a split-spoon sampler is utilized, size limitations (2 in. O.D. by 1-3/8 in. I.D.) preclude the ability to recover representative samples in soil strata with significant percentages of gravel and larger size components. Care must be exercised in the field when identifying and describing soils. Care is also required when selecting a representative sample for preservation and possible laboratory testing.

ASTM D2488 defines the minimum amount of soil required for identification and description. The minimum amount required is based on the maximum particle size observed in the soil. However, in many cases it is not possible to obtain the required amount of soil. Therefore, the following table should be used as a guide. Wherever possible, an employee should base his or her soil identification and description on an amount of soil equal to or greater than the minimum amount of soil required in the following table. As a general rule it should be assumed that all split-spoon samples of soils containing coarse gravel do not meet the required sample size. In addition, all jar samples of soil containing particles larger than coarse sand may not meet the required sample size.

Maximum Particle Size			Minimum Specimen Size (estimated in dry weight)	
No. 4	(5 mm)	coarse sand	100 g	(0.25 lb)
3/8 in.	(10 mm)	fine gravel	200 g	(0.5 lb)
¾ in.	(19 mm)	fine gravel	1.0 kg	(2.2 lb)
1.5 in.	(38 mm)	coarse gravel	8.0 kg	(18 lb)
3 in.	(75 mm)	coarse gravel	60.0 kg	(132 lb)

2.4 Soil Identification

Detailed methods used to identify soil are presented below.

2.4.1 Preliminary Identification

The first step in the soil identification process is the preliminary identification of the soil. At this step, it will be determined if the soil will be considered a fine grained soil or a coarse grained soil. To do this, the percentage of each soil component must be estimated.

2.4.1.1 Fine Grained Soil:
If it is estimated that the soil consists of 50 percent or more fines (particles that are finer than a No. 200 sieve), the soil will be identified as either a SILT or a CLAY using Figure 1.

2.4.1.2 Coarse Grained Soil:
If it is estimated that the soil contains less than 50 percent fines (particles that are finer than a No. 200 sieve), the soil will be identified as either a GRAVEL or a SAND using Figure 2.

2.4.1.3 Organic Soils:
If it is estimated that the soil consists of enough organic particles to influence the soil properties, see Section 3.4.5 and Figure 1.

2.4.2 Methods for Identifying Soil

The following items must be determined to identify a soil:

2.4.2.1 Percent of Gravel, Sand, and Fines
Estimate and note the percentage of gravel, sand, and fines. Estimate percentages to the nearest 5 percent. The percentages of gravel, sand, and fines should equal 100 percent.

2.4.2.2 Percent of Oversized Particles

Estimate and note the percentage, if any, of boulders and cobbles. Estimate percentages, relative to the total volume observed, to the nearest 5 percent.

Methods of estimating the percentages of various soil components are found in Appendix B.

2.4.3 Identification of Coarse Grained Soils

If the soil to be identified contains more than 50 percent coarse grained material it will be identified as a SAND or a GRAVEL. If a coarse grained soil contains no more than 5 percent fines, it is not necessary to determine the characteristics of the fines.

If the sample contains more than 5 percent fines, proceed to section below, Identification of Fine Grained Soil Fractions.

2.4.4 Identification of Fine Grained Soil Fractions

The identification of fine grained soil is determined using a combination of four manual tests: dilatancy, toughness, plasticity, and dry strength. It may not be necessary to perform all four tests to determine the identity of a soil. Figure 3a, Sample Identification Procedure Chart, and 3b, Summary of Test Characteristics, are used as guides for identifying fines.

Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dilatancy, toughness, plasticity, and dry strength tests.

To identify the fine grained fraction of a soil, ASTM D2488 requires that particles larger than the No. 40 be removed from the sample. However, with some soils it may be impractical to remove medium and coarse sand from a sample in the field. In such a case, it should be noted on the log and a best estimate made.

Contaminated soils may also pose a problem for fine grained soil identification. Gloves should be worn whenever contaminated fine grained soils are identified in the field. In some cases, contaminants present in the soil (such as coal tar or gasoline) make manual testing impractical, unreliable or unsafe. In such a case, it should be noted on the log and a best estimate made.

2.4.4.1 Tests for Fine Grained Soil

A. *Dilatancy* - Dilatancy is the expansion of soil when subjected to a shearing deformation or, more simply, describes the soil's reaction to hand shaking.

From the specimen, select enough material to mold into a ball about 1/2 in. (13 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake

horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria listed below. The appearance of water on the surface of the specimen resembles a glossy, "liver-like" consistency. When then squeezed, the water and gloss disappears from the surface. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

B. *Toughness* - Toughness is the consistency of the soil near its plastic limit.

On the basis of observations made during the plasticity test, describe the toughness of the material as low, medium, or high in accordance with the criteria below.

Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll a 1/8 in. (3 mm) thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

C. *Plasticity* - Plasticity is the property of soil which allows it to be deformed beyond the point of recovery without cracking or appreciable volume change. The plasticity of soil is determined manually by observing how it behaves when it is rolled into a thread, the degree of cohesiveness at the plastic limit, and the general range of moisture contents over which the soil remains in a plastic state.

The test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms. Attempt to roll the soil into a thread about 1/8 in. (3 mm) in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation. If the sample is too dry, add water.

Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. (3 mm). The thread will crumble at a diameter of 1/8 in. (3 mm) when the water content in the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles.

Note the plasticity of the soil as nonplastic, low, medium, or high in accordance with the criteria listed below.

Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8 in. (3 mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

D. *Dry Strength* - Dry strength describes the crushing characteristics of a dry soil crumb under finger pressure.

Select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary. From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/2 in. (13 mm) in diameter. Allow the test specimens to dry in air or sun, or by artificial means as long as the temperature does not exceed 140° F (60°C). If the test specimen contains natural dry lumps, those that are about 1/2 in. (13 mm) in diameter may be used in place of the molded balls. (The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.)

Test the strength of the dry balls or lumps by crushing between the fingers. The dry strength increases with increasing plasticity. Note the strength as none, low, medium, high, or very high in accordance with the criteria listed below.

Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand. The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (HCl).

2.4.4.2 Identifying the Fine Grained Fraction

Decide whether the fine grained soil fraction is an *inorganic* or an *organic* fine grained soil (see 2.4.5). If inorganic, follow the steps listed below using Table 1 as a guide.

Identify the fine grained soil fraction as a *silt*, ML, if the soil has slow to rapid dilatancy, low toughness, no to low plasticity, and no to low dry strength.

Identify the fine grained soil fraction as an *elastic silt*, MH, if the soil has no to slow dilatancy, low to medium toughness and plasticity, and low to medium dry strength. These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

Identify the fine grained soil fraction as a *lean clay*, CL, if the soil has no or slow dilatancy, medium toughness and plasticity, and medium to high dry strength.

Identify the fine-grained soil fraction as a *fat clay*, CH, if the soil has no dilatancy, high toughness and plasticity, and high to very high dry strength.

TABLE 1 - Identification of Inorganic Fine Grained Soils from Manual Tests

Soil Symbol	Dilatancy	Toughness	Plasticity Designation	Dry Strength
ML	Slow to rapid	Low or thread cannot be formed	Non-plastic	None to low
MH	None to slow	Low to medium	Low	Low to medium
CL	None to slow	Medium	Medium	Medium to high
CH	None	High	Highly	High to very high

2.4.5 Organic Soils

Organic soils are those soils that contain sufficient organic matter to significantly affect the engineering properties or usage of the soil. Topsoil, peat and organic silt are typical examples. Peaty diatomaceous earth is a common organic soil found at the lower stratum of peat bogs. Fibrous peats may be found in both fresh-water (bogs) and marine settings. Organic clays are common in some sections of the country. Certain types of anthropogenic fills contain significant percentages of organic matter.

- Identification of Organic Fine Grained Soils - Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties (see Figure 1). Organic soils usually have a gray, dark gray brown to black color and may have an "earthy" or hydrogen sulfide odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air-dried. Organic soils frequently contain carbonate shell fragments, silica tests (diatoms) or woody, fibrous matter, although the presence of these materials is not an exclusive indicator of organic soils. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy or elastic. In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

- Identification of Peat - A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT.

Because organic soils can exhibit some of the characteristics of inorganic clay soils, they may be differentiated by the following criteria:

- Inorganic Clay Soils - Any color may be expected. For more plastic clays, appreciable effort is required to pull the material apart. The broken pieces show the structure standing on end from the pulling. For high plasticities, the smear has a shiny, waxy appearance.

- Organic Soils – Gray, dark gray, black and various shades of brown are characteristic colors. Fresh organic soils, particularly marine peats and silts, commonly have a strong odor of hydrogen sulfide and heating the sample will intensify the odor. Less effort is required to pull fine grained non-fibrous organic soils apart than in the case of inorganic fine grained soil, and a clean break is generally formed. The smear, although smooth, is very dull and appears silty. Fibrous structure is, of course, an obvious identifying property. Organic silts respond positively to the dilatancy test. Organic soils customarily have very low shear strength in their natural state. Organic clays may be very difficult to identify visually without supplemental laboratory testing.

2.4.6 Identifying Soil

Proceed to sections below to determine a Group Symbol and Group Name.

2.5 Determining the Group Symbol

Based on the properties of the soil, determine the Group Symbol using Figure 1 for fine grained soil and for organic soil, or Figure 2 for coarse grained soil.

If a soil has properties that do not distinctly place it into a specific group, Borderline Symbols may be used. A Borderline Symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. **Borderline Symbols** should not be confused with **Dual Symbols** such as GP-GM (well graded GRAVEL with silt) or SW-SC (well graded SAND with clay). A Dual Symbol is two symbols separated by a dash and represents a standard identification group.

2.6 Determining the Group Name

2.6.1 Fine Grained Soil

If the fine grained soil is estimated to have 15 to 25 percent sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the Group

Name. For example: “lean CLAY with sand, CL” or “SILT with gravel, ML” (see Fig. 1. If the percentage of sand is equal to the percentage of gravel, use “with sand.” If the soil is estimated to have 30 percent or more sand or gravel, or both, the adjectives “sandy” or “gravelly” shall be added to the Group Name. Add the word “sandy” if there appears to be more sand than gravel. Add the word “gravelly” if there appears to be more gravel than sand. For example: “sandy lean CLAY, CL”, “gravelly fat CLAY, CH”, or “sandy SILT, ML” (see Fig. 1). If the percentage of sand is equal to the percent of gravel, use “sandy.”

2.6.2 Coarse Grained Soil

1. The soil is a *GRAVEL* if the percentage of gravel is estimated to be more than the percentage of sand. The soil is a *SAND* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.
2. The soil is a *clean GRAVEL* or *clean SAND* if the percentage of fines is estimated to be 5 percent or less.
3. Identify the soil as a *well graded GRAVEL*, GW, or as a *well graded SAND*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.
4. Identify the soil as a *poorly graded GRAVEL*, GP, or as a *poorly graded SAND*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).
5. Identify the soil as a *clayey GRAVEL*, GC, or a *clayey SAND*, SC, if the percentage of fines is estimated to be 15 percent or greater, and the fines are clayey as determined by the procedures in sections below.
6. Identify the soil as a *silty GRAVEL*, GM, or a *silty SAND*, SM, if the percentage of fines is estimated to be 15 percent or greater, and the fines are silty as determined by the procedures in sections below.
7. If the soil is estimated to contain 10 percent fines, give the soil a dual identification using two Group Symbols. The first Group Symbol corresponds to a clean gravel or sand (GW, GP, SW, SP) and the second Group Symbol corresponds to a gravel or sand with fines (GC, GM, SC, SM). The Group Name corresponds to the first Group Symbol plus the words “with clay” or “with silt” to indicate the plasticity characteristics of the fines. For example: “well graded GRAVEL with clay, GW-GC” or “poorly graded SAND with silt, SP-SM” (see Fig. 2). If the specimen is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse grained constituent, the words “with gravel” or “with sand” are added to the Group Name. For example: “poorly graded GRAVEL with sand, GP” or “clayey SAND with gravel, SC” (see Fig. 2).

2.7 Soil Description

Appropriate descriptive information is also recorded. The twelve categories of descriptive information are listed below.

2.7.1 Required Descriptive Information

2.7.1.1 Density

The density of cohesionless or granular soils is determined by the Standard Penetration Test. The density of a soil based on the Standard Penetration Test is obtained from the following table:

Standard Penetration Test (SPT)

N-Value (Blows per foot)	Density
0 - 4	Very loose
5 - 10	Loose
11 - 30	Medium dense
31 - 50	Dense
Over 50	Very dense

2.7.1.2 Consistency

The consistency of cohesive soils is determined in one of two ways. The preferred method of determining consistency in the field is based upon undrained strength as determined by a Torvane, pocket penetrometer or Field Vane shear test. In general, however, consistency is determined by the Standard Penetration Test (SPT), ASTM Designation D 1586, performed in test borings. The SPT consists of counting the number of blows of a 140 pound hammer freely falling 30 inches while driving a 2 inch O.D. split spoon sampler 18 inches into the soil. The number of blows is recorded for each 6 inches of penetration for an 18 inch drive. The first 6 inches of penetration are discounted and the number of hammer blows required to drive the sample over the 6 to 18 inch range of sampler penetration is termed the standard penetration resistance (N). Cable or wire-winch attached weights are unacceptable for determining STP.

The scale used for the consistency of a soil is presented in the following table:

Approximate Undrained Shear Strength (tsf)	Standard Penetration Test N-Value (Blows/foot)	Consistency
Below 0.13	0 - 2	Very soft
0.13 to 0.25	3 - 4	Soft
0.25 to 0.5	5 - 8	Medium stiff
0.5 to 1.0	9 - 15	Stiff
1.0 to 2.0	16 - 30	Very stiff
Over 2	Over 30	Hard

If required, the ASTM procedure for determining consistency can be used, which is based on indentation of the soil with the thumb and is presented in Appendix C. If the ASTM procedure is used, it should be noted on the logs.

2.7.1.3 Color

Color may be useful in identifying materials of similar geologic origin. Color is an important property in identifying organic soils.

Moist soil samples should be used to describe soil color. Color description is generally confined to a few basic terms such as brown, black, gray and yellow. These terms are often combined in pairs. Examples of combined color descriptors are gray green, yellow brown or yellow gray. In listing two colors, the second color listed is the predominant of the two colors. The ending "ish" is never added to a color description. If dictated by specific project requirements, more accurate color descriptions based on hue and chroma may be obtained by use of the "Munsell Soil Color Charts."

If the soil color is not homogeneous due to layering, describe the color of all layers. If the soil is not layered, use the term mottled, if appropriate, to describe the colors. (Example: mottled brown and gray.)

2.7.1.4 Group Name and Group Symbol

The primary constituent is typed in all uppercase in the Group Name and the Group Symbol is uppercase and set in parentheses.

2.7.1.5 Percent Oversized

When the sample contains cobbles or boulders or both, estimate the percent relative to the total volume observed to the nearest 5 percent.

2.7.1.6 Maximum Particle Size

Describe the maximum particle size found in the sample. The maximum particle size is used to determine the sample size required for field identification and various laboratory tests.

2.7.1.7 Structure

Several terms have been found useful in simplifying the description of some special characteristic of a soil or to add additional information. A list of a few of the more common terms is given in Appendix D, Descriptive Terminology for Soil Structure.

2.7.1.8 Odor

Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. Unusual odors may indicate soil contamination and should be avoided. This should be called to the attention of the project manager unless contamination was expected in the soil.

2.7.1.9 Moisture Condition

The moisture condition of a soil should be described as dry, moist or wet according to the criteria listed below.

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

2.7.1.10 Geologic Interpretation

A geologic interpretation of the soil is very helpful and should be added; e.g., Glaciofluvial Deposits. Note however that if you are uncertain about an interpretation, it is your responsibility to review it with a senior geologist.

2.7.2 Additional Descriptive Information

The following additional information should be included as a part of a soil description. Methods for describing these soil properties are listed in Appendix E

a. Hardness of the Plus No. 10 Fraction
b. Angularity of the Plus No. 10 Fraction
c. Particle Shape of the Plus No. 4 Fraction
d. Reaction with Hydrochloric Acid
e. Cementation of Intact Samples

f. Torvane and Pocket Penetrometer Readings
g. Additional Comments

2.8 Contaminated Soils

Contamination of soil can occur from an extremely wide range of hazardous and non-hazardous anthropogenic pollutants being released into the environment from a variety of disposal methods. Naturally deposited undisturbed soils may be stained from liquids passing through them. "Clean" undisturbed soils can absorb and retain strong odors from adjacent vapor sources. The actual soil constituents may be partially or completely comprised of anthropogenic materials: ash, cinders, clinker, slag, glass, brick, concrete, etc. If so, the sample should be described with respect to these constituents.

Contaminated soil may be any color, may have some odor level, and may retain the actual product. Indicators of potential contamination include, but are not limited to, soil with an unusual color or distinct odor such as gasoline, diesel fuel, solvents, moth balls, etc. However, the soil may not show any of the above indicators and still be contaminated. If unexpected soil contamination is encountered and there is no site-specific Health & Safety plan, or appropriate Health & Safety equipment is not available, immediately cease exploration operations, clear personnel from work area, and contact the Project Manager and Health and Safety Representative for instructions.

2.8.1 Description of Fills

For methods used to describe fills, see Appendix F.

2.9 Presentation of Soil Identification and Descriptive Information

The soil identification should consist of the Group Name, the Group Symbol, and all required descriptive information. **If using this procedure to identify soil, it must be distinctly and clearly stated in all logs, summary tables, and reports that the Group Names and Group Symbols are based on visual-manual procedures.**

As a rule, descriptive information should be listed in the following order:

1. **Percent of Gravel, Sand, and Fines**
2. **Dilatancy**
3. **Toughness**
4. **Plasticity**
5. **Dry Strength**
6. **Density/Consistency***
7. **Color**

8. **Group Name and Group Symbol**
9. **Percent Oversized (boulders and cobbles)**
10. **Maximum Particle Size**
11. **Structure***
12. **Odor**
13. **Moisture**
14. Optional Descriptions
15. **Geologic Interpretation**

Descriptors in **BOLD** should always be included with descriptions. Descriptors followed with an asterisk (*) apply only to intact samples such as split-spoon samples.

Examples:

Several examples of soil identifications and descriptions based on this procedure are presented below. Note not only the order of descriptive terms, but also the use of commas, hyphens, slashes, parentheses, and upper case letters. Abbreviations should not be utilized in writing soil identifications and descriptions.

Example 1

The example below is a standard identification and description of 50 lb. grab sample from a test pit:

10% fine gravel, 30% coarse sand, 30% medium sand, 30% fine sand, no fines

Brown, poorly graded SAND (SP)

10% boulders, 15% cobbles, maximum particle size 18" (450 mm).

Stratified with coarse to medium grained layers 3" to 6" thick (75-150 mm) alternating with fine grained layers 6" to 12" thick (150-300 mm).

No odor, dry.

GLACIOFLUVIAL DEPOSIT

If the soil above was described from an 8 oz. driller's jar, the following statement should be added to the description:

(Note: Sample size smaller than recommended.)

Example 2

The example below is a standard identification and description of a split-spoon sample:

10% fine gravel, 5% coarse sand, 5% medium sand, 10% fine sand,

70% fines: no dilatancy, medium toughness, medium plasticity, medium dry strength

Stiff, gray green, sandy lean CLAY (CL).

Maximum particle size 13 mm. Laminated. Frequent fine sand partings, occasional medium to fine sand seams. Fine gravel and coarse sand present as dropstones.

No odor. Moist.

MARINE DEPOSIT

Example 3

The example below is a standard identification and description of split-spoon sample:

5% coarse gravel, 10% fine gravel, 5% coarse sand, 10% medium sand, 40% fine sand, 30% fines: rapid dilatancy, low toughness, low plasticity, low dry strength.

Very dense, brown, silty SAND with gravel (SM)

Maximum particle size 1 in. (25 mm).

Foliated and well bonded, no odor, moist, uncemented.

Coarse fraction generally hard and rounded igneous and metamorphic lithologies, imbedded.

Minor soft and angular, flat to elongated sedimentary lithologies (argillite).

Weak reaction with HCl on minor white 0.5-0.1 mm grains (possible seashell particles).

Note: Drill action indicates occasional cobbles. Possible sand lenses indicated by wash water return.

GLACIAL TILL DEPOSIT

Example 3 (abbreviated):

5% c GVL, 10% f GVL, 5% c SA, 10% m SA, 40% f SA

30% fines: D=R, T=L, P=L, DS=L

Very dense, brown, silty SAND with gravel (SM)

mps 25 mm. Foliated and well bonded, no odor, moist.

Cobbles indicated by drill action.

GLACIAL TILL DEPOSIT

In general, final identification of soil samples for typed boring logs and reports requires a careful review, taking into consideration the laboratory identification tests that were not available at time of sampling.

2.10 Precision and Bias

This procedure provides qualitative information only; therefore, a precision and bias statement is not applicable.

Figure 1:
Flow Chart for Identifying Fine-Grained Soils (50% or more fines)

Group Symbol				Group Name
ML (SILT)	<30% plus No. 200	<15% plus No. 200		SILT
		15-25% plus No. 200	% sand ≥% of gravel	SILT with sand
			% sand <% of gravel	SILT with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy SILT
			≥15% gravel	sandy SILT with gravel
		% sand <% of gravel	<15% sand	gravelly SILT
			≥15% sand	gravelly SILT with sand
MH (ELASTIC SILT)	<30% plus No. 200	<15% plus No. 200		elastic SILT
		15-25% plus No. 200	% sand ≥% of gravel	elastic SILT with sand
			% sand <% of gravel	elastic SILT with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy elastic SILT
			≥15% gravel	sandy elastic SILT with gravel
		% sand <% of gravel	<15% sand	gravelly elastic SILT
			≥15% sand	gravelly elastic SILT with sand
CL (LEAN CLAY)	<30% plus No. 200	<15% plus No. 200		lean CLAY
		15-25% plus No. 200	% sand ≥% of gravel	lean CLAY with sand
			% sand <% of gravel	lean CLAY with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy lean CLAY
			≥15% gravel	sandy lean CLAY with gravel
		% sand <% of gravel	<15% sand	gravelly lean CLAY
			≥15% sand	gravelly lean CLAY with sand
CH (FAT CLAY)	<30% plus No. 200	<15% plus No. 200		fat CLAY
		15-25% plus No. 200	% sand ≥% of gravel	fat CLAY with sand
			% sand <% of gravel	fat CLAY with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy fat CLAY
			≥15% gravel	sandy fat CLAY with gravel
		% sand <% of gravel	<15% sand	gravelly fat CLAY
			≥15% sand	gravelly fat CLAY with sand
OL/OH (ORGANIC SOILS)	<30% plus No. 200	<15% plus No. 200		ORGANIC SOIL
		15-25% plus No. 200	% sand ≥% of gravel	ORGANIC SOIL with sand
			% sand <% of gravel	ORGANIC SOIL with gravel
	≥30% plus No. 200	% sand ≥% of gravel	<15% gravel	sandy ORGANIC SOIL
			≥15% gravel	sandy ORGANIC SOIL with gravel
		% sand <% of gravel	<15% sand	gravelly ORGANIC SOIL
			≥15% sand	gravelly ORGANIC SOIL with sand

Note: Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%

Figure 2:
Flow Chart for Identifying Coarse-Grained Soils (less than 50% fines)

				Group Symbol		Group Name
GRAVEL % gravel > % sand	≤5% fines	Well-graded		**GW**	<15% sand	well-graded GRAVEL
					≥15% sand	well-graded GRAVEL with sand
		Poorly-graded		**GP**	<15% sand	poorly-graded GRAVEL
					≥15% sand	poorly-graded GRAVEL with sand
	10% fines	Well-graded	fines = ML or MH	**GW-GM**	<15% sand	well-graded GRAVEL with silt
					≥15% sand	well-graded GRAVEL with silt and sand
			fines = CL or CH	**GW-GC**	<15% sand	well-graded GRAVEL with clay
					≥15% sand	well-graded GRAVEL with clay and sand
		Poorly-graded	fines = ML or MH	**GP-GM**	<15% sand	poorly-graded GRAVEL with silt
					≥15% sand	poorly-graded GRAVEL with silt and sand
			fines = CL or CH	**GP-GC**	<15% sand	poorly-graded GRAVEL with clay
					≥15% sand	poorly-graded GRAVEL with clay and sand
	≥15% fines		fines = ML or MH	**GM**	<15% sand	silty GRAVEL
					≥15% sand	silty GRAVEL with sand
			fines = CL or CH	**GC**	<15% sand	clayey GRAVEL
					≥15% sand	clayey GRAVEL with sand
SAND % sand ≥ % gravel	≤5% fines	Well-graded		**SW**	<15% gravel	well-graded SAND
					≥15% gravel	well-graded SAND with gravel
		Poorly-graded		**SP**	<15% gravel	poorly-graded SAND
					≥15% gravel	poorly-graded SAND with gravel
	10% fines	Well-graded	fines = ML or MH	**SW-SM**	<15% gravel	well-graded SAND with silt
					≥15% gravel	well-graded SAND with silt and gravel
			fines = CL or CH	**SW-SC**	<15% gravel	well-graded SAND with clay
					≥15% gravel	well-graded SAND with clay and gravel
		Poorly-graded	fines = ML or MH	**SP-SM**	<15% gravel	poorly-graded SAND with silt
					≥15% gravel	poorly-graded SAND with silt and gravel
			fines = CL or CH	**SP-SC**	<15% gravel	poorly-graded SAND with clay
					≥15% gravel	poorly-graded SAND with clay and gravel
	≥15% fines		fines = ML or MH	**SM**	<15% gravel	silty SAND
					≥15% gravel	silty SAND with gravel
			fines = CL or CH	**SC**	<15% gravel	clayey SAND
					≥15% gravel	clayey SAND with gravel

Note: Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%

FIGURE 3a. SAMPLE IDENTIFICATION PROCEDURE CHART

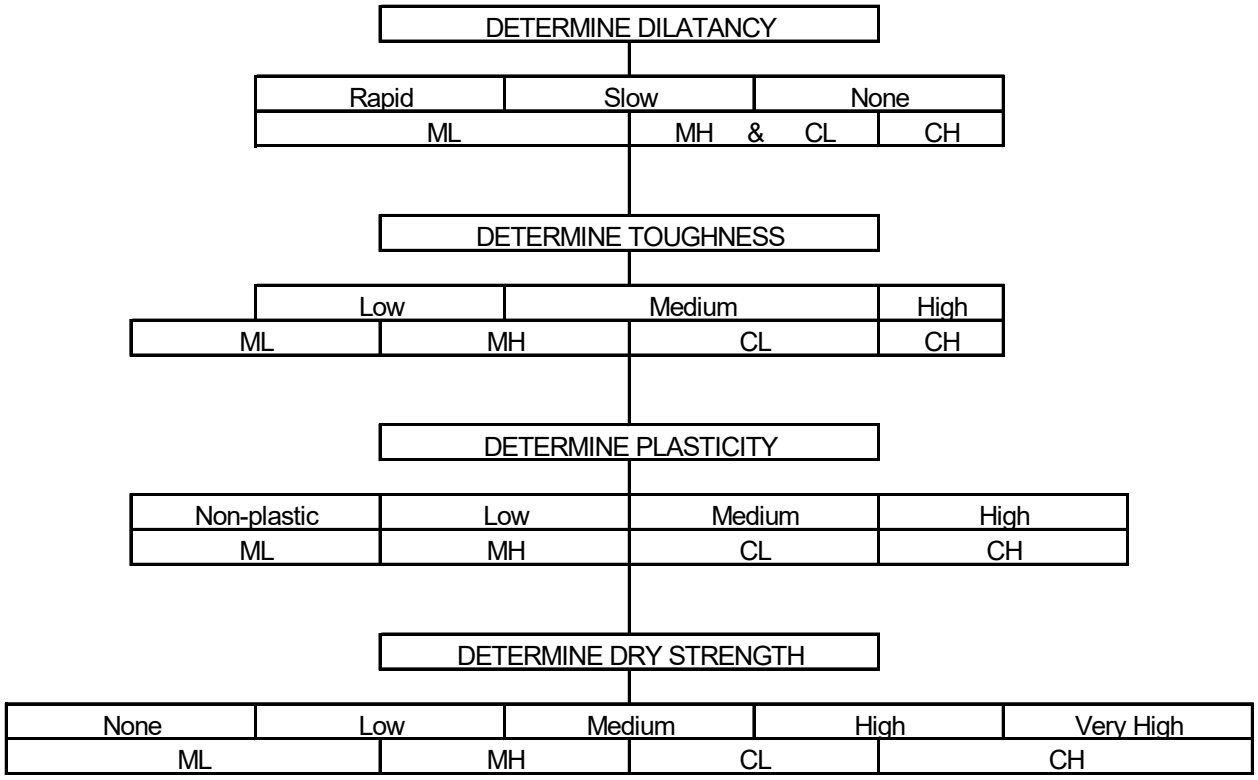


FIGURE 3b. SUMMARY OF TEST CHARACTERISTICS

	Dilatancy	Toughness	Plasticity	Dry Strength
ML	slow - rapid	low	none - low	none - low
MH	none - slow	low - medium	low - medium	low - medium
CL	none - slow	medium	medium	medium - high
CH	none	high	high	high - very high

APPENDIX A - REFERENCES

A.1 Reference Procedure

American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D2488-93, “Description and Identification of Soils (Visual-Manual Procedure).”

A.2 Other References

American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D2487-98, “Classification of Soils for Engineering Purposes (Unified Soil Classification System).”

American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.08, D1586-99, “Penetration Test and Split-Barrel Sampling of Soils.”

American Society for Testing and Materials, current edition, "Annual Book of ASTM Standards," Vol.04.09, D5434-97, “Field Logging of Subsurface Explorations of Soil and Rock.”

A.3 Comments on Reference Procedure

The procedure described in in SOP NMI-S-006 has been developed to assist field personnel in identifying and describing soil, and in some cases simplifies the ASTM Reference Procedure. This SOP deviates from the ASTM Reference Procedure in the following:
ASTM D2488-93 defines the minimum amount of soil required for identification and description. The minimum amount required is based on the maximum particle size observed in the soil. However, in many cases it is not possible to obtain the required amount of soil due to the limitations of the sampling techniques used. As a general rule it should be assumed that all split-spoon samples of soils containing coarse gravel do not meet the required sample size. In addition, all jar samples of soil containing particles larger than coarse sand may not meet the required sample size.

ASTM D2488-93 requires the percentage of cobbles and boulders to be estimated on the basis of volume percentage. The gravel, sand, and fines percentages are to be determined based on an estimate of dry weight. However, in almost all cases this method overly complicates estimating the percentage of different soil components. The project team considers that estimates of percentage based on particle volume and particle weight (either wet or dry) are equivalent for practical purposes. Average specific gravities of soil range between 2.65 and 2.75. Percentages of particle fractions based on volume should, in general, vary by no more than 5 percent from percentages based on weight—well within the error limits of the procedure.

To identify the fine grained fraction of a soil, ASTM D2488 requires that particles larger than No. 40 be removed from the sample. With some soils it may be impractical to remove medium and coarse sand from a sample in the field.

Consistency of cohesive soil is based upon undrained strength as determined by a Torvane or Field Vane shear test. The Standard Penetration Test (SPT) is used in cases where no other data are available.

The density of granular soils is determined by the Standard Penetration Test, ASTM Designation D1586, performed in test borings.

APPENDIX B - ESTIMATING SOIL COMPONENT PERCENTAGES

B.1 Estimating Percentages by Weight or Volume

ASTM D2488 goes to great lengths to differentiate between soil component percentages determined by estimates of particle volume, particle weight, and particle dry weight. The dry weight of soil is calculated by dividing the weight of the moist soil by (1+ soil water content percentage expressed as a decimal). ASTM D2488 requires the percentage of cobbles and boulders to be estimated on the basis of volume percentage. Of the fraction of the soil smaller than 3 in., the gravel, sand, and fines percentages are to be determined based on an estimate of dry weight.

However, in almost all cases, this method overly complicates estimating the percentage of different soil components. Haley & Aldrich considers that estimates of percentage based on particle volume and particle weight (either wet or dry) are equivalent. Averages of specific gravity of soil range between 2.65 and 2.75. Percentages of particle fractions based on volume should, in general, vary by no more than 5 percent from percentages based on weight, well within the error limits of the procedure.

There are two cases where weight and volume measurements will not agree.
The first case is for organic soils. The organic portions of the soil will have a low specific gravity

($\leq$ 1.0) and even large quantities will weigh little, while the mineral portions will have a much higher specific gravity and higher weights for smaller volumes. Care and experience are needed to estimate percentages in an organic soil.

The other case where weight and volume measurements will not agree is in areas were soils contain an unusual amount of particles made up of minerals with a very low or very high specific gravity, such as mica and vermiculite, or pyrite and magnetite. Again, care and experience are required to accurately estimate soil fraction percentages.

Listed below are methods for estimating particle size fractions suggested by ASTM D2488. A review of these ASTM methods will show that the recommended methods are based not on dry weight of soil but on volume estimates.

B.2 Preparation for Identification

The soil identification portion of this procedure is based on the portion of the soil sample that will pass a 3 in. (75 mm) sieve. The larger than 3 in. (75 mm) particles must be removed—manually for a loose sample, or mentally for an intact sample—before classifying the soil.

Estimate and note the percentage of cobbles and the percentage of boulders.

B.3 Estimating Soil Component Percentages

Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage of the gravel, sand, and fines. Considerable experience is required to estimate the percentages of particle-size components. Frequent comparisons with laboratory particle-size analyses should be made. The percentages shall be estimated to the closest 5 percent. The percentages of gravel, sand, and fines must add up to 100 percent. If one of the components is present but not in sufficient quantity to be considered 5 percent of the smaller than 3 in. (75 mm) portion, indicate its presence by the term *trac*e, for example, trace of fines. A trace is not to be considered in the total of 100 percent for the components.

B.4 Suggested Procedures for Estimating the Percentages of Gravel, Sand, and Fines in a Soil Sample (ASTM D2488-93)

B.4.1 Jar Method

The relative percentage of coarse and fine grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 seconds. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

B.4.2 Visual Method

Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then do the same with the sand size particles and the fines. Then mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (A.4.3).

B.4.3 Wash Test (for relative percentages of sand and fines)

Select and moisten enough minus No. 4 sieve size material to form a 1 in. (25 mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

B.4.4 Other

While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

APPENDIX C - ASTM D2488 CONSISTENCY TEST

ASTM D2488 determines consistency using a scale based on a thumb penetration test. This scale is presented here in the event that a client on a project requires it, but it is not used in H&A's general practice. If this scale is used, it should be noted on the exploration log.
For intact fine grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria listed below. This observation is inappropriate for soils with significant amounts of gravel.

ASTM Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

APPENDIX D - DESCRIPTIVE TERMINOLOGY FOR SOIL STRUCTURE

Describe the structure of intact soils in accordance with the criteria in listed below.

Criteria for Describing Soil Structure

Description	Criteria
Bed	A sedimentary layer bounded by depositional surfaces.
Blocky	A characteristic in which cohesive soil can be broken down into small angular lumps which resist further breakdown.
Bonded	Attached or adhering.
Fissured	Broken along definite planes of fracture.
Foliated	Planar arrangement of textural or structural features.
Frequent	More than one per foot of thickness.
Homogeneous	Same color and appearance throughout.
Interbedded	Alternating soil layers of different composition.
Laminae	A very thin cohesive layer.
Layer	A general term for material lying essentially parallel to the surfaces against which it was formed.
Lens	A lenticular deposit, larger than a pocket.
Occasional	One or less per foot of thickness.
Parting	A very thin granular layer.
Pocket	Small erratic deposits less than 12 in. in thickness.
Seam	A thin layer separating two distinctive layers of different composition or greater magnitude.
Stratified	Alternating layers of varying material or color.
Stratum	A stratigraphic unit.
Varve	A cyclic sedimentary couplet consisting of a coarser and a finer layer representing the variation in depositional energy resulting from the annual freeze-thaw cycle typically found in glaciolacustrine environments.

APPENDIX E - ADDITIONAL DESCRIPTIVE INFORMATION

The following additional descriptive information should be included as a part of a soil description.

E.1. Angularity of the Plus No. 10 Fraction

If requested by the Project Manager, the angularity of the plus No. 10 fraction (gravel and coarse sand) can be described as angular, subangular, subrounded, or rounded in accordance with the criteria in listed below and Fig. H-1. A range of angularity may be stated, such as: subrounded to rounded.

Criteria for Describing Angularity of Coarse Grained Particles (see Fig. H-1)

Description	Criteria
Angular	Particles have sharp edges and relatively planar sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly planar sides but have well rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

E.2. Particle Shape of the Plus No. 4 Fraction

Describe the shape of the Plus No. 4 fraction (gravel, cobbles and boulders) as flat, elongated, or flat and elongated if they meet the criteria listed below using the dimensions shown in Figure G-2. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

Criteria for Describing Particle Shape (see Fig. E-2)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness ratio > 3
Elongated	Particles with length/width ratio > 3
Flat and elongated	Particles meet criteria for both flat and elongated

E.3. Hardness of the Plus No. 10 Fraction

Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer; for example, gravel size particles fracture with considerable hammer blow, some gravel size particles crumble with hammer blow. “Hard” means particles do not crack, fracture, or crumble under a hammer blow.

E.4 Reaction with Hydrochloric Acid

Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria listed below. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

Criteria for Describing the Reaction with HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

E.5. Additional Comments

Additional comments shall be noted. These may include:

- In-situ bonding, particularly of glacial till soils: poor, moderate, well bonded.
- Presence of obstructions: specifically for man-made features (not boulders).
- "Running" or "Flowing" sands: typically below the water table, these are a good liquefaction indicator.
- Validity of apparent density: Blow counts increased by gravel content.
- Water loss: Very important in coring bedrock, but appropriate for soils.
- Presence of roots or root holes.
- Caving of trench or hole.

E.6. Additional Descriptive Information for Intact Samples - Cementation

Describe the cementation of intact coarse grained soils as weak, moderate, or strong as follows:

Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

FIGURE E-1 Typical Angularity of Grains

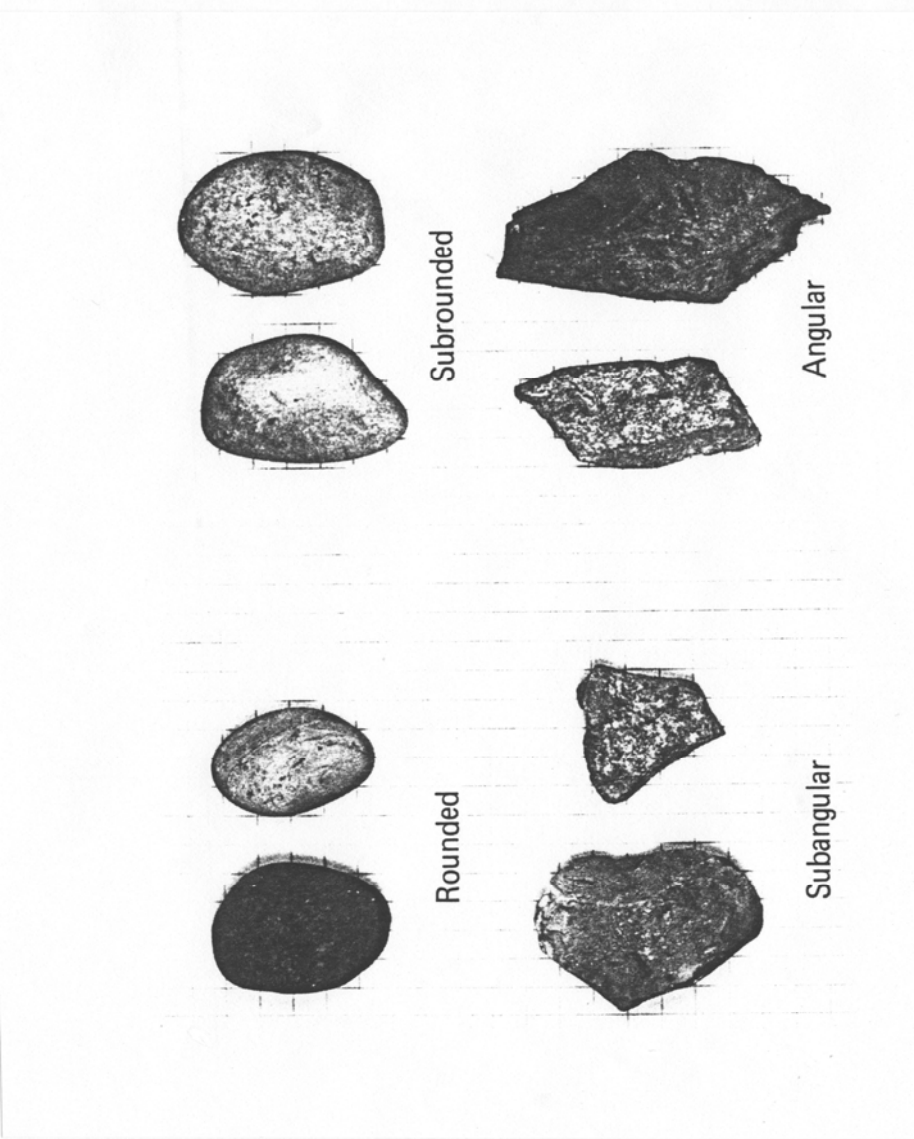
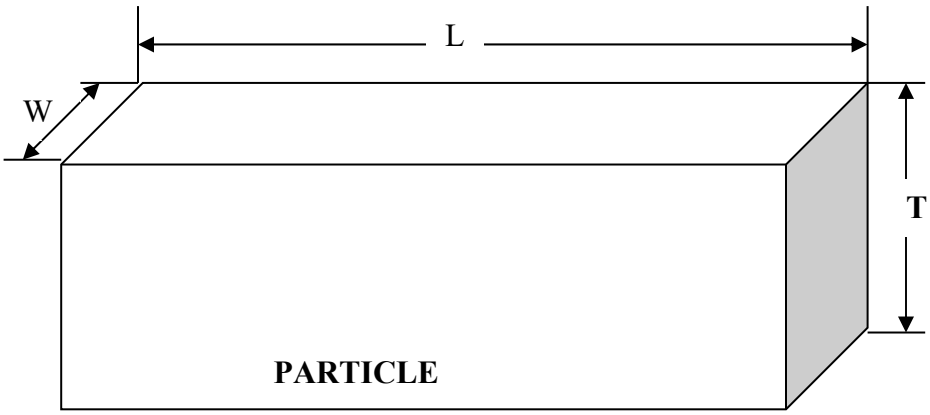


FIGURE E-2 Criteria for Particle Shape
Particle Shape
W = Width
T = Thickness
L = Length



FLAT: W/T >3

ELONGATED: L/W >3

FLAT and ELONGATED:

APPENDIX F - FILLS

F.1 Fill Description

Fills can be separated into two distinct categories:

Fills consisting largely of natural components can usually be described in a similar manner to natural soils including a particle breakdown and designation of a USCS Group Symbol and Group Name.

Fills containing man-made or deleterious materials that constitute a significant percentage of the total volume cannot be described in the typical fashion, nor can a USCS Group Symbol and Group Name be designated. In fills with substantial quantities of man-made or deleterious materials the typical particle breakdown is not conducted and constituent estimates are simply listed in order of abundance.

The distinction between the two categories of fills defined above will in some cases be unclear. Determination of which method to use to describe fills is a field decision based on the character of the fills observed and the method which best conveys an accurate representation of the materials present.

Many artificial and deleterious materials have very low densities but may constitute a significant percentage of the total fill volume. In such cases constituent estimates may be based upon volume, not weight, and noted in the description.

Since artificial materials will commonly occur across a wide range of sizes it may be impractical to distinguish them separately from the total as oversize components. To do so may necessitate including them twice within a single description. In such cases the descriptive terms for size ranges may be included with the constituent estimates or noted in the description.

The presence of certain materials in extremely small quantities can be of critical importance in fills. Constituents comprising less than 5% of the total are qualified and preceded by the term "trace" and included in the particle breakdown, constituent estimates, or noted in the description.

F.2 Fill Types

Characterizing fill types based upon similarities can aid in estimating quantities for reuse, treatment or disposal. Caution must be exercised that any characterization of fill type is an accurate reflection of site conditions and that field assumptions do not conflict with the site history or project objectives. Consultation with the Project Manager to develop criteria upon which to base fill types is required. The following terminology is used by Haley & Aldrich to denote size ranges of artificial materials within fills:

Descriptive Fill Term	Size Range	Size Range Metric	Comparative Soil Term
Specks	<No. 200 Sieve	<0.075 mm	Silt
Particles	No. 200 to 3/16 in.	0.075 mm to 5 mm	Sand
Fragment	3/16 in. to 3 in.	5 mm to 75 mm	Gravel
Pieces Cobbles		3 in. to 12 in.	75 mm to 305 mm
Blocks	>12 in.	>305 mm	Boulders

Definitions of Common Fill Constituents and Terminology

Term	Definition
Anthropogenic	Impacted by man.
Artificial	Man-made.
Ash	Inorganic residue of combusted matter.
Ceramic	Nonmetallic mineral products manufactured by firing.
Charcoal	Carbonaceous residue of incompletely combusted organic material.
Cinder	General term for ash, charcoal, clinkers or slag.
Clinker	Solid waste formed in furnaces consisting of fused stony matter.
Concrete	Solid mass of cemented aggregate.
Deleterious	Having a harmful or obscure affect.
Loam	Soil containing roughly equal proportions of sand, silt and clay. Usually organic matter is present in varying amounts.
Slag	Clinker or solid waste from iron blast furnaces.
Tar	Viscous, dark, bituminous liquid.

Examples of Fills consisting largely of natural materials:
Example1 (Test Boring Description)
10% medium sand, 25% fine sand, 15% roots
50% fines: slow dilatancy, low toughness, nonplastic, low dry strength
Very loose, dark brown sandy ORGANIC SOIL (OL/OH)
15% roots estimated by volume, trace brick particles.
mps 2.0 mm.
No structure, musty odor, dry.
LOAM FILL

Example 2 (Stockpile Description)
100% coarse gravel
Purple, poorly graded GRAVEL (GP)
No oversize, mps 2.5 in.
Consists entirely of very hard angular processed rhyolite.
No odor, dry.
CRUSHED STONE

Example 3 (Test Pit Description)
15% coarse gravel, 10% fine gravel, 15% coarse sand, 15% medium sand, 25% fine sand
5% brick fragments to particles, 5% concrete or mortar, 10% fines: rapid dilatancy
Brown to dark brown, well graded SAND with silt and gravel (SW-SM)
10% cobbles, 5% boulders, mps 18 in.
Concrete present generally as moderately hard fragments with several elongated blocks observed measuring less than 30 in. maximum dimension. Minor decomposed concrete or mortar observed on brick fragments. Possible asbestos observed in trace quantities as friable white fibers in occasional extremely small pockets. Slight decomposed gasoline odor associated with observed water. Wet at 8.5 ft.
FILL

Examples of Fills consisting of significant percentages of artificial or deleterious matter:
Example 1 (Test Pit Description)
55% concrete, 20% brick, 10% medium to fine sand, 5% coarse to fine gravel
5% fines, 5% cobbles, mps 6 in., trace metal strips and wire, wood fragments, plastic pieces, glass shards, cinder particles to specks, unidentified apparent precipitate present as blue specks. Soil components light brown. Consists entirely of apparent demolition debris. Concrete present primarily as hard flat or irregular blocks measuring 18 in. to 36 in. maximum dimension with most containing #6 to #8 rebar. Brick present generally as fragments. No odor, moist.
RUBBLE FILL

Example 2 (Test Pit Description)
20% ash, 20% charcoal particles, 15% clinker fragments to particles, 15% fines, 10% sand
5% paper, 5% glass pieces to fragments, 5% ceramic fragments, 5% wood blocks to fragments, trace metal pieces to fragments, asphalt pieces to fragments.
Color variable changing to dark gray below 4.0 ft. Fines not identified. Consists primarily of partially burned and decomposed household refuse by identifiable remains of newspaper, bottles and cans. Distinct fuel odor and oil saturation below observed water at 4.5 ft. Free product noted 5 mm thick on water surface after a 15 minute stabilization period.
REFUSE FILL

Example 3 (Test Pit Description)
50% cinder fragments to particles, 20% fines, 15% fly ash, 10% gravel, 5% sand, trace possible ceramic particles, glass shards.
Dark gray to black discoloration. Fines not identified. Heavily contaminated with coal tar in discrete zones or pockets of apparently higher permeability ranging in thickness from 6 in. to 24 in. at depths of 2.0 ft. to 7.5 ft. Strong naphthalene odor. Moist below 9.0 ft.
MGP WASTE

Example 4 (Test Boring Description)
15% coarse sand, 15% clinker fragments to particles, 15% fine gravel, 15% ash, 10% ceramic particles, 10% unidentified fines, 10% wood, 5% fine sand, 5% glass particles, trace brick particles.
Medium dense. Soil components brown to dark brown with dark gray discoloration. Coarse sand and gravel generally hard and angular. Possible organics present partly as fines. Wood present as lumber fragments and possible roots. Strong septic odor and faint possible solvent odor detected. Sample moisture probably due to drilling fluid.
FILL

Suggested Nomenclature
Suggested nomenclature for possible fill types are included below.

Primarily Natural Components	Significant Percentage Artificial or Deleterious
Loam Fill	Bark Mulch
Cohesive Fill	Stump Fill
Hydraulic Fill	Rubble Fill
Granular Fill	Refuse Fill
Structural Fill	Urban Fill
Till Fill	Medical Waste
Crushed Stone	Tannery Waste
Ballast	MGP Waste

STANDARD OPERATING PROCEDURE NMI-S-007

EXTRACTION/PRESERVATION OF SOIL/SEDIMENT FOR VOCS

1.0 INTRODUCTION

1.1 Objective

This operating procedure describes recommended procedures for the collection and handling of soil and sediment samples, specifically for analysis of volatile organic compounds (VOCs), in general accordance with United States Environmental Protection Agency (USEPA) Method 5035 and analysis by Method 8260. This class of compounds includes low molecular weight aromatics, hydrocarbons, halogenated hydrocarbons, ketones, acetates, nitriles, acrylates, ethers, and sulfides with boiling points below 200° Celsius (C).

Two methods of VOC sample collection and preservation are discussed below: pre-weighed, pre-preserved VOA vial sample glassware (using a plunger, Terra Core™, Easy Draw Syringe®, etc.), and En Core® samplers. This operating procedure provides guidance on the usage, maintenance and calibration of electronic field equipment, owned by the Contractor, or obtained from an equipment rental agency.

1.2 Equipment

- VOC sample coring device (plastic corer with plunger, Terra Core™, En Core®, etc.)
- Other VOC sampling equipment: spatula, scoop
- Chains of Custody
- Glassware - VOA vials with preservative (not needed if you are using En Core®); dry weight analysis glassware (if needed)
- Paper towels
- In-field sample preservation supplies: ice/ice packs, cooler
- Packing materials for glassware and/or En Core® samplers (e.g., Zip-Loc®, garbage bags, bubble wrap, custody tape)
- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan
- Field book, field data forms and sampling sheets with writing utensils
- Decontamination supplies/equipment

2.0 PROCEDURES

2.1 Where to Collect a VOC Sample

Where to collect a soil sample for VOC analysis depends on the sampling objectives, as well as regulatory guidance and field observations. Before field work begins, discuss and understand the sampling objectives and plan with the project manager or project engineer/geologist.

General considerations:

- Collect VOC samples from freshly exposed surfaces of the soil, while minimizing disturbance of the sample matrix during and after collection.
- Typically, soil is collected from areas with either the highest PID readings or areas with visual or olfactory evidence of contamination. Note: Do not bring the sample close to your face. While sampling, if the sample appears to have a noticeable odor, describe and document the odor in an appropriate field form. Otherwise, do not sniff the samples.
- Avoid collecting VOC samples from surface soil (i.e., 0 to 6 inches), unless that is a sampling objective. If a sample interval of 0 to 2 feet depth (for example) is specified in a work plan, collect the VOC samples from the lower portion of the interval. The top of the interval likely has more interaction with air, which can strip VOCs from the soil.
- Be careful not to sample near machine exhaust, fuel storage containers or other potential sources that could cross contaminate the sample.

2.2 Working with VOA Vials

- Check the expiration date on each VOA vial and confirm that the type of preservative is appropriate for VOC samples. Also check that the weight of preservative and the vial are clearly marked on the label. (Some labs may include a barcode instead that has the weight information.)
- Do not let preservative spill out of glassware.
- The preserved sample container should be opened only to add the sample. Do not open the cap early, since the preservative could evaporate, or external contaminants could enter.
- Be careful not to overfill or underfill the glassware with soil, especially for the low-level analysis. The soil sample must be completely submerged in preservative. If a fill line is provided on the glassware, the bottom of the meniscus should be on the line.
- Keep threads, cap, and outer surfaces of glassware clean and free of soil.
- Always check lab instructions for specific hold times and handling protocol. Hold times can be as short as 24 hours and may require specific handling and storage such as freezing the soil sample. General sample handling, packing, and shipping procedures are outlined in SOP NMI-001.

2.3 VOC Sample Considerations

- Soil to be analyzed for VOCs is generally not collected from a composited sample. Instead, it is collected from a discrete location.

- Collect a VOC sample before collecting other types of samples, to minimize loss of VOCs.
- Minimize the amount of time soil is exposed to air during sample collection and filling of glassware.
- If collecting a sample only for VOCs analysis, collect additional soil sample in a separate piece of unpreserved glassware for moisture content analysis.
- Be aware of short hold times for VOC analysis when arranging for sample delivery to the laboratory. General sample handling, packing, and shipping procedures are outlined in SOP NMI-001.

2.4 Sample Collection – Pre-Weighed, Pre-Preserved VOA Vials

1) VOC sampling devices are intended to be used as dedicated samplers and should not be used for soil collection at more than one sample location. Obtain a sample by pressing the end of the clean soil sample coring device (plunger, Terra Core™, Easy Draw Syringe®, etc.) into a freshly exposed surface and remove the coring device once filled.

- When inserting a coring device into a freshly exposed surface for sample collection, air should not be trapped behind the sample.
- Avoid getting organic materials (roots, grass, leaves, sticks, etc.) in the samples.
- Soil sample coring devices are not appropriate for sample storage. These coring devices help maintain the sample structure during collection and transfer of soil to the VOA vial.
- When sampling gravel or a mixture of gravel and fines that cannot be easily obtained using coring devices, use a spatula or scoop. Quickly transfer the sample to the VOA vial with minimal splashing. Don't let the spatula or scoop contact the liquid contents of the vial. Be careful to collect only the required amount of soil.
    - Tip: Sometimes soil stays behind in the core after you have tried to plunge it, especially cohesive clays. Try gently rocking the coring device back-and-forth or use a gentle twisting motion so that the soil stays in the coring device when you pull it out.

2) Remove the coring device and, if necessary, clean the exterior of the sampler barrel by wiping with a clean paper towel.

3) Extrude the sample into a pre-weighed, pre-preserved VOA vial by gently pushing the plunger. Take care so that soil does not contact the lid or threads of the vial, which can prevent an airtight seal.
- Obtaining and transferring a sample to the VOA vial should occur as quickly as possible to minimize the loss of VOCs.
- Hold the preserved VOA vial at an angle when extruding the sample to minimize splashing.
- Be careful when handling bottles containing preservative - avoid spilling or contact. The preservatives can be caustic. Methanol preservative is both toxic and flammable, so avoid

ignition sources during use and transport. Safety Data Sheets (SDSs) for the sample preservation chemicals should be on-site or readily accessible. Take time to understand the information in the SDS.

4) Just before capping, check the lip and threads of the VOA vial to check that they are clean. Remove foreign debris with a clean paper towel.

5) Cap the glassware to form an airtight seal. Once capped, check that the sample is completely submerged in the preservative. Store the vials upright to prevent leaking. Be careful: the caps can be over-torqued easily and will split. Tighten them just until you can feel the septum start to compress.

6) Complete glassware labels and attach to VOA vials (if required) after the sample has been collected and the VOA vials are sealed. When applying sample labels, do not cover up the pre-printed preservative and vial weights listed on glassware.

7) After the VOC samples have been collected and capped, collect a sample for dry weight (percent total solids) analysis, since VOC sample results are typically reported on a dry-weight basis. This sample should be collected from within 2 centimeters of the VOC sample area and must come from the same geological stratum. Place the sample in a 2- or 4-oz glass jar.

8) Immediately package glassware appropriately in an ice/ice pack filled cooler. Vials should be packaged in Zip-Loc bags, remain upright, and be protected from breakage and other glassware (e.g., using bubble wrap, foam or other padding).

9) Record visual and olfactory soil conditions of the sample source on the relevant sample log. While sampling, if the sample appears to have a noticeable odor, describe the odor. Otherwise, do not sniff the samples.

2.5 Associated Glassware

The following glassware/equipment is provided by the laboratory for VOC sample collection and analysis using pre-weighed, pre-preserved VOA vials. These vials should be made of glass. They should also have a thick septum cushion between the sealing material (PTFE) and cap (rigid plastic screw cap or aluminum crimp top) to achieve an airtight seal.

Item	Quantity needed per sample	Analysis	Amount of sample needed	Hold time
VOA vial preserved with methanol	1	High-level analysis	5 to 15 grams	14 days
VOA vial preserved with ultra-pure blank water (UPBW) or NaHS04	2	Low-level analysis	5 grams per vial 48 hours (UPBW)*	14 days (NaHSO4)

*If a UPBW-preserved VOA vial is stored at a low temperature (i.e., typically in a freezer set to -12°C), the hold time can be extended to 14 days at most. Note: Take care when handling frozen glass, since it can break more easily.

The laboratory also provides vials for Trip Blanks upon request (used as field quality control samples).

2.6 SAMPLE COLLECTION – EN CORE® SAMPLERS

En Core® samplers are used to both collect and store the soil during shipment before it is analyzed at the laboratory. Thus, there is no associated glassware. En Core® samplers must be preserved or analyzed at the lab within 48 hours of collection. (Some regulatory agencies have approved extended hold times; make sure to check.)

1) Install sampler (5 gram or 25 gram) onto the decontaminated sample collection handle.
2) Obtain a sample by pressing the T-handle with attached sampler into a freshly exposed surface. A 5-gram En Core® sampler is full when the rubber O-ring on the plunger is visible in the lower hole on the T-handle. A 25-gram En Core® sample is full when the O-ring is visible in the upper hole on the T-handle.
3) Once filled, remove the sampler and clean the exterior of the sampler by wiping with a clean disposable paper towel, if necessary. You may need to use a spatula to scrape off excess soil from the top of the sampler.
4) Cap the sampler. Fit the cap "locking arms" into the "flats" on the sampler body and then twist ¼ turn.
5) Release the sampler by depressing the lever on the handle body.
6) After removing the sampler from the handle, use the slot in the handle of the T-handle as a wrench to turn the plunger to the closed position, which creates a zero-headspace environment in the sampler for the soil.

7) Placed the capped sampler in the VOC-proof bag provided. No additional preservative considerations are required. Collect and submit three En Cores® for each sample. That way if a dilution is required, or something goes wrong during analysis, the lab will still have sample volume.

8) After the VOC samples have been collected and capped, collect a sample for dry weight (percent total solids) analysis. This sample should be collected from within 2 centimeters of the VOC sample area and must come from the same geological stratum. Place the sample in a 2 or 4-oz glass jar.

9) Immediately package En Core® samplers with ice packs for shipment to the laboratory. You can place all of the samplers in the same VOC-proof bag for simplicity.

10) Record visual and olfactory soil conditions of the sample source on the relevant sample log. Remember, do not bring the sample close to your face. While sampling, if the sample appears to have a noticeable odor, describe the odor. Otherwise, do not sniff the samples.

11) The T-handle should be decontaminated with a non-phosphate detergent (e.g., Alconox®) and water and rinsed with clean water between sample intervals. If the handle gets covered with petroleum/tar/oil/NAPLs, clean it with isopropyl alcohol before. General field equipment decontamination procedures are included in SOP NMI-007.

2.7 Documentation

Field documentation of sampling use shall be recorded daily field logs. It is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel.

STANDARD OPERATING PROCEDURE NMI-GW-001

WELL INTEGRITY SURVEY

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) specifies the procedures for performing inventories of existing monitoring wells and piezometers. Monitoring well inventories are periodically conducted to assess the integrity of existing monitoring locations and to identify the need for repairs, replacement of parts, or replacement of wells that are determined to no longer be usable. In general, individual wells selected for integrity testing include:

- wells with anomalous water levels and slated for replacement;
- wells with anomalous water levels and not slated for replacement;
- wells listed for possible redevelopment;
- wells with unknown screen lengths;
- wells that are damaged/destroyed; and/or
- wells that appear to be compromised.

A well inventory may also be performed to determine the reliability of water level measurements and hydraulic testing results of all existing wells at the site. A well inventory involves an inspection of the overall condition of the well, comparison of measurable quantities (e.g., riser stickup relative to grade and total depth), general verification of survey coordinates and elevation, and measurement of depth to water in the well.

2.0 PERSONNEL QUALIFICATIONS

All personnel shall meet the requirements of the site-specific Health and Safety Plan (HASP).

The Project Manager is responsible for ensuring that the activities described herein are conducted in accordance with this SOP and any other appropriate procedures. This will be accomplished through staff training and by maintaining quality assurance/quality control (QA/QC).

The Field Manager is responsible for periodic observation of field activities and review of field generated documentation associated with this SOP. The Field Manager is also responsible for implementation of corrective action if well conditions necessitate them.

3.0 EQUIPMENT LIST

The following materials will be available, as required, during performance of a monitoring well inventory:

- Health and safety equipment (as required by the site-specific HASP);
- Ruler or tape measure;
- Water level indicator and/or interface probe (i.e., depth to water meter);
- Indelible pen;
- Paint pen;
- Well keys;
- Wrenches for accessing flush-mount well covers;
- Hammer and flathead screwdriver for prying or knocking loose stuck well covers, if necessary;
- Cleaning and decontamination equipment;
- Well construction information; and
- Field notebook and field forms.

If feasible, a supply of typical replacement parts (e.g., locks, bolts, and well caps) should be available to perform immediate repairs if a well is found to be damaged. The use of lubricants or grease on locks and bolts is strongly discouraged due to the potential for cross contamination.

4.0 CAUTIONS

It is important to confirm the correct identity of wells, particularly when they are installed in a cluster. During the well integrity survey, verify that all wells are properly labeled by comparing their measured depth to the reported depth as installed. The well identity should be confirmed by measuring the total depth of the well and comparing this to the well construction log. If the well is incorrectly labeled or not labeled, provide a clear, correct label such as by using an indelible pen on the inside of the steel protective cover for the well, or on the outside of the steel protective cover using a paint pen.

5.0 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Care should be taken using tools to access flush-mount curb boxes. Wells in or near roadways can only be accessed with proper traffic cones and flagging. Access to wells containing chemicals of concern may pose a hazard of chemical exposure. Considerations for stinging insects, bees and spiders should be taken as they are often found nesting under monitoring well covers and within riser standpipes. Reference the HASP for appropriate precautions.

6.0 PROCEDURE

The typical procedure for assessing the integrity of a monitoring well is outlined below.

1) Prior to mobilizing in the field, obtain a list of wells/piezometers to be inventoried and available information concerning their location and physical characteristics such as diameter, material of construction, total depth, etc. The well keys should be obtained from the *de maximis* field manager.

2) Identify the site and well identification number on the Well Integrity Assessment Form (Attachment 1). Record all observations on this form, supplemented by notes in the field notebook if necessary.

3) Examine the well for the presence of an identification label. If absent, label the well with the appropriate well number after measuring the total depth of the well to verify that the depth matches the well number (see Step 9 below). If the well identity is incorrectly labeled or not labeled, provide a clear, correct label using an indelible pen on the inside of the steel protective cover for the well, and on the outside of the steel protective cover using a paint pen.

4) Examine the surface condition of the well. Record the type of well surface structure (i.e., flush mount or above-grade standpipe stickup), condition of the well cover and surface seal. Confirm the protective casing is not bent, the PVC casing is not broken or chipped, and there is no evidence of frost heaving.

5) Unlock and open the well. Record the type (e.g., PVC or stainless steel), dimensions (i.e., casing diameter and stickup relative to grade), condition of the well casing, and type of well cap. If well cap is missing, replace with available parts or record the type of cap that is required so that it can be purchased. For flush-mount wells, document on the inspection form whether water is observed within the flush mount protective casing. Runoff from parking areas entering the flush mount cover and filling well risers may create localized groundwater mounding or damaged if the water freezes during the winter.

6) Measure the above-grade portion of the well riser stickup and compare to the known length of the stickup measured during well installation (surveyed top of inner casing elevation minus ground surface elevation).

7) If the difference between the observed stickup length and the known stickup length is greater than 0.1 foot, the monitoring well location and elevation should be re-surveyed.

8) Locate the marked measuring point along the top of the well casing. If no mark is visible, add a mark at the highest point of the casing using an indelible pen. BE CAREFUL NOT TO DROP THE PEN DOWN THE WELL.

9) Measure the depth to water and total depth of the well from measuring point along the top of the well casing. For total depth measurements, account for any difference in calibration of the measuring tape on the probe (i.e., distance from part of probe that measures depth to water and the physical bottom of the probe which will measure total

depth of the well). Record any obstructions encountered and a description of the feel of the well bottom (i.e., soft due to sediment or hard).

10) (Optional Step) Determine whether the well casing is straight and accessible to the bottom of the screen interval using a 2.5 feet long solid slug of the appropriate diameter.

11) Compare all observations concerning the measured dimensions of the well with the previously recorded/listed values. Based on these results, as well as other observations concerning the condition of the well, record any appropriate recommendations on the Monitoring Well Integrity Assessment form (Attachment 1). Perform any recommended maintenance activities that can be accomplished with available equipment.

12) Remove all equipment from the well. If no additional maintenance activities are to be performed, close and lock the well, and collect all personal protection equipment (PPE) and other wastes generated for disposal (see Section 8.0 below).

7.0 FOLLOW-UP ACTIVITIES

Depending on the results of the well inventory, several additional activities may be warranted prior to future use of the well. Typical follow-up activities include replacement of missing parts, well redevelopment, re- surveying of the well, or complete replacement if the well is determined to be unusable. These activities are briefly discussed below.

As stated above, a supply of locks, bolts, and well caps should be available when performing the well inventory. However, it may not be feasible to maintain a supply of all potential replacement parts due to the variety of well types in use. Therefore, a list of required replacement parts should be compiled during the well inventory event. At the conclusion of the event, the necessary replacement parts for all wells can be obtained and installed.

Sediment accumulation occurs to some degree in all monitoring wells, particularly those that are not pumped on a routine basis. If a sufficient quantity of sediment which may adversely impact future groundwater sampling activities (i.e., a sediment accumulation of greater than one-half foot above the bottom of the well screen), activities should be taken to remove the sediment. These activities typically involve the removal of sediment by either pumping (e.g. inertial pump) or bailing the well, followed by re-measurement of the total depth of the well to confirm that the total depth is near the reported values. The removed sediment should be inspected for the presence of filter pack materials which may indicate that the well screen has been damaged. If initial efforts are unsuccessful in clearing the sediment accumulations, the well may need to be re-developed or replaced.

The measuring points marked on the well risers are utilized as a reference location when measuring the depth to water for determining groundwater elevation. The distance of these markers from the ground surface are verified against listed values during well inventory activities. Minor variations between listed and measured values may be attributed to an uneven ground surface around the well or to changes to the ground surface such as paving or grading activities which may have been performed since installation of the well. Discrepancies in the

measuring point can also occur if the well is damaged or modified such as cutting or lengthening the well riser. In these situations, the well should be re- surveyed to establish a measuring point for future depth to water measurements.

Replacement or decommissioning of a well may be warranted if the well is broken, obstructed, or otherwise compromised. If the well cannot be adequately repaired and is required for future monitoring purposes, a replacement well should be installed if no suitable alternate wells are located in the vicinity.

8.0 WASTE MANAGEMENT

Materials generated during well inventory activities, including disposable equipment and decontamination materials (e.g., paper towels, soapy water, and rinse water). These materials should be disposed of in appropriate containers.

9.0 DATA RECORDING AND MANAGEMENT

Field observations will be recorded on the Well Integrity Assessment Form (Attachment 1), and/or in an appropriate Field Notebook or PDA. Well integrity inventory results will be retained in the project file.

10.0 QUALITY ASSURANCE

To verify accurate measurements of well stickup, depth to bottom, depth to groundwater, etc., measurements can be double-checked periodically (e.g., at least one of these measurements per well can be repeated).

11.0 REFERENCES

No references apply to this SOP.

12.0 ATTACHMENTS

1. Well Integrity Assessment Form

WELL INTEGRITY ASSESSMENT FORM

Site Name:_____Well I.D.:_____Date:_____

(For each item, circle the appropriate response or fill in the blank)

Well I.D. Clearly Marked: YES NO

Well Completion: FLUSH MOUNT ABOVE-GRADE
STANDPIPE Lockable Cover: YES NO DAMAGED *(Describe below)*

Lock Present: YES NO ADDED Key Brand/Number:_
Measuring Point Marked: YES NO ADDED
Well Riser Diameter (inches): _____
Well Riser Type: PVC Stainless Steel Other *(Describe)* _____

Surface Condition YES NO *(Describe below)*

Cement Intact:
Curb Box/Well Cover YES NO DAMAGED *(Describe below)*
All Bolts Present: YES NO *(Describe below)* NOT APPLICABLE
Ground Surface Slopes
Away from Well YES NO *(Describe below)*

Well Condition

Well Cap: PVC Slip Cap Pressure-fit Cap None
Well Vent: Slot Cut in Riser Vent Hole in Cap None Not Applicable *(Flush Mount Well)*

Reported Well Riser Stickup (feet): _____*(use negative number if below grade)*

Measured Well Riser Stickup (feet): _____ *(use negative number if below grade)*

Depth to Water (feet from Top of Well Riser): _____ *-or-* DRY

Reported Total Depth (feet below grade): _____

Measured Total Depth (feet below grade): _____

Well Obstructed: YES NO If yes, list depth in feet from Top of Well Riser: _____

Well Bottom: SOFT *(contains sediment)* FIRM *(no sediment)*

Recommendations

Repair Concrete/Surface Completion: YES NO If yes, list date performed:_
Re-Survey Well: YES NO If yes, list date performed:_
Remove Sediment, Redevelop & Re-Measure YES NO If yes, list date performed:_
Replace Well Cap: YES NO If yes, list date performed:_
Replace Bolts: YES NO If yes, list date performed:_
Replace Lock: YES NO If yes, list date performed:_
Other/Miscellaneous Observations:

Inspector(s):_

_____

Photograph of Well (optional):

Date of Photograph: _____

Additional Comments:

STANDARD OPERATING PROCEDURE NMI-GW-002

MONITORING WELL DEVELOPMENT

1.0 INTRODUCTION

This standard operating procedure describes the protocol to be followed during the development of monitoring wells with diameters ranging from 1 to 4 inches. As the work progresses and if warranted, appropriate revisions to this standard operating procedure may be made by the project manager. Detailed procedures in this protocol may be superseded by applicable regulatory requirements.

Development of larger diameter wells to be used for extraction (e.g. 6-inch or greater) typically requires a vehicle-mounted crane to lower pumps or an air-lift assembly into the well. The development of these wells is not discussed in this SOP and the procedures will be detailed in the specific work plans supporting their installation.

1.1 Objective

Objectives of monitoring well development are to remove sediment that may have accumulated during well installation, to consolidate the filter pack around the well screen, and to enhance the hydraulic connection between the target zone and the well.

1.2 Equipment

The following equipment may be used during well development. Site-specific conditions may warrant addition or deletion of items from this list.

- Inertial pump (e.g. Waterra Hydrolift II), Submersible pump, peristaltic pump, and/or bailer;
- Surge block and check valve, plus hose/tubing for the valve and surge block;
- Container for purge water (drums or fractionation tank);
- Container with known volume (e.g., 5-gallon bucket) for flow estimation;
- Water level indicator;
- Stopwatch or timer;
- Clear glass jars (at least 2);
- Well development record;
- Field notebook;
- Plastic sheeting to lay on the ground surrounding the well; and
- Appropriate health and safety gear (e.g., PPE) per the Health and Safety Plan.

2.0 PROCEDURES

2.1 General

Monitoring well development shall be performed, as soon as practical, after well installation but not sooner than 48 hours following placement of the grout or bentonite chip seal. Weather conditions may increase grout set time and, consequently, require more than 48 hours between well construction and well development.

Development of monitoring wells (e.g., 1, 2, 4-inch diameter) shall preferably be accomplished with a submersible pump, peristaltic pump, and/or bailer. These may be dedicated to that well (e.g., a bailer). Bailers shall be used to develop wells only where the volume of water is so small that other development methods are infeasible. Pumps used for well development shall be periodically raised and allowed to drain back into the hole in order to induce flow out through the well screen. A surge block equipped with a check valve (inertial pump) may be used to flush the filter pack of fine sediment in instances where field personnel expect that development may be improved by surging. Surging will be conducted slowly to reduce disruption to the filter pack and screen. A mechanical Waterra Hydrolift pump may be set up on the wellhead and connected to the tubing and check valve to reduce the manual labor. The Hydrolift surging should be performed at a low speed setting to avoid damage to the well screen. It is preferable that the surging is initiated at the top of the screen and advanced downward toward the bottom of the well. The personnel should not leave the Hydrolift pump unattended.

Following surging, the well will be pumped or bailed again to remove sediment drawn in by the surging process until suspended sediment is reduced to acceptable levels (see below). Small-diameter submersible pumps with bottom-facing intakes and capable of removing fine sediment (e.g. Proactive Mini-Typhoon or Whale pump) accumulated at the bottom of the screen are recommended for development of 2-inch diameter wells because the pump diameter is slightly smaller than the inside diameter of the well casing allowing the pump to serve as a surge block and pump. Caution must be taken not to lower these pumps directly into the sediment but rather slowly move the pump up and down the screen while pumping to agitate the sediment. If a thick layer (i.e., more than an inch or two) exists on the bottom of a well, it is advised to remove the fine sediment from the bottom of the well with an inertial pump prior to operating an electrically powered pump. Other submersible pumps such as Proactive Hurricane and Monsoon are not well suited for operating in high turbidity conditions so sediments should be removed before deploying the pump to prevent damage to the pump or pump controller. Water shall not be added to the well to aid in development.

A well is considered fully developed when all the following criteria are met:

- the well water turbidity readings are below 5 Nephelometric Turbidity Units (NTUs) as measured using a turbidity meter;
- the sediment thickness remaining in the well is less than one percent of the screen length; and

- the total volume of water removed from the well equals five times the standing water volume in the well (including the well riser and well screen plus saturated filter pack, assuming 30 percent porosity) plus the volume of drilling fluid lost.

In some cases, all of the above criteria cannot be achieved (i.e., turbidity does not decrease to below 5 NTU), so these criteria may be modified with approval by the field manager. Should the recharge to the well be so slow that the required volume cannot be removed in 2 to 3 consecutive hours, if the water remains discolored, or excess sediment remains after the five-volume removal, the project team shall terminate purging and/or discuss other options for improving water quality. Limited development may also be specified when gross contamination is observed (e.g., the presence of NAPL).

Prior to (and if needed during development), the cap and all internal components of the well casing above the water table shall be rinsed with deionized water to remove all traces of soil, sediment, and cuttings.

Non-dedicated pumps shall be decontaminated prior to use in the next well (See NMI-007 - Field Equipment Decontamination) and dedicated tubing and/or bailers shall be used during subsequent sample collection from the well. Development fluids shall be containerized and handled in accordance with site investigation derived waste procedures.

2.2 Documentation

The following data shall be recorded for development:

- well designation;
- date of well installation;
- date of development;
- static water level before and after development;
- quantity of drilling fluid lost during drilling;
- calculated quantity of standing water in well and annulus (30-percent porosity of saturated annulus assumed for calculation) prior to development;
- depth from top of well casing to bottom of well;
- screen length;
- depth from top of well casing to top of sediment inside well, before and after development;
- physical character of removed water, including changes during development in clarity, turbidity, color, particulates, and odor;
- type and size/capacity of pump and/or bailer used;
- height of well casing above/below ground surface;
- typical pumping rate;

- estimate of recharge rate; and
- quantity of water removed and time for removal.

This information shall be documented on a Well Development Record (attached).

3.0 REFERENCES

2013. *U.S Environmental Protection Agency Science and Ecosystem Support Division: Design and Installation of Monitoring Wells.* Guidance

MONITORING WELL DEVELOPMENT PURGING & SAMPLING RECORDS

Geosyntec consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Well ID: _____ Well Diameter: _____

Project Name: _____ Total Depth of Well: _____

Project Number: _____ Initial Depth to Water: _____ Time: _____

Date: _____ Casing Volume: _____

Recorded By: _____ Depth to Water After Purging: _____ Time: _____

Sample ID: _____ Method of Purging: _____

Duplicate ID: _____ Method of Sampling: _____

Weather: _____

time	intake depth	pumping rate	cumulative volume	temp.	pH	specific conductance	D.O.	ORP	comments
	ft / m	gpm / Lpm	litres / gallons	°F / °C	(units)	(µS / cm)	(mg / L)	(mV)	odour, colour, sediment, load, well condition, presence of product

samples collected	time collected	container type	container size	container lot no.	preservative

Notes: (well condition, nearby activities or changes in land use, odors, problems, deviations from plan, etc.)

STANDARD OPERATING PROCEDURE NMI-GW-003

MONITORING WELL INSTALLATION

1.0 INTRODUCTION

1.1 Objective

This standard operating procedure describes the protocol to be followed during the installation of monitoring wells, groundwater extraction and vapor extraction wells and piezometers. Drilling and logging of soil borings for the well installation will be in conformance with the standard operating procedures for the drilling and sampling of soil borings. The procedures presented herein are intended to be of general use and may be supplemented by a work plan and/or a health and safety plan. As the work progresses and if warranted, appropriate revisions to this standard operating procedure may be made by the project manager. Detailed procedures in this procedure may be superseded by applicable regulatory requirements.

1.2 Equipment

The field engineer/geologist overseeing the construction of the monitoring well should have the following equipment in the field during well installation:

- Field logbook and/or data sheets;
- Water Level Indicator Tape (i.e., Water Level Meter);
- Calculator;
- Well design and specifications for screened interval, filter pack length and construction, pipe diameter and type, etc. This information may be provided in the field work plan or design; and,
- Appropriate health and safety equipment.

2.0 PROCEDURES

2.1 Monitoring Well Installation

A daily field report should be completed for each day of fieldwork. These reports can be scanned and submitted to the project portal. Proposed well locations must be pre-marked. The area encompassing new wells shall be identified on public right of ways (for example, by using spray paint on the pavement) and a Dig-Safe (Call 811) request must be made at least 72 hours prior to the planned start of the drilling so that public utility providers can mark their underground lines within the area encompassing the new wells. If required, permits must be acquired from the appropriate agency(s), or a specific utility company to provide access to a drilling location before drilling begins. In cases where information exists that a utility is present, but its specific locations are unknown or for drilling locations far from public ways (i.e., where Dig-Safe does not mark utilities), a private utility locator should be considered. Prior to initiating drilling, the field engineer/geologist and the driller will review the spray paint markings

made by the utility companies and private utility locator relative to each proposed borehole location. IF THERE ARE NO MARKINGS, THE DRILLING WILL NOT START UNLESS DIG SAFE AND THE UTILITIES ARE CONTACTED BY THE PROJECT MANAGER TO CONFIRM THAT THE LOCATION WAS EVALUATED FOR THE PRESENCE OF UTILITIES.

In some cases, boring must be advanced in areas that have nearby utilities. In such cases, "soft dig" techniques can be used to advance a borehole to below the expected depth of utilities. Soft dig techniques include hand digging or air knifing (i.e., breaking-up soil using compressed air projected using an air wand and then removing these soils using a soil vacuum). The need for soft digging is project and location specific and should be made by the Project Manager and/or Field Manager.

The field engineer/geologist will keep detailed notes on the advancement of the borehole during drilling, including the volume of cuttings generated, volume of water lost to the formation, borehole diameter and depth. Prior to the start of well construction (preferably the day before), the diagram of the proposed well should be reviewed with the driller, and an inventory the well construction material should be performed to confirm that all appropriate well materials are on site. Along with confirming that appropriate type, size and length of material is available, inventory shall include confirming that the well screen slot size for the well screen and filter sand gradation is correct. If sufficient materials are not on-site and/or in unacceptable condition, well construction will not begin until all appropriate materials are on-site. All proposed monitoring wells will be constructed from materials specified in the field work plan (e.g., two-inch diameter, Schedule-40 polyvinyl chloride (PVC)). All well materials shall be new and clean. Soiled materials will be replaced or cleaned prior to use and decontaminated if there is a potential that well materials contacted contaminated surfaces.

2.2 Well Screen and Casing

The well casing and screen will generally consist of threaded stainless steel or schedule 40 (minimum) polyvinyl chloride (PVC) pipe, although Teflon, polyethylene, steel and polypropylene pipe are occasionally used. The use of Teflon or Teflon-lined materials should be evaluated by the project team prior to the well installation due to the potential for PFAS leaching (see NMI-GW-011 – Groundwater Sampling for PFAS). The casing material shall be defined in the field work plan; however, the inside diameter of the casing should be large enough to permit unobstructed passage of an appropriate water-level probe and equipment for purging wells and water sample collection.

All well casings and screens will be joined through threaded connections equipped with seals. Solvent welds are not suitable due to the potential for contamination from the solvent glue.

The well screen will generally consist of machine-slotted PVC or wire-wrapped stainless-steel screen. The screened sections will provide flow between the target zone and the well, allowing efficient well development and representative sample collection.

2.3 Filter Material

Filter material will be well-graded, clean sand (generally less than 2 percent by weight passing a No. 200 sieve and less than 5 percent by weight of calcareous material). The filter material will be either a standard sand gradation designed for a range of anticipated soil types or a sand gradation specifically designed to fit the soils collected from anticipated well completion zone. The material specification for the filter pack will be identified in the field work plan.

2.4 Setting Screens and Riser Casing

Upon completion of drilling and/or geophysical logging, the boring will be measured using a weighted tape or water level tape to verify the total depth of the boring. Approximately six inches of filter pack sand shall be poured into the boring and allowed to fall to the bottom of the boring. The boring shall be re-measured after placing the sand to verify its thickness. For monitoring wells installed inside open bedrock boreholes where a significant portion of the borehole is located below the proposed well screen, bentonite chips or bentonite-cement grout should be used. The driller shall fill the well with bentonite chips to an elevation that is several feet below the target bottom of the screen. This is done to provide space in the boring for the bentonite chips to hydrate and expand. Bentonite chips will be allowed to hydrate overnight when used to fill the bottom of a borehole. The depth of the borehole will be re-measured the following day prior to well installation. Additional bentonite chips can be added as needed to reach 6-inches below the target elevation for the bottom of the well screen; filter pack sand shall be used to fill the last 6-inches to reach the elevation for the bottom of the well screen.

Well Screen and Casing

The well casing and well screen will then be assembled ex-situ and lowered into the borehole. If the boring is too deep to assemble the entire well ex-situ and lower it into the boring, then the well can be fabricated ex-situ in manageable lengths and each length attached as the well casing and screen are lowered into the boring. If the well casing and screen are assembled as they are lowered into the boring, extreme caution must be used to ensure materials (including the well casing and screen) do not accidentally fall down the well. Well casing materials should be measured to the nearest 0.1 foot. The bottom of the well will be fitted with a secure bottom-end cap. The field engineer/geologist will confirm that a plug screwed in or otherwise securely attached to the bottom of the screen has been installed. The field engineer/geologist will also count the screen and riser sections that the driller assembles and lowers into the well to confirm the well is constructed correctly.

Stainless steel or PVC centralizers can be used to keep the well in the center of the borehole. Centralizers are required for well in bedrock and overburden wells deeper than 30 feet. Centralizers will be used immediately above and below the well screen and every 30 to 50 feet along the length of the casing. Centralizers need not be placed on well assemblies installed within augers or drill casings because the auger or drill casing will adequately center the well casing and screen in the borehole.

Filter Pack

For borings drilled using the hollow stem auger method, the filter sand will be placed after the well assembly has been lowered to the specified depth through the augers. The augers will be incrementally raised, while not raising the well, allowing filter sand to free fall through the augers, exit the base of the augers and fill around the well screen. Increments of one to two feet are recommended. The depth to the top of the filter pack will be measured after each increment to detect possible bridging (bridging is the interlocking of sand particles between the well and boring which results in a void in the well annulus). If bridging occurs, it will be broken by washing the filter materials into proper place with potable water, by repeatedly raising and lowering the augers slightly, or by tapping the bridge with a steel rod. The amount of water, if any, added to the borehole must be noted on the field logbook.

For monitoring wells, the filter sand will be placed in a calculated quantity sufficient to fill the annular space to a level of approximately 2 feet above the top of the well screen (the length of the filter pack will be defined in the field work plan). For extraction or pumping wells, the level of filter sand above the well screen will be based on site conditions. The depth to the top of the filter pack will be verified by measuring with a weighted tape. Groundwater extraction wells or monitoring wells may be surged before placement of the transition seal to promote filter material settlement, as specified by the project manager.

Transition Seal

Once the depth to the top of the filter material has been verified, bentonite or fine sand (choker sand) may be placed in the annular space as a transition between the filter material and the grout. A sufficient quantity of bentonite or fine sand will be poured to fill the annular space to a level of approximately 5 feet above the top of the filter pack or in accordance with the well design. If bentonite is to be placed below standing water, a high-solids bentonite grout will be pumped through a tremie pipe, or bentonite chips may be poured through the annulus. If bentonite is to be placed above standing water, a high-solids bentonite grout should be used, or bentonite chips may be placed in 6-inch lifts. Unless prohibited by well conditions, each 1/2-foot lift of bentonite chips should be hydrated using approximately 1 gallon of potable water s. The completed bentonite transition seal will be allowed to hydrate for at least 30 minutes prior to placing the grout. If a layer of fine sand (i.e., choker sand) is placed as the transition seal, the fine sand will be mixed with potable water and placed as a slurry through the tremie pipe or poured dry through the annulus. The depth to the top of the transition seal will be verified by measuring with a weighted tape.

Grout Seal

A neat cement grout, cement/bentonite grout, or high-solids bentonite grout, whichever is specified in the well design, will be placed from the top of the transition seal to the ground surface. The grout seal will be placed in hollow stem auger borings b by pumping through flexible hose or tremie pipe lowered to near the bottom of the zone being grouted.

Grout/additive/water mixtures will be determined on a site-specific basis and specified in the field work plan. Typical specifications of grout mixtures include:

- Neat cement grout shall be composed of Class A Type I Portland Cement mixed with not more than 7 gallons of clean water per bag (one cubic foot or 94 pounds) of cement with a density of 15 to 16 pounds per gallon, or to manufacturer's specifications.

- Bentonite-cement grout shall be composed of powdered bentonite (less than 5% by weight) mixed at not more than 8 gallons of water to the bag, with a density of 14 to 15 pounds per gallon, or to manufacturer's specifications.

- High solids sodium bentonite grout shall have a minimum of 20% solids and be mixed per manufacturer's specifications with water and/or other required additives.

2.5 Surface Completion

Upon completion of the well, the riser pipe will be cut cleanly so that the top of the well is horizontal. A mark or notch shall be made on the top of the riser pipe to identify the measuring point for survey of the well and water level measurements. The well will then be fitted with a suitable slip-on cap, threaded end cap, or waterproof cap (e.g., J-plug) to reduce the potential for entry of surface runoff or foreign matter. Either a steel protective well cover (e.g., stick-up or stovepipe), or a vault (e.g., roadbox) that may have a traffic-rated cover will be completed at the ground surface. Wells may be locked for security and will be designed to limit surface water infiltration. Protective well casing and vaults shall be sufficiently large for the well cap and lock, and shall be fixed in place using cement, concrete or a similar material. If the well is completed with a vault, the vault shall be slightly (e.g., ¼ inch) above the surrounding ground surface and the concrete apron around the vault shall be sloped slightly away from the well to encourage surface water drainage away from the vault (as opposed to ponding atop the vault).

2.6 Documentation

A well construction diagram for each well will be completed in the field on the monitoring well construction diagram or in the logbook by the field geologist/engineer and submitted to the reviewing geologist or engineer upon completion of each well. Well installation and construction data will be summarized in the field logbook and on a specialized form produced for this purpose.

2.7 Cleaning of Drilling Equipment

Cleaning the drill rig and associated drill equipment will follow the procedures discussed in SOP NMI-007 Field Equipment Decontamination.

WELL CONSTRUCTION

Geosyntec consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Well ID _____ Site Location _____

Project Name _____ Field Personnel _____

Project Number _____ Recorded By _____

Permit Number _____

Installation Date(s) _____

Drilling Method _____

Borehole Diameter _____

Drilling Contractor _____

Driller _____

Drilling Fluid _____

Fluid Loss During Drilling _____

Materials Used

Riser Pipe: Diameter 2.0 inches

Construction

- ☐ PVC schedule _____
- ☐ Stainless Steel
- ☐ Other _____

Slotted Area: Length _____

Diameter _____

Slot Size _____

Construction

- ☐ PVC schedule _____
- ☐ Stainless Steel
- ☐ Other _____

Silt Trap Used ☐ Yes ☐ No

Bottom End Cap: ☐ Male ☐ Female ☐ Slip

- ☐ PVC
- ☐ Stainless Steel
- ☐ Other _____

Top Cap: ☐ Male ☐ Female ☐ Slip ☐ J Plug

- ☐ PVC
- ☐ Stainless Steel
- ☐ Other _____

Protective Casing: Length _____ ft/m

Diameter _____

Construction

- ☐ Cast Aluminum
- ☐ Cast Steel
- ☐ Other _____

Casing Installation: Length _____ metres/feet

Diameter _____ cm/inches

Material _____

Sandpack:

Coarse Sand: ___ bags of ___ kg/lb pe r bag Size _____

Fine Sand: ___ bags of ___ kg/lb per bag Size _____

Seal:

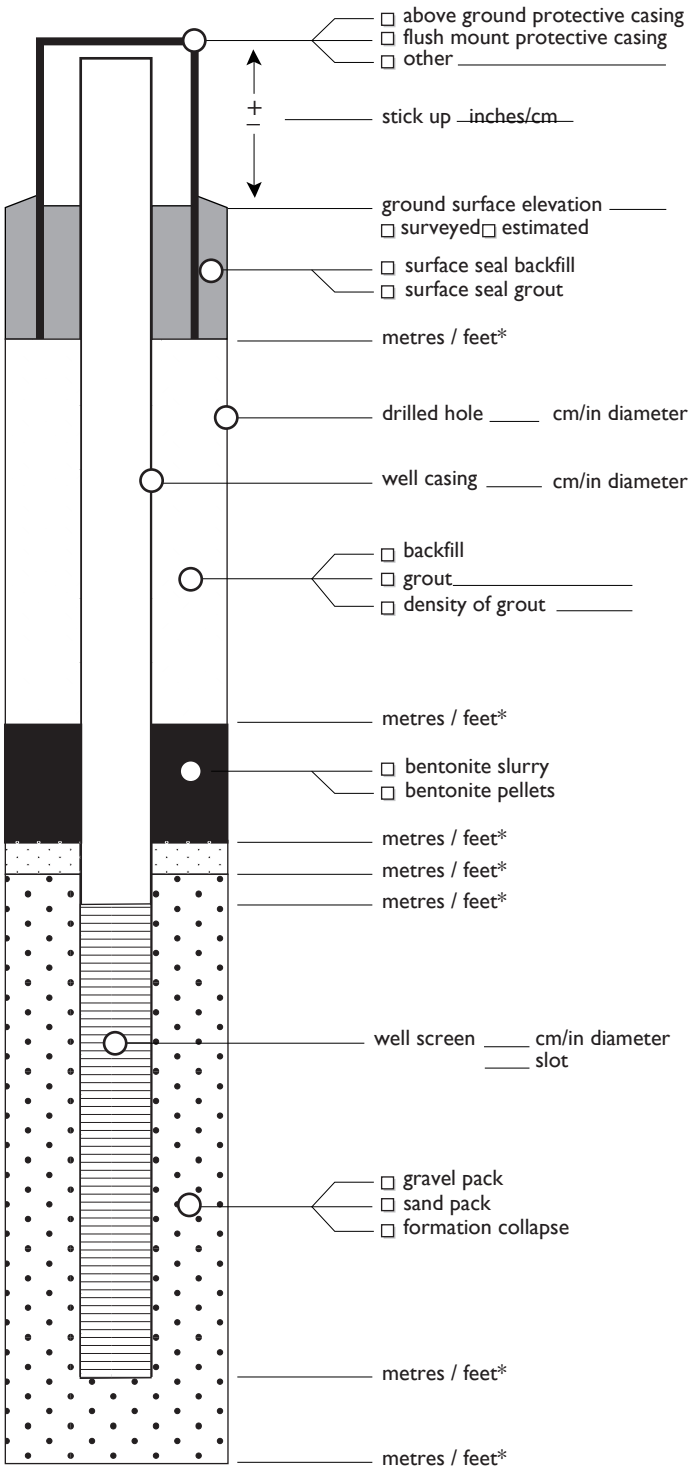
Bentonite Pellets: ___ bags of ___ kg/lb per bag Type _____

Bentonite Slurry: ___ bags of ___ kg/lb per bag Type _____

Grout:

Cement: ___ bags of ___ kg/lb per bag Type _____

Bentonite: ___ bags of ___ kg/lb per bag Type _____



Measuring Point is Top of Well Casing
Unless Otherwise Noted

* Depth Below Ground Surface

STANDARD OPERATING PROCEDURE NMI-GW-004

WELL ABANDONMENT

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) provides instructions to decommission and abandon monitoring wells. The methods provided in this SOP are designed to prevent contaminant migration from the ground surface to the water table or between separate aquifer systems.

1.1 Equipment

Abandonment of drilled wells requires the services of a state-licensed drilling subcontractor (Driller). The Driller will provide the equipment needed for well abandonment. A field geologist/engineer will oversee and document the well abandonment. The field engineer/geologist should have appropriate personal protective equipment, a camera, a depth to water meter, a calculator, field logbook, and appropriate instructions and documentation (e.g., Field Plan, maps, Health and Safety Plan, and SOPs) upon arriving at the Site. The field geologist/engineer will identify the well proposed for abandonment and verify that it is the correct well by measuring the total depth of the well and comparing this measurement to well construction records. A depth to water measurement will also be taken and recorded prior to commencing with abandonment activities.

2.0 PROCEDURES

The EPA preferred method of well abandonment requires the following steps:

1. Remove well casing and screen;
2. Clean out borehole;
3. Backfill the cleaned bore hole with cement, bentonite grout, neat cement, or concrete; and
4. Notify appropriate state agency.

2.1 Removal of well screen and casing (for Well 1 to 4-inch in Diameter)

The driller will remove the protective standpipe taking caution to minimize damage to the well riser. The driller will then attempt to pull the well riser and screen intact from the borehole. If the riser and screen cannot be pulled out of the borehole, a tremie pipe will be lowered to the bottom of the screen and a volume of cement bentonite grout equal to the well screen and riser will be pumped in. The driller will excavate around and cut the well riser approximately 3 feet below the ground surface. If the grout settles after placement, then additional grout will be poured into the well to bring the grout up to the top.

If required by the regulatory agencies or remedial investigation contractor, the driller will then over-drill the original borehole using a hollow-stem auger to remove any remaining well materials. The resulting borehole shall then be backfilled using a cement and/or bentonite grout

placed using a tremie pipe. The tremie pipe shall initially extend to the base of the well and be raised as the borehole is filled, keeping the end of the tremie pipe 1 to 3 feet above the top of grout. Grout shall be allowed to rest for 24 hours after which time additional grout shall be added if needed to fill the borehole. The ground surface at the borehole should be restored to the condition of its surroundings by adding clean fill, grass seed, cold patch or concrete. If the well is located in a heavily trafficked area, a design may be needed for the patch covering the former well location.

2.2 Removal of well screen and casing (Well >6-inch Diameter or Old Corroded Wells)

A hollow stem auger may not be practical for the removal of a well that is larger than 6-inch diameter. In such cases, a solid stem auger or tapered well assembly may be able to extract the casing and screen from the borehole.

Old wells with corroded casing and/or surrounded by thickly grouted annular space will typically break or twist within a borehole. If the well is in poor condition and unable to remove without potentially leaving pieces of the broken well or creating voids, the casing and screen can be left in the borehole. For these wells, the borehole may be tremie grouted using cement-bentonite grout. The casing can then be cut even with the ground surface of up to 3 feet below the ground surface. The resulting void from the cut well can then be filled with concrete to two feet below ground surface. The top two feet can then be restored by placing fill, topsoil and grass; or by placing fill and pavement.

STANDARD OPERATING PROCEDURE NMI-GW-005

GROUNDWATER SAMPLING USING HYDROPUNCH II™

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for collecting groundwater samples using a Hydropunch II™ groundwater sampler. The Hydropunch II™ is a stainless steel and Teflon sampling tool that connects to a drive pipe. The Hydropunch II™ is pushed into the formation and then opened at the target depth to allow formation water to flow into the tool and be collected.

The Hydropunch II™ can be operated in two modes: groundwater sampling and hydrocarbon sampling. The groundwater sampling mode consists of a sample camber with two check valves at either end of the chamber. The tool is driven to a specified depth below the water table, and then it is opened at the drive point to allow formation water to flow into the chamber. When the tool is retracted, the check valves close, trapping the water in the chamber. The groundwater can then be poured into sample vials at ground surface. The hydrocarbon sampling mode for a Hydropunch II™ uses a disposable well screen and no check valves. The tool is driven to the sampling depth and opened to expose the screen and allow formation water to enter the sample chamber. This formation water is then collected through the drive pipe by lowering a bailer or sample pump tubing to the Hydropunch II™.

1.1 Objective

The objectives of using Hydropunch II™ for groundwater sample collection include assessing presence/absence of contamination, determining monitoring well placement location, or estimating groundwater flow patterns. The Hydropunch II™ in hydrocarbon mode can be used to collect water across the water table or across formations to assess vertical contaminant profile.

1.2 Equipment

The following list of equipment may be utilized when using Hydropunch II™ for groundwater sampling:

- Hydropunch II™ tooling
- 1-inch I.D. stainless steel or disposable bailer;
- Drill rig or wireline hammers
- Water for decontamination and grout mixing;
- Decontamination supplies
- Daily field forms or field logbook
- Sample containers

- Inertial pump and dedicated tubing – in case samples are to be collected at continuous intervals
- Required personal protective equipment (gloves, boot, eye wear, hard hat, etc.)

2.0 PROCEDURES

The following procedures should be followed for collecting groundwater samples using Hydropunch II™. Note that sampling depth should be pre-determined before advancing the Hydropunch II™. For pre-drilled locations, ensure the hole terminates at least 2 feet above the sampling zone of interest.

Knowledge of the site hydrogeology is helpful to estimate the duration a Hydropunch II™ chamber may take to fill; the chamber volume for a Hydropunch II™ in groundwater sample mode is approximately 1.2 liters so low yielding formations may require substantial time for this volume of water to flow into the chamber. Groundwater collected using Hydropunch II™ may also be turbid which can pose a problem for some analytes.

It is recommended that field teams review manufacturer/supplier instructions when attaching the tool to drill rods and/or adjusting tool valves and fittings. A general procedure for Hydropunch II™ sampling is below.

1. Assemble the Hydropunch II™ per manufacturer instructions and then attach the Hydropunch II™ to drill rods - Ensure all connections are tightly sealed.
2. At each sampling location, drive the tool using drill rig to the specified depth. It is recommended that this is at least 5 feet below the top of the water table (when using the groundwater sample mode). Then retract rods at least two feet to open the tool. Allow the tool to rest at the sampling depth while formation water flows into the chamber.
3. Retract the tool to the surface. As the tool is being retracted, the check valves should close under hydrostatic pressure thereby trapping formation water in the chamber.
4. Detach the tool from the drill rods and then invert the tool to pour groundwater into sample bottles.
5. If using the Hydropunch II™ in hydrocarbon mode, a bailer or pump tubing must be lowered through the drill rods to the Hydropunch II™ to collect the formation water.
6. Label sample bottles and record sample description, including location, depth, and driving-probe condition, into the field report forms.
7. Decontaminate the Hydropunch II™ following procedures outlined in SOP NMI-007 before moving to the next sampling location.

3.0 BOREHOLE ABANDONMENT

Following the completion of the Hydropunch II™ sampling, the hole remaining from the tooling can be abandoned by filling the hole with bentonite grout via a tremie pipe as described in SOP NMI-GW-004.

4.0 REFERENCES

1994. "Alternative Groundwater Sampling Techniques." *New Jersey Department of Environmental Protection Site Remediation Program: Groundwater Sampling with the use of a HydropunchR Direct Push Sampler.*

2015. "California Environmental Protection Agency: State Water Resources Control Board." *Water Quality Petitions.*

Edge, Russel W, and Kent Cordry. 2007. *The HydroPunch: An In Situ Sampling Tool for Collecting Groundwater from Unconsolidated Sediments.*

2011. *New Jersey Department of Environmental Protection Site Remediation Program: Groundwater Sampling with the use of a HydropunchR Direct Push Sampler.*

STANDARD OPERATING PROCEDURE NMI-GW-006

GROUNDWATER PROFILING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for collecting groundwater samples during rotosonic or direct push technologies (DPT) drilling using Push-Ahead™, Hydropunch™, orWaterloo samplers. Sequencing of tooling advancement and methods may vary based on borehole conditions or the formation. The objective of collecting groundwater samples during drilling is to characterize groundwater conditions at the profiling locations.

1.1 Equipment and Supplies

Pumps and probes may differ depending on the well diameter, groundwater constituents, depth to groundwater and sampling device, but generally, sampling will require the following equipment:

- Peristaltic, submersible, or double-valve pump and appropriate power supply. The pump type will principally depend on the depth to water and well diameter;
- Sample collection equipment (e.g., Push-Ahead™, Hydropunch™) and appropriate connections to drill rig;
- Field probe and flow-through cell (e.g., YSI) for measuring pH, temperature, conductance (and/or specific conductance), dissolved oxygen and oxidation-reduction potential of groundwater, and a turbidity meter;
- Water level tape;
- Tubing, connections and tools as appropriate. PTFE (Teflon®) or PTFE-lined polyethylene tubing should not be used when sampling for PFAS. A suitable alternative, such as high-density polyethylene tubing should be used;
- 5-gallon bucket and funnel for purge water;
- Field forms, notebook and PPE (as specified in the Health and Safety Plan);
- Decontamination supplies (e.g., water, Alconox soap, spray bottles, paper towels);
- Sample containers and cooler (typically provided by the laboratory);
- Paper towels and miscellaneous supplies;
- Boring abandonment materials (typically provided by the drilling company); and
- Air monitoring equipment (as specified in the Health and Safety Plan).

2.0 PROCEDURES

2.1 Pre-Mobilization Activities

The following activities should be performed prior to mobilizing to the Site:

- Obtain the desired sampling depth(s) for each location.
- Obtain a listing of parameters that will be measured in the field or laboratory as part of the sampling program. This may include the required analytical method, sample volume, holding time for each analytical parameter and target maximum turbidity or stability criteria of other field parameters necessary to sample.
- Order or obtain all necessary equipment for sample collection.

2.2 Calibration

Prior to sampling or at the start of each field day, the field meters should be calibrated consistent with the manufacturer's specifications and SOP NMI-003 (Calibration of Field Instruments – ORP, NTU, and DO Meters), as appropriate. At the end of the day, the field meter accuracy should be checked for all parameters being monitored by comparing it to the appropriate calibration solutions.

2.3 Push-Ahead Profiling with Sonic

The Push-Ahead™ sampler consists of a 2-7/8-inch inner diameter drill rod threaded onto a carbide tipped drive point with flanges and sampling ports. The drive point sampling ports have a steel machined seal that remains closed until the tool is advanced to the desired sampling interval. Once the flanged drive tip is seated at the correct interval, the sampling ports are exposed by rotation of the drill rod. The sampling ports typically consist of four ¼-inch holes through the base of the sampler drive head.

The Push-Ahead™ sampler is installed after the core barrel and outer casing are advanced to the chosen depth interval using standard sonic drilling technologies. After the removal of the core barrel, a decontaminated and sealed Push-Ahead™ sampler is inserted through the outer casing to the bottom of the boring. The Push-Ahead™ sampler is then driven beyond the bottom of the outer casing and into virgin material. The sampler is driven beyond the zone of influence from any induced drill fluids (approximately 5 to 15 feet in advance of the outer casing depending on lithology). A water level meter will then be lowered within the drill rods to verify the seal and ensure drilling fluid has not entered the drive point assembly. Once the seal is verified, the water level meter will be removed and the Push-Ahead™ sampler will be opened to allow formation water to enter the drill rods through the sampling ports. The water level meter will then be re-lowered into the drill rods to verify formation water has entered the drill string. A submersible pump, plastic sample tubing connected to a peristaltic pump at the surface, or a bailer is then lowered through the drill rods to the top of the sampler to extract formation water. If using a

pump, groundwater can be purged and sampled once the desired turbidity and/or other field parameter stability has been achieved.

2.4 Hydropunch Profiling with Direct Push

The Hydropunch II™ sampling tool is composed of stainless steel and Teflon and connects to the end of a direct push drill rod as described in SOP NMI-GW-005. The tool is advanced to a specific depth in the formation where it is opened to allow formation water to flow into the tooling to be collected. The Hydropunch II™ can be operated in two modes: groundwater sample and hydrocarbon sample.

See the Groundwater Sampling Using Hydropunch II™ SOP NMI-GW-005 for additional information and specifications.

2.5 Waterloo Profiling with Direct Push

The Waterloo Profiler is a 6-inch long sampling tool composed of stainless steel with a fine-mesh screen covering several sampling ports. The tool is connected to DPT drill rods and advanced to the desired sample depth. As it is pushed into the formation, distilled or deionized organic-free water is pumped down tubing running through the drive rod to the sample ports of the Waterloo Profiler (via a peristaltic pump for depths less than 25 feet, or a double-valve pump if sampling greater depths). This water flow prevents groundwater from entering the sampling ports as the tool is advanced. When the first target depth is reached, pump flow is reversed thereby collecting groundwater. Water is purged in order to obtain a representative sample of the aquifer at a specified depth. After samples have been collected, the pump flow is reversed again to pump water into the sampler (and into the formation) as the profiler is advanced to the next sample depth. This process is repeated for as many depths as needed.

3.0 SAMPLING PROCEDURES

Sample collection procedures will vary by profile sampling method/tooling, but generally samples will be collected either as grab samples or, if using a pump, will be collected after field parameter measurements have stabilized.

If all the below parameters are to be analyzed, sample containers are to be filled in the order listed below using the following protocols:

1. Volatile organic compound (VOC) samples will be collected first. Sample containers are to be completely filled so that a meniscus forms over the opening of the container. The container lid will be moistened with groundwater and screwed to the container body. The container is then inverted and inspected for air bubbles. If air bubbles exist in the container, then it is "topped off" to eliminate bubbles. This procedure is repeated until there are no entrapped bubbles in the container. Filled samples should then be stored on ice at 4°C (±2°C).

2. Semi-volatile organic compound (SVOC) samples will be collected second. Water will be dispensed into SVOC sampling containers provided by the laboratory, typically without a preservative. Sample containers will be filled to the neck of the jar and the lid will be screwed shut. Filled samples should then be stored on ice at 4°C (±2°C).

3. Remediation General Permit (RGP) parameters (if sampled) or samples for geochemical parameters will be collected third. These parameters will be collected in containers supplied by the laboratory and collection procedures will follow recommendations from the laboratory. Container size, quantity, and preservative information is provided in the QAPP.

4. Total and dissolved metals will be collected last. Samples should be collected into containers provided by the laboratory with the appropriate preservative. For dissolved metals samples, a 0.45 micrometer (µm) filter will be placed in line as samples are collected. Approximately 100 mL of purge water should be run through to rinse the filter before collecting samples. The sampler should make sure that no air bubbles remain in the filter prior to collecting the samples.

Note that some samples require a preservative which will be dispensed to the container by the laboratory prior to the sampling containers being shipped to the site. Care will be taken not to spill the preservative or overflow the container. Samples containing preservative cannot be emptied and refilled, so they must be collected without air bubbles on the first filling attempt or carefully topped off.

Following sample collection, bottles must be labeled, logged onto the Chain of Custody, and placed in a cooler at 4°C (±2°C). See Sample Custody and Shipping SOP NMI-001 for additional information and specifications.

4.0 DOCUMENTATION

Field documentation includes completed calibration records, daily field logs, sampling purge records, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody), and that the level of documentation is consistent among different personnel.

5.0 DECONTAMINATION PROCEDURES

Non-dedicated equipment will be decontaminated prior to collecting additional samples. However, the Waterloo Profiler will not be decontaminated between collection of samples as it is pushed to successively deeper sampling intervals during each tooling run.

See Field Equipment Decontamination SOP NMI-007 for additional information and specifications.

STANDARD OPERATING PROCEDURE NMI-GW-007

DOWNHOLE GROUNDWATER FIELD PARAMETER MEASUREMENT

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in downhole groundwater field parameter measurement at contaminated sites.

1.1 Objective

The objective of downhole groundwater field parameter measurement is to monitor in-situ field parameters such as temperature, dissolved oxygen, oxidation reduction potential, specific conductivity, and pH in the water column of an open borehole or well with a long screened interval using a sonde (e.g., YSI 600 series). These parameters are used to profile the water column and identify intervals which exhibit different water quality parameters compared to the rest of the water column. Changes in water quality along an open borehole or long screen could indicate the presence of bedrock fractures, high permeability strata or differing geology.

1.2 Equipment

The following equipment may be utilized when measuring downhole groundwater field parameters. Site-specific conditions may warrant the use or deletion of items from this list.

- Alconox or other non-phosphate concentrated soap;
- Water for equipment decontamination;
- Pump sprayer;
- Two large plastic wash basins or buckets;
- Paper towels or single-use rags;
- Water level meter;
- YSI 600 Series multiparameter sonde (or equivalent);
- A spool of cable connecting the sonde to the handheld unit;
- A solid or hollow PVC slug similar in diameter to the multiparameter sonde; and
- Personal protective equipment (gloves, eyewear, apron, Tyvek suites, as needed).

2.0 PROCEDURES

The following procedures should be used for downhole groundwater field parameter measurement. Procedures may slightly vary with the specific borehole, objective, equipment used, and parameters being measured.

2.1 Solid Slug Run

The depth to water and total borehole or well depth should be measured and compared to the existing records for the well. A solid or hollow slug should be lowered to the target depth and taken out prior to lowering the sonde into the borehole/well. This is done to avoid risk associated with the sonde becoming lodged in an obstructed or collapsed borehole. This step is crucial in newly drilled open borehole bedrock wells where weathered or unstable rock zones were observed during drilling and in existing wells which have been extensively used for sampling. Once the solid slug is brought back to the surface, it should be decontaminated.

Lowering and raising the slug will result in mixing of the water column, therefore, it is recommended that this step be conducted at least two weeks in advance of the downhole groundwater field parameter measurement. This delay will allow the water column to return to equilibrium and improve the accuracy of measurements during the profiling run.

2.2 Calibration

Prior to the use, the YSI 600 Series sonde (or equivalent) shall be calibrated in accordance with SOP NMI 003. At the end of the day, the probe accuracy should be checked for all parameters being monitored by comparing it to the appropriate calibration solutions.

2.3 Water Column Profiling of Open Boreholes and Screened Wells

Don nitrile gloves prior to handling the equipment and sonde to prevent cross-contamination or contact with the probe. The transport/calibration cup on the sonde should be replaced with the plastic probe guard which protects the sensors from physical damage.

The sonde is lowered carefully down the well until it reaches the top of the water column (if necessary, a water level meter can be used to determine the depth to the top of the water column). The sonde should be fully immersed in water for a short period of time to equilibrate to the temperature of the water column prior to recording field measurements. Using the software on the handheld YSI unit (attached to the sonde), field parameters should be logged at the desired interval as the probe is lowered to the target depth. While lowering the probe down the open borehole, it should be held still at each interval until the parameters have stabilized, at which point the field parameters should be recorded on the field form. Depending on the objective of the water quality profiling, the depth interval(s) and quantity of measurements may vary.

Near the bottom of the borehole, the field staff should lower the sonde slowly; dropping the sonde hard against the bottom of the borehole can damage the probe guard and sensors. In

addition, some fine material (i.e. silt or rock flour) can accumulates at the bottom and it is best not to disturb and mobilize this material into the water column since it may impact the field parameters and scour the sensor tips.

Once the last target depth has been reached and the desired parameters have been logged and recorded, the sonde can be removed from the well and decontaminated.

3.0 DECONTAMINATION

Once the probe and rod have been removed from the borehole, both should be decontaminated in accordance with SOP NMI-007 to prevent the transport and contamination of personnel or other wells/boreholes.

4.0 DOCUMENTATION

Field documentation includes completed calibration records, daily field logs, sampling purge records, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody), and that the level of documentation is consistent among different personnel.

STANDARD OPERATING PROCEDURE NMI-GW-008

DIRECT PUSH DRIVE-POINT PIEZOMETERS

1.0 INTRODUCTION

This operating procedure describes installing drive-point piezometers manually by direct-push methods using a slide hammer, sledgehammer, hydraulically operated hammer/driver or a portable propane-driven hammer. Piezometers are small-diameter observation wells installed to monitor shallow groundwater in a discrete subsurface formation. Piezometers can be installed as permanent well points or for temporary, short term monitoring applications.

1.1 Objective

The objective of this procedure is to describe the installation of piezometers to obtain shallow groundwater information including water levels, hydraulic groundwater flow data, and for groundwater sampling.

1.2 Equipment

The following equipment is needed for drive-point piezometer installation:

- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan;
- Field logbook and/or Piezometer Installation Report;
- Manual Slide Hammer or Sledge Hammer;
- Hydraulic or Propane-powered Hammer and associated power or fuel equipment;
- Drive point piezometer (Solinst Model 615 or equivalent);
- 6 ft. Ruler;
- 0.75-inch, 1-inch or 1.25 inch inside diameter (ID) riser sections, including; schedule 40 PVC, black or galvanized steel, or stainless steel pipe. Associated threaded fittings, couplings, drive head, reducers, etc. to construct riser sections and protective cover caps. No glues or solvents should be used to assemble the piezometer;
- Silicon or HDPE sample tubing to attach to piezometer for groundwater sampling;
- Decontamination equipment

2.0 PROCEDURES

The following steps will be followed during drive-point piezometer installation. Any deviations from these steps should be discussed with the project manager and documented in the field notes.

2.1 Pre-sampling Observations, and Required Data Entries

The information listed below will be recorded in a project Field Log book and/or Piezometer Installation Report form. The following measurements and observations should be made at each location:

- Piezometer Location Number/ID
- Date and Time Installed
- Field Representatives
- Description of Sample Location with Sketch or Map
- Latitude/Longitude (using GPS, collect Waypoint as well).
- Depth profile of Soil/Rock Conditions
- Piezometer Screen and Riser Length and Depth Installed
- Piezometer construction details
- Photograph details (i.e. Picture number, orientation, subject matter, etc.)

2.2 Direct Push Installation

1. Don health and safety equipment (as required by the Health and Safety Plan).
2. Drive-point locations will be selected with respect to specific site conditions.
3. Identify sampling location in field notebook along with other appropriate information.
4. At the sample location, use GPS to collect Latitude/Longitude information as a 'Waypoint.'
5. Decontaminate piezometer components which may contain cutting oil or other potential contaminants (black steel pipe and fittings).
6. Assemble piezometer, riser sections and drive head, and install dedicated sampling tubing to piezometer head.
7. Drive piezometer to the target depth by striking drive head. Add additional riser sections as need to achieve target depth.
8. Following installation, notch or mark the top riser section where depths and water level measurements are to be taken.
9. Install protective cover on riser pipe to protect sample tubing.
10. Fill out Piezometer Installation Report (SOP NMI-008).
11. Label each individual piezometer casings with location ID and screened section depth intervals.

2.3 Decontamination

Piezometer components which are not factory sealed and/or which may contain cutting oil or other potential contaminants (e.g. black steel pipe and fittings) shall be decontaminated prior to piezometer installation. Sample tubing is dedicated and permanently installed in the piezometer for water level measurements and groundwater sampling.

2.4 Documentation

Field documentation including installation details and field observations shall be recorded in daily field logs. It is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel.

PIEZOMETER INSTALLATION REPORT

HALEY ALDRICH

Piezometer No.

Boring No.

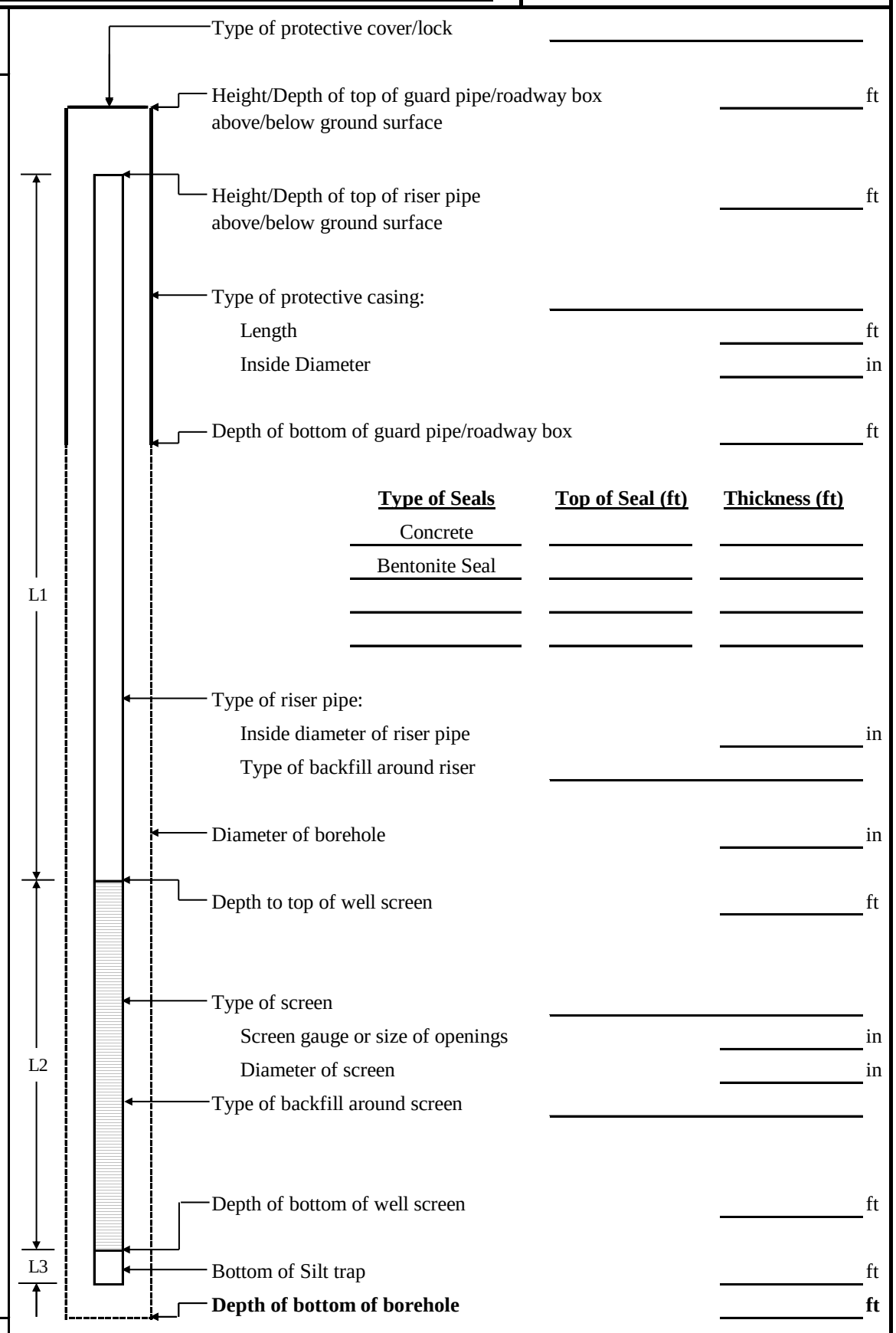
PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP.**	
CONTRACTOR		**DATE INSTALLED**	
DRILLER			

Ground El. _____ ft
El. Datum _____

Location _____

☐ **Guard Pipe**
☐ **Roadway Box**

SOIL/ROCK CONDITIONS	**BOREHOLE BACKFILL**



Type of protective cover/lock _____

Height/Depth of top of guard pipe/roadway box above/below ground surface _____ ft

Height/Depth of top of riser pipe above/below ground surface _____ ft

Type of protective casing: _____

Length _____ ft

Inside Diameter _____ in

Depth of bottom of guard pipe/roadway box _____ ft

Type of Seals	**Top of Seal (ft)**	**Thickness (ft)**
Concrete		
Bentonite Seal		

Type of riser pipe: _____

Inside diameter of riser pipe _____ in

Type of backfill around riser _____

Diameter of borehole _____ in

Depth to top of well screen _____ ft

Type of screen _____

Screen gauge or size of openings _____ in

Diameter of screen _____ in

Type of backfill around screen _____

Depth of bottom of well screen _____ ft

Bottom of Silt trap _____ ft

Depth of bottom of borehole _____ **ft**

(Bottom of Exlporation)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

ft	+	ft	+	ft	=	ft
Riser Pay Length (L1)		Length of screen (L2)		Length of silt trap (L3)		Pay length

COMMENTS: _____

STANDARD OPERATING PROCEDURE NMI-GW-009

WATER LEVEL MEASUREMENT PROCEDURES

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for conducting water level measurements in monitoring wells during field investigations at hazardous and non-hazardous waste sites.

1.1 Objective

The objective of water level measurements is to gain accurate measurements (to within 0.01 ft) of the depth to groundwater from a reference point (e.g., mark on the top of a well casing). This procedure is used during groundwater sampling but may also be used during well installation. Data from water level measurements is commonly used for the preparation of groundwater elevation contour maps, purge volume calculations during groundwater sampling, slug tests, packer tests, and pump tests.

This SOP assumes that an electronic water level meter will be used. There are other (older) methods for obtaining water level measurements; if one of these less common methods is needed, then this SOP should be updated.

1.2 Equipment

The following list of equipment may be utilized during water level measurements. Site-specific conditions may warrant the use of additional or deletion of items from this list.

- Electronic water level indicators – graduated
- Water for decontamination
- Alconox, liquinox or other non-phosphate concentrated laboratory grade soap
- Spray bottles
- Site specific personal protective equipment (e.g., gloves, eyewear, tyvek suits)
- Air monitoring instruments as required (e.g., PID or FID as specified in HASP)
- Field forms (or Field logbook) (SOP NMI-008)
- Well keys
- Previous depth to water measurement data (if available)
- Oil/water interface probe (if necessary)

2.0 PROCEDURES

2.1 General

The following procedures should be followed during water level measurements. Procedures may vary depending on the equipment used and contaminants present at the site.

Site-specific conditions may warrant the use of stringent air monitoring and potentially more significant decontamination scenarios.

1. Record the condition of the well (protective casing, concrete collar, lock in place etc.) on the field form.
2. Check that the water level tape has no obvious kinks or damage.
3. Put on latex or other sterile gloves. Stand upwind of the well; unlock and open the well. If a vented cap is present, conduct well head air monitoring from the vent. If a non-vented well cap is present, remove the cap and monitor air quality at the well head. Record all pertinent air monitoring results (sustained, dissipating, background, odor). Proceed to the nest steps if conditions at the wellhead are safe for field staff.
4. Identify the previous measuring point for the well which may be a marking or notch on the riser or casing (if present). Record this location in the field logbook or on the water level monitoring form.
5. Using a clean (i.e., decontaminated) water level indicator, turn on the meter, check the audible indicator using the test button if present, reel the electronic probe into the well riser (with the increments visible) slowly until the meter sounds. Grasp the tape and slowly raise and lower the probe to the depth where the meter just begins to sound. Check the depth to water on the tape from the measuring point for the well - make a mental note of the depth to within 0.01 feet. Slowly raise and lower the probe again and repeat the measurement to confirm the prior reading. Be careful when reading increments on the tape. It is easy to make a one-foot error in the measurement if the tape is read backwards.
6. Record the depth to water from the measuring point on the field form (or field logbook).
7. Remove the probe from the well using the reel, decontaminate the probe using SOP NMI-007, reseal the well and proceed to the next monitoring location.
8. Procedures utilized during water level measurements where free phase petroleum products are floating on the water table should be modified to include the use of an oil/water interface probe. When gauging free product depth and water depth, the procedures is similar to that described above except the meter will have two sounds – one for free product and another for water. The meter is lowered to the top of free product and raised up/down slightly to accurately measure the depth to the top of free

product. The meter is then lowered to the top of water and raised up/down to measure the depth to the top of water from the measuring point.

2.2 Documentation

Field documentation includes completed calibration records, daily field logs, sampling purge records, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, and that the level of documentation is consistent among different personnel.

2.3 Decontamination

The water level indicator will be decontaminated between each monitoring location. Decontamination shall be performed according to NMI-007. Personnel and PPE decontamination shall be performed in accordance with the HASP.

WATER LEVEL DATA

Geosyntec
consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Project Name: _____
Project Number: _____
Date: _____
Field Personnel: _____
_____
Recorded By: _____
Weather: _____

Measuring Instrument:
Steel Tape
Electric Sounder
Other - Type _____
Instrument Serial Number: _____

Well ID	Time	depth to water (metres / feet)			comments odour, color, sediment load, well condition, presence of product
		1st	2nd	3rd	

STANDARD OPERATING PROCEDURE NMI-GW-010

GROUNDWATER SAMPLING USING THE LOW-FLOW PROTOCOL

1.0 INTRODUCTION

This standard operating guideline provides instructions for groundwater sampling using the EPA low-flow/minimal drawdown well purging protocol. Included in this standard operating procedure are field forms for sampling, instructions and forms for meter calibration, and directions and documentation. When sampling for PFAS compounds, this SOP should be used in conjunction with NMI-GW-011– Groundwater Sampling of Monitoring Wells and Analysis for Per- And Polyfluoroalkyl Substances.

1.1 Equipment and Supplies

Pumps and probes may differ depending on the well diameter, groundwater constituents and depth to groundwater, but generally, sampling will require the following equipment:

- Peristaltic, bladder or Waterra pump capable of a flow rate between 50 and 500 ml/minute and appropriate power supply. The pump type will principally depend on the depth to water and well diameter. Bladder pumps are preferred; peristaltic pumps are acceptable only for wells where the depth to water is less than about 25 feet; Waterra pumps are only recommended for narrow diameter wells that cannot be sampled using a bladder or peristaltic pump. Prior to sampling for per-and polyfluoroalkyl substances (PFAS), please ensure that the pump and all other equipment and supplies as well as sampler clothing used are free of PFAS containing substances including polytetrafluoroethylene (PTFE, i.e. Teflon);
- Field probe and flow-through cell (e.g., YSI) for measuring pH, temperature, conductance (and/or specific conductance), dissolved oxygen and oxidation-reduction potential of groundwater;
- a turbidity meter (unless turbidity is integrated into the field probe;
- Calibration solutions for the field probes;
- Water level tape;
- Tubing, connections and tools as appropriate. PTFE (Teflon®) or PTFE-lined polyethylene tubing should not be used when sampling for PFAS; a suitable alternative, such as high-density polyethylene tubing should be used;
- Graduated cylinder and stopwatch;
- A three-way (T-valve);
- 5-gallon bucket and funnel for purge water;
- Field forms, notebook and PPE (as specified in the Health and Safety Plan);

- Decontamination supplies (e.g., DI water, Alconox soap, alcohol, paper towels);
- Sample containers and cooler (typically provided by the laboratory);
- Clean plastic sheeting, paper towels and miscellaneous supplies; and
- Photoionization Detector (PID) or Flame Ionization Detector (FID). If appropriate, to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

2.0 PROCEDURES

2.1 Pre-Mobilization Activities

- Obtain information (e.g., a table) with the construction, diameter, depth, material, screened interval, to extent available, and a map showing location for each monitoring well or multi-point sampler to be sampled.
- Obtain a listing of the parameters that will be measured in the field or laboratory as part of the sampling program including the required analytical method, sample volume, and holding time for each parameter. The parameters that will be measured in the field are the low flow stabilization parameters including temperature, pH, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity. These parameters will be recorded as required during low flow sampling, and immediately prior to collection of samples for laboratory analysis.
- In some cases, other parameters may be measured in the field using field test kits. Obtain the necessary test kits and supplies (e.g., deionized water).
- If dissolved metals will be analyzed, confirm that the laboratory will provide filters for field filtering of the groundwater samples.

2.2 Pre-Sampling Procedures

Several steps are required before sampling any of the wells. These steps ensure that instruments are functioning and properly calibrated, and that the necessary equipment has been supplied for efficient and accurate sampling.

2.2.1 Inventory

Verify that the correct equipment is ready to be shipped to the field site and that it is clean (decontaminated). Inventory sample containers to verify that the laboratory has provided the correct number of containers of the proper size and contain preservative if required. It is recommended that sample containers are pre-labeled and bundled for each well (and depth at each well, and/or filtered versus non-filtered samples) to limit errors (such as forgetting to fill a bottle) during sample collection.

Verify that the appropriate personal protective equipment and ancillary supplies (e.g., paper towels, decontamination solution) are ready to be shipped to the field site. The appropriate protective equipment, as specified in the site-specific Health and Safety Plan, can be reviewed

during a morning tailgate meeting. Contact the field supervisor or project manager immediately if there are discrepancies.

2.2.2 Calibration

Calibrate the field probes consistent with the manufacturer's specifications and the following at the start of each field day:

1. the pH probe should be calibrated using three points (pH = 4, 7, 10) using fresh calibration solutions;
2. the dissolved oxygen (DO) meter should be calibrated to moist air (100% saturation) and to zero DO using a saturated sodium bisulfite solution;
3. the redox potential (ORP) meter should be calibrated using Zobell 231 mV solution;
4. the specific conductance meter should be calibrated using a potassium chloride or equivalent solution (typically 1413 µS/cm); and
5. the turbidity meter should be calibrated using three points (typically 20, 100, 800 NTU), however exact calibration values may vary by manufacturer.

Record the calibration data on the field calibration record provided in this SOP. Periodic checks of the calibration should be performed during the field day, including a check at the end of the field day. Instruments will be recalibrated as necessary (e.g., when calibration checks indicate incorrect operation) to ensure accurate measurements, and all checks and recalibrations will be recorded on field calibration forms. Also check calibration if any readings are suspect. Although, instruments typically do not require temperature sensor calibration, the accuracy of the sensor should be checked at least once per year. Rental companies should perform the temperature sensor calibration check and include it with the instrument documentation that it was performed. If the information is not included with the instrument, or the last check was over a year, then the accuracy should be checked against a thermometer traceable to National Institute of Standards and Technology (NIST).

Inspect the well for the presence of lock, cap, surface seal integrity, obstructions, evidence of tampering, debris, or surface water collecting in the flush mount. Calibration form is provided in Attachment A.

2.3 Well Purging and Sampling

Sampling is performed using a five-step procedure that will be followed upon arrival at each well:

1. set-up;
2. purging;
3. measurement of field parameters and field testing;
4. sampling; and

5. clean-up.

Detailed procedures for each of these steps are provided in the following subsections. A monitoring well purge record form is provided in Attachment B.

2.3.1 Set-up

All necessary equipment for purging, sampling and sample storage will be brought to the well before the well is opened. Equipment will be placed on a clean plastic sheet near the well. General parameters describing the well and field condition (e.g., well ID, depth, weather, date and time) will be documented on a field data sheet. Sampling begins by screening the well cap area using the PID and, if there are no dangers due to vapors, opening the well. The headspace of the well is then checked again for vapors using the PID (see HASP for action levels)

Next, the sampler will proceed with measuring the depth to the water surface, if possible (this may not possible for the multiport wells) according to the SOP NMI-GW-009. The tubing, field probe, and reservoir for purged water are then set up. A T-valve will be put in line between the pump and the flow-through cell and used to collect turbidity samples before the purged water enters the flow-through cell.

2.3.2 Purging (Low Flow Protocol)

Wells are purged using the low flow/minimum drawdown protocol as described by Puls and Barcelona (1996) and subsequent EPA low-flow protocols. The general procedural requirements for low-flow purging are as follows.

- Lower the pump slowly down the well positioning the pump intake at the middle of the well screen (unless another sampling depth is prescribed in the sampling plan).
- Minimize disturbance of the water column in the well by initiating pumping at a low rate (see below). Dedicated tubing (left in-place between sampling events) is also recommended to minimize disturbance to the water column before and during sampling.
- Begin pumping at a steady rate of 100 mL/min and measure the depth to water frequently (e.g., every minute for the first few minutes) to ensure that less than 0.3 ft of drawdown occurs, in accordance with the USEPA Low Stress (Low Flow) Purging and Sampling Procedure dated September 2017. The pumping rate may be increased if drawdown is less than 0.3 ft, but the pumping rate should not exceed 500 mL/min. In some silty and/or clayey formations, drawdown may exceed 0.3 ft when pumping at 100 mL/min. If possible, decrease the pumping rate to the minimum pumping rate of the pump but not lower than the rate required to "turn over" at least one flow through cell volume between measurements (e.g. every five minutes). If the drawdown exceeds 0.3 ft, purging can continue as long as the drawdown stabilizes. If the drawdown exceeds 0.3 ft, the volume required to be purged before sampling must be greater than the stabilized drawdown volume plus the volume in the tubing. The drawdown volume and the tubing volume can be calculated as follows:

- Stabilized Drawdown (ft) = Stable Pumping Depth to Water (ft) – Initial Depth to Water (ft)
- Stabilized Drawdown Volume = Stabilized Drawdown (ft) * Volume Per Foot for the Well (see table below)

Diameter of Well (inches)	Volume per foot (L)	Volume per foot (Gal)
1	0.154	0.041
2	0.618	0.163
3	1.389	0.367
4	2.470	0.653

- Tubing Volume = Tubing Length (ft) * Volume per foot for a given Tubing Diameter (see table below)

Tubing Diameter (inches)	Volume per foot (L)	Volume per foot (Gal)
0.25	0.010	0.003
0.5	0.039	0.010
0.75	0.087	0.023
1	0.154	0.041

- If the drawdown exceeds 0.3 feet and does not stabilize within two hours of purging, refer to sections below on *Variations from Low Flow Protocol* for alternatives to the low flow/minimum drawdown protocol.
- Field parameters and depth to water will be recorded on field data sheets a minimum of every 5 minutes while purging.
- Turbidity measurements will be collected by closing the valve to the flow-through cell and opening the valve to a separate output stream for filling turbidity vials.
- Measurements using the flow-through cell will be collected after closing the valve to the turbidity stream and opening the valve to the flow-through cell.
- Purging will continue until pH, temperature, specific conductance, ORP, DO concentration, and turbidity stabilize, which is defined as follows:
    - ±0.1 units for pH
    - ±3% for specific conductance
    - ±10 mV for ORP
    - ±3% for temperature
    - ±10% for turbidity and dissolved oxygen.

Dissolved oxygen and turbidity tend to stabilize last. Drawdown should not exceed 0.3 ft during purging or sampling.

In the case that the above criteria for stabilization are not met before three well volumes have been pumped, then up to five well volumes can be pumped and then samples collected. If, at any time during this additional purging, the stabilization criteria are met for three consecutive data logging events, then samples can be collected.

2.3.3 Variations from Low Flow Protocol

Wells in low yield formations, such as poorly fractured bedrock or silt/clay soils, may not yield sufficient water for purging at 100 mL/min without more than 0.3 ft of drawdown. In these cases, a modified low flow method can be used; the choice of which alternative will be made by the project team based on site conditions.

Currently, there is no published protocol for sampling low recharge wells. The two modifications described below have been endorsed at one site by the EPA for sampling and purging wells that yield less than 100 mL/min at a drawdown of 0.3 ft.

Alternative Method 1: Wells with less than half the casing volume located above the well screen

Purge the well with the pump intake located at the mid point of the well screen by constant pumping at a rate no greater than 500 mL/min until the water level reaches the top of the well screen. Measure and record the field parameters and water depth at 5-minute intervals or at the end of every purge cycle, although it may be difficult to obtain stable measurements of certain parameters (i.e., DO, ORP, turbidity). Cease pumping and allow at least 90% of drawdown to recover. Repeat the purging and cessation cycle until a minimum of one casing volume is removed from the well. The well will then be allowed to recover with sufficient volume to collect the required groundwater samples from the midpoint of the screened interval, within 24 hours of the last purging event.

Alternative Method 2: Wells with more than half the casing volume located above the well screen.

The well will be purged with the pump intake located at midscreen at a rate no greater than 500 mL/min until the water level reaches the top of the well screen. This purging will remove at least one-half of a casing volume of water from the well. The well will then be allowed 8 hours to recover, after which time a volume of water equal to the casing volume of the screened interval will be removed, removing approximately a full casing volume during the two purging events. Directly following the second purging event, the required groundwater samples can be collected from the midpoint of the screened interval.

Other Modifications to Low Flow Sampling

Other modifications of the low-flow protocol may be required on a site-specific basis. Low-recharge wells screened across the water table are not amenable to either of the methods described above. It may not be practical to sample extremely low recharge wells using any of

the cited modifications, which case, the field team can evacuate all casing water and re-sample the well as soon as sufficient recharge has entered the well. Data from such wells will be qualified to indicate an alternative sampling approach has been used.

In some cases, none of the above situations apply or are practical. For example, a site may have a low yielding bedrock wells which exhibits >0.3 feet of drawdown during purging, does not stabilize and the depth of the well makes purging a well volume impractical (e.g., a 4-inch diameter bedrock well that is 100-feet deep has a casing volume >65 gallons which would take more than 8 hours to purge at 500 ml/minute). In such cases, the field team should use an approach which balances practicality with sample quality (e.g., collect a sample after two hours of purging even if only some field parameters have stabilize) and appropriate notes should be added to the field form.

2.3.4 Field Measurements

Field parameter measurements will be recorded during purging and following parameter stabilization (purging) (i.e., just before sampling). The pumping rate and sampler intake location in the well are not to be adjusted after purging. The field parameters measured are pH, temperature, specific conductance, DO, ORP, and turbidity.

2.3.5 Sampling

Samples will be collected after field parameters have stabilized and been recorded. The pump rate and sample intake location will not be adjusted between purging and sampling with the exception that the pump rate can be increased after the SVOC samples are taken. Samples are to be obtained from the influent line (prior) to the three-way valve and flow-through cell (i.e., field parameters cannot be measured during sampling). The following sampling strategy is to be followed at each location.

Sampling for VOC and Biodegradation Parameters

Sample containers are to be filled in the order listed below and on the field data sheet using the following protocols:

1. VOC samples will be collected first. Sample containers are to be completely filled so that a meniscus forms over the opening of the container. The container lid will be moistened with groundwater and screwed to the container body. The container is then turned upside down and inspected for air bubbles. If air bubbles exist in the container, then it is "topped off" to eliminate bubbles. This procedure is repeated until there are no entrapped bubbles in the container. Filled samples are stored on ice at 4°C (±2°C).

2. SVOC (including 1,4-dioxane) samples will be collected second. Water will be dispensed into up to two 1000 ml amber glass bottles without a preservative, Sample containers will be filled to the neck of the glass jar and the lid will be screwed shut. Filled samples are stored on ice at 4°C (±2°C). Remediation General Permit (RGP) parameters (if sampled) or samples for geochemical parameters will be collected third.

These parameters will be collected in containers supplied by the laboratory and collection procedures will follow recommendations from the laboratory. Container size, quantity, and preservative information is provided in the QAPP.

3. Total and Dissolved metals will be collected last. Groundwater will be placed into containers provided by the laboratory with the appropriate acid preservative. A 0.45 µm filter will be placed in line to fill sample containers that will be analyzed for dissolved metals. An approximately 100 mL of purge water should be run through the filter as a rinse before collecting samples. The sampler should make sure that no air bubbles remain in the filter prior to collecting the samples.

Note that some samples require a preservative, which will be dispensed to the container by the laboratory prior to bottles being shipped to the site. Care will be taken not to spill the preservative or overflow the container. Samples containing preservative cannot be emptied and refilled, so they must be collected without air bubbles on the first filling attempt or carefully topped off.

2.3.6 Observations During Sampling

Field sampling staff will identify and log any observations that may be considered *unusual* into a field notebook or on the field data sheet for each well. These observations include but are not limited to: excessive bubbling within the tubing or in the sample containers as they are filled; odors such as sulfide; excessive turbidity, solids, or formation of precipitates in the samples; color changes in the water; unusual sounds made by the equipment. In addition, sampling personnel will note the condition of the well upon arrival and inspection. If the well casing is damaged and there are anomalies in the calculated water level at the well, then the casing damage may indicate compromised sample quality.

2.3.7 Storage and Shipping

All samples will be immediately placed on ice (preferably double-bagged wet ice packs) to remain at 4°C (±2°C) prior to and during shipment to the laboratory. The sample containers will be stored in a cooler until further processing. The Chain of Custody forms for each sample suite will be sealed inside of a Ziploc® container (doubled if necessary) and placed in the cooler with the corresponding samples. Fragile material (glass or other breakable sample vials) may be wrapped with bubble wrap or a similar material. Storage, packing, and shipping are provided in SOP NMI-001 - Chain of Custody, Handling, Packing, and Shipping, while procedures for PFAS samples are provided in NMI-GW-011.

2.4 Documentation

Field documentation includes completed calibration records, low flow sampling data sheets, daily field logs and other field notes deemed relevant. It is essential that field data sheets be filled out completely and legibly at each location, and that entries are consistent for each location and among different personnel. As referenced above, low-flow data and calibration forms are

provided with this SOP. The attached field sheets may be modified to represent the specific parameters of interest for a given project, but should include the following information:

- Job, site, date and sampler;
- Well identification and description;
- Reference elevation and depth to water;
- Casing volume calculation;
- Depth of pump intake during purging and sampling;
- check list of items for pre-sampling well condition inspection;
- Equipment used (field probes, tubing, model and serial numbers);
- Purge rate, field parameters (temperature, conductivity, DO, ORP, pH, and, if specified, turbidity) and depth to water recorded every 5 minutes;
- Sampling parameters;
- Stabilized field parameters;
- Identification, time, container types, preservatives, and analytical methods for samples; and,
- Space for comments.

Sample documentation must include a Chain of Custody form (COC) which logs all samples collected and analyses to be performed. The COC must remain with the samples and it is recommended that the COC be complete as samples are collected and placed into the cooler. The COC must document each time the samples are relinquished (e.g., sample team to lab courier). Typically, the laboratory provides a blank COC and the field team completes the COC.

3.0 REFERENCES

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U.S. Environmental Protection Agency, Region 1, Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. Quality Assurance Unit. EQASOP-GW4, Revision 4. September 19, 2017.

METER CALIBRATION REPORT

Geosyntec consultants
289 Great Road, Acton, MA 01720
Phone: 978-263-9588, Fax: 978-263-9594

Project Name:		Date:	Page ____ of ____
Project Number:		Primary Activities:	
Field Personnel:			
Recorded By:		Weather:	
Sampler's Initials:			

Meter Summary

Meter	Make/Model (ex. YSI 600XL)	Serial #	Rental Company	Rental Company ID #
Multi-Parameter Probe (pH, DO, ORP, Conductivity)				
Turbidity Meter				

dissolved oxygen (DO) and pH calibration		dissolved oxygen calibration solutions		pH buffer solutions		
		100%	0 mg/L	4.01	7.00	10.00
initial	temperature (°C)					
	instrument reading					
	Calibrated To		N/A			
	Final Reading					
final	temperature (°C)					
	instrument reading					
	Post Cal Check Pass (yes/no)					

Specific conductivity, ORP[1] and turbidity calibration ([1]check temperature correction)		Specific conductivity calibration	ORP[1] calibration solution (Zobell)	turbidity calibration solutions		
		_____ µs/cm @ 25 °C	_____ mV Ag/AgCl @ 25 °C	#1	#2	#3
				____ NTUs	____ NTUs	____ NTUs
initial	temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Calibrated To					
	Final Reading					
final	Temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Post Cal Check Pass (yes/no)					

initial calibration completed at: _____ (time)	final calibration check completed at: _____ (time)

Comments (DO membrane changed, other equipment issues, etc)

[1]*See Back for Temperature Correction*

ORP (Zobell Solution)

mV	**-5°C**	**0°C**	**5°C**	**7.5°C**	**10°C**	**12.5°C**	**15°C**	**17.5°C**	**20°C**
Ag/AgCl	270.0	263.5	257.0	253.8	250.5	247.3	244.0	240.8	237.5
mV	**22.5°C**	**25°C**	**27.5°C**	**30°C**	**32.5°C**	**35°C**	**40°C**	**45°C**	**50°C**
Ag/AgCl	234.3	231.0	227.8	224.5	221.3	218.0	211.5	205.0	198.5

Post Calibration Criteria

Dissolved Oxygen	± 0.5 mg/L of sat. value, < 0.5 mg/L for the 0 mg/L solution, but not a negative value
Specific Conductance	±5% of standard or ± 10 *µs/cm (whichever is greater)*
pH	± 0.3 pH unit with pH 7 buffer*
ORP	± 10 mv*
Turbidity	± 5% of standard

Note: * Table 8.1, USEPA Region 1 *YSI6-Series Sondes and Data Logger SOP*, January 27, 2016, revision 13.

MONITORING WELL DEVELOPMENT PURGING & SAMPLING RECORDS

Geosyntec consultants
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Acton, Massachusetts, 01720
(978)263-9588 Fax(978)263-9594

Well ID:_____ Well Diameter:_____ Intake Depth:_____
Project Name:_____ Total Depth of Well:_____
Project Number:_____ Initial Depth to Water:_____ Time:_____
Date:_____ Casing Volume:_____
Recorded By:_____ Depth to Water after Purging:_____ Time:_____
Sample ID:_____ Method of Purging:_____
Duplicate ID:_____ Method of Sampling:_____
Weather:_____ Multi-meter ID:_____ Turbid ID:_____

Time	Depth to water	Pumping rate	Cumulative volume	Temp	pH	Specific conductance	D.O	ORP	Turbidity	Comments
	(ft btoc)	mLpm	L or gals	°F or °C	(units)	(µS / cm)	(mg / L)	(mV)	(NTU)	odor, color, sediment load, well condition, presence of product

Samples collected	Time collected	Container type	Container size	Preservative

Notes: (well condition, nearby activities or changes in land use, odors, problems, deviations from plan, etc.)

Stability according to the United States Environmental Protection Agency - Region 1 requires **three readings spaced at least five minutes apart as follows**[1]:

Parameter	Within
pH:	0.1 unit
Specific Conductivity:	3%
Dissolved Oxygen:	10% or under 0.5mg/L
ORP:	10mV
Turbidity:	10% for values over 5 NTU or 3 readings under 5 NTU
Temperature:	3%

1. EPA. (2017). Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. North Chelmsford, MA.

STANDARD OPERATING PROCEDURE NMI-GW-011

GROUNDWATER SAMPLING OF MONITORING WELLS FOR PER- AND POLYFLUOROALKYL SUBSTANCES

1.0 INTRODUCTION

1.1 Purpose and Scope

Standard operating procedures (SOPs) were prepared to guide per- and polyfluoroalkyl substance (PFAS) sampling activities. This SOP describes recommended procedures to be used by field personnel when collecting groundwater samples from monitoring wells. Because PFAS are potentially present in a variety of materials that may come into contact with water samples, and because laboratory analytical method detection limits are low (low to sub nanogram per liter concentrations), conservative precautions are recommended to avoid sample cross-contamination and false positive results. The procedures in this SOP are consistent with best practices at the time of authoring.

1.2 Referenced Documents and SOPS

- NMI-GW-010 Groundwater Sampling Using the Low-Flow Protocol.
- *de maximis*. 2020. Field Sampling Plan (FSP). Remedial Design and Remedial Action, Nuclear Metals Superfund Site., Concord, Massachusetts.
- *de maximis*. 2020. Quality Assurance Project Plan (QAPP), Remedial Design and Remedial Action, Nuclear Metals Superfund Site., Concord, Massachusetts.
- Massachusetts Department of Environmental Protection, 2018. Interim Guidance on Sampling and Analysis for PFAS at Disposal Sites Regulated under the Massachusetts Contingency Plan. Fact Sheet. 19 June.
- Massachusetts Department of Environmental Protection, 2019. Field Sampling Guidelines for PFAS, Using EPA Method 537 or 537.1. MassDEP Drinking Water Program. February.

1.3 Definitions and Acronyms

1.3.1 Definitions

Bladder pump	A positive displacement pump that is acceptable for collection of all analytes and depths. Can be small enough to sample from wells as small as 3/4-inch in diameter.
Dedicated equipment	Equipment that is installed in or used in just one monitoring well for purging and sampling, and that remains in that well for the duration of the monitoring program or is used new and then discarded for each event and well. Dedicated equipment does not need to be decontaminated between sampling events.

Inertia pump	A riser tube fitted with a one-way foot valve. Best used on small diameter wells (2 inches or less). No depth restriction except for the weight of the water-filled tubing.
Peristaltic pump	A positive displacement pump that can be used to move fluids at a fixed rate. Peristaltic pumps are typically used if the depth to water is less than approximately 25 feet; ineffective for depths to water exceeding 33 feet.
PFAS-free water	Water that has been analyzed by an accredited laboratory (see Section 3.1) and determined to be below the method detection limit (i.e., non-detect) for the suite of PFAS to be analyzed for in environmental samples. Method detection limits (MDLs) used during analysis of PFAS- free water should be at or below the MDLs used for environmental samples.
Potable water	Water that meets state and federal drinking water requirements. Note this water may or may not have detectable PFAS concentrations.
Submersible pump	A positive-pressure pump that is acceptable for collection of all analytes. Achievable depths are limited by the power of the pump and length of wiring. Well must typically be at least 2 inches in diameter to fit these pumps.

1.3.2 Acronyms

ASTM	American Society for Testing and Materials
CoC	chain of custody
DO	dissolved oxygen
DoD	Department of Defense
DOT	Department of Transportation
ETFE	ethylene tetrafluoroethylene
FEP	fluorinated ethylene propylene
HDPE	high-density polyethylene
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
LDPE	low-density polyethylene
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate

ORP	oxidation-reduction potential
PFAS	per- and polyfluoroalkyl substances PFTE polytetrafluoroethylene
PPE	personal protective equipment
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
QA	quality assurance
QC	quality control
QSM	quality systems manual
SOP	standard operating procedure
SOG	standard operating guidance
USGS	United States Geological Survey

1.3.3 Equipment and Products

Sections 1.3.1 and 1.3.2 detail items that are safe to use versus not recommended for use on the job site to protect PFAS samples from potential cross-contamination. Science-based evidence is not currently available to support a determination of the realistic impact of these commonly used field items and materials on PFAS samples. In the absence of scientific-based sampling guidance, field staff, contractors, and analytical laboratories should try to avoid using items that may pose a risk for cross-contamination and false positive results and instead use acceptable alternatives identified in this section when feasible. If the field team needs to use products and equipment on site that are not recommended, additional quality assurance/quality control (QA/QC) samples may be collected to evaluate any potential impact on PFAS environmental samples. This information is also provided in an abbreviated format as a checklist for field staff to reference (Attachment A). The information provided herein is consistent with the MassDEP field sampling Guidelines for PFAS using Method 537 or 537.1 (MassDEP, 2019).

1.3.4 Field Equipment

Items that are safe to use on site when sampling for PFAS include the following:

- Sampling containers, screw caps and other equipment made from high-density polyethylene (HDPE)[1], polypropylene, silicone, acetate, or stainless steel;
- Sample preservatives (e.g., Trizma®);
- QA/QC samples (e.g., temperature and field blanks);

[1] HDPE plastics are commonly identified by a recycling symbol with a number 2 inside it.

- Sample container labels;
- Low-density polyethylene (LDPE)[2] materials not in direct contact with the sample (e.g., Ziploc® bags);
- Materials made of HDPE, silicone, acetate, or stainless steel;
- Masonite or aluminum clipboards;
- Ballpoint pens;
- Sampling forms, loose paper or field notebooks, chain of custody (CoC) record, and sample container labels;
- Alconox®, Liquinox® and Luminox® detergents (Liquinox® is acceptable for PFAS sampling but shall not be used for decontamination of sampling equipment used for collection of media to be submitted for analysis of 1,4-dioxane);
- Paper towels;
- Trash bags;
- HDPE sheeting;
- Hard-shell coolers;
- Shipping and handling labels;
- Regular (wet) ice;
- Bubble wrap;
- Duct tape and packing tape;
- Large (e.g., 55-gallon) containers;
- Submersible pumps, bladder pumps, peristaltic pumps, and inertia pumps that do not have Teflon components;
- Dedicated Silicon and/or HDPE tubing;
- Analytical field meter (e.g., temperature, pH, conductivity, oxidation-reduction potential [ORP], dissolved oxygen [DO], and turbidity);
- Water level probe(s); and
- Paper towels made with virgin materials.

Items to be avoided (i.e., not recommended) when sampling for PFAS include the following:

- Glass sample containers, due to PFAS adherence to glass surfaces;
- Water-resistant paper, notebooks, and labels (e.g., certain Rite in the Rain® products), due to use of PFAS in water-resistant inks and coatings;

[2] LDPE plastics are commonly identified by a recycling symbol with a number 4 inside it.

- Sticky notes (e.g., certain Post-It® products), due to potential use of a paper coating product Zonyl™ or similar fluorotelomer compounds;
- Plastic clipboards, binders, and spiral hardcover notebooks;
- Pens with water-resistant ink;
- Felt pens and markers (e.g., certain Sharpie® products) – some PFAS SOPs (e.g., Michigan) specifically allow Fine or Ultra-Fine Point Sharpies® and TestAmerica Laboratories, Inc. routinely uses Sharpies® in the laboratory following unpublished analytical tests that reportedly showed no impact on PFAS sample results;
- Aluminum foil, as PFAS are sometimes used as a protective layer;
- Decon 90™ liquid detergent, which reportedly contain fluorosurfactants;
- Chemical (e.g., blue) ice packs, unless it is contained in a sealed bag. Blue ice has the potential to be contaminated from previous field sampling events;
- Materials containing polytetrafluoroethylene (PFTE) including Teflon™ and Hostaflon® (e.g., tubing, tape, plumbing paste, O-rings);
- Equipment with Viton™ components (i.e., fluoroelastomers);
- Stain- or water-resistant materials, as these are typically fluoropolymer-based;
- Material containing LDPE, particularly if used in direct contact with the sample (e.g., LDPE tubing, as PFAS can sorb to the porous tubing); and
- Material containing "fluoro" in the name – this includes, but is not limited to, fluorinated ethylene propylene (FEP), ethylene tetrafluoroethylene (ETFE), and polyvinylidene fluoride (PVDF).
- Paper towels and other paper products made from recycled materials

1.3.5 Clothing, Personal Protective Equipment (PPE), and Consumer Products

Items that are safe to use on site when sampling for PFAS include the following:

- Boots made of polyurethane, polyvinyl chloride (PVC), rubber, or untreated leather;
- Other field boots covered by PFAS-free (e.g., polypropylene) over-boots;
- Rain gear made of neoprene, polyurethane, PVC, wax-coated, vinyl, or rubber;
- Clothing made of synthetic (e.g., polyester) or natural (e.g., cotton) fibers;
- Safety glasses;
- Reflective safety vests;
- Hardhats;
- Disposable powder-free nitrile gloves;

- Uncoated HDPE suits (e.g., certain Tyvek® products); and
- Bottled water and hydration drinks.
- Sunscreens [3] and insect repellants[4] that have been tested and found to be PFAS-free.

Items to be avoided (i.e., not recommended) when sampling for PFAS include the following:

- Water- or stain-resistant boots and clothing (e.g., products containing GORE-TEX®);
- Clothing recently laundered with a fabric softener;
- Coated HDPE suits (e.g., certain Tyvek® products);
- Sunscreen and insect repellants containing fluorinated compounds as ingredients, such as polyfluoroalkyl phosphate esters;
- Latex gloves;
- Cosmetics, moisturizers, hand cream, and other related products containing fluorinated compounds as ingredients, such as polyfluoroalkyl phosphate esters;
- Food wrappers and packaging; and
- Food and drinks other than bottled water or hydration drinks.

Field staff should try to find acceptable alternatives to these items that still allow them to complete the field work safely and efficiently. For example, wearing long-sleeved clothing and a hard hat or sun hat may eliminate the need to use sunscreen in some climates. If an item cannot be easily

[3] Examples of PFAS-free sunscreens include Alba Organics Natural, Aubrey Organics, Banana Boat Sport Performance Sunscreen Lotion Broad Spectrum SPF 30, Banana Boat for Men Triple Defense Continuous Spray Sunscreen SPF 30, Banana Boat Sport Performance Coolzone Broad Spectrum SPF 30, Banana Boat Sport Performance Sunscreen Stick SPF 50, Coppertone Sunscreen Lotion Ultra Guard Broad Spectrum SPF 50, Coppertone Sport High-Performance AccuSpray Sunscreen SPF 30, Coppertone Sunscreen Stick Kids SPF 55, Jason Natural Sun Block, Kiss my Face, L'Oréal Silky Sheer Face Lotion 50+, Meijer Clear Zinc Sunscreen Lotion Broad Spectrum SPF 15, 30 and 50, Meijer Wet Skin Kids Sunscreen Continuous Spray Broad Spectrum SPF 70, Neutrogena Beach Defense Water + Sun Barrier Lotion SPF 70, Neutrogena Beach Defense Water + Sun Barrier Spray Broad Spectrum SPF 30, Neutrogena Pure & Free Baby Sunscreen Broad Spectrum SPF 60+, Neutrogena Ultra-Sheer Dry-Touch Sunscreen Broad Spectrum SPF 30, Yes to Cucumbers, and sunscreens for infants. Products with fluorinated compounds as ingredients (e.g., polyfluoroalkyl phosphate esters) should not be worn during sampling.

[4] Examples of PFAS-free insect repellent include Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus Insect repellant, Herbal Armor, California Baby Natural Bug Spray, BabyGanics, OFF! Deep Woods® spray for clothing and skin, Sawyer® do-it-yourself permethrin treatment for clothing, Insect Shield Insect® pretreated clothing, DEET products, and sunscreen/insect repellent combination product Avon Skin so Soft Bug Guard-SPF 30. Products with fluorinated compounds in their ingredients (e.g., polyfluoroalkyl phosphate esters) should not be worn during sampling.

avoided, additional consideration should be given to QA/QC samples to evaluate the potential impact of sample cross-contamination (e.g., field blanks).

2.0 FIELD PROCEDURES

2.1 Pre-Mobilization Activities

2.1.1 Health and Safety Plan

Prior to each field event, the site health and safety plan should be reviewed and updated, as necessary. Health and safety plan requirements should be reviewed for consistency with this SOP and modified as appropriate to resolve any differences.

2.1.2 Laboratory Coordination

Field personnel should communicate with the laboratory that will conduct PFAS analysis regarding the following items:

- Laboratory accreditation for PFAS analysis (see Section 3.1);
- Appropriate sample containers, labels, and preservatives (see Sections 2.2.3 and 2.2.4);
- Sample storage conditions and holding time (see Section 2.2.5); and
- The number and type of QA/QC samples (see Section 2.3).

Because there is no standard United States Environmental Protection Agency method for analyzing PFAS samples in media other than drinking water, commercial laboratories typically offer analysis for a suite of approximately 24 PFAS using a modified version of Method 537 or recently published Method 537.1. Laboratories may have developed their own variations. Project staff may consider the impact of differences in reported PFAS concentrations and the potential value of collecting and sending a split sample to a second commercial laboratory to assess variability in reported PFAS concentrations.

2.1.3 Equipment Decontamination

Equipment should be decontaminated prior to mobilization to the site if it appears to be contaminated or if there is reason to believe that it is contaminated. Equipment decontamination should follow the steps outlined in Section 2.4.

2.2 Sampling

2.2.1 Pre-Sampling Activities

Prior to the sampling event, field staff can review information from previous groundwater monitoring events to inform their knowledge of well locations, field equipment, and field conditions. Field staff should also identify upgradient wells and downgradient wells relative to

potential source area wells. Wells with the lowest anticipated PFAS concentrations should be sampled first.

At the beginning of each sampling day, field staff should prepare for sampling as follows:

1. Inspect field equipment to ensure that it is in good working order; and
2. Calibrate analytical field meter(s) according to the instrument manufacturers' specifications. Record calibration results on the appropriate form(s). Instruments that cannot be calibrated should not be used.

2.2.2 Sampling PPE

Gloves: Disposable powder-free nitrile gloves should be worn at all times during sample collection and handling of sampling equipment.

At a minimum, field personnel should put on a new pair of nitrile gloves after the following activities:

- Handling samples, including QA/QC samples and blanks;
- Handling sampling equipment; and
- Between each sampling location.

At a minimum, personnel should (1) thoroughly wash their hands with detergent (preferably Alconox® or Luminox®) and PFAS-free water. Liquinox® is also acceptable for PFAS sampling but shall not be used for decontamination while collecting media to be submitted for analysis of 1,4-dioxane); (2) thoroughly dry their hands with paper towels; and (3) put on a new pair of nitrile gloves after the following activities:

- Contact with a material potentially containing PFAS;
- Change in sampling locations;
- Breaks in work;
- Washroom breaks; and
- Exit and entry into the project site exclusion zone.

2.2.3 Sampling Equipment

Sample Containers: HDPE containers with screw caps are commonly used for sample collection. Different laboratories may supply sample containers of varying sizes. Sample container caps are typically unlined.

Preservatives: Field personnel should communicate with the laboratory to determine what, if any, sample preservatives will be used. Preservatives may include Trizma® or sodium thiosulfate to remove residual chlorine from chlorinated drinking water samples.

Pumps: A variety of pumps, including submersible pumps, bladder pumps, peristaltic pumps, or inertia pumps, may be used for groundwater sampling. The choice of sampling device should be based on site-specific considerations, including well diameter, depth to groundwater, and purge rates. Regardless of the type of pump, the pump components, fittings, O-rings, sampling tubing, and other sampling equipment should not include Teflon™ or other PFAS-containing materials if possible. Dedicated HDPE or silicon tubing is recommended for sampling each groundwater monitoring well.

Analytical Field Meter(s): Water quality parameters commonly evaluated during sampling of groundwater monitoring wells include temperature, pH, conductivity, ORP, DO, and turbidity. Analytical field meters to measure these parameters should be free of Teflon™ and other PFAS materials (e.g., tubing, O-rings) if possible.

Water Level Meter: A water level meter is typically used to monitor drawdown during groundwater purging prior to sampling. Water level meters should be decontaminated prior to and after each sampling location using PFAS-free water, as described in Section 2.4.

2.2.4 Sample Collection and Labeling

Container Rinsing: Sample containers should not to be rinsed prior to sampling.

Well Purging and Sample Collection: If known, wells with the lowest PFAS concentrations should be sampled first and wells with the highest PFAS concentrations sampled last. Well purging and sample collection should be conducted in accordance with SOP NMI-GW-010. Groundwater samples for PFAS analysis will be collected first, before samples for other analyses, to prevent cross contamination and PFAS samples will be maintained in a separate cooler from other types of groundwater samples to prevent cross contamination.

Labels: Some water-resistant inks may be potential sources of PFAS. PFAS-free container labels should be filled out using a ballpoint pen that does not have water-resistant ink, if possible. Field staff should try to avoid filling out container labels using felt pens and markers (e.g., certain Sharpie® products). Container labels should include the following information:

- A unique sample identifier;
- QA/QC sample type, if applicable;
- Sampling date and time (24-hour format);
- Sampler's name or initials; and
- Method of sample preservation.

Except for temperature blanks, all QC samples should be labeled and included on the CoC record. Labeling of QC samples should follow the protocol described in the QAPP.

Wet Weather Considerations: Field sampling during wet weather (e.g., rainfall and snowfall) should be conducted wearing appropriate clothing that does not pose a risk for cross contamination if poossible. Field personnel should try to avoid water-resistant clothing and

boots. Rain gear made of polyurethane, PVC, vinyl, or rubber is an acceptable alternative. Samples and sample containers should not be opened prior to sample collection to avoid collecting precipitation. Should samples or sample containers become contaminated with precipitation, they should be discarded.

2.2.5 Sample Handling, Storage, and Shipment

Handling: Clean nitrile gloves should be worn when handling sample containers. Precautions should be taken to not drop or otherwise damage sample containers. Sample containers should not be placed in close proximity to a potential PFAS source.

Storage and Holding Times: Samples should be placed in a dedicated cooler and stored at a temperature between 0-4°C until transportation to the laboratory. Additional storage conditions and holding times should be determined by the laboratory. Measures should be taken to meet storage and holding time criteria (e.g., expedited shipping).

Shipment: Sample containers should be packed for shipment using the following steps:

1. Choose a cooler with structural integrity that will withstand shipment.
2. Secure and tape the drain plug with duct tape from the inside and outside.
3. Fill cooler at least one-third full with wet ice (try to avoid using chemical blue ice) double-bagged in sealed bags. Taping the ends of bags with duct tape will aid in waterproofing.
4. Check that the caps on all sample containers are tight and will not leak.
5. Check that the sample labels are intact, filled out, legible, and that the sample identifier exactly matches the CoC record.
6. Seal each sample container in a sample bag to prevent melt water from getting into the sample or degrading the sample label.
7. Place sample containers into the cooler with their caps upright.
8. Fill excess space within the cooler with bubble wrap (try to avoid using paper, cardboard, or polystyrene foam).
9. Seal the entire cooler with duct tape, particularly the lid, to prevent leaks.

Ship samples as non-hazardous material unless the samples meet the established Department of Transportation (DOT) criteria for a "hazardous material" or the International Air Transport Association (IATA)/International Civil Aviation Organization (ICAO) for air definition of "dangerous goods". If the samples meet criteria for hazardous materials or dangerous goods, then DOT and IATA/ICAO regulations must be followed. Prior to shipping samples, field personnel should complete the appropriate air waybill or manifest. A copy of the air waybill or manifest should be kept for recordkeeping.

2.3 Sampling QA/QC

2.3.1 Field Duplicates

Field duplicates are samples collected in the same manner and at the same time and location as a primary sample. They should be collected from locations of known or suspected contamination. Field duplicates are used to assess field and analytical precision and sample heterogeneity. The number of required field duplicate samples should be determined as outlined in the QAPP.

2.3.2 Matrix Spike and Matrix Spike Duplicate Samples

Matrix spike and matrix spike duplicate (MS/MSD) samples are aliquots of environmental samples that are spiked with a known concentration of PFAS by the laboratory. MS/MSD samples are used to assess interferences caused by the sample matrix. MS/MSD samples are not needed if the analytical laboratory is using an isotopic dilution method but are technically required to meet Department of Defense (DoD) accreditation requirements, if this accreditation is required by the project. If necessary, MS/MSD samples are to be collected in the same manner and at the same time and location as a primary sample (i.e., additional sample volume). It is preferred that this location have little to no PFAS contamination. Samples should have the same matrix to ensure a valid result; if the samples do not appear visually similar (e.g., discoloration, suspended solids), choose another location for collection of MS/MSD samples. The number of required MS/MSD samples should be determined based on discussions with the laboratory and as outlined in the QAPP. MS/MSD samples should be labeled with the same sample name and time as the primary sample and denoted as MS/MSD samples on the CoC and sample label.

2.3.3 Blanks

Blanks should be shipped and handled in the same manner as environmental samples. Field blanks should be labeled as such on sample bottles and on the CoC. The number and type of blanks should be determined by discussions with the laboratory.

Equipment Blanks: Equipment blanks are used to assess sources of field and laboratory contamination. Equipment blanks are prepared by pouring PFAS-free water over or through decontaminated reusable field sampling equipment and collecting the rinsate in a sample container. The number of required equipment blank samples should be determined as outlined in the QAPP.

Field Blanks: Field blanks are used to assess ambient contamination within the field and laboratory. Field blanks should be prepared by filling a sample container with PFAS-free water in the field in the same manner as environmental samples. Field blanks are an effective way of assessing potential cross-contamination as a result of sample handling. The number of required field blank samples should be determined as outlined in the QAPP.

Temperature Blanks: Temperature blanks are used to assess the temperature of samples during shipping. Temperature blanks should be provided by the laboratory and prepared by filling a sample container with PFAS-free water prior to shipment of the sample containers. The blank

should be kept in the cooler during sampling and shipment to the laboratory. Once the cooler returns to the laboratory, the temperature of the blank should be measured to ensure that recommended sample storage criteria are met.

2.4 Decontamination

Decontamination should occur prior to leaving the sampling area or at a central decontamination location and at the end of each work day. Additionally, sampling equipment exposed to PFAS contaminated water should be decontaminated between sample locations.

Alconox® and Luminox ® detergents are acceptable for decontamination purposes. Liquinox® is acceptable for PFAS sampling but shall not be used for decontamination of sampling equipment used for collection of media to be submitted for analysis of 1,4-dioxane. Use of Decon 90 should be avoided. Decontamination wastes must be properly contained and disposed of in accordance with applicable local, state and federal regulations.

2.4.1 Field Equipment Decontamination

All non-disposable sampling equipment that is in contact with groundwater (e.g., field probes) must be cleaned prior to and between uses at each groundwater sampling location according to the following procedures:

1. Remove any gross (e.g., soil) contamination from sampling equipment.
2. If heavy petroleum residuals are encountered during sampling, use methanol or another appropriate solvent to remove any residues from sampling equipment.
3. Wash water-resistant equipment thoroughly and vigorously with potable water containing detergent (Alconox® or Luminox®) using a bristle brush or similar utensil to remove any remaining residual contamination. Liquinox® is acceptable for PFAS sampling but shall not be used for decontamination of sampling equipment used for collection of media to be submitted for analysis of 1,4-dioxane.
4. Rinse equipment thoroughly with potable water (1st rinse).
5. Rinse equipment thoroughly with PFAS-free water (2nd rinse).
6. For field instruments, rinse again with PFAS-free water (3rd rinse).
7. Dry wet equipment with a paper towel or leave the equipment to air dry in a location away from dust or fugitive contaminants. All equipment should be dry before reuse.

Cleaning and decontamination of the equipment should be accomplished in stages and in such a way that the contamination does not discharge into the environment. Dedicated or disposable sampling equipment should be considered to minimize the need for decontamination.

2.4.2 Personnel and PPE Decontamination

A decontamination area for personnel and portable equipment may be specified in the health and safety plan. The area may include basins or tubs to capture decontamination wastes, which can be

transferred to larger containers as necessary. Decontamination following groundwater monitoring well sampling should follow these steps:

1. Gross (e.g., soil) contamination should be scraped and wiped from boots, safety glasses, hardhats, reflective vests, and other reusable PPE. Once gross contamination has been removed, gloves should be removed by rolling off the hands in such a way to avoid exposing skin to PFAS-contaminated materials.

2. A new pair of gloves should be put on and reusable PPE should be decontaminated using PFAS-free water mixed with detergent (preferably Alconox® or Luminox®) and brushes, or similar means. Liquinox® is acceptable for PFAS sampling but shall not be used for decontamination when collecting media to be submitted for analysis of 1,4-dioxane. After debris is removed, reusable PPE should be rinsed with PFAS-free water.

3. Hands and any exposed body parts should be washed thoroughly using detergent (preferably Alconox® or Luminox®) and PFAS-free water. Liquinox® is acceptable for PFAS sampling but shall not be used for decontamination when collecting media to be submitted for analysis of 1,4-dioxane. Hands should be dried with paper towels.

2.5 Food and Drink

Food and drink should not be brought within the exclusion zone. Food that is kept in the staging area should preferably be contained in HDPE or stainless-steel containers.

3.0 LABORATORY PROCEDURES

3.1 Accreditations

All samples for PFAS will be analyzed by Alpha Analytical (Alpha) of Westborough, Massachusetts. Alpha is an approved laboratory for this Site and is accredited pursuant to the National Environmental Laboratory Accreditation Program (NELAP), and Clean Water Act and is RCRA certified for the category of parameters analyzed. Consistent with MassDEP policy (MassDEP 2018), the samples for PFAS compounds will be performed using a modified USEPA Method 537 Version 1.1. with isotope dilution.

4.0 DOCUMENTATION

4.1 Chain of Custody

Chain of custody procedures described in the current QAPP will be followed during PFAS sample collection and handling.

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Attachment A. Daily Sampling Checklist

Date: _____

Site Name: _____

Weather (temperature/precipitation): _____

Please check all boxes that apply and describe any exceptions in the notes section below along with QA/QC methods used to assess potential sample cross-contamination as a result.

Field Clothing and PPE:

- No water- or stain-resistant boots or clothing (e.g., GORE-TEX®)
- Field boots (or overboots) are made of polyurethane, PVC, rubber, or untreated leather Rain gear are made of polyurethane, PVC, vinyl, wax-coated or rubber
- Clothing has not been recently laundered with a fabric softener No coated HDPE suits (e.g., coated Tyvek® suits)
- Field crew has not used cosmetics, moisturizers, or other related products today
- Field crew has not used sunscreen or insect repellants today, other than products approved as PFAS-free

Field Equipment:

- Sample containers and equipment in direct contact with the sample are made of HDPE, polypropylene, silicone, acetate or stainless steel, not LDPE or glass
- Sample caps are made of HDPE or polypropylene and are not lined with Teflon™ No materials containing Teflon™, Viton™, or fluoropolymers
- No materials containing LDPE in direct contact with the sample (e.g., LDPE tubing, Ziploc® bags)
- No plastic clipboards, binders, or spiral hard cover notebooks No waterproof field books
- No waterproof or felt pens or markers (e.g., certain Sharpie® products) No chemical (blue) ice, unless it is contained in a sealed bag
- No aluminum foil
- No sticky notes (e.g., certain Post-It® products) Decontamination:

Reusable field equipment (e.g., dip sampler) decontaminated prior to reuse

- "PFAS-free" water is on-site for decontamination of field equipment Alconox®, Liquinox® or Luminox® used as decontamination detergent
- Food and Drink:

- No food or drink on-site, except within staging area
- Food in staging area is contained in HDPE or stainless steel container

Notes:

Field Team Leader Name (Print): _____

Field Team Leader Signature: _____ Date/Time: _____

STANDARD OPERATING PROCEDURE NMI-GW-012

GROUNDWATER SAMPLING WITH HYDRASLEEVES™ INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for collecting groundwater samples using Hydrasleeve™ samplers. The Hydrasleeve™ sampler is a passive sampling device that does not require well purging. The objective of using a passive sampler is to minimize the generation of purge water and enable collecting groundwater samples in wells screened in low permeability formations which do not yield sufficient water for low-flow sampling. The Hydrasleeve™ sampler consists of five components: a suspension line, sample sleeve, a polyethylene check valve, a reusable stainless-steel weight clip, and a discharge tube. The size of the sample sleeve varies and can be selected based on the well diameter and required sample volume. The sample sleeve is designed to collect a sample directly from the well screen and fill as it is pulled up through the screened interval.

1.0 EQUIPMENT

The following equipment is needed for Hydrasleeve™ sampling.

- Latex gloves, eye protection and other PPE as required by the Health and Safety Plan (HASP);
- Well construction information, specifically the depth to the top and bottom of the well screen relative to the ground surface or top of well riser;
- Sample containers (e.g., 40 milliliter VOA vials, 1 liter amber glass jars, 1 liter plastic bottles, etc.) with preservative as required by the sampling plan;
- Hydrasleeve™ samplers and associated equipmentField activity forms; and,
- Chain-of-custody forms and sample cooler with ice packs.

2.0 PROCEDURE

The device must be placed and retrieved in a manner that will ensure that only water from the screened interval of the well is collected. Detailed deployment and collection procedures are provided below in the attached SOP from the manufacturer. Sampling containers should be filled in proper order (VOC, SVOCs etc.) follow sample collection procedures outlined in the Quality Assurance Project Plan (QAPP). Samples should be placed on ice immediately after bottles are filled.

3.0 DECONTAMINATION AND DISPOSAL

The Hydrasleeves™ are single-use sampling devices and therefore decontamination procedures do not apply to the sample sleeves. Re-usable stainless-steel weights should be decontaminated using procedures detailed in SOP NMI-007 prior to deployment at other monitoring wells. The sampling sleeves and PPE (e.g. latex gloves) should be accumulated in waste containers for proper disposal per SOP NMI-005.

4.0 DOCUMENTATION

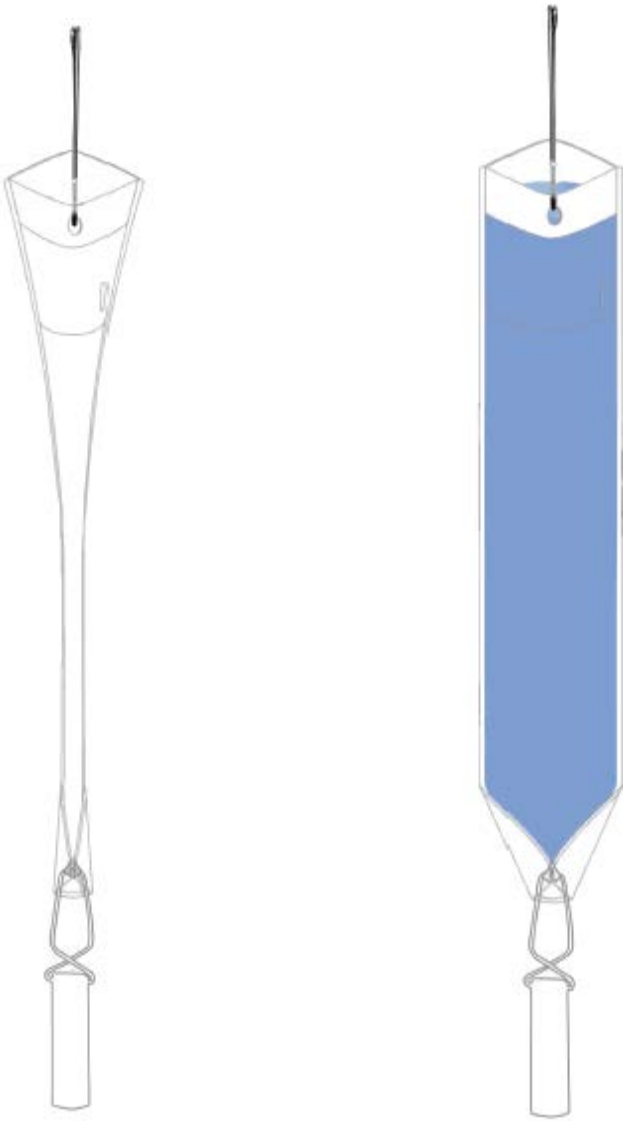
Field sampling activities will be documented in the appropriate field forms per SOP NMI-009. The field staff should provide a consistent level of documentation among different personnel. , The field staff will ensure that Chain of Custody forms are filled out completely and legibly, and follow sample handling and shipping procedures detailed in SOP NMI-001.

HYDRASleeve™

Simple by Design

US Patent No. 6,481,300; No. 6,837,120 others pending

Standard Operating Procedure: Sampling Groundwater with a HydraSleeve



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This guide should be used in addition to field manuals and instructions appropriate to the chosen sampling device (i.e., HydraSleeve, SpeedBag or Super/Skinny Sleeve and W3 HybridSleeve).

Find the appropriate field manual and instructions on the HydraSleeve website at http://www.hydrasleeve.com.

For more information about the HydraSleeve, or if you have questions, contact:
GeoInsight, P.O. Box 1266, Mesilla Park, NM 88047
800-996-2225, info@hydrasleeve.com.

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Table of Contents

Introduction

The HydraSleeve is classified as a no-purge (passive) grab sampling device, meaning that it is used to collect groundwater samples directly from the screened interval of a well without having to purge the well prior to sample collection. When it is used as described in this Standard Operating Procedure (SOP), the HydraSleeve causes no drawdown in the well (until the sample is withdrawn from the water column) and only minimal disturbance of the water column, because it has a very thin cross section and it displaces very little water (<100 ml) during deployment in the well. The HydraSleeve collects a sample from within the screen only. It excludes water from any other part of the water column in the well through the use of a self-sealing check valve at the top of the sampler. It is a single-use (disposable) sampler that is not intended for reuse, so there are no decontamination requirements for the sampler itself.

The use of no-purge sampling as a means of collecting representative groundwater samples depends on the natural movement of groundwater (under ambient hydraulic head) from the formation adjacent to the well screen through the screen. Robin and Gillham (1987) demonstrated the existence of a dynamic equilibrium between the water in a formation and the water in a well screen installed in that formation, which results in formation-quality water being available in the well screen for sampling at all times. No-purge sampling devices like the HydraSleeve collect this formation-quality water as the sample, under undisturbed (non-pumping) natural flow conditions. Samples collected in this manner generally provide more conservative (i.e., higher concentration) values than samples collected using well-volume purging, and values equivalent to samples collected using low-flow purging and sampling (Parsons, 2005).

Applications of the HydraSleeve

The HydraSleeve can be used to collect representative samples of groundwater for all analytes (volatile organic compounds [VOCs], semi-volatile organic compounds [SVOCs], common metals, trace metals, major cations and anions, dissolved gases, total dissolved solids, radionuclides, pesticides, PCBs, explosive compounds, and all other analytical parameters). Designs are available to collect samples from wells from 1” inside diameter and larger. The HydraSleeve can collect samples from wells of any yield, but it is especially well-suited to collecting samples from low-yield wells, where other sampling methods can’t be used reliably because their use results in dewatering of the well screen and alteration of sample chemistry (McAlary and Barker, 1987).

The HydraSleeve can collect samples from wells of any depth, and it can be used for single-event sampling or long-term groundwater monitoring programs. Because of its thin cross section and flexible construction, it can be used in narrow, constricted or damaged wells where rigid sampling devices may not fit. Using multiple HydraSleeves deployed in series along a single suspension line or tether, it is also possible to conduct in-well vertical profiling in wells in which contaminant concentrations are thought to be stratified.

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As with all groundwater sampling devices, HydraSleeves should not be used to collect groundwater samples from wells in which separate (non-aqueous) phase hydrocarbons (i.e., gasoline, diesel fuel or jet fuel) are present because of the possibility of incorporating some of the separate-phase hydrocarbon into the sample.

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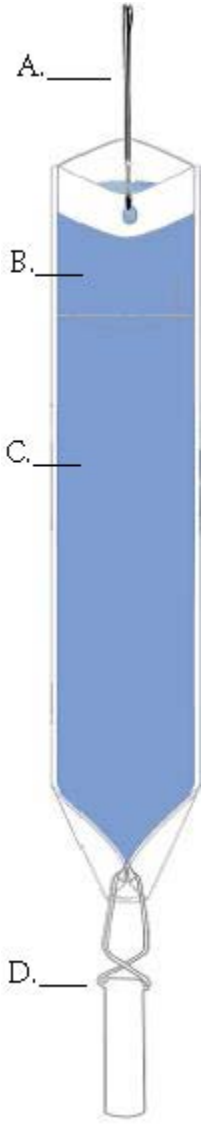
Description of the HydraSleeve

The basic HydraSleeve (Figure 1) consists of the following components*:

- A suspension line or tether (A.), attached to the spring clip or directly to the top of the sleeve to deploy the device into and recover the device from the well. Tethers with depth indicators marked in 1-foot intervals are available from the manufacturer.
- A long, flexible, 4-mil thick lay-flat polyethylene sample sleeve (C.) sealed at the bottom (this is the sample chamber), which comes in different sizes, as discussed below with a self-sealing reed-type flexible polyethylene check valve built into the top of the sleeve (B.) to prevent water from entering or exiting the sampler except during sample acquisition.
- A reusable stainless-steel weight with clip (D.), which is attached to the bottom of the sleeve to carry it down the well to its intended depth in the water column. Bottom weights available from the manufacturer are 0.75" OD and are available in a variety of sizes. An optional top weight may be attached to the top of the HydraSleeve to carry it to depth and to compress it at the bottom of the well (not shown in Figure 1);
- A discharge tube that is used to puncture the HydraSleeve after it is recovered from the well so the sample can be decanted into sample bottles (not shown).
- Just above the self-sealing check valve at the top of the sleeve are two holes which provide attachment points for the spring clip and/or suspension line or tether. At the bottom of the sample sleeve are two holes which provide attachment points for the weight clip and weight.



*Other configurations such as top weighted assemblies, Super/SkinnySleeves, Speedbags, and W3 Hybrids are available.

Note: The sample sleeve and the discharge tube are designed for one-time use and are disposable. The spring clip, weight and weight clip may be reused after thorough cleaning. Suspension cord is generally disposed after one use although, if it is dedicated to the well, it may be reused at the discretion of the sampling personnel.

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Selecting the HydraSleeve Size to Meet Site-Specific Sampling Objectives

It is important to understand that each HydraSleeve is able to collect a finite volume of sample because, after the HydraSleeve is deployed, you only get one chance to collect an undisturbed sample. Thus, the volume of sample required to meet your site-specific sampling and analytical requirements will dictate the size of HydraSleeve you need to meet these requirements.

Table 1. Dimensions and Volumes of HydraSleeve Models.

Diameter	Volume	Length	Lay-Flat Width	Filled Dia.
2-Inch HydraSleeves				
Standard 600 mls HydraSleeve	~600mls	30”	2.5”	1.4”
Standard 1-liter HydraSleeve	~1 Liter	38”	3”	1.9”
Super/SkinnySleeve 1-liter	~1 Liter	38”	2.5"	1.5”*
Super/SkinnySleeve 1.5-liter	~1.5 Liters	52”	2.5”	1.5”*
Super/SkinnySleeve 2-liter	*~2 Liters*	*66"*	*2.5"*	*1.5"**
4-Inch HydraSleeves				
Standard 2.5 liter	~2 Liters	38”	4”	2.7”

* outside diameter on the Heavy Duty Universal Super/SkinnySleeves is 1.5" however when using with schedule 40 hardware the O.D. of the assembly will be 1.9"

It's also recommended that you size the diameter of the HydraSleeve according to the diameter of the well (i.e. use 2-inch HydraSleeves in 2-inch wells). Using smaller sleeves in larger diameter wells (i.e. 2-inch HydraSleeves in 4-inch wells) will result in a longer fill rate and will require special retrieval instructions (explained later).

The volume of sample collected by the HydraSleeve varies with the diameter and length of the HydraSleeve. Dimensions and volumes of available HydraSleeve models are detailed in Table 1.

HydraSleeves can be custom-fabricated by GeoInsight in varying diameters and lengths to meet specific volume requirements. HydraSleeves can also be deployed in series (i.e., multiple HydraSleeves attached to one tether) to collect additional sample to meet specific volume requirements, as described below.

If you have questions regarding the availability of sufficient volume of sample to satisfy laboratory requirements for analysis, it is recommended that you contact the laboratory to discuss the minimum volumes needed for each suite of analytes. Laboratories often require only 10% to 25% of the volume they specify to complete analysis for specific suites of analytes, so they can often work with much smaller sample volumes that can easily be supplied using a HydraSleeve.

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HydraSleeve Deployment

Information Required Before Deploying a HydraSleeve

Before installing a HydraSleeve in any well, you will need to know the following:

- The inside diameter of the well
- The length of the well screen
- The water level in the well
- The position of the well screen in the well
- The total depth of the well

The inside diameter of the well is used to determine the appropriate HydraSleeve diameter for use in the well. The other information is used to determine the proper placement of the HydraSleeve in the well to collect a representative sample from the screen (see HydraSleeve Placement, below), and to determine the appropriate length of tether to attach to the HydraSleeve to deploy it at the appropriate position in the well.

Most of this information (with the exception of the water level) should be available from the well log; if not, it will have to be collected by some other means. The inside diameter of the well can be measured at the top of the well casing, and the total depth of the well can be measured by sounding the bottom of the well with a weighted tape. The position and length of the well screen may have to be determined using a down-hole camera if a well log is not available. The water level in the well can be measured using any commonly available water-level gauge.

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HydraSleeve Placement

The HydraSleeve is designed to collect a sample directly from the well screen. It fills by pulling it up through the screen a distance equivalent to the length of the sampler when correctly sized to the well diameter. This upward motion causes the top check valve to open, which allows the device to fill. To optimize sample recovery, it is recommended that the HydraSleeve be placed in the well so that the bottom weight rests on the bottom of the well and the top of the HydraSleeve is as close to the bottom of the well screen as possible. This should allow the sampler to fill before the top of the device reaches the top of the screen as it is pulled up through the water column, and ensure that only water from the screen is collected as the sample. In short-screen wells, or wells with a short water column, it may be necessary to use a top-weight on the HydraSleeve to compress it in the bottom of the well so that, when it is recovered, it has room to fill before it reaches the top of the screen.

Example

2" ID PVC well, 50' total depth, 10' screen at the bottom of the well, with water level above the screen (the entire screen contains water).

Correct Placement (figure 2): Using a standard HydraSleeve for a 2" well (2.5" flat width/1.5" filled OD x 30" long, 600 ml volume), deploy the sampler so the weight (a 5 oz., 2.5" long weight with a 2" long clip) rests at the bottom of the well. The top of the sleeve is thus set at ~34" above the bottom of the well. When the sampler is recovered, it will be pulled upward approximately 30" before it is filled; therefore, it is full (and the top check valve closes) at approximately 64" (5.3 feet) above the bottom of the well, which is well before the sampler reaches the top of the screen. In this example, only water from the screen is collected as a sample.

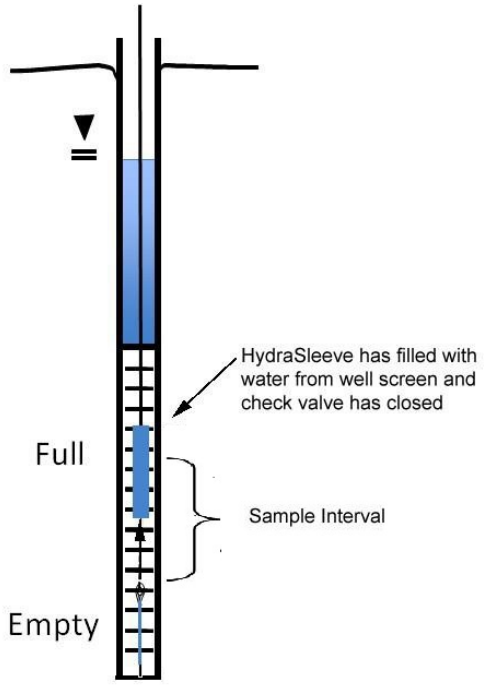

Figure 2. Correct Placement of HydraSleeve.

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Incorrect Placement (figure 3): If the well screen in this example was only 5' long, and the HydraSleeve was placed as above, it would not fill before the top of the device reached the top of the well screen, so the sample would include water from above the screen, which may not have the same chemistry.

The solution? Deploy the HydraSleeve with a top weight, so that it is collapsed to within 6" of the bottom of the well. When the HydraSleeve is recovered, it will fill within 36" (3 feet) from the bottom of the well, or 2-feet before the sampler reaches the top of the screen, so it collects only water from the screen as the sample.

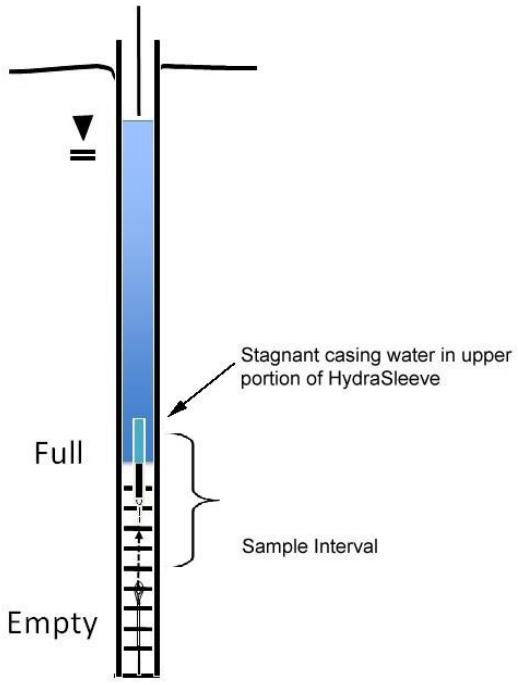

Figure 3. Incorrect placement of HydraSleeve.

This example illustrates one of many types of HydraSleeve placements. More complex placements are discussed in a later section.

NOTE: Using smaller diameter HydraSleeves (2-inch) in larger diameter wells (4-inch) causes a slower fill rate. Special retrieval methods are necessary if this is your set up (shown later in this document).

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Procedures for Sampling with the HydraSleeve

Collecting a groundwater sample with a HydraSleeve is usually a simple one-person operation.

Note: Before deploying the HydraSleeve in the well, collect the depth-to-water measurement that you will use to determine the preferred position of the HydraSleeve in the well. This measurement may also be used with measurements from other wells to create a groundwater contour map. If necessary, also measure the depth to the bottom of the well to verify actual well depth to confirm your decision on placement of the HydraSleeve in the water column.

Measure the correct amount of tether needed to suspend the HydraSleeve in the well so that the weight will rest on the bottom of the well (or at your preferred position in the well). Make sure to account for the need to leave a few feet of tether at the top of the well to allow recovery of the sleeve.

Note: Always wear sterile gloves when handling and discharging the HydraSleeve.

I. Assembling the Basic HydraSleeve*

1. Remove the HydraSleeve from its packaging, unfold it, and hold it by its top.
2. Crimp the top of the HydraSleeve by folding the hard polyethylene reinforcing strips at the holes.
3. Attach the spring clip to the holes to ensure that the top will remain open until the sampler is retrieved.
4. Attach the tether to the spring clip by tying a knot in the tether.

Note: Alternatively, if spring clips are not being utilized, attach the tether to one (NOT both) of the holes at the top of the Hydrasleeve by tying a knot in the tether.

5. Fold the flaps with the two holes at the bottom of the HydraSleeve together to align the holes and slide the weight clip through the holes.
6. Attach a weight to the bottom of the weight clip to ensure that the HydraSleeve will descend to the bottom of the well.

*See Super/SkinnySleeve assembly manual and HydraSleeve Field Manual for other assembly instructions.

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II. Deploying the HydraSleeve

1. Using the tether, carefully lower the HydraSleeve to the bottom of the well, or to your preferred depth in the water column

   During installation, hydrostatic pressure in the water column will keep the self-sealing check valve at the top of the HydraSleeve closed, and ensure that it retains its flat, empty profile for an indefinite period prior to recovery.

Note: Make sure that it is not pulled upward at any time during its descent. If the HydraSleeve is pulled upward at a rate greater than 0.5'/second at any time prior to recovery, the top check valve will open and water will enter the HydraSleeve prematurely.

2. Secure the tether at the top of the well by placing the well cap on the top of the well casing and over the tether.

Note: Alternatively, you can tie the tether to a hook on the bottom of the well cap (you will need to leave a few inches of slack in the line to avoid pulling the sampler up as the cap is removed at the next sampling event).

III. Equilibrating the Well

The equilibration time is the time it takes for conditions in the water column (primarily flow dynamics and contaminant distribution) to restabilize after vertical mixing occurs (caused by installation of a sampling device in the well).

- Situation: The HydraSleeve is deployed for the first time or for only one time in a well

  The basic HydraSleeve is very thin in cross section and displaces very little water (<100 ml) during deployment so, unlike most other sampling devices, it does not disturb the water column to the point at which long equilibration times are necessary to ensure recovery of a representative sample.

  In some cases, like when useing the SpeedBags, the HydraSleeve can be recovered immediately (with no equilibration time) or within a few hours. In regulatory jurisdictions that impose specific requirements for equilibration times prior to recovery of no-purge sampling devices, these requirements should be followed.

  NOTE: If using top weights additional equilibration time is needed to allow the top weight time to compress the HydraSleeve into the bottom of the well.

- Situation: The HydraSleeve is being deployed for recovery during a future sampling event.

  In periodic (i.e., quarterly, semi-annual, or annual) sampling programs, the sampler for the current sampling event can be recovered and a new sampler (for the next sampling event) deployed immediately thereafter, so the new sampler remains in the well until the next sampling event.

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Thus, a long equilibration time is ensured and, at the next sampling event, the sampler can be recovered immediately. This means that separate mobilizations, to deploy and then to recover the sampler, are not required. HydraSleeves can be left in a well for an indefinite period of time without concern.

IV. HydraSleeve Recovery and Sample Collection

1. Hold on to the tether while removing the well cap.
2. Secure the tether at the top of the well while maintaining tension on the tether (but without pulling the tether upwards)
3. Measure the water level in the well.
4. Use one of the following 3 retrieval methods. In all 3 scenarios, when the HydraSleeve is full, the top check valve will close. You should begin to feel the weight of the HydraSleeve on the tether and it will begin to displace water. The closed check valve prevents loss of sample and entry of water from zones above the well screen as the HydraSleeve is recovered.

   a. In one smooth motion, pull the tether up 30"-60" (the length of the sampler) at a rate of about 1 foot per second (or faster). The motion will open the top check valve and allow the HydraSleeve to fill (it should fill in about 1:1 ratio or the length of the HydraSleeve if the sleeve is sized to fit the well). This is analogous to coring the water column in the well from the bottom up.

   b. There are times it is recommended that the HydraSleeve be oscillated in the screen zone to ensure it is full before leaving the screen area. Pull up 1-3 feet, let the sleeve assembly drop back down and repeat 3-5 times before pulling the sleeve to the surface. The collection zone will be the oscillation zone. ***When in doubt use this retrieval method.***

   c. SpeedBags require check valve activation and oscillation during recovery: When retrieving the SpeedBag, pull up hard 1-2 feet to open the check valve; let the assembly drop back down to the starting point; REPEAT THIS PROCESS 4 TIMES; and then quickly recover the SpeedBag through the well sceen to the surface.

5. Continue pulling the tether upward until the HydraSleeve is at the top of the well.
6. Discard the small volume of water trapped in the Hydrasleeve above the check valve by pinching it off at the top under the stiffeners (above the check valve).

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v. Sample Discharge

NOTE: Sample collection should be done immediately after the HydraSleeve has been brought to the surface to preserve sample integrity.

Be sure you have discarded the water sitting above the check valve – see step #6 above.

1. Remove the discharge tube from its sleeve.
2. Hold the HydraSleeve at the check valve
3. Puncture the HydraSleeve at least 3-4 inches below the reinforcement strips with the pointed end of the discharge tube. NOTE: For some contaminants (VOC's/sinkers) the best location for discharge is the middle to bottom of the sampler. This would be representative of the deeper portion of the well screen.
4. Discharge water from the HydraSleeve into your sample containers. Control the discharge from the HydraSleeve by either raising the bottom of the sleeve, by squeezing it like a tube of toothpaste, or both.
5. Continue filling sample containers until all are full.

Measurement of Field Indicator Parameters

Field indicator parameter measurement is generally done during well purging and sampling to confirm when parameters are stable and sampling can begin. Because no-purge sampling does not require purging, field indicator parameter measurement is not necessary for the purpose of confirming when purging is complete.

If field indicator parameter measurement is required to meet a specific non-purging regulatory requirement, it can be done by taking measurements from water within a HydraSleeve that is not used for collecting a sample to submit for laboratory analysis (i.e., a second HydraSleeve installed in conjunction with the primary sample collection HydraSleeve [see Multiple Sampler Deployment below]).

Alternate Deployment Strategies

Deployment in Wells with Limited Water Columns

For wells in which only a limited water column needs to be sampled, the HydraSleeve can be deployed with an optional top weight in addition to a bottom weight. The top weight will collapse the HydraSleeve to a very short (approximately 6" to 24") length, depending on the length and volume of the sampler. This allows the HydraSleeve to fill in a water column only 3' to 10' in height (again) depending on the sampler size. Note the SuperSleeves accomplish the same thing but provide greater sample volume at a lower per sample cost.

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Multiple Sampler Deployment

Multiple sampler deployment in a single well screen can accomplish two purposes:

1. It can collect additional sample volume to satisfy site or laboratory-specific sample volume requirements.
2. It can be used to collect samples from multiple intervals in the screen to allow identification of possible contaminant stratification.

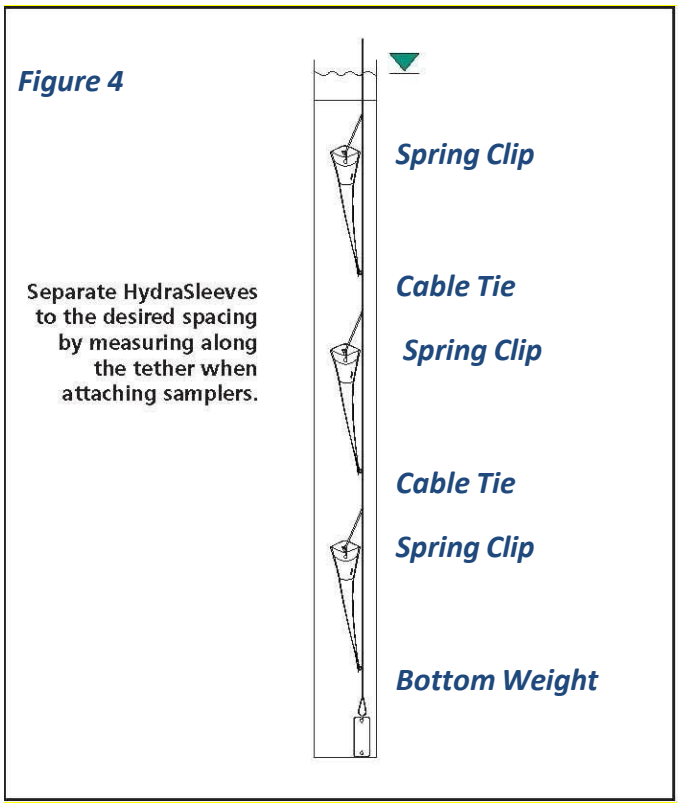

Figure 5. Multiple HydraSleeve deployment

If there is a need for only 2 samplers, they can be installed as follows. The first sampler can be attached to the tether as described above, a second attached to the bottom of the first using your desired length of tether between the two and the weight attached to the bottom of the second sampler (figure 6). This method can only be used with 2 samplers; 3 or more HydraSleeves in tandem need to be attached as described above.

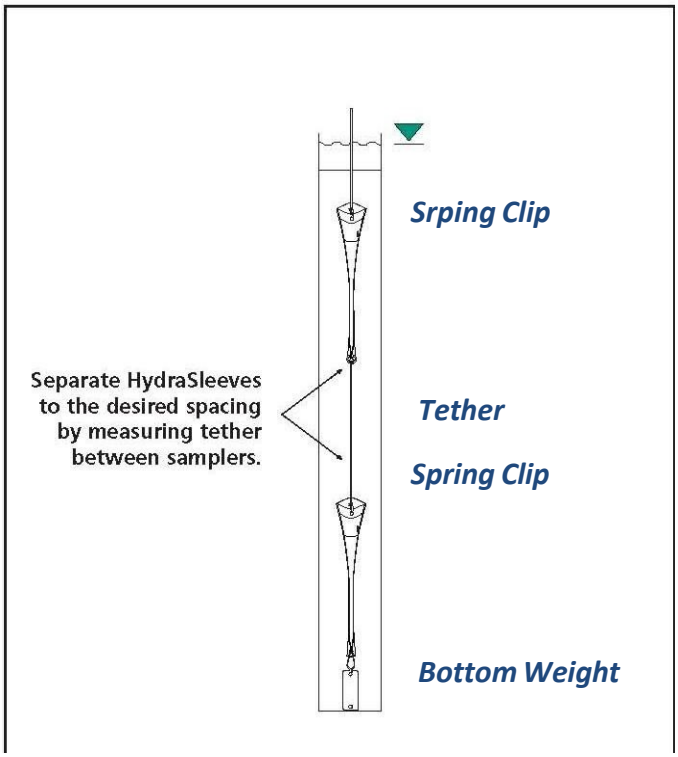

Figure 5. Alternative method for deploying multiple HydraSleeves.

In either case, when attaching multiple HydraSleeves in series, more weight will be required to hold the samplers in place in the well than would be required with a single sampler. Recovery of multiple samplers and collection of samples is done in the same manner as for single sampler deployments.

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Post-Sampling Activities

The recovered HydraSleeve and the sample discharge tubing should be disposed as per the solid waste management plan for the site. To prepare for the next sampling event, a new HydraSleeve can be deployed in the well (as described previously) and left in the well until the next sampling event, at which time it can be recovered.

The weight and weight clip can be reused on this sampler after they have been thoroughly cleaned as per the site equipment decontamination plan. The tether may be dedicated to the well and reused or discarded at the discretion of sampling personnel.

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References

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Robin, M. J. L. and R. W. Gillham, 1987, Field Evaluation of Well Purging Procedures, groundwater Monitoring Review, Vol. 7, No. 4, pp. 85-93

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STANDARD OPERATING PROCEDURE NMI-GW-013

GROUNDWATER SAMPLING WITH SNAP SAMPLERS®

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the procedure for collecting and documenting groundwater samples collected using the Snap Sampler® passive sampling devices. The Snap Sampler® configuration, bottle size, and quantity will be based on the well riser diameter and the analyses required for the collected samples.

1.1 Objective

The objective of using Snap Sampler® is to obtain a representative sample of groundwater flowing through the well screens under ambient conditions. This objective requires that the sample be free of unsuitable material and of sufficient quantity and quality for prescribed analysis. Snap Samplers® collect groundwater samples without a need to purge or pump the well.

1.2 Equipment

The following equipment is needed for Snap Sampler® sampling:

- Appropriate health and safety gear (e.g., PPE) per the Health and Safety Plan;
- Depth to water measuring device (e.g. Electric water level indicator);
- Snap Sampler® containers (e.g., 40 ml, 125 ml, or 350 ml) and, if required, laboratory-prepared sample containers (i.e. 40 mL VOA vials, amber jars, 1-liter plastic bottles, etc.);
- Snap Sampler® PTFE bonder liner car with silicone septum;
- Snap Sampler® PTFE bonder liner car with silicone septum and sample preservatives (e.g. hydrochloric acid [HCl]) as required by the laboratory analyses (only if laboratory-prepared sample containers are not used);
- Field logbook and/or Sample Log Form;
- Chain-of-custody forms; and
- Sample cooler with ice packs.

2.0 PROCEDURES

The sampling procedures are detailed on pages 5 and 6 of the attached Standard Operating Procedure developed by the Snap Sampler® Manufacturer. Any deviations from these steps should be discussed with the project manager and documented in the field notes.

2.1 Order of Samples

Sampling shall begin at the well locations expected to have the lowest contaminant concentration and completed at the wells expected to have the highest contaminant concentration. This order of sampling will minimize the level of cross-contamination between the sampling locations.

2.2 Sampling Procedure

The following procedure will be used to collect Snap Sampler® system samples:

1. Ensure all field staff are wearing appropriate PPE. Label all sample containers with a waterproof ink pen and ensure proper sample preservatives are present.

2. Deploy and retrieve the samplers according to procedures detailed on pages 5 and 6 of the attached Standard Operating Procedure developed by the Snap Sampler® Manufacturer.

3. Fill laboratory sample containers, if necessary, by pouring sample volume from Snap Sampler® into laboratory sample container.

4. Place samples on ice immediately to remain at 4°C (±2°C) prior to and during shipment to the laboratory. The sample containers should be stored in a cooler until further processing.

5. Complete the Chain of Custody forms for the sample.

6. Ensure that the completed and signed Chain of Custody is sealed inside of a Ziploc® container (doubled if necessary) and placed in the cooler with the samples. Fragile material (glass or other breakable sample vials) may need to be wrapped with bubble wrap or a similar material. Place a seal on the cooler if required by the project.

2.3 Decontamination

The snap sampler trolley and all reusable parts shall be decontaminated between wells being sampled. Decontamination shall be performed using soap and water, at a minimum. The attached SOP from the Snap Sampler Manufacturer provide a decontamination procedure.

2.4 Documentation

Field documentation includes completed calibration records, daily field logs, groundwater purge records, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody), and that the level of documentation is consistent among different personnel.

SNAP SAMPLER®
ZERO
PASSIVE SAMPLING SYSTEM

STANDARD OPERATING PROCEDURE FOR THE SNAP SAMPLER® PASSIVE GROUNDWATER SAMPLING METHOD (NOVEMBER 2019)

2019 UPDATE

The 2019 update includes minor additions to reflect further technical validation of the Snap Sampler® method add and clarifications to some sample and equipment handling procedures, including the PFAS-Zero™ version of the Snap Sampler passive groundwater sampler. The update includes reference to the ASTM Standard Guide for Passive Sampling, D7929-14 (ASTM, 2014).

This Standard Operating Procedure (SOP) should be used to familiarize the user with the application and protocol for use the Snap Sampler® passive groundwater monitoring system. *The laminated picture instruction cards contain step-by-step field instructions. The picture instructions in the Appendices, rather than the SOP itself, should be the primary tool for Snap Sampler® operation in the field.* The SOP is designed for overall understanding and rationale for passive groundwater sampling with the Snap Sampler®, and for regulatory submittal with Sampling and Analysis Plans. Should the user require information beyond that included in this SOP, additional information can be found on the Snap Sampler® website **www.SnapSampler.com, www.qedenv.com/global** or by contacting your Snap Sampler representative at **QED Environmental Systems, Inc.**

FORWARD

This SOP was adapted from SOPs in USEPA's groundwater guidance for RCRA and Superfund project managers (U.S. Environmental Protection Agency 2002). Portions of the applicable text are included here. With this forward, the authors and USEPA are acknowledged in sincerest appreciation. Edited and supplemental text is added to detail application information and procedures for use and deployment of the Snap Sampler® passive groundwater sampling device and method.

INTRODUCTION

The goal of groundwater sampling is to collect samples that are representative of *in situ* groundwater conditions and to minimize changes in groundwater chemistry during sample collection and handling. Experience has shown that groundwater sample collection and handling procedures can be a source of variability in water quality concentrations due to differences in sampling personnel, sampling procedures, and equipment (U.S. Environmental Protection Agency 1995; McHugh *et al.* 2010; Parker and Britt, 2012).

Traditionally, the collection of representative water samples from wells is neither straightforward nor easily accomplished. Groundwater sample collection through pumping or bailing can be a source of variability through differences in sampling personnel and their individual sampling procedures, the equipment used, and ambient temporal variability in subsurface and environmental conditions. Many site inspections and remedial investigations require the sampling at groundwater monitoring wells within a defined criterion of data confidence or data quality, which necessitates that the personnel collecting the samples are trained and aware of proper sample collection procedures.

The purpose of this SOP is to provide a description of the Snap Sampler® passive groundwater sampling method. The method and specialized equipment is designed to minimize the impact the sampling process on groundwater chemistry. This is accomplished through deployment and passive re-equilibration of the monitoring well to ambient groundwater flow and/or diffusive contaminant flux within the well/aquifer system. The Snap Sampler® method eliminates well purging prior to sample collection.

As a passive groundwater sampling device, the Snap Sampler® is a proven, cost-effective alternative to well purge and low-flow sampling (Parker *et al*. 2011; Britt *et al*. 2010). Historical and recent research shows that most if not virtually all well screen zones exhibit ambient flow-through under natural groundwater gradients (Gillham

1982; Pankow *et al.* 1985; Robin and Gillham 1987; Powell and Puls 1993; Puls and Barcelona 1996; Vroblesky *et al.* 2001a; ASTM 2002; ITRC 2004, 2007, ASTM 2014). The screen sections of these wells naturally exchange formation water without pumping. Ongoing research suggests that natural ambient flow-through induces a contaminant redistribution effect within wells (Britt *et al.* 2011; Britt 2005, 2006; Martin-Hayden and Britt 2006; Vroblesky *et al.* 2006; Britt and Calabria 2008). This redistribution regularly results in a flow-weighted averaging effect in the well *without purging*. Though not all wells are thoroughly mixed, many wells show relatively narrow ranges of vertical concentrations when vertically profiled (Vroblesky *et al.* 2001b; Parsons 2003; Britt and Calabria 2008). These studies and others indicate flow-weighted contaminant concentration averaging within wells is common. The Snap Sampler® takes advantage of these "naturally purged" wells by capturing a whole water sample after a period of sampler deployment in the well.

Wells in poor yielding formations with slow recharge during pumping have always been problematic for pumping methods. Wells with short water columns are also problematic for some of the same reasons. Passive sampling of poorly yielding wells has been suggested as a better method than purging to dryness in VOC impacted wells (McAlary and Barker 1987; Puls and Powell 1993; Puls and Barcelona 1996). *The Snap Sampler® can be deployed in low yield and short water column wells to take advantage of this passive sampling approach*.

The Snap Sampler® (Figure 1) passive groundwater sampling method limits sample collection variables by sealing the sample while it is still in the well, at the same position in the well during each sampling event. Where appropriate, the sample is maintained in the same sample container that is transmitted to the laboratory rather than pouring into sample bottles at the ground surface. Using this approach, sampling personnel are essentially prevented from introducing error, variability, or bias during the sample collection process. Sample collection is virtually the same for any user because the sample is captured downhole the same way every event, without impact from user technique, and in many cases, not exposed to the ambient air from the well to the laboratory. Research shows that variability reduction may improve long-term data trend analysis (Britt *et al.* 2011; McHugh *et al.* 2010; Britt *et al.* 2010; Britt 2008).

SCOPE AND APPLICATION

This SOP should be used primarily for monitoring wells that have a screen or an open interval large enough to accept a downhole device of 1.8 inches (46mm) in diameter or larger. Long screen interval sampling may be conducted, but stratification testing may be warranted if previous information about aquifer and/or well contaminant stratification is not available. Vertical profiling requirements depend on site-specific data quality objectives (DQO's) and site-specific requirements (ASTM 2014, Vroblesky 2001a; ITRC 2004, 2007).

FIGURE 1, example with 2 of the VOA-size Snap Sampler Modules. Up to 6 modules can be assembled in any combination of sizes.

Groundwater samples that are collected using this procedure are useable for the analyses of groundwater contaminants that may be found at Superfund and RCRA contamination sites, as well as sites with a variety of contamination types. The analytes may be volatile organic compounds, semi-volatile organic compounds, pesticides, PCBs, metals, and other inorganic compounds, including perchlorate and other emerging contaminants

such as explosive compounds, 1,4-dioxane, 1,2,3-TCP, NDMA and others. No analyte limitations have been found for the Snap Sampler® (Parker and Mulherin, 2007, Parker *et al*. 2008, 2009, 2011a and 2011b; Britt *et al*. 2010). Sufficient sample volume is the only practical analyte limiting factor for the method. When sampling for Per- and Polyfluoroalkonated compounds (PFAS), the user should choose the PFAS Zero™ versions of the Snap Sampler product line. These components contain no fluorinated compounds. The user should note that bottles and pneumatic actuator devices not specifically marked as "PFAS Zero™" items may contain fluoropolymers. Lot testing shows these tested items to be PFAS free, but some sampling plans prohibit use of any fluoropolymers regardless of testing status.

For contaminant plume monitoring, the sampler should be placed within the screened interval of the well. For consistency and comparability of results over time, the sampler should be placed in same location and depth for each subsequent sampling event. To accommodate this preference, dedicated sampling devices with dedicated trigger lines should be used whenever possible. The Snap Sampler® should not be placed resting on the bottom well to avoid disturbing any sediment at the bottom of the well during deployment or when the sampler is triggered.

The Snap Sampler® relies on natural flow-through and/or diffusion of contaminants from the aquifer to the well (Powell and Puls 1993; ASTM 2002; ITRC 2004, 2007). Well purging is not conducted before sampling, therefore, measurement of water-quality-indicator parameters is not a prerequisite to sample collection. If parameters are required for certain monitoring programs independent of sampling method (e.g. for monitored natural attenuation assessment), parameters can be collected by utilizing one of the deployed Snap Sampler® bottles or post-sampling by another method (*e.g.* a downhole probe).

Samples collected for metals, semi-volatile organic compounds, pesticides, and other analytes may be impacted by sample turbidity. They also may be subject to transport by colloidal flow in the natural groundwater regime (Kearl *et al.* 1992; Puls and Powell 1992). Deployment and re-equilibrium of the Snap Sampler® allows natural colloidal flow to be monitored within the well. This is a distinct advantage over sampling methods such as the polyethylene diffusion bag (PDB), where colloidal particles are excluded from the sample; and an advantage over purge methods where colloids may be artificially mobilized (Britt *et al.* 2010). Field filtering is not required for samples collected with the Snap Sampler® but can be conducted if required by the site Sampling and Analysis Plan.

Proper well construction, development, and maintenance are essential for any groundwater sampling procedure. Prior to conducting field work, information on the construction of the well and well development should be obtained and that information factored into the site specific sampling procedure. This SOP is not to be used where non-aqueous phase liquids (NAPL) (immiscible fluids) are present in the monitoring well.

MATERIALS AND EQUIPMENT

- Field Sampling and Quality Assurance Project Plan.
- Site Health and Safety Plan with specifications for personal protective equipment and air monitoring equipment.
- Personal protective equipment in good working order as specified in the site Health and Safety Plan.
- Air monitoring equipment in good working order as specified in the Site Health and Safety Plan.
- Site access/permission documentation for site entry.
- Well keys and map of well locations.
- Tool box - All needed tools for all site equipment used.
- Snap Sampler® Modules - Dedicated samplers are recommended in most applications.
- Snap Sampler® Trigger lines, – Dedicated trigger lines are recommended in most applications. Trigger lines may be manual, with a mechanical wire connection from surface to sampler; or pneumatic, with an airline from surface to sampler.
- Snap Sampler® Well Caps – Lockable well caps for Snap Sampler® -deployed wells—includes a support ring to hang Snap Sampler equipment.
- Sample bottles, sample preservation supplies, sample tags or labels, and chain-of-custody forms.
- Well construction, field, and water quality data from the previous sampling event.
- Field notebook, groundwater sampling logs, and calculator.
- Polyethylene sheeting placed on ground around the well head.
- Depth-to-water measuring device - An electronic water-level indicator or steel tape and chalk, with marked intervals of 0.01 foot. Interface probe for determination of liquid products (NAPL) presence, if needed.

- Steel tape and weight - Used for measuring total depth of well.

- Multi-parameter meter, if required. The water-quality-indicator parameters that may be monitored under common monitoring programs include pH, ORP/Eh, (ORP) dissolved oxygen (DO), turbidity, specific conductance, and temperature. Turbidity readings, if required, must be collected from a sacrificed Snap Sampler® bottle because retrieving the sampler may agitate the well, increasing turbidity values not present in the actual samples. Calibration fluids for all instruments should be traceable and there should be enough for daily calibration throughout the sampling event.

- Decontamination supplies, including a reliable and documented source of distilled water and any solvents (if used). Pressure sprayers, buckets or decontamination tubes for pumps, brushes and non-phosphate soap will be needed for non-dedicated equipment that is moved from well to well.

- A suitable container for excess sample and decontamination water, as needed or required.

Construction materials of non-dedicated sampling equipment (samplers, tubing, and other equipment that comes in contact with the sample) should be limited to inert materials. This will reduce the chance that sampling materials alter the groundwater where concentrations of the site contaminants are expected to be near the detection limits. The tendency of organics to sorb into and desorb out of plastic materials makes dedicated equipment preferable where possible.

It should be noted that plastic materials used in the Snap Sampler® are not usually problematic for sorption. Using methods described in this SOP, the sampler is deployed for one to two weeks (or more). This deployment period allows materials prone to sorption to achieve equilibrium with groundwater before the sample is collected (Parker, et al. 2007).

DEPLOYMENT/SAMPLING PROCEDURES

The following describes the deployment and sampling procedures for the Snap Sampler® passive groundwater sampling method. These procedures describe steps for dedicated and non-dedicated systems.

Pre-Sampling Activities

1. Well location maps, construction information, keys and sampling equipment should be assembled and transported to the site.

2. Water level monitoring and sampling must begin at the monitoring well with the least contamination, generally up-gradient or farthest from the site or suspected source. Then proceed systematically to the monitoring wells with the most contaminated ground water.

3. Check and record the condition of the monitoring well for damage or evidence of tampering. Lay out polyethylene sheeting around the well to minimize the likelihood of contamination of sampling equipment from the soil and exposure of soil to liquids dripping from the sampling equipment.

4. Unlock well head. Record location, time, date, and appropriate information in a field logbook or on the groundwater sampling log.

5. Remove inner casing cap.

6. If required, monitor the headspace of the monitoring well at the rim of the casing for volatile organic compounds (VOC) with a photo-ionization detector (PID) or flame ionization detector (FID) and record in the logbook. If the existing monitoring well currently has or has a history of positive headspace readings, then the sampling must be conducted in accordance with the Health and Safety Plan.

7. Measure the depth to water (water level must be measured to nearest 0.01 feet) relative to a reference measuring point on the well casing with an electronic water level indicator or other appropriate measuring device and record in logbook or groundwater sampling log. If no reference point is found, measure relative to the top of the inner casing, then mark that reference point and note that location in the field logbook. Record information on depth to ground water in the field logbook or groundwater sampling log. Measure the depth to water a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.

8. Check the available well information or field check for the total depth of the monitoring well.

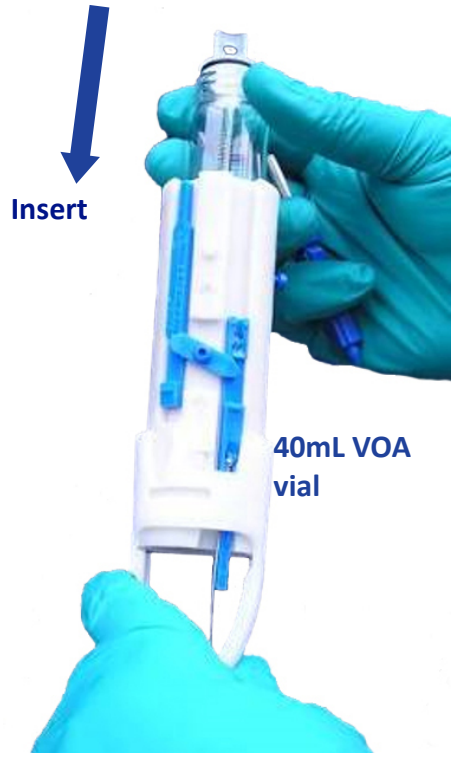

FIGURE 2

Deployment Activities

Selection of the deployment depth within the screen interval is dependent on site specific DQO's. Normally, deployment depth is targeted at the center of the well screen. If depth-specific monitoring is desired, multiple samplers may be deployed at intervals appropriate for the sampling objective.

If multiple sample zones within a well, zone isolation using a packer or baffle device to limit in-well mixing can be used (Britt 2006; Britt and Calabria 2008). These can be attached to the Snap Sampler® trigger line or deployed separately. Installation of an upper baffle designed to isolate the unscreened well casing or well headspace may be desired. The upper baffle will limit mixing of "stagnant" casing water with screen-interval water, an/or gas exchange with the headspace air.

1. Remove the Snap Sampler bottle(s) from its packaging.

2. Turn the translucent "Snap Cap" on each end of the bottle slightly to release any sticking of the o-ring.

3. Insert the bottle into the upper end of the sampler as shown in Figure 2.

4. Place the sampler twist-on connector onto each end of the sampler; turn clockwise to align the set pins/screw (Figure 3); then gently tighten the set screw with the Snap Driver Tool (Figure 4).

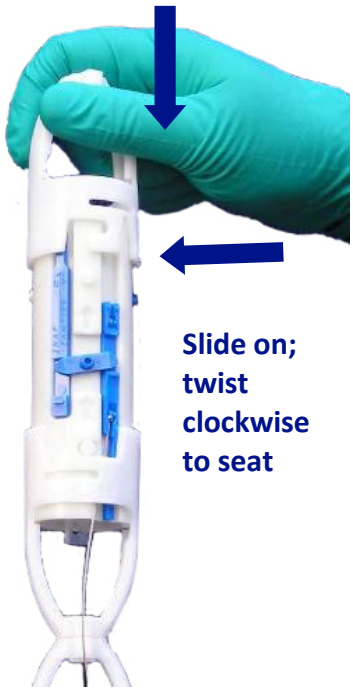

FIGURE 3

FIGURE 4

5. Pivot the vial cap (Snap Cap) into its seat with the Snap driver. Push up the retainer pin through the lower hole in the vial cap. Repeat for all Snap Caps (Figure 5). If an o-ring should dislodge from its seat during setting, remove the sample bottle and carefully replace it in the o-ring groove; repeat setting procedure.

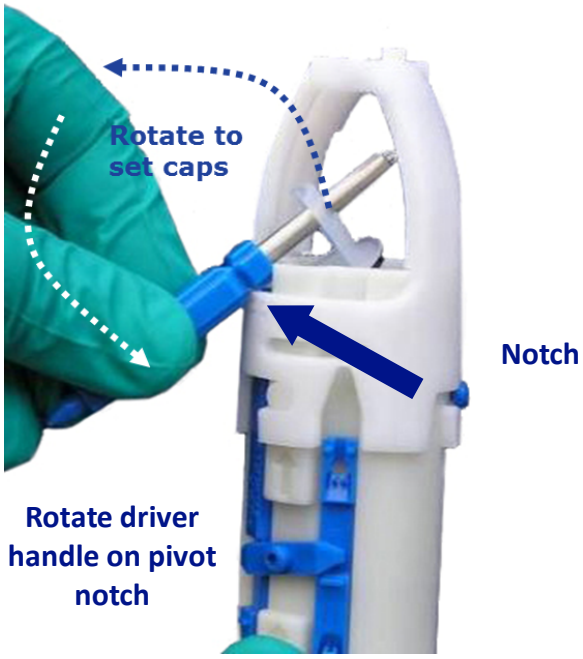

FIGURE 5

6. For the manual trigger, feed ball-fitting end of trigger cable through lower release pin groove; click tube fitting into connector (Figure 6).

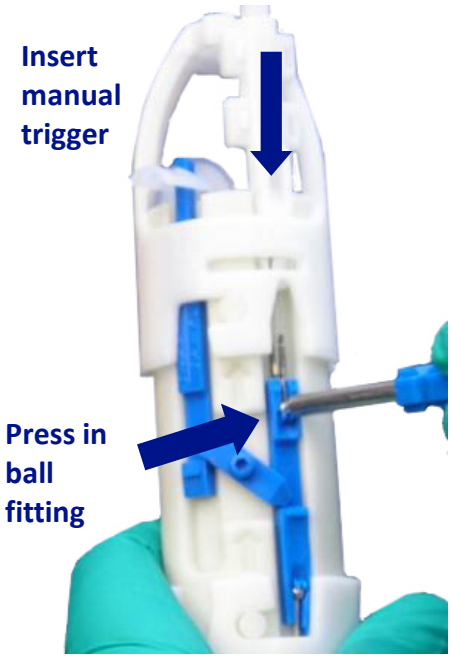

FIGURE 6

7. Press in the ball fitting to attach to lower release pin (Figure 6).

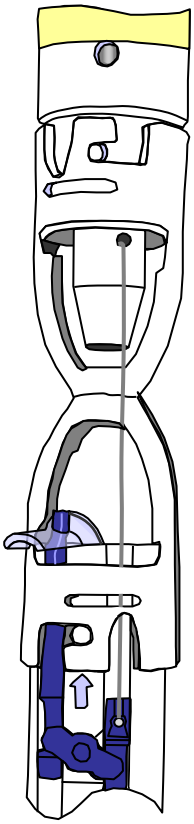

FIGURE 7

8. For the pneumatic trigger system, attach the wireline from the plunger (Figure 7).

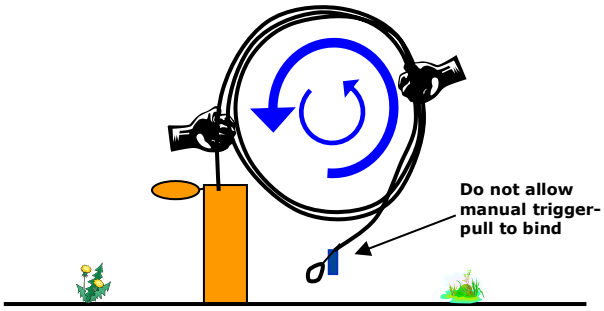

Figure 8

9. Deploy to selected depth with trigger cable/tubing and attach to well head docking station (Figure 8, Figure 9).

10. Additional Snap Samplers® can be deployed with separate trigger lines or in series with a single trigger. If separate triggers are used, the ID tags should be marked at the surface for later reference.

FIGURE 9

11. The recommended deployment period is one to two weeks. There may be hydrogeologic conditions where a shorter deployment is possible, but one to two weeks would generally assure a return of the well to its steady-state condition (Vroblesky, 2001a, 2001b). Parker et al (2009) found that a 72 hour submergence time was sufficient for most analytes tested, but this does not account for well disturbance or other-well-specific factors. The user may determine that shorter or longer deployment times than the standard 1-2 weeks are appropriate for a specific application.

12. The Snap Sampler® can be deployed for extended periods. No upper bound for sampler deployment has been found. Rather, conditions at individual wells seem to control the applicability of deployments lasting a year or longer.

Sample Collection Activities

When the deployment period is completed, the sampler should be triggered at the well head without disturbing the sampler position. For the manual trigger, the cable end should be pulled with sufficient force to move the cable up the tubing. Depending on the length of the cable, closure of the samplers usually can be felt through the trigger line when the samplers trip. For the pneumatic trigger system, pressure is added to the downhole air line to trigger the Snap Samplers to close. If more than one triggering line is present, closure should proceed from the deepest to the shallowest sampler position to limit capture of sediment potentially re-suspended by closure of the first sampler. Additional details on collection activities are included in the Appendices and "Quick Check" instructions.

After the sampler is triggered and retrieved, the upper connector should be removed by loosening the blue retainer screw and turning the white cover piece. The bottom connector piece does not need to be disassembled to remove the bottles.

While the bottles should not leak with reasonable handling, they should not be agitated (to check for headspace, for example) until after the screw caps are tightened. Under most circumstances there will be no air in the vials at retrieval. However, some field conditions—including deep groundwater, natural effervescence, or other causes—may cause some small air bubbles to be present in the bottle or on the spring when retrieved. This is not a concern if the air was entrained while deployed. Air adhering to the vial during deployment would be in equilibrium with the sample water upon sampler closure. Therefore it is not "headspace air" into which sample VOCs could volatilize. Deployment air could be attached to the spring or cap, and should not be larger than 1-2 mm upon retrieval. Pankow (1986) showed that small headspace gas from these or other causes do not substantially impact results for most

common volatiles. If gas bubbles are larger than 5 mm before placing the screw cap, or water is clearly leaking from the vial, the sample may not have sealed properly. There are three options for addressing bubbles: 1) the bottle can be submitted to the laboratory with the headspace bubble, noting the occurrence; 2) the cap can be opened slightly and sample water from another bottle added to fill the vial; or 3) the bottle can be discarded. The user can determine which approach is most appropriate depending on the size of the bubble. For a 1mm bubble, option #1 may be most appropriate; for a 5mm bubble, #2 may be appropriate, while #3 may be appropriate for a 50% full bottle.

There are no special laboratory preparation procedures for Snap Sample bottles. The bottles can be analyzed using common 40-ml autosamplers. The spring inside the VOAs is polymer-coated and will deflect away from the autosampler extraction needle during insertion.

The appendices include step-by-step instructions for deployment and bottle preparation procedures.

Appendix A contains step-by-step field procedures for deployment of both 40 ml Snap Sampler VOAs and 125 ml Snap Sampler POLY bottles.

Appendix B contains step-by-step procedures for preparation of both 40 ml Snap Sampler VOAs and 125 ml Snap Sampler POLY bottles.

DECONTAMINATION PROCEDURES

The electronic water level indicator probe/steel tape, the water-quality field parameter sensors and any *non-dedicated* Snap Sampler® groundwater sampling equipment should be decontaminated by the following procedures:

1. The water level meter will be hand washed with phosphate-free detergent and a scrubber, then thoroughly rinsed with distilled water.

2. Water quality field parameter sensors with distilled water between sampling locations where utilized. No other decontamination procedures are necessary or recommended for these probes since they are sensitive. After the sampling event, the sensors must be cleaned and maintained per the manufacturer's requirements.

3. For *non-dedicated* applications, the Snap Sampler® and trigger tubing must be pressure-sprayed or bristle-brush scrubbed with soapy water, tap water, and distilled water prior to use in a different well. Depending on the condition of the Snap Sampler®, the release pin mechanism may need to be disassembled to effectively clean the pins and grooves. Disassembly can be accomplished by removing the lever screw.

FIELD QUALITY CONTROL

Quality control (QC) samples must be collected to verify that sample collection and handling procedures were performed adequately and that they have not compromised the quality of the groundwater samples. The appropriate EPA or other appropriate program guidance must be consulted in preparing the field QC sample requirements for the site-specific Quality Assurance Project Plan (QAPP).

There are five primary areas of concern for quality assurance (QA) in the collection of representative groundwater samples:

1. Obtaining a groundwater sample that is representative of the aquifer or zone of interest in the aquifer. Verification is based on the field log documenting that the field procedures were followed appropriately during sample deployment and collection.

2. Ensuring that the sampling devices are made of materials, and utilized in a manner that will not interact with or alter the analyses.

3. Ensuring that results generated by these procedures are reproducible; therefore, the sampling scheme should incorporate co-located samples (duplicates).

4. Preventing cross-contamination. Sampling should proceed from least to most contaminated wells, if known. Field equipment blanks should be incorporated for all sampling, and decontamination of the equipment is therefore required.

5. Properly preserving, packaging, and shipping samples.

All field QC samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The chain-of custody procedures for the QC samples will be identical to the field groundwater samples. The following are QC samples that should be collected during the sampling event:

Field duplicates	See QAPP/SAP
Matrix spike	See QAPP/SAP
Matrix spike dup.	See QAPP/SAP
Equipment blank	See QAPP/SAP
Trip blank (VOCs)	See QAPP/SAP
Temperature blank	See QAPP/SAP

HEALTH AND SAFETY CONSIDERATIONS

Depending on the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site Health and Safety Plan should be reviewed with specific emphasis placed on the protection program planned for the sampling tasks. Standard safe operating practices should be followed, such as minimizing contact with potential contaminants in both the liquid and vapor phase through the use of appropriate personal protective equipment.

Depending on the type of contaminants expected or determined in previous sampling efforts, the following safe work practices should be employed:

Particulate or metals contaminants

1. Avoid skin contact with, and incidental ingestion of sample water.

2. Use protective gloves and splash protection.

Volatile organic contaminants

1. Avoid breathing constituents venting from well.

2. Pre-survey the well head space with an appropriate device as specified in the site Health and Safety Plan.

3. If monitoring results indicate elevated organic constituents, sampling activities may be conducted in elevated protective equipment (e.g. level C protection). At a minimum, skin protection will be afforded by disposable protective clothing, such as Tyvek®, appropriate gloves and face protection.

General practices should include avoiding skin contact with water from preserved sample bottles, as this water will have pH less than 2 or greater than 10. Also, when field acidifying VOA bottles, hydrochloric acid fumes may be released and should not be inhaled. Acid should not contact skin, eyes, or unprotected clothing.

POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once groundwater sampling has been completed.

These activities include, but are not limited to the following:

1. Ensuring that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.

2. Processing all sample paperwork, including copies provided to the appropriate sample handling and tracking facility.

3. Compiling all field data for site records.

4. Verifying all analytical data processed by the analytical laboratory against field sheets to ensure all data has been returned to sampler.

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Technology websites: www.QEDENV.com
www.SnapSampler.com

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STANDARD OPERATING PROCEDURE NMI-GW-014

BARCAD® WELL SAMPLING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the procedure for collecting a water sample from a BarCad® groundwater sampling system. The BarCad® mechanism is a permanent sampling system installed at fixed depth in an uncased and backfilled borehole. The BarCad® itself is a 1.5-inch diameter, 16-inch long porous filter with an internal check valve connected to casing or tubing that is extended to ground surface. A smaller inner tubing also extends to the BarCad®. Inert gas, typically from a cylinder, is applied through a manifold at the surface. This gas pressurizes the annular space between the outer and inner tubing thereby pushing the water sample to the surface through the smaller diameter inner tubing. A photograph of a BarCad® well at the site is provided below.

1.1 Objective

The objective of the BarCad® system is to obtain a representative groundwater sample from deeper depths without the need to install downhole pumping devices.

1.2 Equipment

The following equipment is needed for BarCad® well sampling:

- Appropriate health and safety gear (e.g., PPE) per the Health and Safety Plan;
    - Appropriate precautions as listed in SOP-GW-011 – Groundwater Sampling for Monitoring Wells of Per-and Polyfluoroalkyl shall be taken to avoid potential PFAS containing PPE and field supplies when sampling for PFAS;
- Sample containers (e.g., 40 milliliter VOA vials, 1-liter amber glass jars, 1-liter plastic bottles, etc.) with preservative as required by the sampling plan);
- Manifold assembly for sealing annular space and delivering gas;
- Portable nitrogen tank with regulator;
- Polyethylene, Teflon, or Silicon tubing to be attached to inner tubing (if needed);
- Field logbook and/or Sample Log Form;
- Depth to water measuring device (e.g. Electric water level indicator);
- 5-gallon bucket to containerize purge water;
- Chain-of-custody forms; and
- Sample cooler with ice packs.

2.0 PROCEDURES

The following steps will be followed during BarCad® well sampling. Any deviations from these steps should be discussed with the project manager and documented in the field notes. The procedures may be re-evaluated if there are future modifications to the treatment system.

2.1 Order of Samples

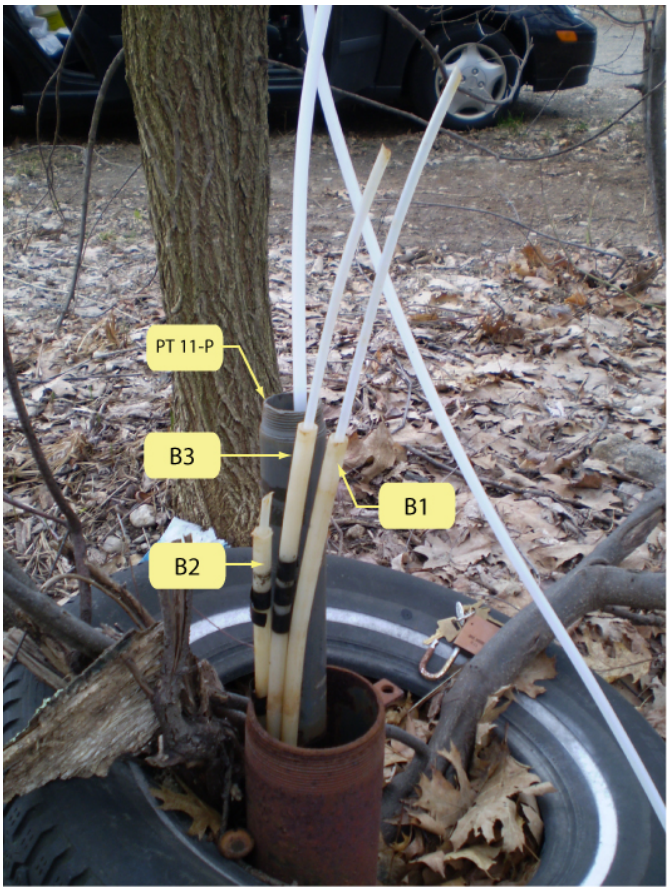
Sampling shall begin at the well locations expected to have the lowest contaminant concentration and completed at the wells expected to have the highest contaminant concentration. This order of sampling will minimize the level of cross-contamination between the sampling locations.

2.2 Sampling Procedure

The following procedure will be used to collect BarCad® well samples:

1. Ensure all field staff are wearing appropriate PPE. Label all sample containers with a waterproof ink pen and ensure proper sample preservatives are present.

2. Slide the small diameter tubing through the manifold assembly and lower the manifold onto the outer casing/tubing. Tighten the outer compression fitting to the outer casing/tubing and tighten the smaller compression fitting around the smaller tubing to create a seal (see illustrations below). Three nested BarCad® samplers adjacent to shallow piezometer PT-11P are presented in the photo below. As shown, each BarCad® sampler port consists of the small inner diameter tubing (water discharge) and the larger diameter outer tubing (inert gas inlet).



Typical BarCad tubing (outer casing can be rigid PVC as well).

Nitrogen connected to manifold via red tube, BarCad® *tubing comes out of well to manifold and small diameter tubing directed into bucket. On some locations the outer* BarCad® *tubing is ridged ½-inch casing.*

3. Attach a section of tubing to the inner tubing and direct the tube into a 5-gallon bucket.

4. Calculate the pressure needed to adequately pressurize the system such that groundwater in the BarCad® assembly is forced to the ground surface. This is done by measuring the height of water from the BarCad® depth to the water level. Because a water level cannot be measured in the BarCad®, the groundwater elevation is measured in a nearby well and this is subtracted from the known elevation of the BarCad®. The depth of all Site BarCad® wells is presented in Table 1. This water column is converted to pounds per square inch (PSI), and 25% is added to account for head loss in the tubing.

   Water Column (ft) = BarCad® elevation (ft) – groundwater elevation (ft)

   *Pressure Required to Purge BarCad® = Water Column (ft) * (0.43 psi/ft) * (1.25)*

5. Connect the nitrogen tank to the manifold assembly while ensuring that the air inlet valve to the manifold is closed. Open the nitrogen tank valve.

6. Purge the stagnant water by opening the gas regulator until the pressure on the gauge equals the calculated pressure required to purge the BarCad®. This will allow air or nitrogen gas to enter the annular space, thereby forcing stagnant water down the annular space and up the inner tubing.

The volume of stagnant water column in the BarCad® outer casing/tubing should be calculated to ensure all stagnant water has been purged

7. Collect the purge water from the inner tubing into a 5-gallon bucket. Maintain air or nitrogen pressure until all water is removed from the inner tubing.
8. Turn off the nitrogen supply and open the manifold valve to vent the tubes to open the check valve at the bottom of the well. This allows fresh water from the formation to flow into the sampler and up the tubing, displacing stagnant water.
9. Repeat Steps 6 through 8 several times to ensure all stagnant water has been removed from the tubing and that fresh water from the formation is being purged. If there is sufficient flow of groundwater from the BarCad® assembly, connect to a flow through cell and collect field parameter measurements (e.g., temperature, pH, dissolved oxygen, oxidation reduction potential, specific conductance) with a calibrated field probe. Field probe calibration is outlined in the SOG-GW-010 for low-flow sampling. If there is no sufficient flow from the sampler, the field personnel will contact the project manager to evaluate a path forward.
10. Once the stagnant water is purged, repeat steps 6 through 8 to collect samples. Fill the pre-preserved sampling containers in proper order (VOC, SVOCs etc.) paying attention to not overflow containers and no-headspace requirements for certain analyses;
11. Place samples on ice immediately to remain at 4°C (±2°C) prior to and during shipment to the laboratory. The sample containers should be stored in a cooler until further processing.
12. Complete the Chain of Custody forms for the sample.
13. Ensure that the completed and signed Chain of Custody is sealed inside of a Ziploc® container (doubled if necessary) and placed in the cooler with the samples. Fragile material (glass or other breakable sample vials) may need to be wrapped with bubble wrap or a similar material. Place a seal on the cooler if required by the project.

2.3 Decontamination

The BarCad® is a dedicated sampler so decontamination is not necessary. Tubing at the wellhead which is used for groundwater discharge should be replaced each sampling event or dedicated for the well.

2.4 Documentation

Field documentation includes completed calibration flow-through cell (if one is used) records, daily field logs, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody) and that the level of documentation is consistent among different personnel.

Table 1 – Nuclear Metals Site BarCad® Well Construction Well Summary

Well ID	Unit	Diameter (in)	Sampler Length (ft)	Borehole Diameter (in)	Top Sampler Depth (ft)	Bottom Sampler Depth (ft)	Top Sampler Elevation (ft NGVD)	Bottom Sampler Elevation (ft NGVD)	Closest Well Screened in the Same Unit at Comparable Elevation	August 2017 Groundwater Elevation in Adjacent Well (ft NGVD)	Approximate BarCad® Purge Pressure (psi)
GZW-7-2	SBR	1.5	1.5	2.5	111.5	113	80.73	79.23	MW-BS02	132.06	28.4
GZW-8-2	BR	1.5	1.5	2	114.5	116	13.95	12.45	MW-BS26	125.39	60.7
ML-1-2	Till	NA	1.5	3.5	65.5	67	107.1	105.6	MW-SD17	132.26	14.3
ML-1-3	SBR	1.5	1.4	3.5	80.1	81.5	92.5	91.1	MW-BS17	132.08	22.0
ML-2-2	OB	1.5	1.5	4	73.5	75	114.74	113.24	MW-SD17	132.26	10.2
ML-2-3	Till	1.5	1.5	4	88.5	90	99.74	98.24	MW-SD17	132.26	18.3
ML-3-2	Till	1.5	NA	4	NA	NA	NA	NA	MW-SD17	132.26	< 20.8
ML-3-3	SBR	1.5	1.5	4	52	53.5	94.9	93.4	MW-BS17	132.08	20.8
PT-11B1	OB	1.5	1.5	NA	86.5	88	45.2	43.7	MW-SD34	123.69	43.0
PT-11B2	OB	1.5	1.5	NA	38.5	40	93.2	91.7	MW-S40	124.02	17.4
PT-11B3	OB	1.5	1.5	NA	28.5	30	103.2	101.7	PT-11P	124.28	12.1

Notes:

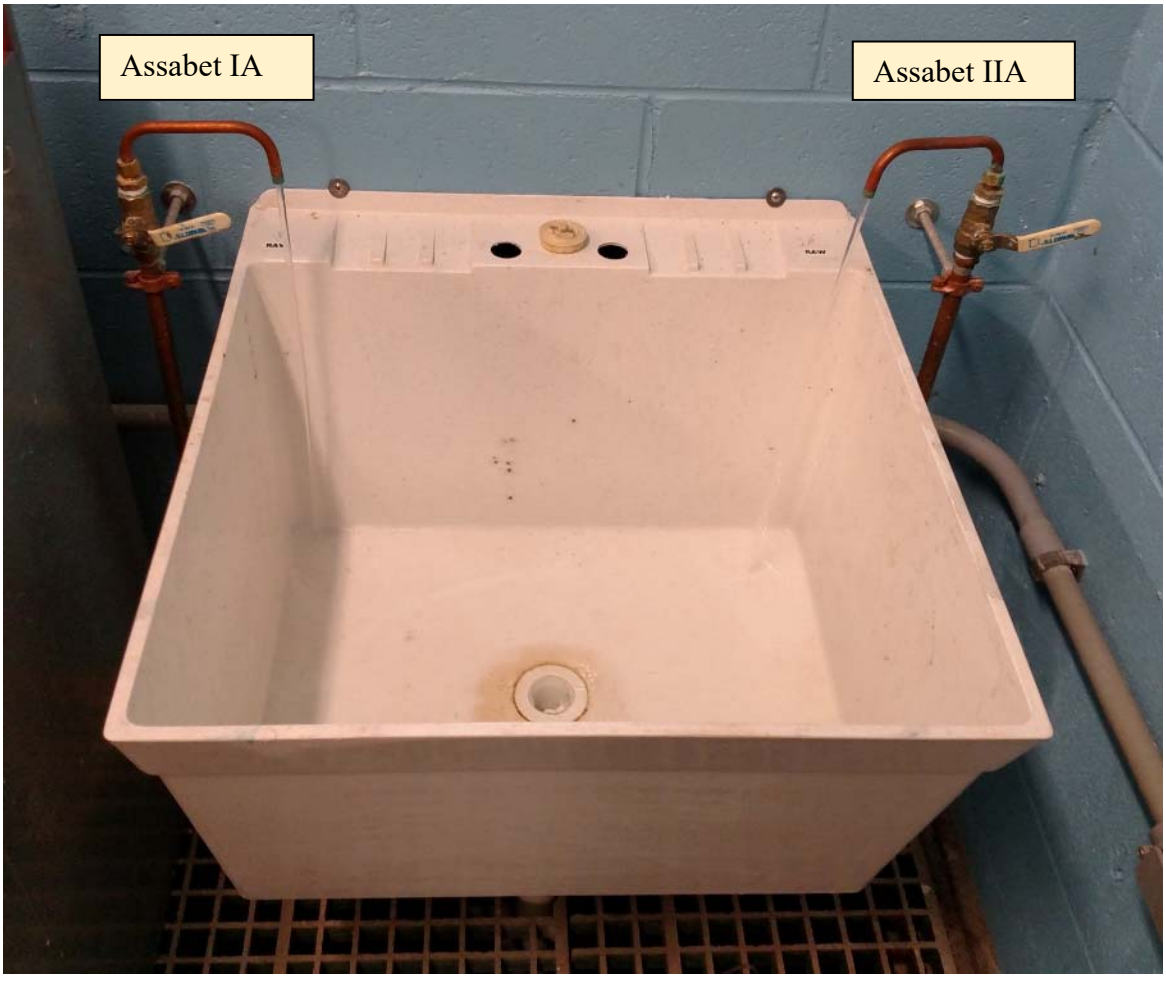
1. SBR – Shallow Bedrock, BR – Bedrock, OB – Overburden.
2. NA – Information Not Available.

STANDARD OPERATING PROCEDURE NMI-GW-015

ASSABET MUNICIPAL WELL SAMPLING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the procedure for collecting water samples from the Acton Water District (AWD) municipal wells Assabet IA/IIA. The raw untreated water from wells Assabet IA/IIA is directed from the wells through subsurface piping to a treatment system building located near High Street. The subsurface piping runs through a small brick building located approximately 40 feet from Assabet IA. A sink with faucet taps connected to Assabet IA/IIA was installed in the building to provide access for sampling. The photo below shows this sink.



1.1 Objective

The objective of this SOP is to obtain representative groundwater samples from the Assabet municipal wells.

1.2 Equipment

The following equipment is needed for Assabet municipal well sampling:

- Latex gloves, eye protection, and other personal protective equipment (PPE) as required by the Health and Safety Plan.
    - Appropriate precautions as listed in SOP NMI-GW-011– Groundwater Sampling for Monitoring Wells of Per-and Polyfluoroalkyl substances (PFAS) shall be taken when sampling for PFAS;
- Sample containers (e.g., 40 milliliter VOA vials, 1-liter amber glass jars, 1 liter plastic bottles, etc.) with preservative as required by the sampling plan;
- Field logbook and/or Sample Log Form;
- Chain-of-custody forms; and
- Sample cooler with ice packs.

2.0 PROCEDURES

The following steps will be followed during Assabet Municipal well sampling. Any deviations from these steps should be discussed with the project manager and documented in the field notes. The procedures may be re-evaluated if there are future modifications to the treatment system.

2.1 Sampling Procedure

The following procedure will be used to collect Assabet Municipal well samples:

1. Ensure all field staff are wearing appropriate PPE.
2. Label all sample containers with ballpoint pen and ensure proper sample preservatives are present.
3. Purge the stagnant water in the sampling ports by opening the Assabet I/IIA faucet taps and allow the water to run for at least 20 minutes – this is the recommendation in New Hampshire Department of Environmental Services (NHDES) 2016 PerFluorinated Compound (PFC) sampling guide - to flush any water that may have been in contact with Teflon® tape or pipe thread paste on pipe fittings or sampling tap threads.
4. Once the line is purged, turn the gate valves slightly to reduce the flow and proceed to collect the samples. Fill the pre-preserved sampling containers in appropriate order (VOC, SVOCs etc.). **If sampling for PFAS, follow procedures outlined in SOP-GW-011 and fill PFAS sampling bottles ahead of all others to prevent contact with other types of sampling containers or package materials (MassDEP, 2018)**. Pay attention to not overflow containers and no-headspace requirements for certain analyses;
5. Place samples on ice immediately (preferably double-bagged ice packs) to remain at 4°C (±2°C) prior to and during shipment to the laboratory. **Chemical ice packs should not**

be used for PFAS sampling (Eurofins Eaton Analytical, 2019). The sample containers should be stored in a cooler until further processing.

6. Complete the Chain of Custody forms for the sample.

2.2 Documentation

Field documentation includes daily field logs, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody) and that the level of documentation is consistent among different personnel.

3.0 REFERENCES

Eurofins Eaton Analytical, 2019. EPA 537/537.1 PFAS Sampling Instructions. www.EurofinsUS.com/Eaton.

Massachusetts Department of Environmental Protection (MassDEP), 2018. Interim Guidance on Sampling and Analysis for PFAS at Disposal Sites Regulated under the Massachusetts Contingency Plan. June 19.

New Hampshire Department of Environmental Services (NHDES), 2016. PerFluorinated Compound (PFC) Sample Collection Guidance. November.

STANDARD OPERATING PROCEDURE NMI-GW-016

STRADDLE PACKER TESTING PROCEDURES

1.0 INTRODUCTION

The following procedure describes the method used to measure hydraulic parameters and collect representative groundwater samples from bedrock boreholes using packers.

1.1 Equipment

- Appropriate health and safety gear per the Health and Safety Plan;
- Field activity forms and Straddle Packer Testing Form (Attached)
- Nominal 6-inch straddle packer unit (2 complete units);
- Water level indicators (2)
- Pressure transducers
- Data logging equipment (if pressure transducers are not equipped with internal dataloggers)
- Laptop computer
- Nitrogen or air compressor for inflating packers
- Duct tape, zip ties and hose clamps
- Alconox, liquinox, or other non-phosphate concentrated laboratory grade soap
- Deionized Water
- Submersible pump with flow regulator and check valve
- Low flow sampling equipment
- Generator and gasoline
- Heavy duty extension cords
- Polyethylene sheeting
- Large capacity barrels, totes, fractionation or holding tanks
- Well completion logs and/or rock cores, or geophysical logs from borehole drilling
- Flow meter and graduated bucket
- Stopwatch

1.2 Packer Set up Procedures

1. Ensure borehole has been flushed of cuttings and allowed to stabilize for at least 48 hours prior to packer testing.

2. Measure the total depth of the borehole and the depth to water.
3. Determine and document the target test zones in the open borehole using observations during drilling and borehole geophysical logs. Target intervals should focus on inferred zones of water inflow.
4. The straddle packer assembly includes two rubber bladders separated by a predetermined distance (i.e., 5 to 10 feet) which are lowered to the desired interval and then inflated. Transducers are located below the bottom packer, between the packers and above the top packer. The piping connecting the bladders will have openings such that a pump located in the piping can extract groundwater specifically within the target interval.
5. To reduce the potential for damaging the bladders or having a faulty seal, avoid placing the packer in a zone of fractured rock or in the bottom of the casing. Keep the rock core logs, drilling logs, or geophysical logs available for reference during the test.
6. Determine the Packer Inflation Pressure (PIP), by performing the following steps:

   Step 1 - Establish Minimum Inflation Pressure (MIP) (i.e., the pressure required to inflate the packers in the casing so that it can no longer be pushed or pulled through the casing). This can be done at ground surface using a section of casing, or in the borehole with the packer installed just below ground surface.

   Step 2 - Establish the Static Head Pressure (Ps) in psi at the test depth by the following calculation:

   $$Ps = (H1 - H2)\ (0.43\ psi/ft)$$

   Where:
   H1 = depth in feet from ground surface to the bottom of the upper packer
   H2 = depth in feet from ground surface to the static water level

   Step 3 - Establish the PIP by adding the MIP and the PS and a 20% factor of safety:

   $$PIP = (MIP + Ps) \times 1.2$$

7. Assemble and install the packer equipment in the borehole at the lowest target interval. Measure each rod to top of coupling as it goes into the hole. Be sure rods are tightened to prevent leakage at the joints. Number the rods for easy tracking of the packer location for sequential tests. Install sampling pump into the discharge pipe in between packer assembly. Figure 1 depicts a configuration for a packer test.
8. Before starting the test record the following:
   - Well name
   - Test interval
   - Water level from each of the transducers (set transducers to record at 30 second intervals)
   - The MIP, PS and PIP

1.3 Hydraulic Test Procedure

1. Initiate pumping at a rate suitable for low flow sampling consistent with the procedures outlined in SOP NMI-GW-010 – Low-Flow Groundwater Purging and Sampling Procedures for monitoring wells. Record initial pumping rate.
2. Record the drawdown observed at two minutes on the packer test form. If significant drawdown is observed, stop pumping and monitor recovery.
3. Adjust the flow rate depending on the responses within the packed zone and in the upper zone. Record the rate, cumulative flow, and time when any changes are made to the pumping rate. The packed zone will be deemed unyielding (impermeable) if the yield to pumping is equivalent to the volume of the packed interval plus the packer unit riser.
4. If the test is to continue, pump at a constant rate for at least 30 minutes or until the readings on the transducers stabilize to complete the hydraulic test. Periodically record the rate, cumulative flow, water level and time.
5. Complete the Packer Test Data Sheet as indicated.

1.4 Groundwater Sampling

- Water pumped from the packered interval will be monitored for field parameters using a flow-through cell consistent with the procedures outlined in SOP NMI-GW-010 – Low-Flow Groundwater Purging and Sampling Procedures for monitoring wells.

- Samples will be collected when; (1) the field geochemical parameters stabilize to the low-flow criteria and a volume equivalent to at least three isolated interval borehole volumes are removed, or (2) if the packered interval is low yielding and the three volumes cannot be purged in a reasonable timeframe the samples will be collected after three hours of batch pumping. The drawdown within the isolated interval may exceed 0.3 feet during purging and although it will be monitored, it will not be a criterion for sampling.

- Record volume purged prior to collecting each sample.

- Complete the following data form.

    - *Straddle Packer Testing Form.* Include well ID, date, time of test, test interval, depth to water/transducer relationships, initial water levels, color, odor, and turbidity of discharge water, and deviations from test protocol. Time of sample collection, volume of flow during sampling, sample IDs, indicate if duplicate.

1.5 Completion of Test

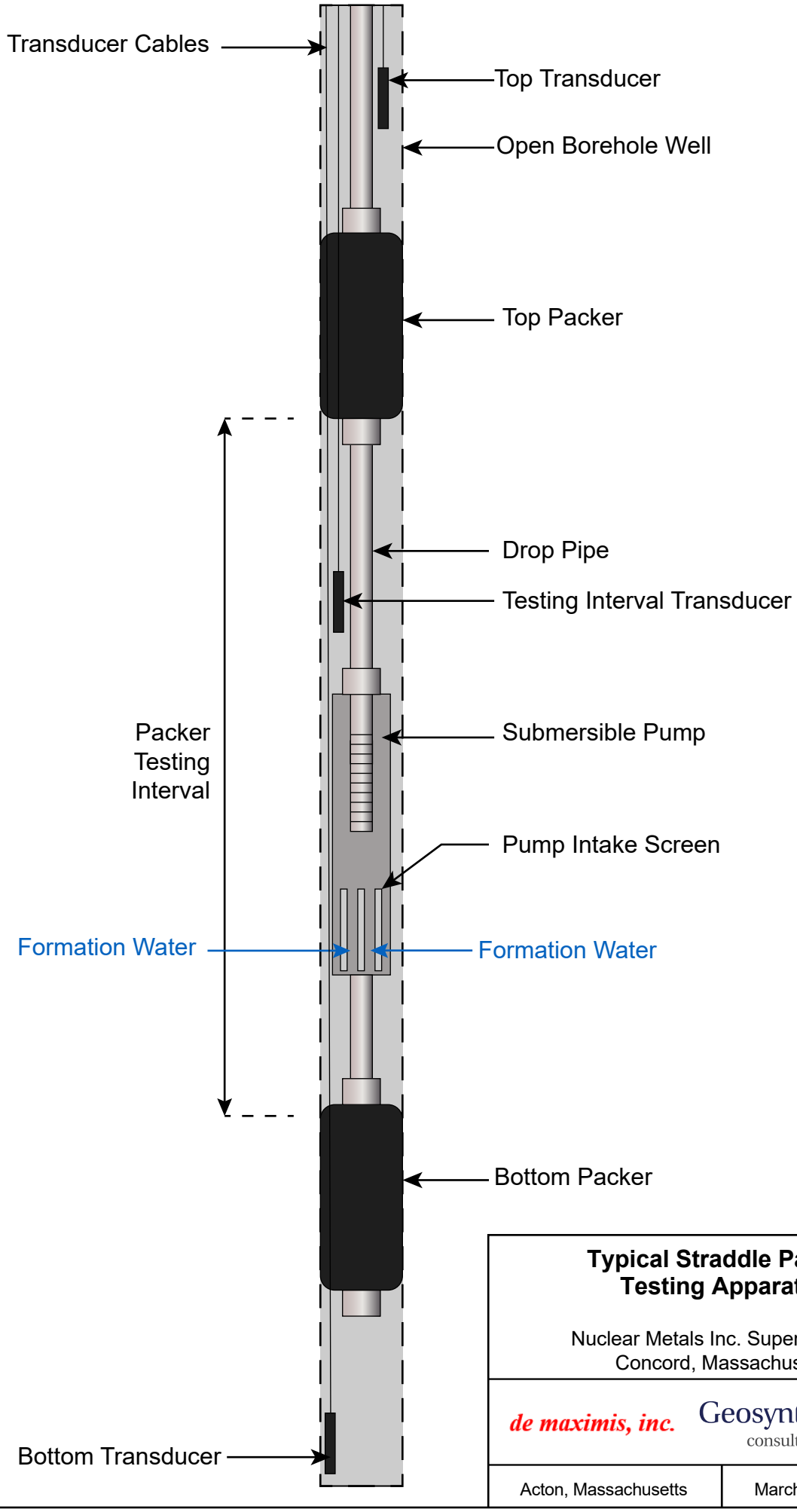
When ready to shut off the pump, take manual water level readings in the casing and record the transducer reading. Shut off the pump and note the total volume pumped. Download the data from pressure transducers and review the data quality before deflating the packers.

2.0 DOCUMENTATION

Field documentation includes completed calibration records, daily field logs, sampling purge records, Chain of Custody forms, and other notes deemed relevant. It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody), and that the level of documentation is consistent among different personnel.

3.0 DECONTAMINATION

All downhole equipment will be decontaminated between boreholes using procedures in SOP NMI-007. Packers and rods will be steam cleaned.



Typical Straddle Packer Testing Apparatus

Nuclear Metals Inc. Superfund Site
Concord, Massachusetts

de maximis, inc. | Geosyntec consultants

Figure 1

Acton, Massachusetts | March 2020

Geosyntec consultants

Straddle Packer Testing Form

Straddle Packer Sample Location (Well Name)	Measuring Point Elevation (ft NGVD)	Static Depth to Water (ft)	Static Groundwater Elevation (ft NGVD)	Test Section Interval (ft bgs)	Test Period	Upper Transducer Reading (ft/PSI)	Middle Transducer Reading (ft/PSI)	Lower Transducer Reading (ft/PSI)	Extraction Rate CIRCLE One (gpm or Lpm)
				to	Pre-inflation				
					Post-inflation				
					Pumping				
Date				to	Pre-inflation				
					Post-inflation				
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Notes:
1. All transducers shall be set to read the static level prior to testing.

STANDARD OPERATING PROCEDURE NMI-GW-017
STEP-DRAWDOWN TESTING AND SPECIFIC CAPACITY ANALYSIS

1.0 INTRODUCTION AND OBJECTIVES

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods and general procedures for conducting step-drawdown tests (step tests) and specific capacity analysis in monitoring and extraction wells at hazardous and non-hazardous sites using a step-drawdown test (step test).

Step tests are performed to measure the well's near steady-state drawdown at multiple pumping rates and used to evaluate a maximum safe yield for long term pumping. A step test is conducted by pumping a well at several successively higher constant rates and monitoring the water levels during pumping. The pumped rate is stepped up to each increasing rate after the drawdown stabilizes and a near steady-state is achieved.

This SOP assumes that only the water level in the pumping well is monitored during the test; however, water levels can be measured at nearby monitoring wells to evaluate their response to pumping.

Generally, step tests are conducted during a single day with each pumping step consisting of a 1- to 2-hour period. Consistent time intervals permit easy comparison of the drawdown data. It is not necessary to allow the water level to recover to static conditions between each pumping step. Allowing the water level to recover between each successive pumping step may significantly increase the time required to complete the step tests.

The objectives of step tests are to determine the specific capacity of a pumping well, optimum pumping rates, and the percentage of drawdown in the pumping well that is attributable to aquifer losses versus well losses due to turbulent flow. Under ideal, laminar-flow conditions, the drawdown in a pumping well is directly proportional to the discharge (Driscoll, 1986). If the flow is not entirely laminar, meaning that some turbulent flow also occurs due to a skin effect or other mechanisms, the drawdown will be proportional to the discharge rate raised to some power. Analytical equations have been developed to estimate the percentage of drawdown in a pumped well that is due to well losses (Driscoll, 1986). From such analyses an efficient long-term test discharge rate can be selected that will avoid excessive turbulent flow.

2.0 EQUIPMENT

The following equipment may be used during the conduct of step-tests. Site-specific conditions may warrant addition to, or deletion of items from this list.

- Appropriate health and safety gear per the Health and Safety Plan;
- Field activity forms and pump test data sheet (Attachment A);
- Water level indicators;

- Pressure transducers with direct read cables (e.g. non-vented Solinst, InSitu or equivalent);
- Data logging equipment (if pressure transducers are not equipped with internal dataloggers);
- Field portable folding table;
- Lap-top computer and charger;
- Duct tape, zip ties, and hose clamps;
- Alconox, liquinox, or other non-phosphate concentrated laboratory grade soap;
- Deionized Water;
- Submersible pump with flow regulator and tubing;
- Generator and gasoline;
- Heavy duty extension cords and ground fault circuit interrupter;
- Polyethylene sheeting;
- Large capacity barrels, plastic totes, or holding tanks;
- Necessary personal protective equipment (e.g. steel toe boots, gloves, eyewear, Tyvek suits);
- Well construction logs;
- Well keys;
- Flow meter and graduated bucket; and,
- Stopwatch.

3.0 PROCEDURES

The following general procedures should be used for conducting step tests and data reduction. Alterations of these general procedures may be necessary in order to accommodate site-specific conditions and data requirements.

3.1 Step-Test

Step-tests should follow the set-up procedures listed below in order to consistently record the desired data as accurately as possible.

1. If required, screen the well headspace using a calibrated field meter (e.g., photoionization detector)

2. Measure and record the static depth to water and total well depth. Compare the total well depth to well construction log. It is recommended that the water level be

monitored for 48-hours prior to the test to identify any trends of rising or falling water levels due to nearby supply wells, tidal influence, or surface water bodies.

3. Determine the appropriate depth for transducer placement in the well based on the anticipated drawdown, and ensure that the pressure transducer cables are sufficiently long. Compare the static water column height above the transducer at the proposed depth to determine the appropriate pressure-rated transducer (i.e., the static water column height should not exceed the transducer pressure rating), required pump hosing length, pump capacity and type, and minimum and maximum anticipated pumping rates.

4. Decontaminate all downhole step-test equipment using procedures listed in SOP NMI-007.

5. Set and secure the pump in the pumping well using SOP NMI-002 – Submersible Pumps, at the planned depth and allow for stabilization of the displaced water level caused by its insertion. The generator should be filled with gasoline at a remote down-wind location and extension cord run to the step test location. Record the pump depth in the logbook or on the field form. Monitor the water level in the pumping well to ensure that static levels are attained.

6. Secure the transducer with zip ties or hose clamps at the desired depth in the pumping well. Allow for the water level to return to static and for the transducer to equilibrate to the ambient ground water temperature. The transducer in the pumping well should be set above the pump. Run the transducer cable to the test control location and connect it to the data logger (if equipped) or directly to a laptop computer. Set the transducer to record real-time data. Compare the real-time transducer readings to the height of the static water column above the transducer to ensure the unit is reading correctly. Record the transducer model, serial number, pressure rating, and depth in the pressure transducer installation log.

7. While the transducer is equilibrating, use the transducer software to synchronize the computer and transducer date and time, specify the appropriate linearity, offset, well ID, recording interval, reference level, and type of reading (surface or top of casing) should be selected.

8. The data logger or the internal datalogger in the transducer should be programmed to collect readings at the desired interval(s) for the entire duration of the test including recovery. It is recommended that the pressure transducer is programmed at a short interval (e.g. 30-second or 1-minute) so that a complete dataset is recorded. The data logger should be programmed to start prior to initiation of pumping the well. Record the programmed duration in the field form.

9. Once the test equipment is ready, the well IDs and parameters for the transducer should then be double checked for accuracy. The connection should be checked by communication with the transducer.

10. The transducer should be set to begin logging data several minutes prior to the initiation of pumping. The pumping rate should be stabilized as quickly as possible at the desired initial flow rate (for the bedrock at NMI a rate of 0.5-1.0 gallons per minute [gpm]) to promote accurate data analysis). Direct the pump discharge to the appropriate containers, if required, or to a surface location outside of the anticipated cone of influence. The pumping rate should be measured and recorded routinely during initial pumping to confirm that the rate is stable. All adjustments to the rate should be recorded. Record the actual start time and pumping rate of the test in the field activity form.

11. If allowed by the pressure transducer software or the datalogger, the pressure transducer measurements should be monitored in real time, while also being recorded on the internal datalogger. Manual measurement of the water level should be performed periodically to confirm the accuracy of the transducer data.

12. Once the water-level in the pumping well has stabilized and a near steady-state is achieved, the pumping rate should be increased to the next pumping rate selected based on the drawdown observed at the initial pumping rate and the available water column above the pump. The successive pumping rates should be adjusted based on the observed drawdown during the previous pumping rate. A typical pumping rate schedule will double the pumping rate during each step (i.e., 0.5 gpm, 1 gpm, 2 gpm). It is desirable to pump for the same duration at each step.

13. If a recovery test is also planned, shut down the pump, record the time, and allow the water level in the pumping well to recover to 90 percent of static levels while the pressure transducer or data logger record the recovery data.

14. Once the test is completed, the field staff should download and review the pressure transducer file(s) to ensure that the data is of sufficient quality to estimate specific capacity. After the data quality is confirmed, carefully remove all downhole equipment.

3.2 Decontamination

Downhole equipment including pumps, transducers, and water levels should be decontaminated prior to deploying and after removing from a well using SOP NMI-007.

3.3 Data Reduction

After completion of the step test, the data from the transducer and manual depth to water measurements will be entered into a spreadsheet. The drawdown (i.e. change in water-level relative to the static level) at the end of each step will be calculated using the pressure transducer data. The pressure transducer data will be plotted versus elapsed time from the beginning of the test. The manual depth to water measurements will be used to verify the transducer data. The specific capacity for each pumping rate will be estimated by dividing the pumping rate in gpm by the total drawdown observed at the duration of each pumping step.

3.4 Data Analysis

The following steps outline the procedure for analyzing step-drawdown data as proposed by Bierschenk (Bierschenk, 1964).

1. Plot the pumping rate (y-axis) versus time (x-axis) on an arithmetic chart;

2. Plot well drawdown (y-axis, positive downward, linear) versus time (x-axis, log) on a log-linear chart;

3. Plot well drawdown (y-axis, positive upward, log) versus time (x-axis, log) on a log-log chart;

4. Inspect the log-log plot and confirm that the data falls into a series of Theis-shaped curves showing an exponential tapering off of drawdown during each step;

5. On the log-linear plot, fit a straight line through the late data from each pumping step. Project these lines using dashed to the edge of the chart. Draw an additional horizontal line representing the maximum available drawdown calculated for the well.

6. Using the maximum drawdown value (s_{max}) at the end of a step and the average pumping rate (Q_{avg}) during the step, plot s_{max}/Q_{avg} (y-axis, positive upward, linear) versus Q_{avg} (x-axis, linear). Compute the slope (C) and y-axis intercept (B) of a best fit straight line through these points extending to Q = 0.

7. The drawdown in the well(s_{total}) has two components; aquifer loss (s_{aq}) and well loss (s_w) and therefore:

$$s_{total} = s_{aq} + s_w$$

   The components of the total drawdown can also be expressed as in terms of pumping rate (Q)

$$s_{total} = BQ + CQ^2$$

   The aquifer (BQ) and well (CQ) components of total drawdown can be computed over the range of pumping rates and used to generate an arithmetic plot to illustrate declining efficiency. The efficiency is calculated as:

$$\% \text{ Efficiency } \quad E = 100 \times (s_{aq}/s_{total})$$

8. It is recommended that the maximum pumping rate for the long-term test be selected to attain a minimum efficiency of 60-75%.

The response data collected during a step test can also be used to estimate the transmissivity of the pumping well using time-drawdown or recovery data using methods detailed by Theis 1935, Doughterty and Babu (1984), and Hantush-Jacob (1955). Flow rate and steady-state

drawdown data pairs can also be used to estimate hydraulic conductivity using the regression method (Henebry and Robbins, 2000). Details of these analyses are not covered in this SOP.

4.0 REFERENCES

Bierschenk, W. H., 1964. "Determining Well Efficiency by Multiple Step-Drawdown Tests," International Association of Scientific Hydrology Pub. #64, pp. 493-508.

Dougherty, D.E and D.K. Babu, 1984. Flow to a partially penetrating well in a double-porosity reservoir, Water Resources Research, vol. 20, no. 8, pp. 1116-1122.

Hantush, M.S. and C.E. Jacob, 1955. Non-steady radial flow in an infinite leaky aquifer, Am. Geophys. Union Trans., vol. 36, pp. 95-100.

Henebry, B and Robbins, G.A. 2000. Reducing the Influence of Skin Effects on Hydraulic Conductivity Determinations in Multilevel Samplers Installed with Direct Push Methods. Ground Water, Vol. 38., No 6. Pages 882-886.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

PUMP TEST DATA SHEET

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Application: ________________ Permit: __________________ Certificate: _________________ Pod_Id: ______________

All water-level measurements must either be in feet and inches, or feet and decimal fractions.

Drawdown Data						Recovery Data					
Date	Time	Time Since Pump Started (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments	Date	Time	Time Since Pump Stopped (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments

STANDARD OPERATING PROCEDURE NMI-GW-018

PUMPING TEST

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods and general procedures for conducting pumping tests in monitoring and extraction wells at hazardous and non-hazardous sites. Additional guidance can be found in Suggested Operating Procedures for Aquifer Pumping Tests (Paul Osborne, 1993, EPA/540/S-93-503).

A pumping test generally consists of pumping groundwater from a single extraction well at a constant rate and monitoring the drawdown response in the extraction well and in nearby observation wells. The water level in the extraction well and observation wells are continuously monitored with pressure transducers throughout the pumping test and verified by manual depth to water measurements.

1.1 Objective

The objectives of pumping tests include quantifying aquifer properties of transmissivity, storativity, specific and sustained yield, and, if applicable, aquifer boundaries. Knowledge of these properties are important variables to understand aquifer characteristics for the design of groundwater remediation systems.

2.0 EQUIPMENT

The following equipment may be used during the performance of pumping tests. Site-specific conditions may warrant addition to, or deletion of items from this list.

- Appropriate health and safety gear per the Health and Safety Plan;
- Field activity forms and pump test data sheet (Attachment A);
- Water level indicator;
- Pressure transducers with direct read cables (e.g. non-vented Solinst, InSitu or equivalent);
- Data logging equipment (if pressure transducers are not equipped with internal dataloggers);
- Field portable folding table;
- Laptop computer and charger;
- Alconox, liquinox, or other non-phosphate concentrated laboratory grade soap;
- Deionized Water (for decontamination);

- Submersible pump with variable frequency drive, check valve, and appropriate downcomer piping;
- Generator and gasoline, or electric feed line;
- Heavy duty extension cords;
- Polyethylene sheeting;
- Fractionation or holding tanks;
- Necessary personal protective equipment (gloves, eyewear, tyvek suits);
- Well completion logs;
- Well keys;
- Digital or manual flow meter and graduated bucket (a digital flowmeter with direct read and totalizer option is preferred); and,
- Stopwatch.

3.0 PUMPING TEST PROCEDURES

The following general procedures should be used for conducting a pumping test. Alterations of these general procedures may be necessary in order to accommodate site specific conditions and data requirements

3.1 Step-Test

Prior to conducting a long-term constant rate pumping test, the sustainable well yield of the extraction wells should be determined using data from a step-test as detailed in SOP NMI-GW-017. In addition, drawdowns observed at monitoring wells during step testing should be evaluated to optimize the well network used to monitor the aquifer response during the constant rate test.

3.2 Constant Rate Pumping Test

The following general procedures should be used for conducting a pumping test. Alterations of these general procedures may be necessary in order to accommodate site specific conditions and data requirements. The duration of the pumping test is selected based on the anticipated time for the aquifer to reach steady-state and may vary depending on the purpose, the aquifer type and configuration, and the geologic setting. Literature indicates that under average conditions, steady state may be reached in 15-20 hours in leaky aquifers, 24 hours or more in confined aquifers, and a longer period, typically 3 or more days in unconfined aquifers (Kruseman and deRidder, 1990).

3.2.1 Baseline Monitoring and Preparation

Prior to commencing a constant rate pumping test, pressure transducers should be deployed in the monitoring wells selected for water level monitoring. It is recommended that the pressure

transducers be deployed at least a week prior to the planned date of the constant rate test to monitor the ambient water level trends in the aquifer. If the pressure transducers are non-vented (i.e. reading absolute pressure which is a sum of the static water column and the atmospheric pressure), a barometric transducer should be deployed at the site to provide data for the barometric compensation of the data.

In conjunction with deployment of transducers for water level monitoring, it is desirable to deploy a rain gage (e.g. bucket type) at the site to monitor the precipitation prior to and during the pumping test. In addition, the weather forecasts should be reviewed prior to commencing the pump test because recharge during the test may obscure the response to pumping and make it difficult to interpret results and estimate aquifer parameters. If significant precipitation is anticipated to occur immediately prior to or during the pumping test, the project team may consider postponing the test.

3.2.2 Pumping Test Setup

1. If required, screen the well headspace using a calibrated field meter (e.g., photoionization detector)

2. Measure and record the static depth to water and total well depth. Compare the total well depth to well construction log. It is recommended that the water level be monitored for 48-hours prior to the test to identify any trends of rising or falling water levels due to nearby supply wells, tidal influence or surface water bodies.

3. Determine the appropriate depth for transducer placement in the well based on the anticipated drawdown, and ensure that the pressure transducer cables are sufficiently long. Compare the static water column height above the transducer at the proposed depth to determine the appropriate pressure-rated transducer (i.e. the pressure head of the static water column height should not exceed the transducer pressure rating), required pump hosing length, pump capacity and type, minimum and maximum anticipated pumping rates.

4. Decontaminate all downhole step-test equipment using SOP NMI-007.

5. The transducer used in the pumping well should either be secured to the pump assembly and downcomer pipe at a depth well below the anticipated pumping level, or installed in a separate stilling pipe. If secured to the pump assembly, use zip ties or hose clamps in a fashion that does not harm the transducer or cable. If a stilling pipe is used it should be open on the bottom with a rod or bolt run perpendicular to the pipe to prevent the transducer from dropping below the bottom upon installation. The stilling tube depth should be below the pump intake if possible.

6. Set and secure the pump in the pumping well at the planned depth following the procedures outlined in SOP NMI-002 – Submersible Pumps and allow for the displaced water level to return to static. If on-site power is not available, a generator should be filled with gasoline at a remote down-wind location and extension cord run

to this location. Record the pump depth in the logbook or on the pump test log. Monitor the water level in the pumping well to ensure that static levels are attained.

7. Connect the transducer cable to the external datalogger (if used) or a laptop computer and program the transducer/datalogger to record real-time data. Compare the real-time reading to the measured height of static water column above the transducer to ensure the unit is reading correctly. Record the transducer model, serial number, pressure rating and installed depth on the transducer installation log.

8. While the transducer is equilibrating, use the transducer software to synchronize the computer and transducer date and time, specify the appropriate linearity, offset, well ID, recording interval, reference level, and type of reading (surface or top of casing) should be selected

9. The data logger or the internal datalogger in the transducer should be programmed to collect readings at the desired interval(s) for the entire duration of the test including recovery. It is preferable that the logger is programmed to log the water level during the drawdown and recovery stages using the logarithmic option recommended with most data loggers, but not mandatory. The actual log scale can also be modified to suit the needs of the test if desired. The data logger should be programmed to start prior to initiation of pumping the well. Record the programmed duration in the field form.

10. Once the test equipment is ready, the well IDs and parameters for the transducer should be double checked for accuracy. The connection should be checked by communication with the transducer.

11. Prior to initiating the pump test, a full round of manual water level readings should be collected so that there are sufficient data to be able to draw pre-pumping water level contours. The distribution of wells should extend at least as far as the anticipated hydraulic response. In discretely fractured bedrock settings, it is good practice to account for unexpected anisotropic conditions by extending the network of wells to monitor, to a larger area than would be anticipated in an equivalent porous media setting

3.2.3 Pumping Test Operation

1. The transducers should be deployed several days to a week prior to the beginning of the pumping test to record a period of background water level data. The pumping rate should be stabilized as quickly as possible at the desired flow rate to promote accurate data analysis. Direct the pump discharge to the appropriate containers, if required, or to a location outside of the anticipated cone of influence. The pumping rate should be measured and recorded routinely during initial pumping to confirm that the rate is stable. All adjustments to the rate, such as increasing a variable frequency drive setting to account for drawdown, should be recorded. Record the actual start time and pumping rate of the test in the field activity form.

2. If allowed by the pressure transducer software or the datalogger, the pressure transducer measurements should be monitored in real time, while also being recorded on the internal datalogger. Look for drawdown in the pumping well to confirm operation. Manual measurement of the water level should be performed periodically in the extraction well and monitoring wells to confirm the accuracy of the transducer data.

3. Once the water-level in the pumping well has stabilized, the pumping test should continue for the planned duration. Prior to the termination of the test, the pressure transducer and manual water level data from monitoring wells should be reviewed and evaluated to determine if a steady-state has been achieved. If the drawdown has not stabilized at one or more monitoring wells, the project team should consider continuing the pumping test past the planned duration of the test.

4. Prior to shutting down the pump, a full round of manual water level readings should be collected in all wells monitored prior to initiating the pump test. These data will be used to develop a set of water level contours representative of pumping conditions and compared to ambient conditions.

5. Once the duration of the test is determined to be sufficient, the field staff should shut down the pump, record the time and allow the pressure transducers in the extraction and monitoring wells to collect the recovery data. It may be preferred to allow the water levels to recover overnight and for the data to be downloaded from the transducers the next day.

6. Once the recovery portion of the test is completed, stop recording at all the pressure transducers, download the data, remove the transducers, and decontaminate all downhole equipment.

3.3 Decontamination

Downhole equipment including pumps, transducers, and water levels should be decontaminated prior to deploying and after removing from a well using SOP NMI-007.

4.0 DATA REDUCTION

After completion of pumping test, the data from the transducers and manual depth to water measurements will be entered into a spreadsheet. Barometric compensation will be conducted if non-vented pressure transducers are used. The pressure transducer readings in the extraction and monitoring wells will be converted to drawdown (i.e. change in water-level relative to the static level). The extraction and monitoring well details (e.g. diameter, screen length, initial static water column, distance from pumping well) will be summarized in a spreadsheet. The well construction details, pump rate, and response data will be input into an aquifer test analysis software (e.g. Aqtesolv© or equivalent). The transmissivity estimates will be derived by fitting type curves to the drawdown response data using methods developed by Theis 1935, Cooper-Jacob (1984), and Hantush-Jacob (1955), which are not affected by well-losses. If

necessary, curve matching solutions for discretely fractured bedrock may be utilized. Further details of these analyses are not covered in this SOP.

Figures should be generated showing the pre-pumping and pumping water level data and can be used to infer the areas of influence and capture zones for individual pumping wells, and hydraulic connectivity between pumping wells and monitoring wells.

5.0 REFERENCES

Dougherty, D.E and D.K. Babu, 1984. Flow to a partially penetrating well in a double-porosity reservoir, Water Resources Research, vol. 20, no. 8, pp. 1116-1122.

Hantush, M.S. and C.E. Jacob, 1955. Non-steady radial flow in an infinite leaky aquifer, Am. Geophys. Union Trans., vol. 36, pp. 95-100.

Kruseman, G.P. and N.A. DeRidder, 1990. Analysis and Evaluation of Pumping Test Data (2nd ed.), Publication 47, Intern. Inst. for Land Reclamation and Improvement, Wageningen, The Netherlands, 370p.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

PUMP TEST DATA SHEET

Page _____ of ______

Application: ________________ Permit: __________________ Certificate: _________________ Pod_Id: ______________

All water-level measurements must either be in feet and inches, or feet and decimal fractions.

Drawdown Data						Recovery Data					
Date	Time	Time Since Pump Started (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments	Date	Time	Time Since Pump Stopped (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments

STANDARD OPERATING PROCEDURE NMI-GW-019
SLUG TESTING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in conducting slug tests. This SOP details equipment and testing procedures for monitoring wells screened above and below the water table in high or low permeability confined or unconfined aquifers. This SOP conforms to "A Compendium of Superfund Field Operations Methods (EPA/540/P-87/001)," the RCRA Ground Water Monitoring Draft Technical Guidance (EPA/530-R-93-001), and other pertinent technical publications.

1.1 Objective and Slug Testing Concept

The objective of slug testing is to obtain an order of magnitude estimate of aquifer hydraulic conductivity in the immediate vicinity of the tested well. This objective requires knowledge of aquifer geology and well geometry, as well as the collection of sufficient test data to allow estimation of aquifer hydraulic characteristics.

The general concept of a slug test is that a solid slug can be used in a well to cause a change in water level from static conditions and the rate of return to the static level can be used to estimate hydraulic conductivity. A slug test can be performed as a rising head or falling head test and is one of several well point hydraulic conductivity measurement techniques that can be employed using a single well. In general, when a solid slug is inserted below the water level in a well, the head in the well will rise and if the slug is not moved the “falling” water level will drop back to static conditions. After static conditions return, the slug may be removed quickly and the water level in the well will drop and then the “rising” conditions can be monitored.

In highly transmissive formations, slug tests can be performed using pneumatic testing apparatus and high frequency pressure transducers (e.g. recording data several times per second) which allow recording nearly instantaneous water level displacement and rapid well recoveries. The concept is that air or nitrogen can be used to lower the water level in the well and the additional pressure can be released and the rate of the rising water level can be monitored. Because the zone above the water level in a well needs to be pressurized, this type of test can only be conducted on wells screened below the water level. Use of a pneumatic testing apparatus also avoids data noise issues associated with placing or removing a solid slug out of the well.

Further, in high permeability formations the water level response to applied pressure release well may be oscillatory, as insufficient damping of inertial forces occurs in the formation. Analysis of oscillatory data is possible using methods such as described by Van Der Kamp (Van Der Kamp, 1976), Kipp (Kipp, 1985), and Butler et.al. (Butler et.al. 2003).

2.0 PROCEDURES

The following sections include a description of necessary equipment to perform the slug testing, followed by procedures for conducting falling and rising slug tests using manual slugs or pneumatic displacement.

2.1 Manual Slug Test Equipment

The following equipment is necessary to perform a rising or falling head slug test in a monitoring well. Site specific conditions may warrant the use of additional equipment.

- Appropriate health and safety gear per the Health and Safety Plan
- Water level measuring device
- Solid slug
- Nylon rope or wire
- Slug test data form (Attached)
- Field activity forms
- Pressure transducer and direct read cable
- Electronic data logger (if the pressure transducer is not equipped with an interval logger)
- Laptop computer (if using pressure transducers)
- Stopwatch or watch with a built-in timer (if not using a transducer)
- Zip ties and hose clamps as appropriate for suspending transducer
- Well completion diagrams
- Decontamination equipment

The solid slug may be constructed of solid or hollow plastic, such as PVC or metal such as aluminum or steel (depending upon the chemical environment in the well). If hollow, the solid slug will be filled with silica sand or other inert material to add weight. The solid slug should be of sufficient size to cause a minimum of two feet of displacement in a well. For a two-inch diameter well, the solid slug should be no more than 1.5 inches in diameter and a minimum of 3.6 feet long. For a four-inch diameter well, the solid slug should be no more than 3 inches in diameter and a minimum of 3.6 feet long. The solid slug should be securely fastened to a nylon rope or wire. Any equipment used for slug testing should be decontaminated prior to being lowered down the well using procedures listed in SOP NMI-007.

2.2 Falling Head Tests Procedures

The following procedure should be utilized for conducting a falling head slug test. Note the physical condition of the well, including damage, deterioration, and signs of tampering.

1. Open the well cap. Note any unusual odors, sounds, or difficulties in opening the well. Record organic vapor reading with a suitable organic vapor screening device.

2. Lower a decontaminated water level measuring device into the well to determine the static water level.

3. Measure the depth to the bottom of the well and the inside diameter of the well casing.

4. If using a pressure transducer equipped with or connected to a data logger, lower the pressure transducer into the well to a sufficient depth in the well so that the transducer will be below the maximum depth reached by the solid slug. Assume that the top of the solid slug when emplaced in the well will be one-foot below the static water level.

5. Secure the pressure transducer to the side of the well using duct tape, zip ties or a hose clamp. The transducer cable should lie flat along the side of the well riser, so that disturbance by the solid slug will be minimized. Do not bend the transducer cable or a kink will develop in the cable that will cut off the pressure equalization vent (if a vented transducer type is used) tube in the cable, which will prevent the transducer from operating. Once the transducer is secured, connect it to the laptop (or external datalogger) and observe the water level and temperature readings until both are calibrated to ambient/static conditions.

6. Determine the distance from the top of the well riser to the water surface in the well and add one foot to this length. The resulting length is the amount of wire or rope needed so that the solid slug will be submerged a minimum of one foot when it is placed in the well. A loop should be placed in the rope or wire at this length and a strong metal rod or wooden stick placed and secured through the loop. If the bottom of the well is less than this length added to the length of the solid slug, the length of the rope or wire should be adjusted so that the solid slug will be no less than one foot above the top of the pressure transducer when the slug is dropped in the well.

7. If using a pressure transducer equipped with a data logger, program it to record linearly. Shorter intervals may be needed for highly transmissive formations where the recovery period can be very short.

8. If depth readings are to be recorded manually (this procedure is recommended only in aquifers suspected of having low hydraulic conductivity, less than 5 feet per day), readings should be taken every 10 seconds for the first minute of the test, every 30 seconds for the first 5 minutes and every minute until 10 minutes. Thereafter, readings may be taken every 5 minutes for the duration of the test. If the well has not recovered within one hour, readings may be taken every 0.5 hour until six hours and at one-hour intervals thereafter. This process will require two people during the first 10 minutes of the test, a person to act as timekeeper/data recorder and a person to measure depth to water.

9. Place the slug in the well until the bottom is no more than 6 inches above the water level in the well.

10. Activate the transducer/datalogger to start recording water levels.

11. Lower the slug into the well until the stick or rod is resting on the well riser. The solid slug should not be dropped.

12. The falling head will be monitored until the level has dropped to 90 percent of the increased head due to insertion of the slug. If 90 percent recovery has not occurred within one hour, the test may be stopped. Field conditions and time constraints may warrant stopping the test in less than one hour.

13. Download the data logger to a computer or to hard copy to ensure that the data is not inadvertently lost. If the data were recorded manually, calculate the relative change in head by subtracting the recorded depths to water from initial static water level and record the absolute value of that change, for each time-depth data pair.

2.3 Rising Head Tests Procedures

The following procedure should be utilized for conducting a rising head slug test. Note, the test may be started after completion of a falling head test described above. The steps are essentially the same as those for a falling head test, except that the test is started only after the slug has been placed in the well and the water level in the well has recovered back to static conditions. If this test is performed after a falling head test, begin with step 11.

1. Note the physical condition of the well, including damage, deterioration, and signs of tampering.

2. Unlock the protective cap on the well.

3. Open the well cap. Note any unusual odors, sounds, or difficulties in opening the well. If required, collect and record organic vapor reading with a suitable organic vapor screening device (e.g. photoionization detector [PID]).

4. Lower a decontaminated water level measuring device into the well to determine the static water level.

5. Measure the depth to the bottom of the well and the inside diameter of the well casing.

6. If using a pressure transducer connected to a data logger, lower the pressure transducer into the well to a sufficient depth in the well so that the transducer will be below the maximum depth reached by the solid slug.

7. Secure the pressure transducer to the side of the well using duct tape, zip ties or hose clamps. The transducer cable should lie flat along the side of the well riser, so that disturbance by the solid slug will be minimized. Do not bend the transducer cable or a kink will develop in the cable that will cut off the pressure equalization vent tube in the cable, which will prevent the transducer from operating.

8. Allow the pressure transducer to temperature equilibrate a minimum of 15 minutes before connecting it to the data logger and starting the test.

9. Allow the water level in the well to recover to static level after emplacement of the pressure transducer, prior to starting the test.

10. Determine the distance from the top of the well riser to the water surface in the well and add one foot to this length. The resulting length is the amount of wire or rope needed so that the solid slug will be submerged a minimum of one foot when it is placed in the well. A loop should be placed in the rope or wire at this length and a strong metal rod or wooden stick placed and secured through the loop. If the bottom of the well is less than this length added to the length of the solid slug, the length of the rope or wire should be adjusted so that the solid slug will be no less than one foot above the top of the pressure transducer when the slug is placed in the well.

11. If using a data logger, program it to record linearly, with a maximum time interval of no more than one minute between readings.

12. If depth readings are to be recorded manually (this procedure is recommended only in aquifers suspected of having low hydraulic conductivity, less than 5 feet per day), readings should be taken every 10 seconds for the first minute of the test, every 30 seconds for the first 5 minutes and every minute until 10 minutes. Thereafter, readings may be taken every 5 minutes for the duration of the test. If the well has not recovered within one hour, readings may be taken every 0.5 hour until six hours and one hour thereafter. This process may require two personnel during the first 10 minutes of the test, a person to act as time-keeper/data recorder and a person to measure depth to water.

13. To start the test, the solid slug should be removed rapidly but smoothly so that water sloshing in the well is minimized.

14. The rising head will be monitored until the level has risen to at least 90 percent of the lowered water level due to removal of the slug. If 90 percent recovery has not occurred within one hour, the test may be stopped. Field conditions and time constraints may warrant stopping the test in less than one hour.

15. Download the data logger to a computer or to hard copy to ensure that the data is not inadvertently lost. If the data were recorded manually, calculate the relative change in head by subtracting the recorded depths to water from initial static water level and record the absolute value of that change, for each time-depth data pair.

2.4 Pneumatic Rising Head Tests Equipment

In high permeability formations where the water level will require quickly and the well screen is below the water level, pneumatic slug test equipment may be used. The following equipment in

addition to the equipment specified above should be utilized when conducting a pneumatic rising head slug test. Site specific conditions may warrant the use of additional equipment.

- Pressure tight "tree" assembly equipped with an air pressure gage;
- Short length (~6-inches) of flexible rubber hose with hose clamps (a Fernco® coupling) the inside diameter of which is the same as the outside diameter of the well riser;
- Laptop computer;
- Spray bottle with Alconox (soap solution); and
- Small output air pump (e.g. Brailsford model TD-4 series or equivalent), compressor or compressed air tank with hose and appropriate adapters.

The pressure-tight "tree" assembly shown on Figure 1, is a device placed on the top of the well that will accomplish the following (a “tree” consist of a several tees in series with the top leg of the tee connected to a pressure source, a side leg of the tee connected to a pressure relief valve, and another leg used to run the pressure transducer cable down the well):

- Form a pressure seal between the well and the atmosphere;
- Allow the injection of compressed air into the well via an air hose connected to an air pump, compressor or compressed air tank;
- Provide a pressure-tight passage for a pressure transducer cable and a water level meter;
- Include a pressure gauge to add the desired pressure; and
- A venting valve to allow for rapid well depressurization.

If the top of the well riser is threaded, the device may be screwed onto the riser, if the threads are wrapped with Teflon tape. If the threaded end of the riser has been cut off, a slip coupling will need to be placed over the base of the tree and the top of the riser. A small length of flexible rubber hose the same inside diameter as the outside diameter of the coupling will be slipped over the coupling and secured in place with tightly closed hose clamps to form a pressure tight seal between the riser and the well.

The simplest method for providing access for the pressure transducer cable and the water level meter is to use a standard large diameter laboratory black rubber stopper with a hole through the cork's axis that has been slit halfway through along that axis. The cork can be firmly placed into the port form a pressure tight seal.

The tree will have a standard ball valve with an inside valve orifice diameter no less than the diameter of the well riser. In addition, a standard swage-lock fitting or quick-connect coupling will be attached to the side of the tree to act as a compressed air inlet port.

2.5 Procedure for Conducting Pneumatic Rising Head Slug Tests

The following procedure should be used for conducting a pneumatic rising head slug test.

1. Note the physical condition of the well, including damage, deterioration, and signs of tampering.
2. Unlock the protective cap on the well.
3. Open the well cap. Note any unusual odors, sounds, or difficulties in opening the well. If required, collect and record organic vapor reading with a suitable organic vapor screening device (e.g., PID).
4. Check for any holes in the side of the riser. The test cannot be conducted in any well that is not airtight.
5. Lower a decontaminated water level measuring device into the well to determine the static water level.
6. Measure the depth to the bottom of the well and the inside diameter of the well casing.
7. Install the test tree to the top of the well, either by screwing it in to existing threads or by using a slip coupling adapter (i.e, Fernco®). If using a slip coupling, ensure that the bottom of the T sits securely on the top of the riser to prevent vertical motion. Make sure the seal to the riser head is pressure tight. Additional support (e.g., a tripod or threaded rods in flush mount wells) may be required to prevent the assembly from swaying vertically or side to side during testing.
8. Lower the pressure transducer into the well through a port in the tree to at least 10 feet below the water table. The pressure transducer should be rated no less than 30 pounds per square inch.
9. Allow the pressure transducer to temperature equilibrate for approximately 15 minutes before connecting it to the data logger or laptop computer and starting the test.
10. Secure the transducer cable and the water level meter and tape in place to the top of the tree with a stopper as described previously. Insert the transducer cable into the hole in the rubber stopper via the slit. Place the stopper firmly in the top of flexible hose at the top of the tree so that no gaps are left in the cork. Tighten the hose clamps to seal the rubber stopper to the flexible hose. If necessary, place small strips of duct tape over the assembly to ensure that the seal is airtight. The seal can be checked by pressurizing the assembly as a test run, spraying Alconox water over the stopper and inspecting for bubbles. Connect the pressure transducer to the computer and begin collecting data at 0.5 second intervals. If allowed by the transducer software, set the transducer to collect and display real-time data on the laptop computer screen
11. Connect the air hose to the air supply or compressor and the tree. Make sure the ball valve is securely closed.
12. Using the regulator attached to the compressor, slowly allow compressed air into the well, stopping when the applied pressure equals approximately 1.0 psi. Allow the well to equilibrate with the depressed water level for several minutes. Monitor and record the pressure gage and the transducer readings to ensure that they are stable. Open the ball

valve quickly to release the pressure. Organic, non-contaminated lubricant (e.g. vegetable oil) can be used to lubricate the ball valve to ensure it operates freely.

13. Run at least two tests at different applied pressures. According to Butler, 2003, low applied pressures are preferred. Assume the two tests will be run at 1.0 and 1.25 pounds per square inch (2.3 to 2.9 ft of head). In highly permeable aquifers the water level in the well should recover to pre-test static water levels within a few seconds. Full recovery should be accomplished in no more than one minute.

14. After the test is complete but before removing the testing assembly, download the data from the datalogger or pressure transducer to a computer and export the data to a spreadsheet to provide a backup. The file naming convention should include the site, well name, date, and initial displacement used. Review the data quality of the test. Because tests in highly transmissive formations are relatively quick relative to the required set up time, it is oftentimes desirable to conduct up to three tests (with some variation in initial displacements) to provide a dataset where the test with the best data quality can be analyzed for hydraulic conductivity estimates.

15. Complete the slug test data sheet with all pertinent data.

3.0 DECONTAMINATION

Downhole equipment including displacement devices, transducers, and water level meters should be decontaminated prior to slug testing and after removing from well using SOP NMI-007.

4.0 REFERENCES

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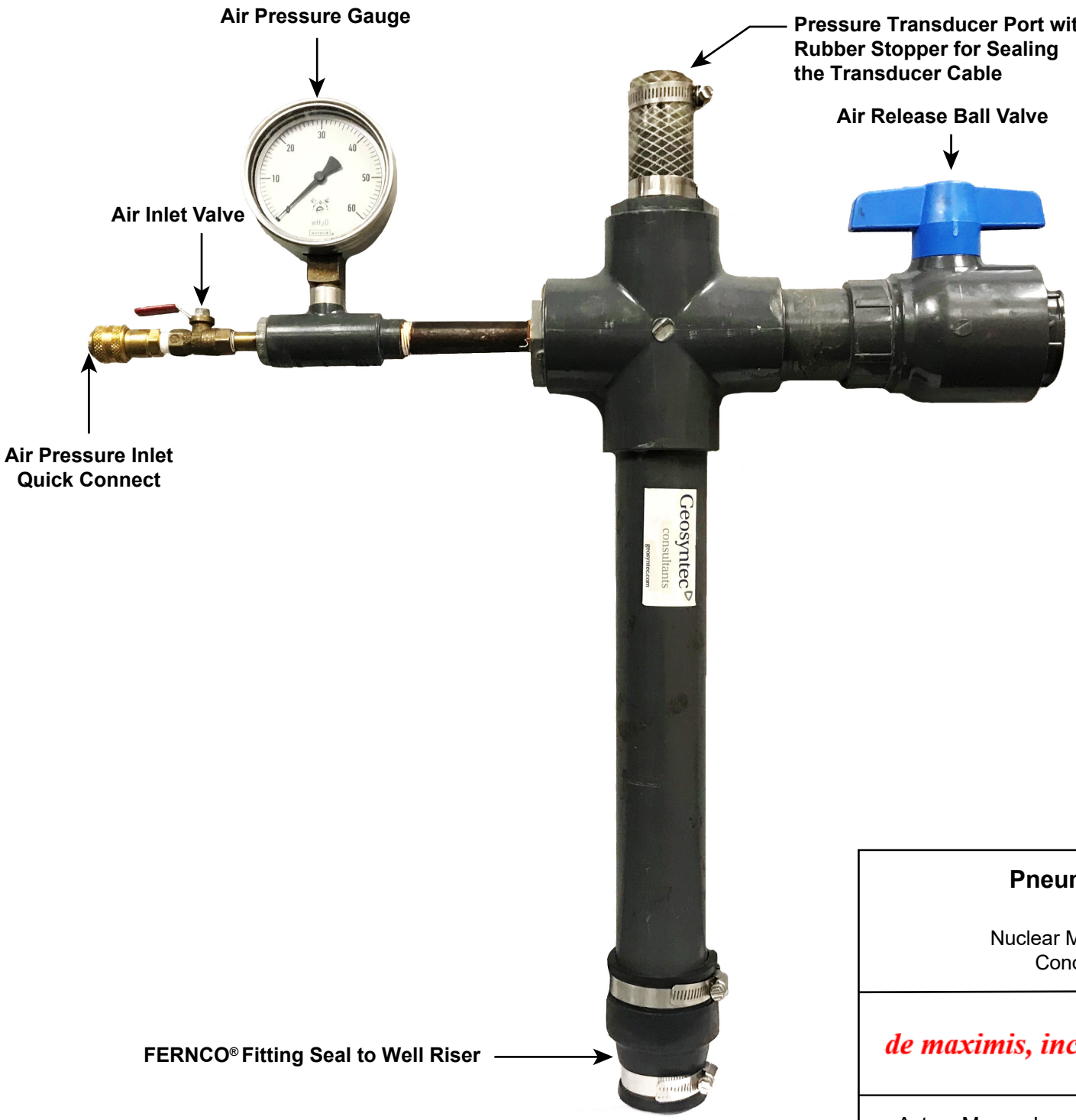

Pneumatic Testing Tree

Nuclear Metals Inc. Superfund Site
Concord, Massachusetts

de maximis, inc. | Geosyntec consultants | Figure 1

Acton, Massachusetts | March 2020

SLUG TEST FIELD FORM

Geosyntec consultants

Project Name: _____ Date: _____

Project Number: _____

Field Personnel: _____ Well Name: _____

_____ Well Location: _____

Recorded by: _____ Weather: _____

Expected Water Table Behavior(Rising/Falling):_____

WELL CONSTRUCTION/WATER LEVEL

Reported Well Depth(ft TOR)_____ Date of Last Development_____

Measured Well Depth(ft TOR)_____ Initial Static Water level from TOR(ft)_____

Casing Diameter(in)/Schedule_____ Final Static Water level from TOR(ft)_____

Screen Length(ft) and Slot Size_____ TOR from land surface(ft)_____

Depth to TOP of Screen from TOR(ft)_____ Borehole Diameter(in)_____

Filter Pack Details_____ Annular Seal Details _____

PRESSURE TRANSDUCER INSTALLATION

	Type	Serial Number	Reading in Air	Pressure Units	Log Method	Log Interval	Log Duration
Transducer							

FALLING HEAD TEST DETAILS

Test Number	TEST 01	TEST 02	TEST 03	TEST 04	TEST 05	TEST 06
PT Depth(TOR)						
Water Volume poured into well(mL)						
Initial Displacement(ft H2O)						
WL Equillibrium Time						
Test Start Time						
Test End Time						

TEST ELECTRONIC FILE NAMES

TEST 01	
TEST 02	
TEST 03	
TEST 04	
TEST 05	
TEST 06	

STANDARD OPERATING PROCEDURE NMI-GW-020

FIELD ANALYSIS OF FLUORESCENT TRACER DYE IN GROUNDWATER

1.0 INTRODUCTION

This standard operating procedure (SOP) provides instructions for field measurement of fluorescent tracer dyes in groundwater using a fluorometer. Fluorescent tracer dyes (e.g., rhodamine WT) will be used to evaluate the radius of injection (ROI) during injection of soluble reagents for in-situ stabilization. Dye will be added by mixing it with the injected solution; groundwater samples are then collected from monitoring wells in the vicinity of the injection point for measurement of the dye concentration. The presence (versus absence) of dye in the samples will inform whether injected reagent was transported from the injection location to the well.

This SOP was developed based on the *Procedures and Criteria Analysis of Fluorescent Dyes in Water and Charcoal Samplers : Fluorescein, Eosine, Rhodamine WT, and Sulforhodamine B Dyes*, Dated March 3, 2015 by Ozark Underground Laboratory, Inc. (Attachment A) and includes instructions for calibration of a handheld fluorometer, field dilution of samples, collection and analysis of samples using a handheld fluorometer, and collection of grab samples for laboratory analysis of tracer fluorescent dyes. This SOP is intended only to support sampling for ROI evaluation during injections. When sampling for other analytical compounds (e.g., volatile organic compounds or metals) or when sampling for fluorescent tracer dyes as part of the performance monitoring program, SOP NMI-GW-010 – Groundwater Sampling Using the Low-Flow Protocol should be used.

1.1 Equipment and Supplies

The following equipment will generally be required for sampling:

- Pump capable of a flow rate between 200 and 500 milliliters per minute (mL/min) and appropriate power supply. The pump type will principally depend on the depth to water and well diameter. Submersible electric or bladder pumps are preferred; peristaltic pumps are acceptable only for wells where the depth to water is less than about 25 feet; Waterra pumps are only recommended for narrow diameter wells that cannot be sampled using a bladder or peristaltic pump. For submersible pump installation and operation refer to SOP NMI-002 – Submersible Pump Operation.
- Handheld fluorometer such as the Turner Designs AquaFluor® or equivalent;
- Cuvettes or test tubes compatible with the handheld fluorometer;
- Calibration standards for each fluorescent tracer dye to be analyzed;
- Field dilution supplies (distilled water, graduated cylinders/beaker);

- Water level tape;
- Tubing, connections and tools as appropriate;
- 5-gallon bucket and funnel for purge water;
- Field forms and notebook;
- Decontamination supplies (e.g., DI water, Alconox soap, alcohol, paper towels);
- Sample containers and cooler for analytical laboratory samples (typically 50 mL polypropylene or glass containers provided by the laboratory);
- Clean plastic sheeting, paper towels and miscellaneous supplies; and
- PPE as required by the Health and Safety Plan.

2.0 PROCEDURES

2.1 Pre-Mobilization Activities

- Obtain the construction information for each monitoring well to be sampled, including diameter, total depth, riser material, and screened interval.
- Obtain a list of the fluorescent dyes that will be measured in the field or in laboratory samples as part of this sampling program.
- Verify that the handheld fluorimeter to be used for field analysis is compatible with the dyes that will be tested. Verify a calibration standard for each fluorescent dye to be measured in the field has been obtained; calibration standards are typically provided by the fluorometer manufacturer or the analytical laboratory. The calibration standards should be at a concentration within the linear range of the fluorometer being used. For example, if using a Turner Designs AquaFluor®, the linear range for fluorescein dye is 0-400 parts per billion (ppb), therefore, the fluorescein calibration standard should be no greater than 400 ppb.
- Inventory sample containers to verify that the laboratory has provided the correct number of containers of the proper size.
- Verify that the appropriate personal protective equipment and ancillary supplies (e.g., paper towels, decontamination solution) are ready to be shipped to the field site. The appropriate protective equipment, as specified in the site-specific Health and Safety Plan, will be reviewed during a morning tailgate meeting. Contact the field supervisor or project manager immediately if there are discrepancies.

2.2 Calibration

Calibrate the fluorometer according to the manufacturer's specifications before sampling at the start of each field day. The fluorometer should be calibrated to a standard for each of the fluorescent tracer dyes being measured in the field, typically using a single point calibration curve for each dye. If the dye to be measured changes during the sampling program, the fluorometer must be recalibrated to a standard using the new dye.

Record the calibration data on the daily field report, including information about the fluorimeter (e.g., manufacturer, model number and serial number), calibration standard such as the type of fluorescent dye and concentration, and concentration measured by the fluorimeter. Periodic checks of the calibration can be performed during the field day especially if the working temperatures fluctuate significantly from when the meter was calibrated. A final calibration check should be conducted at the end of the field day. Instruments will be recalibrated as necessary (e.g., when calibration checks indicate incorrect operation) to ensure accurate measurements, and all checks and recalibrations will be recorded on the daily field report.

After calibrating the fluorometer, field blanks can be measured and recorded in the daily field report or appropriate field form. Field blank readings can be useful to understand if constituents in the distilled water and groundwater, other than the dye, produce nonzero readings on the fluorometer. Field blanks should consist of one sample of the distilled water to be used for field dilutions and, if available, one sample of site groundwater. The brand of water and the fluorometer reading should be recorded for the distilled water blank and the groundwater sample location, purge method, collection date, and fluorometer reading should be recorded for the site groundwater blank.

2.3 Well Purging and Sampling

Detailed procedures for each step of collecting and analyzing groundwater samples for fluorescent tracer dyes are provided in the following subsections.

2.3.1 Set-up

Equipment will be placed on a clean plastic sheet near the well. General parameters describing the well and field condition (e.g., well ID, depth, weather, date and time) will be documented on a field data sheet. Care should be taken not to use any writing implements or equipment with red color (if using Rhodamine) or other color similar to dye used for tracer study, which may contaminate tracer study samples (no colored/red Sharpies, no string/rope with colored/red thread for hanging pumps, etc.). Prior to sampling, the depth to the water surface should be measured per SOP NMI-GW-009. The pump, tubing, and reservoir for purged water are then set up. The pump intake (assuming a submersible pump, otherwise the end of tubing if using a peristaltic or Waterra pump) should be installed at the target sample depth within the well screen.

2.3.2 Purging

Wells being sampled for fluorescent dyes are purged and sampled using a grab method. To purge, begin pumping at a steady flow rate of approximately 200 to 500 mL/min.

2.3.3 Field Measurements

After water begins flowing from the discharge tubing and a sufficient volume has been purged to account for the volume of the tubing and the pump, collect a sample for field screening directly into a cuvette specified for the fluorometer. Measure the tracer dye concentration using the handheld fluorometer according to the manufacturer's instructions. For each measurement,

record the concentration, the sample time, location and depth of the pump intake. Continue to collect and record field fluorometer readings according to project needs, adjusting the depth of the pump intake as necessary to sample from other target depths if needed. Pumping may be stopped between readings to reduce investigation derived waste and to allow the well to recharge.

2.3.4 Field Dilutions

If the field screening sample is above of calibration range of the fluorometer, a field dilution will be performed until the sample can be measured by the instrument. The following procedures should be used when performing field dilutions.

1. Collect 50 milliliters (mL) of groundwater into a graduated cylinder or beaker.

2. Add 450 mL of distilled water to the groundwater sample and mix thoroughly.

3. Take a field fluorometer reading from the diluted sample following the manufacturer's recommended procedures.

4. If the reading is within the fluorometer calibration range, record the readings and the dilution factor (i.e. the inverse of the fraction of groundwater by volume in the sample: 50mL groundwater/500mL total water = dilution factor of 10). If the sample is still outside the calibration range, repeat steps 1 through 3 using the diluted groundwater mixture from this step for the 50 mL in Step 1.

5. To calculate the dilution factor for serial dilutions, multiply the dilution factors from each step of the serial dilution. For example, if two 10x dilutions are conducted prior to a sample falling within the calibration range, the dilution factor would be 10 x 10, or 100.

Depending on project needs and field observations, a higher or lower dilution factor may be used at the discretion of the field sampling team. Additionally, the total volume of groundwater and distilled water used for field dilutions may be reduced, based on project needs. For example, 10 mL of groundwater and 90 mL of distilled water may be mixed to get a dilution factor of 10; however, the smaller the volume used, the greater influence a minor measurement error will have on the final result, especially if multiple dilutions are required.

2.3.5 Sampling

Samples for laboratory analysis of fluorescent tracer dyes may also have to be collected. Laboratory samples, like field samples, will be collected once the pump has purged a volume equal to or larger than the volume of the tubing and the pump. All samples will be immediately placed in coolers with double-bagged ice packs to remain at 4°C (±2°C) prior to and during shipment to the laboratory. The sample containers will be stored in a cooler, away from sunlight, and packaged and shipped using SOP NMI-001.

2.3.6 Clean-up

After completion of field screening and sampling activities at a monitoring well, the pump and tubing should be removed from the well. The pump should be decontaminated following SOP NMI-007 prior to reuse. Fluorescent tracers are detectable at low concentrations, especially using laboratory methods, but are often handled in pure form during testing. Because field teams may be handling very high concentrations to administer tracer and then sampling for very low concentrations, special care should be exercised to avoid cross contamination. These measures may include frequent glove changes, handling pure dyes far from monitoring wells, being aware of wind if handling powdered dyes, and avoiding use of the same equipment in test wells and monitoring wells when practical.

2.4 Documentation

Field documentation includes completed calibration records, sampling data sheets, daily field logs and other field notes deemed relevant. It is essential that field data sheets be filled out completely and legibly at each location, and that entries are consistent for each location and among different personnel. The field sheets should include the following information:

- Job, site, date, and personnel collecting samples;
- Well identification and description;
- Reference elevation and depth to water;
- Depth of pump intake during sampling;
- Location(s) and depth(s) of active liquid reagent injections at the time of sampling;
- Equipment used (tubing, fluorometer model and serial numbers);
- Purge rate, field fluorometer readings, and depth to water recorded as needed;
- Identification, time, container types, and analytical methods for samples collected for laboratory analysis; and
- Additional comments as applicable.

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PROCEDURES AND CRITERIA
ANALYSIS OF FLUORESCENT DYES
IN WATER AND CHARCOAL SAMPLERS:

FLUORESCEIN, EOSINE, RHODAMINE WT, AND SULFORHODAMINE B DYES

Revision Date:
March 3, 2015

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INTRODUCTION

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory (OUL) as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or up-graded. The OUL maintains a summary of changes in standard procedures and criteria.

TRACER DYES AND SAMPLE TYPES

Dye Nomenclature

Dye manufacturers and retailers use a myriad of names for the dyes. This causes confusion among dye users and report readers. The primary dyes used at the OUL and described in this document are included in Table 1 below.

Table 1. Primary OUL Dye Nomenclature.

OUL Common Name	Color Index Number	Color Index Name	Other Names
Fluorescein	45350	Acid Yellow 73	uranine, uranine C, sodium fluorescein, fluorescein LT and fluorescent yellow/green
Eosine	45380	Acid Red 87	eosin, eosine OJ, and D&C Red 22
Rhodamine WT	None assigned	Acid Red 388	fluorescent red (but not the same as rhodamine B)
Sulforhodamine B	45100	Acid Red 52	pontacyl brilliant pink B, lissamine red 4B, and fluoro brilliant pink

The OUL routinely provides dye for tracing projects. Dyes purchased for groundwater tracing are always mixtures that contain both dye and an associated diluent. Diluents enable the manufacturer to standardize the dye mixture so that there are minimal differences among batches. Additionally, diluents are often designed to make it easier to dissolve the dye mixture in water, or to produce a product which meets a particular market need (groundwater tracing is only a tiny fraction of the dye market). The percent of dye in "as-sold" dye mixtures often varies dramatically among manufacturers and retailers, and retailers are sometimes incorrect about the percent of dye in their products. The OUL subjects all of its dyes to strict quality control (QC) testing. Table 2 summarizes the as-sold dye mixtures used by the OUL.

Table 2. As-Sold Dye Mixtures at the OUL.

OUL Common Name	Form	Dye Equivalent
Fluorescein	Powder	75% dye equivalent, 25% diluent
Eosine	Powder	75% dye equivalent, 25% diluent
Rhodamine WT	Liquid	20% dye equivalent, 80% diluent
Sulforhodamine B	Powder	75% dye equivalent, 25% diluent

Analytical results are based on the as-sold weights of the dyes provided by the OUL. The use of dyes from other sources is discouraged due to the wide variability of dye equivalents within the market. However, if alternate source dyes are used, a sample should be provided to the OUL for quality control and to determine if a correction factor is necessary for the analytical results.

Types of Samples

Typical samples that are collected for fluorescent tracer dye analysis include charcoal samplers (also called activated carbon or charcoal packets) and water samples.

The charcoal samplers are packets of fiberglass screening partially filled with 4.25 grams of activated coconut charcoal. The charcoal used by the OUL is Calgon 207C coconut shell carbon, 6 to 12 mesh, or equivalent. The most commonly used charcoal samplers are about 4 inches long by 2 inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1-inch diameter piezometers); this is a special order item and should be specifically requested in advance when needed. All of the samplers are closed by heat sealing.

In specialized projects, soil samples have been collected from soil cores and analyzed for fluorescent tracer dyes. Project-specific procedures have been developed for projects such as these. For additional information, please contact the OUL.

FIELD PROCEDURES

Field procedures included in this section are intended as guidance, and not firm requirements. Placement of samplers and other field procedures require adjustment to field conditions. Personnel at the OUL are available to provide additional assistance for implementation of field procedures specific to specialized field conditions.

Placement of Samplers

Charcoal samplers are placed so as to be exposed to as much water as possible. Water should flow through the packet. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than laying flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The placement of multiple packets is recommended in order to minimize the chance of loss during the sampling period. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are typically placed in sample holders made of plastic pipe fittings. Brass hose fittings can be at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose. The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consist of 1.5 inch diameter pipe and pipe fitting.

Charcoal packets can be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Due to the typically lower volume of water that flows through a well, only one charcoal sampler should be used per well. However, multiple packets can be placed in a single well at depths to test different depth horizons when desirable. A weight should be added near the charcoal packet to ensure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a white or uncolored plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. ***Do not use colored cord*** since some of them are colored with fluorescent dyes. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with small diameter wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a weight may be added to the top of the disposable bailer. Stainless steel weights are ideal, but are not needed in all cases. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

Optional Preparation of Charcoal Samplers

Charcoal packets routinely contain some fine powder that washes off rapidly when they are placed in water. While not usually necessary, the following optional preparation step is suggested if the fine charcoal powder is problematic.

Charcoal packets can be triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach,

approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

Collection and Replacement of Samplers

Samplers are routinely collected and replaced at each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of travel. As an illustration, we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

The sampling interval in wells at hazardous wastes sites should generally be no longer than about a week. Contaminants in the water can sometimes use up sorption sites on the charcoal that would otherwise adsorb the dye. This is especially important if the dye might pass in a relatively short duration pulse.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled to remove dirt and accumulated organic material. This is not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak® bags are ideal). The bag is labeled on the outside with a black permanent type felt marker pen, such as a Sharpie®. ***Use only pens that have black ink***; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels must not be inserted inside the sample bags.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

Water Samples

Water samples are often collected. They should be collected in either glass or plastic; the OUL routinely uses 50 milliliter (mL) research-grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. No more than 30 mL of water is required for analysis. The sides of the vials should be labeled with the project name, sample ID, sample date and time with a black permanent felt tip pen. ***Do not label the lid only***. The vials should be placed in the dark and refrigerated immediately after collection, and maintained under refrigeration until shipment. The OUL supplies vials for the collection of water samples.

Sample Shipment

When water or charcoal samplers are collected for shipment to the OUL they should be shipped promptly. We prefer (and in some studies require) that samples be refrigerated with frozen re-usable ice packs upon collection and that they be shipped refrigerated with frozen ice packs by overnight express. ***Do not ship samplers packed in wet ice*** since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration; yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

We receive good overnight and second day air service from both UPS and FedEx. The U.S. Postal Service does not typically provide next day service to us. DHL does not provide overnight service to us. FedEx is recommended for international shipments. The OUL does not receive Saturday delivery.

Each shipment of charcoal samplers or water samples ***must be accompanied by a sample custody document***. The OUL provides a sheet (which bears the title "Samples for Fluorescence Analysis") that can be used if desired. These sheets can be augmented by a client's chain-of-custody forms or any other relevant documentation. OUL's custody document works well for charcoal samplers because it allows for both the placement date and time as well as the collection date and time. Many other standard chain-of-custody documents do not allow for these types of samples. Attachment 1 includes a copy of OUL's Sample Collection Data Sheet.

Please write legibly on the custody documents and ***use black ink***. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

Supplies Provided by the OUL

The OUL provides supplies for the collection of fluorescent tracer dyes. Supplies provided upon request are charcoal packets, Whirl-Pak® bags (to contain the charcoal packets after collection for shipment to the laboratory), and water vials. These supplies are subjected to strict QA/QC procedures to ensure the materials are free of any potential tracer dye contaminants. The charge for these materials is included in the cost of sample analysis. Upon request, coolers and re-freezable ice packs are also provided for return shipment of samples.

The OUL also has tracer dyes available for purchase. These dyes are subject to strict QA/QC testing. All analytical work is based upon the OUL as-sold weight of the dyes.

LABORATORY PROCEDURES

The following procedures are followed upon receipt of samples at the laboratory.

Receipt of Samples

Samplers shipped to the OUL are logged in and refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number.

It sometimes occurs that there are discrepancies between the sample collection data sheet and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. The purpose of the form is to help resolve discrepancies, even when they may be minor. Many discrepancies arise from illegible custody documents. ***Please write legibly*** on the custody documents and ***use black ink***. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

Cleaning of Charcoal Samplers

Samplers are cleaned by spraying them with jets of clean water from a laboratory well in a carbonate aquifer. OUL uses non-chlorinated water for the cleansing to minimize dye deterioration. We do not wash samplers in public water supplies. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

Elution of the Charcoal

There are various eluting solutions that can be used for the recovery of tracer dyes. The solutions typically include an alcohol, water, and a strong basic solution such as aqueous ammonia and /or potassium hydroxide.

The standard elution solution used at the OUL is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide pellets to saturate the solution. The isopropyl alcohol solution is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution will elute fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in may be found in samplers.

Fifteen mL of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded. Samples are kept refrigerated until analyzed.

pH Adjustment of Water Samples

The fluorescence intensity of several of the commonly used fluorescent tracer dyes is pH dependent. The pH of samples analyzed for fluorescein, eosine, and pyranine dyes are adjust to a target pH of greater than 9.5 in order to obtain maximum fluorescence intensities.

Adjustment of pH is achieved by placing samples in a high ammonia atmosphere for at least two hours in order to increase the pH of the sample. Reagent water standards are placed in the same atmosphere as the samples. If dye concentrations in a sample are off-scale and require dilution for quantification of the dye concentration, the diluting water used is OUL reagent water that has been pH adjusted in a high ammonia atmosphere. Samples that are only analyzed for rhodamine WT or sulforhodamine B are not required to be pH adjusted.

Analysis on the Shimadzu RF-5301

The OUL uses a Shimadzu spectrofluorophotometer model RF-5301. This instrument is capable of synchronous scanning. The OUL also owns a Shimadzu RF-540 spectrofluorometers that is occasionally used for special purposes.

A sample of the elutant or water is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 mL of the sample is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 mL. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The acceptable spectral range of these cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5301. This instrument is controlled by a programmable computer and operated by proprietary software developed for dye tracing applications.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of our first instrument and a training session on its use was provided by the instrument supplier. Repairs are made by a Shimadzu-authorized repairman.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes,

the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is “fast” on the RF-5301. The typical sensitivity setting used is "high."

Table 3. Excitation and emission slit width settings routinely used for dye analysis.

Parameter	**Excitation Slit (nm)**	**Emission Slit (nm)**
ES, FL, RWT, and SRB in elutant	3	1.5
ES, FL, RWT, and SRB in water	5	3

Note: ES = Eosine. FL = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

The instrument produces a plot of the synchronous scan for each sample; the plot shows emission fluorescence only. The synchronous scans are subjected to computer peak picks using proprietary software; peaks are picked to the nearest 0.1 nm. Instrument operators have the ability to manually adjust peaks as necessary based upon computer-picked peaks and experience. All samples run on the RF-5301 are stored electronically with sample information. All samples analyzed are recorded in a bound journal.

Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in both elutant and water samples. Dye quantities are expressed in microgram per liter (parts per billion; ppb). The dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

We run dye concentration standards each day the RF-5301 is used. Six standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
4) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
5) 10 ppb eosine in elutant.
6) 100 ppb sulforhodamine B in elutant.

Preparation of Standards

Dye standards are prepared as follows:

Step 1. A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to ensure that all dye is fully dissolved.

Step 2. One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein, rhodamine WT, eosine, and sulforhodamine B. The resulting solutions contain 100 mg/L dye (100 parts per million dye mixture). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 mL of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 mL at intervals of 0.005 mL. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 mL, 0.90%

At 0.300 mL, 0.28%

At 1.000 mL, 0.30%

The Step 2 solution is called the long term standard. OUL experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

Step 3. A series of intermediate-term dye solutions are made. Approximately 45 mL. of each intermediate-term dye solution is made. All volume measurements of less than 5 mL are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.

2) 1 ppm eosine.

3) 10 ppm sulforhodamine B dye.

Step 4. A series of six short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the OUL these standards have a useful shelf life in excess of one week. However, in practice, Step 4 elutant standards are made weekly, and Step 4 water standards are made daily.

Dilution of Samples

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilutions are either 10 fold (1:10) or 100 fold (1:100). A 1:10 dilution involves combining one part of the test sample with 9 parts of water (if the sample is water) or elutant (if the sample is elutant). A 1:100 dilution involves combining one part of the test sample is combined with 99 parts of water or elutant, based upon the sample media. Typically, 0.300 mL of the test solution is combined with 29.700 mL of water (or elutant as appropriate) to yield a new test solution.

All volume measurements of less than 5 mL are made with a digital Finnpipette. All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value.

The water used for dilution is from a carbonate aquifer. All dilution water is pH adjusted to greater than pH 9.5 by holding it in open containers in a high ammonia concentration chamber. This adjustment takes a minimum of two hours.

Quality Control

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations. Spiked samples are also analyzed when appropriate for quality control purposes.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds that might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing includes approximately 1% of materials used.

Project specific QA/QC samples may include sample replicates and sample duplicates. A replicate sample is when a single sample is analyzed twice. A sample duplicate is where two samples are collected in a single location and both are analyzed. Sample replicates and duplicates are run for QA/QC purposes upon request of the client. These results are reported in the Certificate of Analysis.

Reports

Sample analysis results are typically reported in a Certificate of Analysis. However, specialized reports are provided in accordance with the needs of the client. Certificates of Analysis typically provide a listing of station number, sample ID, and dye concentrations if detected. Standard data format includes deliverables in MS Excel and Adobe Acrobat (.pdf)

format. Hard copy of the data package, and copies of the analytical charts are available upon request.

Work at the OUL is directed by Mr. Thomas Aley. Mr. Aley has 45 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #179) by the American Institute of Hydrology and licenced as a Professional Geologist in Missouri, Arkansas, Kentucky, and Alabama. Additional details regarding laboratory qualifications are available upon request.

Waste Disposal

All laboratory wastes are disposed of according to applicable state and federal regulations. Waste elutant and water samples are collected in 15 gallon poly drums and disposed with a certified waste disposal facilityas non-hazardous waste.

In special cases, wastes for a particular project may be segregated and returned to the client upon completion of the project. These projects may have samples that contain contaminants that the client must account for all materials generated and disposed. These situations are managed on a case-by-case basis.

CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

Normal Emission Ranges and Detection Limits

The OUL has established normal emission fluorescence wavelength ranges for each of the four dyes described in this document. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 4 provides normal emission wavelength ranges and detection limits for the four dyes when analyzed on the OUL's RF-5301 for samples analyzed as of March 3, 2015.

Table 4. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in water and elutant samples.

Fluorescent Dye	**Normal Acceptable Emission Wavelength Range (nm)**		**Detection Limit (ppb)**	
	Elutant	**Water**	**Elutant**	**Water**
Eosine	539.3 to 545.1	532.5 to 537.0	0.050	0.015
Fluorescein	514.1 to 519.2	505.9 to 509.7	0.025	0.002
Rhodamine WT	564.6 to 571.2	571.9 to 577.2	0.170	0.015
Sulforhodamine B	575.2 to 582.0	580.1 to 583.7	0.080	0.008

Note: Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.
Fluorescein and eosine detection limits in water are based on samples pH adjusted to greater than 9.5.

It is important to note that the normal acceptable emission wavelength ranges are subject to change based on instrument maintenance, a change in instrumentation, or slight changes in dye formulation. Significant changes in normal acceptable emission wavelength ranges will be updated in this document as they occur.

Fluorescence Background

Due to the nature of fluorescence analysis, it is important to identify and characterize any potential background fluorescence at dye introduction and monitoring locations prior to the introduction of any tracer dyes.

There is generally little or no detectable fluorescence background in or near the general range of eosine, rhodamine WT, and sulforhodamine B dyes encountered in most groundwater tracing studies. There is often some fluorescence background in or near the range of fluorescein dye present at some of the stations used in groundwater tracing studies.

Criteria for Determining Dye Recoveries

The following sections identify normal criteria used by the OUL for determining dye recoveries. The primary instrument in use is a Shimadzu RF-5301.

EOSINE

Normal Criteria Used by the OUL for Determining Eosine Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the range of 540.0 to 545.8 nm in the sample.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

Normal Criteria Used by the OUL for Determining Eosine Dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 532.8 to 537.3 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

FLUORESCEIN

Normal Criteria Used by the OUL for Determining Fluorescein Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the range of 514.5 to 519.6 nm in the sample.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

Normal Criteria Used by the OUL for Determining Fluorescein Dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 506.8 to 510.6 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

RHODAMINE WT

Normal Criteria Used by the OUL for Determining Rhodamine WT Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the sample in the range of 565.2 to 571.8 nm.

Criterion 2. The dye concentration associated with the rhodamine WT peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the OUL for Determining Rhodamine WT Dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be rhodamine WT dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 572.4 to 577.7 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our rhodamine WT detection limit in water samples is 0.015 ppb, thus this dye concentration limit is 0.045 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

SULFORHODAMINE B

Normal Criteria Used by the OUL for Determining Sulforhodamine B Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the sample in the range of 576.4 to 583.2 nm.

Criterion 2. The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the OUL for Determining Sulforhodamine B dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 580.8 to 584.4 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. The detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Standard Footnotes

Sometimes not all the criteria are met for a straight forward determination of tracer dye in a sample. For these reasons, the emission graph is scrutinized carefully by the analytical technician and again during the QA/QC process. Sometimes the emission graphs require interpretation as to whether or not a fluorescence peak represents the tracer dye or not. Background samples from each of the sampling stations aid in the interpretation of the emission fluorescence graphs. When the results do not meet all the criteria for a positive dye detection, often the fluorescence peak is quantified and flagged with a footnote to the result as not meeting all the criteria for a positive dye detection. Standard footnotes are as follows:

Single asterisk (*): A fluorescence peak is present that does not meet all the criteria for a positive dye recovery. However, it has been calculated as though it were the tracer dye.

Double asterisk (**): A fluorescence peak is present that does not meet all the criteria for this dye. However, it has been calculated as a positive dye recovery.

Other footnotes specific to the fluorescence signature are sometimes also used. These footnotes are often developed for a specific project.

The quantification of fluorescence peaks that do not meet all the criteria for a positive dye detection can be important for interpretation of the dataset as a whole.

ATTACHMENT 1

Sample Collection Data Sheet

OZARK UNDERGROUND LABORATORY, INC.

1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 email: contact@ozarkundergroundlab.com

SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

Project _____ **Week No:** ___ **Samples Collected By:** _____

Samples Shipped By: _____ **Samples Received By:** _____

Date Samples Shipped: _____ **Date Samples Received:** _____ **Time Samples Received:** _____ **Return Cooler? Yes** ☐ **No** ☐

Bill to: _____ **Send Results to:** _____

Analyze for: ☐ **Fluorescein** ☐ **Eosine** ☐ **Rhodamine WT** ☐ **Other** _____ **Ship cooler to:** _____

OUL use only		***Please indicate stations where dye was visible in the field*** *for field technician use - use black ink only*						*OUL use only*
# CHAR REC'D	**LAB NUMBER**	**STATION NUMBER 1-4 Numbers**	**STATION NAME**	**PLACED**		**COLLECTED**		**# WATER REC'D**
				DATE	**TIME**	**DATE**	**TIME**	

COMMENTS _____

_____

This sheet filled out by OUL staff? Yes ☐ **No** ☐ **Charts for samples on this page proofed by OUL:** _____

OUL Project No._____ **Date Analyzed:**_____ **Analyzed By:**_____

STANDARD OPERATING PROCEDURE NMI-SW-001

SURFACE WATER SAMPLING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the logistics, collection techniques, and documentation requirements for collecting surface water samples. The safety procedures related to working over, near, or in water are provided in the Health and Safety Plan (HASP) and should be reviewed prior to field deployment.

1.1 Objective

The objective of surface water sampling is to obtain a representative sample for laboratory analysis of contaminants of concern at a given site. This objective requires that the sample be both free of unsuitable material and be of sufficient quantity and quality for analysis by the selected analytical method.

1.2 Equipment

The following equipment is needed for surface water sampling:

- Boots, waders, personal flotation device (life jacket), and other PPE as required by HASP.
- Sample containers (40 milliliter VOA vials, 1-liter amber glass jars and 1-liter plastic bottles).
- Wooden stakes, highly visible spray paint and flagging.
- Kemmerer bottle, Van Dorn bottle or sterile sampler (if required). The sampler employed will be manufactured of stainless steel, Teflon, or glass. Teflon containers should not be used when sampling for per-and polyfluoroalkyl (PFAS) substances.
- Multi-parameter sonde or other equipment for water quality monitoring with appropriate probes and calibration materials;
- Field logbook and/or Sample Log Form.
- Sample bottle, labels
- Chain-of-custody forms
- Boat, and any associated boating and safety equipment (if needed)

2.0 PROCEDURES

2.1 Order of Samples

If sampling is performed in flowing streams or runoff channels, samples should be collected from the furthest point downstream first so that water column and sediment disrupted by the

sampler do not impact downstream samples. The remaining samples will be taken while proceeding upstream.

2.2 Surface Water Sampling Procedure

The person collecting the samples in most cases will have to enter the water body. The "buddy system" will be used and at least one employee will remain on the bank/shore to support the worker who enters the water body; appropriate tie off shall be used and anyone entering the water must wear a floatation device.

For flowing streams, samplers may need to don boots or waders and wear latex inner gloves and chemical resistant outer gloves. In water bodies with rough bottoms composed of boulders, the sampler may use a wooden stake to scope the bottom ahead of stepping and to support their balance. All samples in flowing water bodies will be taken facing upstream. Samples taken from small lakes or ponds should be taken from a boat using a Kemmerer or Van Dorn bottle. Samples taken from standing puddles, pools, and drainage ditches should be taken without disturbing the sediments. This may be accomplished using a remote sampler, e.g., a sample bottle held on a long pole with a gimballed yoke.

The sampling steps are as follows:

1. Prior to collecting any water samples, place a completed waterproof sample label on each container. Fill in the information with a waterproof ink pen before sample collection. This will prevent difficulty in filling out a wet label.

2. Determine containers for samples that require preservative have correct amount of preservative prior to collection of samples at a given location. Sample containers for metal and volatile organic compound analysis typically come pre-preserved.

3. Face upstream aligned with the stream center line; wearing gloves, take a clean wide-mouth sampler container with the lid screwed on and submerge it without disturbing any sediment. At the desired sample depth (at 6/10ths stream depth (per average flow convention); if the water depth is less than one foot, collect the sample from 1/3 depth, as to avoid disturbing the bottom of the stream), open the lid allowing the jar to fill. Once the jar is filled, screw the lid back onto the sampling jar and retrieve it.

4. Take the filled sampler container and fill pre-preserved volatile organic vials before filling any other containers. Slightly over-fill the vial and screw on the cap. Then turn the vial upside down and tap lightly to check for air bubbles. Air bubbles of any size should not be present as they can introduce significant error in the analysis of the sample. If any air bubbles are present, empty the vial and repeat the process with a new vial containing preservative.

5. Using the same wide-mouth container, continue to fill the remaining pre-preserved sample bottles. Where samples are to be submitted where field filtration is required (dissolved compounds), 500 ml of water collected from the sampling point will be

filtered in the field using a portable pump and sterile, dedicated filtration devices. The filtered sample will be preserved subsequent to the filtration.

6. The temperature, pH, dissolved oxygen, oxidation reduction potential and conductivity of the water at sampling location should be measured and documented immediately after sample collection. Where possible, field measurements of these parameters will be measured in-situ, rather than from a separate transfer container. Measurements will be taken by direct placement of the calibrated water quality monitoring sonde submerged in water body to the sampling depth. If in-situ measurements cannot be conducted, ex-situ measurements should not be taken from any sample bottles being sent to the analytical laboratory for chemical analysis. Calibration of the field probe is outlined in Calibration of Field Instruments Standard Operating Procedures.

7. All samples will be immediately placed on ice (preferably double-bagged ice packs) to remain at 4°C (±2°C) prior to and during shipment to the laboratory. The sample containers will be stored in a cooler until further processing. The Chain of Custody forms for each sample suite will be sealed inside of a Ziploc® container (doubled if necessary) and placed in the cooler with the corresponding samples. Fragile material (glass or other breakable sample vials) is to be wrapped with bubble wrap or a similar material. Refer to the Standard Operating Procedure for sample shipping.

8. Detail in the field logbook the sample location, ID, and time. Complete the Sample Log Sheet (attached) with the following:

    - Sample identification number
    - Location of the sample (sketch of the sample point)
    - Time and date sample was taken
    - Personnel performing the task
    - Description of the sample (color, odor, turbidity, etc.)
    - Weather conditions during sampling
    - Runoff conditions
    - Other pertinent observations

9. Place a spray-painted wooden stake at the edge of the stream or near the sample point with the sample identification number on it. The stake can be located by survey for inclusion on a site map and/or used as a reference for future sampling.

10. At the end of each day, all samples shall be recorded in the field logbook.

2.3 Duplicate Surface Water Sampling

The following procedures should be used for collecting duplicate surface water samples:

1. All labeling procedures used for surface water sampling will be employed and all parameters measured will also be recorded. Since the duplicate is collected simultaneously to the actual sample. The actual source and collection time of the duplicate sample will be recorded in the field logbook.

2. Each duplicate sample will be collected immediately before or immediately after the actual sample and follows the same procedure as the actual sample. Sampling should be collected in the same order for the duplicate as for the actual sample (VOCs, semi-volatiles organic compounds (SVOCs), unfiltered inorganic compounds, and filtered inorganic compounds).

3. All collection and preservation procedures outlined for surface water sampling will be followed for each duplicate sample.

2.4 Documentation

Field documentation includes completed calibration records, daily field logs, sampling purge records, Chain of Custody forms, and other notes deemed relevant (SOP NMI-008). It is essential that field data sheets are filled out completely and legibly, signed where required (e.g., Chain of Custody), and that the level of documentation is consistent among different personnel.

2.5 Decontamination

The surface water sampling will be decontaminated between each sampling location. Decontamination shall be performed according to SOP NMI-007. Personnel and PPE decontamination shall be performed in accordance with the HASP.

STANDARD OPERATING PROCEDURE NMI-SW-002

OPERATION OVER, NEAR, OR ON WATER

1.0 INTRODUCTION

This operating procedure provides provisions for Working Over, Near, or On Water in accordance with the Occupational Safety and Health Administration (OSHA) standard for projects involving working over, near, or on water. The information and requirements within this procedure apply to navigable and non-navigable waterways. The actual determination of whether or not a given project or activity will fall within the requirement of this procedure will be made by the Project Manager (PM) along with the Health and Safety Coordinator providing assistance.

1.1 Objective

The objective of this operating procedure is to ensure that staff are aware of safe operations when working over, near, or on water bodies that are applicable to worker safety and pollution prevention rules and regulations.

2.0 PROCEDURES

Working on or near water can be complicated and requires planning and care in executions of procedures. For the purpose of this SOP, water is defined as ocean, wetland, river, stream, pond, lake, bog, marsh, marine, or estuarine area. Ditches that contain water are regulated in some cases. Before work begins, it is essential to find out if clients and/or governmental agencies require that a permit be obtained. Also, certain areas may require specific environmental permits or plans.

Project Managers are responsible for ensuring that his/her projects with activities over, near, or on water meets the minimum requirements discussed in this procedure. It is the responsibility of the PM to enlist the assistance of the Health and Safety Coordinator if the contractor providing g appropriate field services is not familiar with United States Coast Guard (USCG) or OSHA worker safety, equipment requirements, or pollution prevention responsibilities related to water safety.

2.1 General Requirements

- Projects that require staff members to work near or over bodies of water (over 3 ft. deep) must develop a site-specific health and safety plan, regardless of the type of work that is being performed. This includes construction, geotechnical and environmental related work activities and, in particular, includes drilling and sampling work from boats (including jon, skiff, pontoon, survey vessels, etc.), barges, and jack-up rigs. A site-specific Health and Safety Plan will be accessible on-site at all times.
- When working on a vessel, such as a barge, staff must conduct a visual inspection of the vessel to determine whether the items listed above are present. In the event that an item listed is not present, contact the Project Manager and inform him/her that one is not available on the vessel. Project Managers are expected to communicate OSHA/Coast Guard requirements to the responsible party and to ensure that our subcontractors, such as drillers, have a health

and safety plan for their staff on the site.

- Staff shall never work alone when working on a vessel. One or more additional staff or one or more contractor representative(s) shall be present at all times. The "Buddy System" will be followed and at least two crewmen and/or staff members will be in sight of each other at all times.
- It is the responsibility of the staff members on the site in consultation with the PM to determine whether the water and weather conditions are safe for work activities. Consideration shall be made based on water velocity, water temperature, degree of recreational and commercial use, adverse weather (wind, heavy rain, fog, snow, etc.), and unknown structures and hazards below the water. Vessels shall have the appropriate navigational equipment, emergency lights, and running lights.
- Staff and subcontractors working near or above the water shall be provided with a Type III or Type V USCG approved for commercial use lifejacket, personal flotation device (PFD) or buoyant work vest. Prior to and after each use, the buoyant work vests or life preservers shall be inspected for defects which would alter their strength or buoyancy. Defective units shall not be used and immediately replaced. Except when working on the barge (with proper railing/ fall protection). Wearing a PFD is mandatory when working within 10 feet (ft) of the water's edge and at all times when working over the water.
- A 30-inch-diameter ring buoy with least 90 feet of line shall be provided and readily available for emergency rescue operations. Distance between ring buoys shall not exceed 200 feet.
- At least one life saving skiff or boat will be immediately available for rescues. The skiff or boat shall be inspected each day prior to the start of operations.
- The requirement for additional lifesaving equipment will be evaluated by PM after the initial Site visit and evaluation.
- A log will be maintained at the dock site. Everyone is expected to sign in when arriving and out upon departure.
- A pre-determined distress signal should be agreed upon in case of emergency.
- <u>Prevent man overboard by:</u>
  - Employees are not permitted to work alone when performing work over or near water. Employees, who will be performing work over or near water, where the danger of drowning exists, are not permitted to work alone at any time.
  - Railing should be continuous around the deck. The ends should be secured with lashings or quick release slips so that you can cut or release them to recover a person from the water.
  - Treat any slippery areas with either non-skid paint or stick on strips. Pay particular attention to the tops of hatches and sloping sides which become walkways when the deck is heeled.

- Use harnesses in rough weather and at night. Ensure they are adjusted to a tight fit or you can fall out of them.
- Fit suitably placed harness attachment points close to the companionway so that you can clip on before coming on deck and on both sides of the cockpit.
- Rig jackstays on both sides of the boat so that you can walk the full length of the deck without having to unclip.
- Flat webbing straps are in some ways better than wire because the wire tends to roll underfoot when you stand on it.
- Wear suitable protective clothing and a USCG approved lifejacket (PFD) fitted with reflective tape and a light.

- Accidental immersion in the water, either partial or total (Falling in the water):
  - Transferring into and/or from the vessel has the great potential of falling into the water. Care must be taken during this activity and all personnel must wear their PFD. An appropriate ramp, gangway, ladder or Jacobs ladder must be available to board the vessel.
  - Water temperature should be taken into consideration, especially during the colder seasons. Cold Water is water at a temperature less than 70 degrees Fahrenheit. This is imperative due to the possibility of hypothermia, a lowering of the internal body temperature to below 98.6 F (37°C), caused by exposure to cold. Hypothermia can be fatal.
  - When working in cold temperatures dress appropriately. Clothing made from man-made fibers does not protect the wearer for long when wet. Wool insulates better against the effects of hypothermia when dry or wet.

- Man Overboard Response On the Boat or Land:
  - When you first discover that someone has fallen overboard, the most important thing to remember is DON'T PANIC!
  - If the person is on a lifeline, stop the boat immediately and then recover them using the lifeline/harness as necessary.
  - If you are well prepared and have practiced the drill regularly, you will automatically know how to react.
  - Immediately throw a lifebuoy and attachment overboard.
  - Raise the alarm by shouting: “MAN OVERBOARD" (Even if you are the only one left aboard, shouting "man overboard" may provide reassurance to the person in the water).
  - If there are others on board, instruct a crew member to watch the person in the water and point continuously.
  - Start your recovery maneuver.
  - If you are the only person remaining on board, do not leave the deck as you may become disorientated and lose sight of the person in the water.
  - During the hours of darkness, a white parachute flare, which will pick up the retro reflective tape on clothing/lifejacket, can be used to illuminate area.
  - If you cannot see the person in the water or have any doubt about your ability to recover him/her, send a mayday call on your VHF radio.

- If you fall in Water:
  - DON'T PANIC! Call for help
  - Get into H.E.L.P.: "Heat Escape Lessening Position"
  - Bring your knees to your chest
  - Hold your arms to your sides clasp your hands
  - If possible cover your head to prevent heat loss, 50% of body heat is lost through the head
  - Do not try to swim unless a boat, floating object or the shore is close by:
  - Swimming causes "warm blood" to circulate to your arms and legs where it cools off quickly and reduces your survival time by as much as 35-50%

- If you fall in Ice:
  - DON'T PANIC! Call for help.
  - Turn toward the direction you came from.
  - Place your hands and arms on the unbroken surface, working forward by kicking your feet.
  - Once out, remain lying on the ice (do not stand) and roll away from the hole.
  - Crawl back to your tracks, keeping your weight distributed until you return to solid ice.

Other hazards that needs to be considered when working near or on the water include but it is not limited the following:

- Injury or death from:
  - Accidental collision of personnel or civilian boats/barges with moving barge;
  - Pinch points from rotating/moving equipment during downrigger operation;
  - Falling of unsecured equipment;
  - Slips, trips and falls during barge movement and set-up:
    - Minimizing hazards on deck
    - Precautions in walking
    - Wearing appropriate footgear
    - Preventing elevated falls
  - Unstable barge due to downriggers placed on uneven river bottom and/or soft sediments in the water;
    Falling over/under the safety rails/chains on the barge during moving and set-up activities

- Water and other hydrating liquids must be available and workers should be monitored closely for dehydration.

- A first aid kit equipped must be present on the vessel and near where the work is ongoing.

- The working vessel shall have the required navigational equipment, emergency lights, and running lights, as applicable.

- All safety equipment must be kept in good working condition and worn properly at all times. All damaged equipment must be removed from the Site immediately and work shall not commence until they have been replaced.

- Emergency contact information will be posted and readily available to all personnel onboard the barge. In addition the barge shall have and comply with the following marine emergencies plans and procedures as stated by USCG regulations and in United States Army Corps of Engineer EM 385-1-1 (whichever is more stringent) including but not limited to following:
  - Fire Fighting and extinguishing Plan (46 CFR 25.30-1)
    - Emergency Contact information
    - The firefighting plan and procedures should as a minimum discuss
      - Basics of a Fire
      - Classification of Fires
      - Fire Main Systems
    - Type of fire extinguishing system
    - Fire Control Plans
  - Life Preservers and Other Lifesaving Equipment (46 CFR 25.25)
  - Backfire Flame Control (46 CFR 25.35-1)
  - Ventilation (46 CFR 25.40-1)
  - Abandon ship/boat, and Man Overboard Procedure
  - Abandon ship/boat" and "person overboard" procedures shall include instructions for mustering personnel.
  - Sinking
  - Flooding
  - Severe weather
  - Hazardous material incidents

3.0 RESCUE

In the event of a medical emergency while working over-water, if the individual(s) cannot be transported to safety by the rescue equipment available from shore, a call will be made to 911. First responders will respond to the shore-based area, or other designated location. First responders will be met and briefed by the Site Safety Officer. The first responders will be directed to the location of the individual. Response personnel will have access to project emergency equipment, including vessels, as needed. If the injured individual(s) cannot be decontaminated due to the possibility of causing further injury, the necessary PPE and supplies will be provided to protect emergency response personnel or equipment.

4.0 REPORTING OF AN OIL OR CHEMICAL SPILL

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

damages. Major spills are not in the scope of work activities. Staff members must have advanced training and certification to respond to spills on the water. The PM shall be notified of spill or release incidents.

5.0 UNINSPECTED VESSEL OPERATIONS

If an uninspected vessel is used, the PM shall ensure that the vessel is suitable for its intended service prior to commencing field activities. The vessel shall be examined and made structurally sound by the contractor before commencing any work. If there are any questions regarding the vessels condition, a marine surveyor should be used identify deficiencies. In the event an staff member believes that the vessel is unsafe for use, he/she shall contact the PM immediately to discuss the situation and their concerns.

6.0 TRAINING

This SOP requires that the boat/barge crew will practice emergency procedures as needed but no less than once a month during the project. Project specific requirement may require additional training for field staff.

All motorboat operators of vessels less than 26 feet in length shall complete and document the following training. The subcontractor onsite will be conducting all the boat operation:

- A boating safety course meeting the criteria of the USCG Auxiliary, National Association of Safe Boating Law Administrators (NASBLA), or equivalent;
- Motorboat handling training, based on the type of boats they will operate, provided by qualified instructors (in-house or other). Operators must pass a written and operational test.

STANDARD OPERATING PROCEDURE NMI-A-001

SUB-SLAB SOIL GAS PROBE INSTALLATION AND SAMPLING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for installing a temporary or permanent sub-slab soil gas probe in a building slab and for collecting a representative soil gas sample during field investigations at hazardous and non-hazardous waste sites.

1.1 Objective

The objective of sub-slab soil gas sampling is to collect a sample of soil gas from beneath the building slab of sufficient quality to assess potential human health risks due to subsurface vapor intrusion to indoor air and subsequent inhalation exposures.

1.2 Equipment

The following list of equipment may be utilized during temporary or permanent sub-slab soil gas probe installation. Site-specific conditions may warrant use of additional or deletion of items from this list.

- Hammer drill (SDS Max recommended)
- 5/8-inch concrete drill bit
- 1.5-inch concrete drill bit
- Wet/dry vacuum with concrete dust filter
- Dust pan and brush
- Bottle brush for cleaning 5/8-inch diameter hole
- Sub-slab soil gas probe (1/2-inch brass pipe, ball valve, brass cap, or VAPOR PINs® installation kit)
- Cementing supplies (anchoring cement, water, plastic bags or cups, mixing stick)
- Site specific personal protective equipment (e.g., gloves, eyewear, hearing protection)
- Air monitoring instruments as required (e.g., PID or FID as specified in HASP)
- Field logbook

The following list of equipment may be utilized during temporary or permanent sub-slab soil gas probe sampling. Site-specific conditions may warrant use of additional or deletion of items from this list.

- Photoionization detector (PID)
- Landfill gas meter (e.g., Landtec GEM)
- Helium detector (e.g. Dielectric MGD-2002)
- Lungbox and power supply
- Tedlar bags
- Helium tank (industrial grade)
- Plastic shroud (large enough to cover summa canister and sample probe)
- Nylon tubing and connectors for connecting summa can and lung box to sample probe (e.g. Nylaflow® and Yor-Lok compression fittings)
- Air sample canisters (Summa® or equivalent; supplied by laboratory)
- Digital Vacuum gauge (0-30 inches of mercury [inHg] minimum range)
- 2 crescent wrenches
- Field logbook or soil gas probe measurement field sheet

2.0 PROCEDURES

The following procedures should be followed during sub-slab soil gas probe installation and sampling. Procedures may vary depending on the equipment used and contaminants present at the site.

2.1 Utility Clearance

Underground utilities (water, sewer, electricity, gas, cable, telephone, etc.) should be reviewed prior to any drilling. It is highly recommended that a ground penetrating radar contractor be used to scan and mark out building slabs for utilities prior to coring the cement.

2.2 Probe Design and Installation

Sub-slab probes will be installed within a hole drilled through the concrete floor slab. If the floor is covered with carpet, a flap will be neatly cut in the carpet with a sharp knife and lifted to access the concrete beneath. After all testing is complete; the carpet flap can be re-secured to the floor with an adhesive. If floor tiles are present, they should be cut with a tile-knife and lifted before drilling to avoid chipping to the extent practicable. Asbestos surveys and mitigation should be completed by qualified individuals if asbestos tiles are suspected (often 9”x9” tiles).

Holes in the concrete slab will be drilled using a heavy-duty electrical hammer-drill. Two different diameters of drill bits will be needed: 5/8-inch and 1.5-inch. The 5/8-inch bit must be long enough to penetrate the entire floor slab (typically 6 inches, but occasionally exceeding 12 inches in industrial buildings) and the 1.5-inch bit only needs to be 6-inches in length. The upper

two inches of the hole will be drilled using the 1.5-inch diameter bit. Generated dust will be removed from the hole and then the 5/8-inch diameter hole will be drilled through the center of the hole until it punctures the floor slab and just enters the underlying granular fill materials, but will not continue into the underlying geologic materials. A significant increase in the rate of the drill-bit penetration or decrease in resistance will usually indicate the bottom of the slab.

Upon completion of drilling, the sub-slab probe insert will be installed and sealed promptly to minimize any potential air flow into or out of the drilled hole. The probe insert consists of a 1/4-inch brass or stainless-steel threaded pipe, coupling, and plug and should not extend beyond the bottom of the floor slab. All threaded couplings should be wrapped with Teflon™ tape to ensure air-tight seals. If the sub-slab probe is permanent, then the insert will be set so that the cap is flush with the floor grade. The cap should be secured any time the probe is not being used for monitoring.

The sub-slab probe insert will be set in the drilled hole through the concrete and grouted into place using anchoring cement (available at building supply stores and normally used to seal cracks in concrete foundations). Silicone sealants, caulking, or any other material that could potentially give off vapors will not be used. The seal must be placed to allow the cap to be removed during monitoring events.

Sub-slab probes that don't require cement sealing, such as VAPOR PINs®, may also be used. When installing these probes follow the manufacturer recommended procedures and specifications.

2.3 Sub-Slab Soil Gas Sampling

Following installation of a temporary or permanent sub-slab soil gas probe the following procedure may be used to collect a representative sample using a laboratory supplied air sampling canister.

2.3.1 Pre-Mobilization

It is good practice to complete the following tasks prior to mobilizing to the field.

- Verify the correct number of air canisters and regulator have been delivered by the laboratory. Check the vacuum on all air canisters using the digital vacuum gauge if necessary. If vacuum levels are below 25 inHg the can should not be used and additional cans ordered from the laboratory.

- Verify the necessary equipment is ready to be shipped to the field site. If possible charge all instruments (PID, landfill gas meter, helium meter).

- Check helium tank pressure levels.

- Verify sufficient tubing and connectors have been ordered and are ready to ship to the field. Each sampling location will require at least 1-foot of tubing and 2 compression fittings.

2.3.2 Calibration

Instrument calibrations should be checked at the beginning of the workday, prior to sampling, according to manufacture specifications using appropriate calibration gases. If necessary, instruments will be recalibrated. The instrument calibration will be check at least once more after completion of sampling and it is recommended that they be checked in the middle of the day if using for an extended period and recalibrated as needed. Calibration data will be recorded in a field logbook or appropriate field calibration form.

2.3.3 Vacuum Shut-in Leak Test

The sampling equipment will be assembled as shown in Figure 1 and will be checked for leaks by conducting a "shut-in" test prior to purging. Valves V-1 and V-3 will be closed (valves V-2 and V-4 open) and then the lung box and Tedlar® bag will be used to exert a vacuum on the sampling train (80 - 100 inches of water [in-H_2O]). Valve V-2 will then be closed and the vacuum observed for at least 60 seconds to ensure it does not dissipate.

If the test indicates a leak, the connections should be disconnected and carefully reconnected one at a time until the leak is fixed. The leak test must be repeated until all leaks have been fixed.

2.3.4 Purging, Field Screening, and Helium Leak Test

After the "shut –in" test, a Tedlar bag will be attached to the tubing inside the lung-box and the lid of the lung box will be secured. V-2 will remain closed while the valve under the shroud (V-1 and V-4) will be opened and the shroud filled with helium (10 to 30%). The minimum and maximum concentrations of helium observed in the shroud during the collection of each Tedlar bag sample will be recorded. The lung box will be turned on and V-2 opened to begin purging. The Tedlar bag will fill at flow rate constrained by the flow controller, typically about 200 milliliter per minutes (mL/min). The time to fill the Tedlar bag should be recorded. The Tedlar bag will visibly fill inside the lung box. As it approaches ¾ full, valve V-2 will be closed and the lung box will be turned off.

The lid of the lung box will be opened, the valve on the Tedlar bag closed, and the Tedlar bag removed from the lung box. The Tedlar bag will be connected to the helium meter, photoionization (PID), and landfill gas meter (oxygen, carbon dioxide and methane) in sequence, by opening the Tedlar bag valve, and recording the stabilized readings.

If the concentration of helium in the Tedlar bag is greater than 5% of the concentration in the shroud, the probe seal and fittings should be checked to determine the location of the leak. Once the leak has been fixed, resume purging and field screening. The purging and field screening procedure will be repeated for a minimum of three sets of readings.

2.3.5 Air Sample Canister Leak Test

Valve V-1 and V-4 will be closed and then valve V-3 (summa canister valve) will be opened to induce a vacuum on the sample train. Valve V-3 will then be closed to leave a vacuum of about 30 in Hg in the sample train. The vacuum in the sample train will be observed for a short duration (30 seconds) to ensure it does not dissipate as a final check that the sample train does not contain any leaks. Valve V-1 will then be opened and the sample collection time recorded. The vacuum gauge on the Summa canister should be monitored and closed when the residual vacuum in the canister is about 5 in Hg.

2.3.6 Blank Samples (Optional)

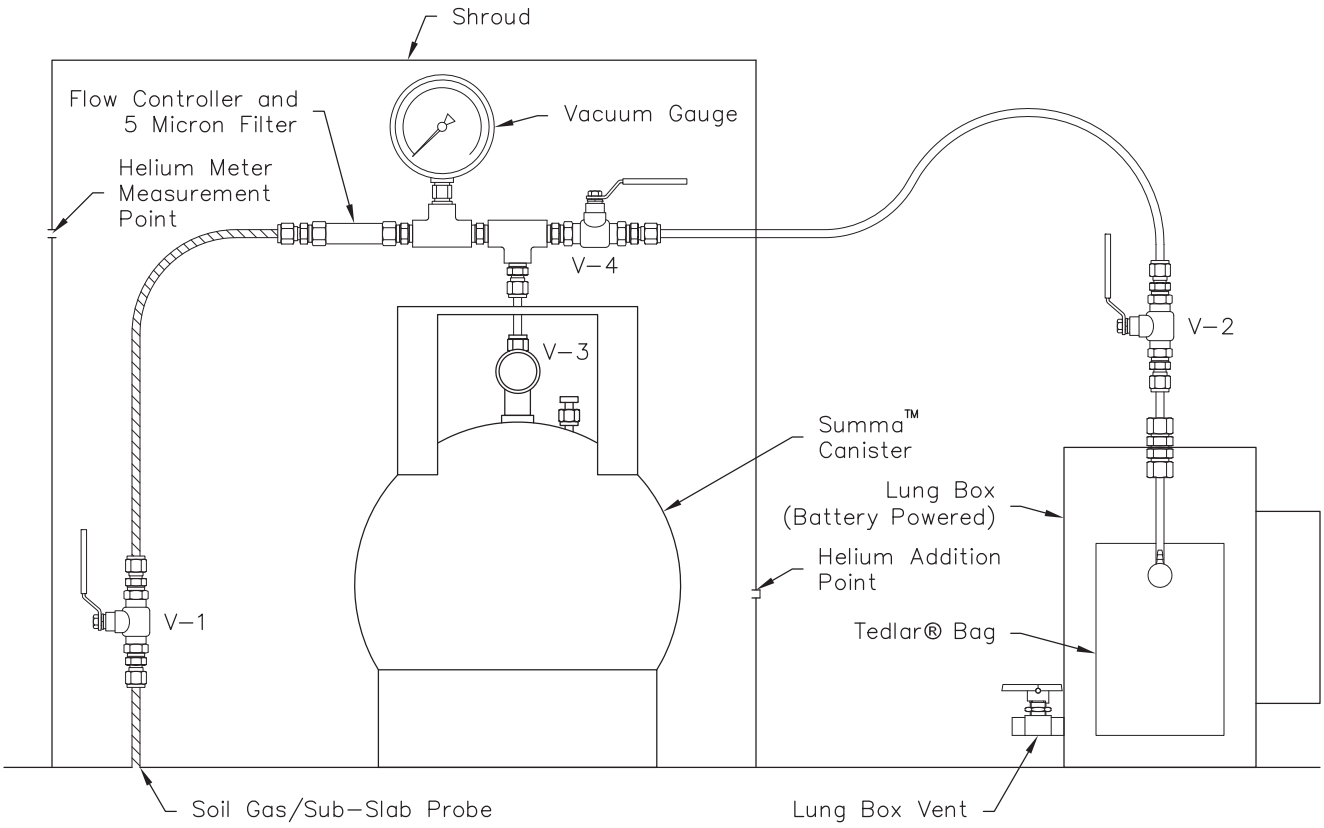
Blank samples will be collected based on the project specific data quality objectives. An equipment blank is collected by connecting a Summa canister to a fully assembled soil gas probe (screen, tubing, and valve) prior to installation, via Swagelok fittings through a 200 mL/min flow controller. The Summa canister valve is opened to draw the contents of the tubing and outdoor air into the canister through the probe tip and Swagelok valve.

Trip blanks are required by some jurisdictions and consist of an unused Summa canister being sent by the laboratory to travel with the primary laboratory samples and then being returned to the laboratory unused but labeled as a trip blank. The laboratory will then proceed to analyze the contents of the Summa canister per standard laboratory methods.

3.0 DOCUMENTATION

Field documentation will be recorded in a field logbook/daily field report or appropriate field form and will include at least the following information.

- Name and number of the project
- Name of field personnel
- Date and time of sampling event
- List of the primary activities performed
- Identification of probes installed and their location
- All related information (weather, attendees, equipment problems, any departures from standard procedures and the reasons and responses) observed throughout the day; and
- Field instrument information and calibration data (includes time and reading for each instrument calibration check).
- Field screening data including, shut-in test results, purge rate, PID readings, landfill gas readings (methane, CO_2, oxygen), and helium meter readings.
- Sample parameter and start/stop times and vacuum readings.



Legend

New Nylaflow® Tubing

Non–Dedicated Tubing

Soil Gas Purging and Sampling Assembly

Geosyntec consultants

Guelph | January 2020

Figure 1

P:\PRJ\Marketing-Sales\Indoor Air Quality\SOPs\AutoCAD Figures\Soil Gas Sampling Assembly.dwg

SUB-SLAB SAMPLING FORM

Geosyntec consultants

Project Name: _____ Date: _____

Project Number: _____ Address: _____

Field Personnel: _____

Location Description* :

Location Sketch* :

Sub Slab Sampling Location Description.ai

* note floor type, location of probes, walls, fuel tanks, sumps, stored chemicals, stains, etc.

SOIL GAS PROBE MEASUREMENTS

Geosyntec consultants

① Project Name: _____ Probe No.: _____ ☐ Sub-slab probe ☐ Soil gas probe

Date: _____ Project Number: _____ Mini Rae 2000 Serial No.: _____ Lamp: 10.6 / 11.7 eV

Site Location: _____ Landtech GEM 2000 Landfill Gas Meter Serial No. M: _____

Weather: _____ MDG 2002 Helium detector Serial No.: _____

Field Personnel: _____ Tracer Gas: ☐ Helium ☐ Other _____

Recorded By: _____

② Surface Type: ☐ Asphalt ☐ Concrete ☐ Grass ☐ Other_____

Surface Thickness _____ inches/centimeters ☐ Unknown
(i.e., asphalt or concrete)

③ 1 Casing Volume

☐ Sub-slab
<0.1 L

Soil gas probe _____ (L)

④ Initial Vacuum (prior to pumping) _____ in. H_2O

⑤ Shut in test prior to pneumatic test completed,____ in. H_2O held for ___ seconds.

⑥ Start of Pneumatic Test: _____

Elapsed Time (min.)	Pump Flow Rate (LPM)	Well Head Vacuum in. H_2O
	0.1	
	0.2	
	0.5	

⑦ Field tubing blank reading (ppm_v) completed? ☐Yes ☐No PID Reading _____ ppm_v

⑧ Shut in test prior to purging completed? Yes ☐ No ☐

⑨ Purging

Date	Start Time	End Time	Elapsed Time (min.)	Bag Volume (L)	Purge Rate (LPM)	Cumulative Volume (L)	CH_4 (%)	CO_2 (%)	O_2 (%)	Tracer Gas: Shroud (%) Min	Tracer Gas: Shroud (%) Max	Tracer Gas: Sample (ppm_v, %) (circle one)	VOCs by PID (ppm_v)

⑩ Helium concentration in field screened samples is less than 5% of minimum concentration in the shroud? ☐ Yes ☐ No **Note:** 1% helium = 10,000 ppm_v

⑪ Shut in test prior to sample collection completed? Yes ☐ No ☐

⑫ Sample Collection

Date	Time	Sample ID	Summa Canister ID	Flow Controller #	Vacuum Gauge #	Initial Vacuum (in. Hg)	Final Vacuum (in. Hg)

Comments:

SGP measurements - pneumatic testing.ai

STANDARD OPERATING PROCEDURE SOP NMI-A-002

INDOOR AIR SAMPLING

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the collection of ambient indoor and outdoor air samples using air sampling canisters such as Summa® or equivalent. This SOP includes direction on completing a building survey prior to sampling, selecting sampling locations, as well as sampling methods.

1.1 Objective

The objective of ambient indoor and outdoor air sampling using air sampling canisters is to collect a representative, time-averaged sample to be analyzed for volatile constituents of concern by a certified analytical laboratory. This data can be used with other data to evaluate indoor air exposure point concentrations, the site conceptual site model (CSM), and vapor intrusion pathway.

1.2 Equipment

- Photoionization detector (PID)
- 6-liter air sampling canister (e.g. Summa®) and 8- or 24-hour regulator with vacuum gauge.
- Two adjustable wrenches or size 9/16-inch and ½-inch wrenches.
- Information signs to post with samples with site specific information.
- Chain, zip-ties, rope, buckets, and/or boxes to elevate canisters.
- Field logbook or appropriate field forms.

2.0 PROCEDURES

The following section describes the procedures for collecting ambient air samples from a building including (1) a building survey (2) selecting sampling locations and (3) sampling methods. This procedure assumes that access to the building has been approved and that a building manager or tenant is available to provide access.

2.1 Building Survey

The purpose of the building survey is to better understand the building layout and construction, identify any potential background sources of volatile organic compounds, identify any potential preferential pathways through the building slab, and in non-residential buildings, understand any air handling systems. The survey should be conducted with a property owner and/or building occupant, if possible, to provide relevant information, secure access, and review instructions.

2.1.1 Calibration

If a PID is to be used during the building survey it should be calibrated at the beginning of the workday according to manufacture specifications. The meter calibration should be checked at the end of the day and if used over an extended period of time, it is recommended that the PID be checked in the middle of the workday as well. If the check shows deviation from the initial calibration greater than 5%, the meter should be recalibrated. All calibration data will be recorded in a field logbook or appropriate field calibration form.

2.1.2 Site Walk

A walk through of as much of the lower levels of the building (i.e. basement or ground floor) should be completed with the property owner and/or building occupants as feasible. The following information should be recorded in a logbook or appropriate field form to the extent practicable and with the occupant's permission. This list of tasks to complete during the site walk is not conclusive and tasks may be added or removed as needed for an individual project.

- Document building layout and construction including a sketch showing the approximate dimensions of the rooms and approximate locations of any vents, windows, doors, chemical storage areas, and potential preferential pathways through the building slab (e.g. large cracks or sumps). Document any features with photographs as applicable.
- Document information on building air handling system and zones where applicable.
- Using a handheld PID, screen for potential background chemical sources of VOCs in the rooms. If available, screen large cracks or sumps for potential VOC entry points.
- Conduct a chemical inventory recording information including a full description of the product name, container, size, ingredients listed on container labels, and condition of container (e.g. unopened, empty, opened). When required by state regulations or project needs, photographs will be taken of all products with the potential to contribute VOCs in indoor air.

The Massachusetts Department of Environmental Protection (MassDEP) created an Indoor Air Quality Building Survey field form as part of the October 2016 Vapor Intrusion Guidance. Field staff may find it helpful to use this form (see attached) to guide the building survey and ensure the necessary information is collected.

The results of the survey should be taken into consideration when selecting locations for the indoor air samples. Where possible, consumer products identified during the chemical inventory that potentially include VOCs should be temporarily relocated to a secure storage outside of the building for a minimum of two days prior to any sampling. If background sources cannot be controlled, then the utility of the potentially confounding indoor air results should be evaluated by the project team and potentially abandoned.

2.1.3 Indoor Air Samples

Indoor air samples are typically collected in basements/ground floors and, subject to state and project requirements on the first floor of the building. The samples should be taken from the lowest elevation, potential living/working space in the building, away from vents and windows and in a centrally located area at a height of approximately 3 to 5 feet above the floor. Additional considerations should be taken when selecting sampling locations within a building such as the CSM, how the results will be used, the results of the building survey and access limitations based on building occupant use.

Unless mitigation system performance is to be evaluated, buildings with effective operating radon mitigation systems typically need not be sampled. If the building is to be sampled, then the radon system should be turned off for at least one week prior to sampling and remain off during sampling.

2.1.4 Outdoor Air Samples

At least one ambient air sample will be collected outside the buildings at the same time and duration of indoor air samples. The outdoor air samples will be collected immediately outside the buildings, on the upwind side, away from any exhaust from the buildings (e.g. exhaust vents) or wind obstructions, at a height of approximately 3 to 5 feet above ground level, and distant from any obvious sources of VOCs. The results of the outdoor air samples will assist in the determination of potential ambient background source of VOCs in the indoor air samples.

2.1.5 Sampling Methods

Indoor and outdoor air samples will be collected and analyzed using 6-liter, passivated (inert), stainless-steel evacuated sampling canisters. The canisters are received from the laboratory, certified clean, evacuated, and prepared for sampling. Canister cleaning certification can be either on a batch or individual basis, depending on project requirements. The vacuum in the canister is approximately 30 inches of mercury at sea level.

The canisters are then fitted with a sampling valve that uses a critical orifice and mass flow controller to regulate the air flow into the canister. The orifice is selected by size to typically allow for either an 8-hour or a 24-hour sampling period. The mass flow controller helps maintain relatively constant air flow rates throughout the sampling period. The sample collection time should be selected based on project and state regulatory requirements.

The air canisters and regulator are typically shipped from the laboratory separately and should be connected following laboratory provided instructions using adjustable wrenches prior to sampling. The air canisters can then be placed at the indoor and outdoor air sample locations. If the canisters are in public locations, it is highly recommended that a sign be affixed to the canister describing that air monitoring is in progress, request that the canister not be touched, and provide contact information for someone to call with questions. If necessary additional precautions should be taken to ensure the canister is not tampered with such as a cage or chain and lock. It is recommended that another survey of the room be conducted when deploying the

sample canisters to ensure there are no potential sources of VOCs that were not previously documented.

The air canister is monitored with a pressure gauge at the beginning and the end of the sampling period. The sample canister and regulator ID should be documented for each sample along with the start and end times and measured vacuums in the logbook or field form. The target final field vacuum is 5 inches of mercury. Samples with a final field vacuum of greater than 10 inches of mercury, or equal to zero, will be flagged (usability of data will depend on sample volume and reporting limits that can be achieved). A project specific decision can be made to close an air canister before the target sample time if vacuum levels are low and to allow an air canister to run longer than the target sample time if vacuum levels are still too high.

Samples will be shipped to the laboratory within one to four days of sampling so that no sample will exceed the holding time. Full chain of custody will be maintained for all canisters from time of shipping from the laboratory to the time of analysis. Chain of custody and shipping and handling should be completed using SOP NMI-001.

3.0 DOCUMENTATION

Field documentation includes completed calibration records, building survey records, daily field logs, air sample records, and other field notes deemed relevant. Example field forms for indoor air building survey and indoor air sampling are attached. The following information should be included in logbooks and field forms when conducing ambient air sampling with air canisters.

- Job, site, date, and sampler
- Building identification and survey information
- Building construction information including heating and ventilation systems and preferential pathways into the building
- Calibration data
- Sketch of rooms to be sampled
- Potential indoor and outdoor VOC sources
- Sample identification and location description
- Start and end time and canister vacuums
- Sample canister ID and regulator ID
- Space for comments

Indoor Air Quality Building Survey

Date: _____ RTN: _____

Address: _____

_____

Building Contact: _____ Phone: Tel: _____
Cell: _____
Work: _____

Current Occupants:

INITIALS	AGE	SEX (M/F)

Building Construction Characteristics: (Circle or underline appropriate responses)

Single Family	Multiple Family	School	Commercial
Ranch	2-Family		
Raised Ranch	Duplex		
Cape	Apartment House		
Colonial	# of units ____		
Split Level	Condominium		
Colonial	# of units ____		
Mobile Home	Other _____		
Other _____			

General Description of Building Construction Materials:

Wood Brick Stone Metal Other_____

How many occupied stories does the building have? _____

Has the building been weatherized with any of the following?

Insulation Storm Windows Energy-Efficient Windows Other _____

Indoor Air Quality Building Survey, continued

What type of basement does the building have?

Full basement Crawlspace Slab-on-Grade Other _____

What are the characteristics of the basement? Finished Unfinished Other_____

Basement Floor:	Foundation Walls:	Moisture:
Concrete	Poured Concrete	Wet
Dirt	Block	Damp
	Stone	Dry

Is a basement sump present? (Y/N) ____

Does the basement have any of the following characteristics (i.e., preferential pathways into the building) that might permit soil vapor entry?

Cracks Pipes/Utility Conduits Foundation/slab drainage

Sump pumps Other _____

Heating and Ventilation System(s):

What type(s) of heating system are used in this building?

Hot Air Circulation	Heat Pump	Wood Stove
Hot Air Radiation	Unvented Kerosene Heater	Electric Baseboard
Forced Hot Water	Steam Radiation	Other _____

What type(s) of fuel are used in this building?

Natural Gas	Electric	Coal	Other _____
Fuel Oil	Wood	Solar	

What type(s) of mechanical ventilation system are present and/or currently operating in this building?

Central Air Conditioning	Mechanical Fan	Bathroom Ventilation Fan
Kitchen Range Hood	Open Window	Individual Air Conditioning Unit
Air-to-Air Heat Exchange	Other _____	

Indoor Air Quality Building Survey, continued

Sources of Chemical Contaminants:

Potential VOC Source	Check if present in building prior to sampling	Location of Source	Removed 48 hours prior to sampling? (Yes/No/NA)
Paints or paint thinners			
Gas-powered equipment			
Gasoline storage cans			
Cleaning solvents			
Air fresheners			
Oven cleaners			
Carpet/upholstery cleaners			
Hairspray			
Nail polish/polish remover			
Bathroom cleaner			
Appliance cleaner			
Furniture/floor polish			
Moth balls			
Fuel tank			
Wood stove			
Fireplace			
Perfume/colognes			
Hobby supplies (e.g., solvents, paints, lacquers, glues, photographic darkroom chemicals)			
Scented trees, wreaths, potpourri, etc.			
Other			
Other			

☐ YES ☐ NO Do one or more smokers occupy this building on a regular basis?

☐ YES ☐ NO Has anybody smoked in the building in the last 48 hours?

☐ YES ☐ NO Does the building have an attached garage?

☐ YES ☐ NO If so, is the garage used for parking cars

Indoor Air Quality Building Survey, continued

☐ YES ☐ NO Do the occupants of the building frequently have their clothes dry-cleaned?

☐ YES ☐ NO Was there any recent remodeling or painting done in the building?

☐ YES ☐ NO Are there any new pressed wood products in the building (e.g., hardwood plywood, wall paneling, particleboard, fiberboard)?

☐ YES ☐ NO Are there any new upholstery, drapes or other textiles in the building?

☐ YES ☐ NO Has the building interior been treated with any insecticides/pesticides?

If yes, what chemicals are used and how often are they applied?

Outdoor Sources of Contamination/Conditions:

Do any of the occupants apply pesticides/herbicides in the yard or garden? If yes, what chemicals are used and how often are they applied?

Is there any stationary emission source in the vicinity of the building?

Are there any mobile emission sources (e.g., highway, bus stop, high-traffic area) in the vicinity of the building?

Type of ground cover (e.g., grass, pavement, etc.) outside the building: _____

Other Information:

Is there other information about the structural features of the building, habits of its occupants or potential sources of contaminants to the indoor air that may be of significance to the evaluation of the indoor air quality of the building?

Weather Conditions during Sampling:

Outside Temperature (^{o}F): _____

Prevailing wind direction and approximate wind speed: _____

Describe the general weather conditions (e.g., sunny, cloudy, rain): _____

Was there significant precipitation (≥ 0.1 inches) within 12 hours preceding the sampling? _____

AIR MONITORING FORM

Geosyntec consultants

Site Name _____ **Project #** _____

Sampler Name _____ **Weather Conditions** _____

Sample Location: Building _____

Sample Type: (circle one): Summa Radiello SKC Ultra 3M OVM WMS ATD

Sample ID	Canister ID	Regulator ID	Start			End		
			Vacuum (in Hg)	Time	Date	Vacuum (in Hg)	Time	Date

Room Temperature _____

PID Reading _____ **(ppm)**

Other Comments (e.g., PID readings, intermediate vacuum readings)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Sketch of Sample Location (s)

Air Monitoring Form.ai

STANDARD OPERATING PROCEDURE NMI-001

CHAIN OF CUSTODY, HANDLING, PACKAGING AND SHIPPING OF ENVIRONMENTAL SAMPLES (NON-RADIOACTIVE SAMPLES)

1. INTRODUCTION

1.1 Objective

The objective of this standard operating procedure (SOP) is to establish chain of custody, handling, packaging and shipping requirements and guidelines for non-radioactive environmental sample shipping. Proper chain of custody storage, handling, packaging and shipping is necessary to ensure the protection of the integrity of environmental samples shipped for analysis. For specific procedures to be used for polyfluoroalkyl substance (PFAS) samples, please refer to SOP NMI-GW-011 Groundwater Sampling of Monitoring wells for Per- and Polyfluoroalkyl Substances (PFAS). For specific procedures to be used for samples that may contain radioactive samples, please refer to SOP HP-NMI-12 Radioactive Materials Receipt.

1.2 Equipment

- Coolers with return address of Site office written on inside lid
- Permanent marker or indelible pen
- Heavy-duty plastic bags
- Plastic zip-top bags, small and large
- Plastic electrical tape
- Fiber tape
- Duct tape
- Vermiculite and/or packing peanuts
- Bubble Wrap (optional)
- Ice
- Chain-of-Custody seals
- Draft Chain-of-Custody record or CLP custody records (if applicable)
- Draft Bill of Lading (if needed)

The term “Environmental Sample” refers to any sample that has less than reportable quantities of any hazardous constituents according to Department of Transportation (DOT) 49 CFR - Section 172.

2.0 SAMPLE HANDLING

Each sample container will be sealed in a separate plastic bag following collection. Samples will then be stored in an insulated cooler containing ice packs or ice sealed in a plastic bag. If samples are not immediately shipped to the laboratory, then they may be stored in a secure location and kept at the proper temperature. All samples shipped to a laboratory will be carefully checked against the chain-of-custody form (discussed below). Each cooler will be packed as it is being prepared for shipment in a manner that will prevent damage to sample containers during transit and in accordance with procedures presented in Section 4 below.

3.0 SAMPLE CUSTODY AND DOCUMENTATION

Chain-of-custody (COC) forms will be used to trace the possession and handling of all samples, from their collection, through analysis, until their final disposition. These forms will document the names of the relinquishing and receiving parties, the time and date of the transfer of custody, and the reason for the transfer of custody. One chain-of-custody form will accompany each cooler shipped to the laboratory. In the event that multiple coolers of samples are being sent to the same location, a unique, task specific, sample shipment group identifier and the number of coolers will be added to the top and special instructions portions of each chain-of-custody. The identifier will include the sample task (e.g., SW for surface water, SED for sediment), date (day, month and year), and cooler destination. The chain-of-custody form will be placed in a sealed plastic bag inside the cooler.

A custody seal will be placed on each cooler after packing and prior to shipment. For multiple cooler shipments, the sample shipment group identifier listed on the chain-of-custody will be written on the custody seal, as well as the cooler number designation (e.g., cooler 1 of 2, cooler 2 of 2). Shipping of samples to the laboratory will be accomplished by Federal Express, UPS or equivalent overnight service. Alternatively, samples for local laboratories, such as Alpha Analytical, given by the field team to a laboratory courier who takes custody of the coolers; the courier must sign the COC when they take custody of the cooler(s). The team leader will keep a copy of the COC that is signed by the laboratory courier. Samples will remain in the custody of the sampling team until custody is relinquished to the courier service that will transfer the samples to the laboratory. Each sample shipment will be tracked via the courier weigh bill (i.e. FedEx or UPS tracking number) to ensure that prompt delivery of the shipment to the laboratory has occurred.

Upon receipt by the laboratory sample custodian, the Sample Custodian will note on the form whether the custody seal is intact, the cooler temperature, the presence of air bubbles in any of the water samples submitted for VOC analysis, any damaged sample containers and/or discrepancies between the sample label and information on the COC, and sign and date the COC. A copy of the COC will then be transmitted to the Project Manager or their designate for their records. Sample receipts emailed by the laboratory to the Project Manager will be compared to the COC prepared by the field team to ensure that samples are accounted for and are assigned correctly by the laboratory for appropriate analyses.

3.1 Rush and Short Hold Time Samples

Prior to collection of samples for rush turn-around-times (TATs) or those with short hold times, the project manager should contact the laboratory and ensure that the laboratory has the capacity to receive and process samples on the desired expedited schedule (24-hr, 48-hr, or 72-hr). Samples that may require advanced planning with the laboratory may include samples submitted for expedited analysis to support decision making or analytes with short hold times (e.g. 24-hr hold time for Total Residual Chlorine by EPA Method 4500CL-G). The laboratory may request that the rush TAT and/or short hold time samples are transported in separate rush air shipments or picked up by the courier immediately after collection. The personnel collecting these samples should coordinate with the project or field manager for specific instructions on the logistics.

4.0 PACKING PROCEDURES

4.1 Air Shipment

The following steps shall be followed when packing for shipment by air:

1. Select a sturdy cooler in good condition. Plug the drain valve from the inside of the cooler and secure the drain plug on the outside with fiber or duct tape.
2. Be sure the caps on all bottles are tight (will not leak); check to see that labels and are non-removable. Check that sample labels are filled out correctly with the site name, project number, a unique sample identification name or number, initials of the sample collector, time and date each sample was collected, analysis required, and sample preservative (if applicable).
3. Review and ensure that the chain-of-custody records are completed properly.
4. Place all bottles in separate and appropriately sized plastic zip-top bags and close the bags. Up to three VOA vials may be packed in one bag. Due to their fragility, it is preferable that VOA bottles are placed in bubble wrap pouches typically provided by laboratories or wrapped in bubble wrap. It is preferable to place glass sample bottles and jars into the cooler vertically. Due to the strength properties of a glass container, there is much less chance for breakage when the container is packed vertically rather then horizontally.
5. Place two to four inches of packing peanuts or vermiculite into the bag in the cooler and then place the bottles in the bag with sufficient space to allow for the addition of more packing peanuts or vermiculite between the bottles. While packing material is necessary to absorb shock during shipping, the personnel must ensure that an ample supply of ice or other cooling material in the coolers, especially for samples that will be transported by carriers such as UPS or FedEx.
6. Put ice in large plastic zip-top bags (double bagging is preferred) and properly seal the bags. Place bags of ice on top of, or between, the samples. Fill remaining space between the bottles with packing peanuts or vermiculite.

7. Place the completed Chain-of-Custody Record for the laboratory into a plastic zip-top bag, tape the bag to the inner side of the cooler's lid, and then close the cooler.
8. Fiber tape shall be wrapped around each end of the cooler and completed Chain-of-Custody seals affixed to the top opposite sides of the cooler half on the fiber tape so that the cooler cannot be opened without breaking the seal. Wrap clear tape over custody seals.
9. Unless it is otherwise obvious, shipping containers can be marked with THIS END UP and arrow labels to indicate the proper upward position of the containers. A label containing the name and address of the shipper shall be placed on the outside of the container. Labels used in the shipment of hazardous materials (such as Cargo Only Aircraft, Flammable Solids, etc.) are not permitted to be on the outside of the container used to transport environmental samples and shall not be used.

4.2 Local Laboratory Courier

The following sample packing procedures will be used for samples designated for pickup by a local laboratory courier;

1. Follow steps 1 through 5 in Section 4.1 above;
2. Put ice in large plastic zip-top bags or place loose ice between and on top of samples that have been packed in zip-top bags. Fill remaining space between the bottles with ice.
3. Keep the COC form in a zip-top bag inside the cooler or affixed to the top of the cooler lid until the laboratory courier arrives.
4. Upon the courier's arrival, add the signature, date and time in appropriate sections of the COC form and present the COC to the laboratory courier for their signature.
5. Once the laboratory courier signs the COC, document the custody transfer by scanning, taking a hard copy, or a photograph of the COC for project records prior to couriers' departure. Put the signed COC into a zip-top plastic bag and place the COC into the cooler, then relinquish samples to the courier.

STANDARD OPERATING PROCEDURE NMI-002

SUBMERSIBLE PUMP OPERATION

1.0 INTRODUCTION

This standard operating procedure (SOP) was prepared to direct field personnel in the operation and limited troubleshooting of submersible pumps that may be used for purging monitoring wells and collecting liquid environmental samples. The safety procedures related to working with electric and pneumatic energy sources are provided in the Health and Safety Plan (HASP) and should be reviewed prior to field deployment.

1.1 Objective

The objective of submersible pump operation is to pump liquids from within a screened well to the ground surface for field screening and/or collection. Along with sampling wells, submersible pumps can, in many cases, be used for collecting liquid samples from water bodies such as from the bottom of ponds.

USEPA low-flow sampling procedures are covered in SOP NMI-GW-010.

1.2 Equipment

The following equipment is needed for submersible pump operation:

General

- Boots, work gloves, and other Personal Protective Equipment (PPE) as required by the HASP.

Small Diameter Electric Submersible Pump

- Electric pump with power lead
- Tubing or hose for water discharge
- Small diameter cable, rope, or twine
- Pump controller (if needed, or a flow control valve)
- Portable generator or other power source (e.g., battery)
- Fuel to run generator

Portable Bladder Pump

- Bladder pump (a spare bladder is recommended)
- Pneumatic air tubing
- Water discharge tubing (may be bonded to air tubing)
- Small diameter cable, rope, or twine
- Pump controller with necessary air hose connectors and adapters

- air compressor or compressed gas cylinder (e.g. nitrogen) with regulator
- Portable generator, if necessary, for the air compressor.
- Fuel to run generator

Inertial Pump

- Tubing
- Check valve sized to tubing
- Surge block, appropriately sized to tubing and well (if used for well development)
- Pump actuator (e.g., Waterra Hydrolift) is optional
- Portable generator or battery, as needed for the pump actuator
- Fuel to run generator

2.0 PROCEDURES

2.1 General Submersible Pump Procedure

In general, a submersible pump setup consists of a pump connected to a power lead (e.g., electrical cable or pneumatic tubing) and tubing for carrying water to the ground surface. A power supply (e.g., generator or compressor) is often used to provide energy to operate the pump and a controller is used to regulate the flow rate of water from the pump. Because the submersible pump operates within the water column, prior to deployment, the pump and associated components that may contact the water column should be cleaned following the Field Equipment Decontamination procedures outlined in SOP NMI-007.

2.2 Small Diameter Electric Submersible Pumps

Small diameter submersible pumps are generally used in 2-inch diameter monitoring wells or larger. There are several electric pump options for 2-inch and larger wells; some of these are capable of moving large volumes of water and overcoming significant head differentials such as when the water table is deeper below ground surface (e.g., more than 25-30 feet below the ground surface which is the practical limit for suction pumps). Submersible pumps are often powered by a generator and an electric controller. Many times a pump controller is used to adjust the flow rate of the pump although sometimes a single speed pump is used so a valve can be installed in the discharge piping to control flow. Examples of common small diameter electric submersible pumps include the Grundfos Redi-Flo2, Geotech GeoSub, and 12 volt pumps (e.g., Whale or various 'Monsoon' pumps manufactured by Proactive).

2.2.1 Safety

- Inspect the electrical extension cord, as well as the lead to the pump, for frays, breaks, expose wiring, or other signs of damage.
- If there are concerns of an explosive atmosphere developing in well head space, then screen the wellhead space for vapors using a PID/FID prior to pump deployment.

- Avoid touching the steel well casing, controller housing, cabling, or other metals objects with the pump wires to prevent damaging the cables and to avoid electrical shock hazards.
- If a generator is needed, be sure that it is supplying the correct voltage for the controller and is located downwind of to the well. Do not add gasoline or oil to the generator while it is running and keep these fluids away from sampling apparatus.
- Review the HASP for additional safety precautions when using an electrical submersible pump.

2.2.2 Pre-Mobilization Procedures

- Check the oil and gasoline levels in the generator. The capacity for the portable Honda generator is 0.95 US Gallons (3.6 L). It is always preferable to start with a full tank of gasoline and avoid having to stop and add gasoline during well purging/sampling. Place the generator as far from the sampling location as practical to limit noise disturbance, exhaust fumes, presence of gasoline/oil, etc. Add gasoline and/or oil if necessary.
- Inspect the pump, tubing, rope, and electrical cord and connections for signs of damage. Replace or repair these items as needed.

2.2.3 Operation

- Place the cleaned/decontaminated pump, controller, tubing, and twine/rope on plastic sheeting next to the well and place the generator in a dry location downwind of the well. Do not connect the controller to the generator.
- Tie the twine/rope to the appropriate support eyelet on top of the pump, connect the tubing to the pump, and then lower the pump, power lead, and tubing into the well. Always support the weight of the pump and tubing with the twine/rope.
- Lower the pump until it is at the target sample depth and secure the twine/rope so that the pump is stable and hanging at the desired depth.
- If using a generator: start the generator, connect the pump to the controller, and then connect the power cord from the pump controller to the generator. If using a battery: connect the power lead from the pump to the electric controller or directly to the battery as appropriate for your setup.
- Start the pump at the lowest setting and then adjust the flow rate upward as needed using the electric controller or inline valve and monitor the drawdown in the well. If the water level drops more than desired, decrease the flow rate for the pump. Be careful to not run the pump dry as this will damage most electric pumps.

2.2.4 Troubleshooting

Mechanical equipment can pose challenges in the field. The table below provides some suggested troubleshooting for submersible pumps. When problems arise, field staff can also consult manufacturer's manuals and/or call the rental company for additional troubleshooting suggestions.

Symptom	Potential Cause	Suggested Troubleshooting
Generator running, no pump output	Loose wiring connection.	Check all connection (power lead to controller and controller to generator). Adjust or repair as need. **Shut generator off before touching electrical connections.**
	Over voltage or under voltage on controller.	Adjust generator output/idle speed; allow generator more warm-up time.
	Pump out of water.	Lower pump into water column and adjust flowrate as needed.
	Power to pump is insufficient to overcome lift head to ground surface.	Increase power to pump on the controller. If drawdown occurs while pumping it will be necessary to occasionally increase the power to maintain a constant flow rate.
	Hose collapsed or kinked.	Un-kink hose.
	Hose/tubing disconnected from pump.	Pull pump from well and reconnect tubing. Use clean/decontaminated hose clamp if needed to secure tubing.
	Pump will not run or shuts down with thermal overload signal. Controller display indicates zero amps.	Ensure pump is set in the water column. Use cooling shroud in wells larger than 2-inch.

2.3 Portable Bladder Pump

Portable bladder pumps are well suited for low-flow purging, and bladder pumps are available for wells with a casing diameter as small as ¾-inch. A bladder pump consists of a series of check valves connected to a plastic bladder. The pump is connected to water discharge line and pneumatic drive line. A compressor or pressurized gas cylinder (usually nitrogen) and controller are used to regulate the pump flow rate. When in operation, the controller supplies compressed gas to the pump which collapses the flexible bladder forcing water through a check valve and up the discharge line towards the ground surface. The controller then releases gas pressure, closing a check valve on the discharge line and allowing the bladder to expand thereby refilling the pump with groundwater. The controller then collapses the bladder again with compressed gas and the cycle repeats. One feature of a bladder pump is that flow occurs in squirts, not a steady and continuous flow. Examples of common bladder pumps include the QED SamplePro and the GeoTech portable bladder pump.

2.3.1 Safety

- Never blow compress air or gas directly onto expose skin.
- If using a compressed gas cylinder, ensure that it is securely fastened to a stable object when in use and during transportation.
- Be sure to regulate gas pressure.
- If using a generator or gas-powered air compressor, ensure that it is placed downwind from the well. Do not add gasoline or oil to the generator while it is running and keep these fluids away from sampling apparatus.
- Review the HASP for additional safety precautions when using a submersible bladder pump.

2.3.2 Pre-Mobilization Procedures

- If using a generator to power an air compressor, check the generator/compressor oil and gasoline levels. If using a compressed gas cylinder, check the pressure level to avoid having to refuel during purging or sampling. Add gasoline and/or oil if necessary.
- Inspect tubing and hoses for holes and kinks.

2.3.3 Operation

- Place the clean and decontaminated pump, tubing, twine/rope, controller, and air compressor next to the well on plastic sheeting. Place the generator/air compressor in a dry location downwind of the well.
- Tie the twine/rope to the appropriate support eyelet on top of the pump, connect the pneumatic drive tubing and water discharge tubing to the pump, and then lower the pump and tubing into the well. Always support the weight of the pump and tubing with the twine/rope.
- Lower the pump until it is at the target sample depth and secure the twine/rope so the pump is stable and hanging at the desired depth.
- Cut the tubing, if needed, to a convenient length and connect it to the controller. Ensure the controller is connected to the air compressor or compressed gas cylinder.
- If using a gas-powered air compressor, start the generator and turn on the compressor. Allow pressure in the compressor storage tank to rise. If using a compressed gas cylinder, attach the regulator securely to the gas cylinder head using a wrench and slowly open the regulator to supply the compressed air to the controller.
- With both the air compressor and compressed gas cylinder make sure there is enough pressure supplied to the controller to purge water to the ground surface, but not too much so as to exceed the controller inlet pressure maximum (see controller specific documentation for maximum inlet pressures). As a guide, the air line should be pressurized to about 1 pound per square inch (psi) for each foot the water level is below the ground surface.

- Turn the controller on and ensure the pressure cycle is long enough for the drive line to reach the target pressure identified above. The longer the length of tubing, the longer it will take for the tubing to pressurize. The fill time should initially be set to allow the air pressure to return to zero at the end of each cycle.
- If the pump does not discharge or is still discharging at the end of the pressure cycle, the discharge time can be increased. The fill time can be adjusted for maximum or desired flow.

2.3.4 Troubleshooting

Mechanical equipment can pose challenges in the field. The table below provides some suggested troubleshooting for bladder pumps. When problems arise, field staff can also consult manufacturer's manuals and/or call the rental company for additional troubleshooting suggestions.

Symptom	Potential Cause	Suggested Troubleshooting
Air in sample line	Damaged bladder or O-rings or bladder shifted.	Inspect and replace. Decrease air pressure to pump.
No sample line output	Pump above water	Check and adjust pump level. reduce output to achieve stable drawdown.
	Loose pneumatic drive or water discharge tubing	Check tubing and push firmly on to connection points.
	Kinked pneumatic drive or water discharge tubing.	Check tubing and un-kink or replace.
	Inadequate air pressure	Increase discharge time or applied pressure.
	Silt in check valve	Surge pump in well or remove from well and clean. Consider further well development with alternate pump.

2.4 Inertial Pump

An inertial pump consists of tubing with a check valve on the submerged end. Inertial pumps operate by manually (or mechanically with an actuator) cycling the tubing up and down in the water column. During the down cycle, the check valve opens and a portion of the tubing fills with water. During the up cycle, the check valve closes and lifts the water upward with the tubing. Inertial pumps are very useful for well development because they can remove solids and provide agitation (especially when a surge block is attached) and they are useful for very narrow diameter wells. However, inertial pumps are generally not a preferred sampling approach because they can cause high turbidity due to the up/down action. Thus, initial pumps are frequently used for groundwater sampling only when other pumps cannot be used. Examples of common inertial pumps are those made by Geoprobe and Waterra.

2.4.1 Safety

- If a battery or generator is being used to power the actuator (e.g. Waterra Hydrolift), follow electrical safety procedures noted above.
- Keep hands and loose clothing away from the moving parts of an electric actuator to avoid getting pinched or caught.
- If manually surging, wear gloves, use proper lifting techniques, and take breaks as need to avoid injury.
- Review the HASP for additional safety precautions when using an inertial pump.

2.4.2 Pre-Mobilization

- If using a generator to power the actuator, check the oil and gasoline level; if using a battery, ensure it is fully charged. Add gasoline and/or oil if necessary.
- If the well to be purged has a protective stick-up casing, ensure that the pump actuator has a way to be supported above the top of the well. The Waterra pump actuator is designed to be affixed to the side of the well protective casing.
- Inspect the top of the casing for sharp edges that could damage the tubing as it is raised and lowered in the well (e.g., steel casings). If necessary, protect the pump tubing or guard against the sharp edges.

2.4.3 Operation

- Attach a check valve to the bottom of the appropriately sized tubing by threading it on. For common initial pumps, the valve will cut shallow threads into the tubing.
- Lower the tubing, valve end first, into the well until the valve is at the sampling interval, and then cut the tubing to convenient length.
- Either by hand or by attaching the tubing to a mechanical actuator, move the tubing up and down in the water column to lift water to the surface.
- Adjust the rate of actuation to control the flow rate (if possible).

2.4.4 Troubleshooting

Initial pumps are simple devices, so they seldom have problems. Nevertheless, the motion needed for an inertial pump can cause pieces to come loose or they can be damaged in the well. The table below provides some troubleshooting ideas for these pumps.

Symptom	Potential Cause	Suggested Troubleshooting
Actuator moving, no water discharge output	Silt in check valve	Vigorously surge tubing or remove and clean to allow ball check to seat properly in check valve.
	Tubing loose in actuator	Tighten actuator grip around tubing to prevent slipping.

STANDARD OPERATING PROCEDURE NMI 003

CALIBRATION OF FIELD INSTRUMENTS

MULTIPARAMETER (ORP, NTU, DO, ETC.) METERS

1.0 INTRODUCTION

1.1 Objective

The objective of collecting water quality data is to obtain physical/chemical parameters of aquifer being studied and collecting water quality parameters is frequently used during groundwater sampling to determine when a well has been adequately purged. The measurement methods may include deployment of down-hole multiparameter water meter/sondes (e.g. YSI 600 series, In-Situ AquaTROLL 600) in open boreholes or screened wells or monitoring field parameters for a sonde installed in a flow-through cell during low-flow groundwater purging. Obtaining accurate water quality data requires that the instrument (i.e., sonde) be calibrated. This standard operating procedure (SOP) establishes procedures for calibrating a multiparameter water meter.

1.2 Referenced Documents and SOPs

- *de maximis*. 2020. Remedial Design/Remedial Action. Health and Safety Plan (HASP) Nuclear Metals Superfund Site, Concord, Massachusetts;
- *de maximis*. 2020. Remedial Design/Remedial Action. Quality Assurance Project Plan (QAPP) Nuclear Metals Superfund Site, Concord, Massachusetts; and
- SOP NMI-007 Decontamination Procedure for Sampling Equipment; and
- SOP NMI-008 Field Activity Forms

1.3 Equipment

- Water quality multiparameter meter/sonde (e.g., YSI 6-series) or low-flow sampling multimeters (e.g. YSI 556, Pro-Plus, or equivalent) with read-out instruments and cables;
- Maintenance kit with applicable o-rings, tools, brushes, lube, etc.
- Calibration solutions;
- Cups sufficiently large for calibration fluids and the sonde;
- Flow-through cells;
- Paper towels;
- Trash bags for general trash;
- Spare equipment batteries;

- Laptop computer (for data download, verification of proper data storage on the YSI, and direct data logging) with ECOWIN software; and
- Decontamination equipment (see SOP NMI-007).

2.0 PROCEDURES

2.1 Calibration of Water Quality Sonde

Water quality sondes and multiparameter water meters are to be calibrated for each parameter at the beginning of each sample day and checked for accuracy at the end of each sample day.

2.1.1 Daily Calibration

Water quality instruments shall be used to monitor *in situ* turbidity levels (in NTU), temperature, dissolved oxygen (DO), pH, conductivity, and oxidation-reduction potential (ORP). Daily calibration shall be performed at the beginning of each workday. Calibration will be performed using calibration solutions and procedures prescribed by the manufacturer instructions. Calibration details will be recorded on the applicable field forms (e.g. Field Calibration Form; SOP NMI-008). The general method of calibration for each sensor is described below.

- Dissolved Oxygen

  a) Sondes - two-point calibration including zero DO solution and 100% saturation (in air) or

  b) Low-flow multiparameter instruments - a one-point calibration at 100% saturation (in air) followed by a check with a zero DO solution;
- Conductivity: single-point calibration (typically with a 1413 µS/cm or 1,000 µS/cm standard);
- Temperature: factory-calibrated (temperatures of all calibration standards should be recorded during calibration);
- pH: three -point calibration including pH values of 4.0, 7.0, and 10.0.;
- ORP: single-point calibration (Zobell or 100mV solution); and
- Turbidity:

  a) Sondes - two-point calibration including standards using 0 NTU, 10.0 NTU, 20NTU, 12.7 NTU, 100.0 NTU, 800.0 NTU or 1000.0 NTU solutions.

  b) Multiparameter instruments used for low-flow sampling are not typically equipped with a turbidity sensor therefore a standalone Turbidity meter (e.g. LaMotte 2020we, HF Scientific MicoTPW, HACH 2100Q, or equivalent) is used. The turbidity meters typically require a two or three-point calibration including standards using 0 NTU, 0.2 NTU, 10.0 NTU, 20NTU, 100.0 NTU, 800.0 NTU or 1000.0 NTU solutions.

The instruments will be recalibrated as necessary (e.g., when field data are suspect, or calibration checks indicate incorrect operation) to ensure accurate measurements. All checks and recalibrations will be recorded on the applicable field forms (e.g. field calibration form).

2.1.2 End-of-Day Check

At the end of each day, the instruments used for manual sampling should be checked against known standards to confirm that probes are reading correctly. This is done by submerging the probe in the calibration solutions used at the beginning of the day for calibration and recording the readings. The instrument must be decontaminated per SOP NMI-007 prior to end-of-day check and rinsed between checks. If the reading is not within the accuracy limits of the probe compared to the calibration value, the information should be recorded in the logbook and on the Field Log for the locations visited that day.

2.1.3 Decontamination

The sonde will be decontaminated between each sampling location. Decontamination shall be performed according to SOP NMI-007. Personnel and PPE decontamination shall be performed in accordance with the HASP.

METER CALIBRATION REPORT

Geosyntec consultants
289 Great Road, Acton, MA 01720
Phone: 978-263-9588, Fax: 978-263-9594

Project Name:		Date:	Page ____ of ____
Project Number:		Primary Activities:	
Field Personnel:			
Recorded By:		Weather:	
Sampler's Initials:			

Meter Summary

Meter	Make/Model (ex. YSI 600XL)	Serial #	Rental Company	Rental Company ID #
Multi-Parameter Probe (pH, DO, ORP, Conductivity)				
Turbidity Meter				

dissolved oxygen (DO) and pH calibration		dissolved oxygen calibration solutions		pH buffer solutions		
		100%	0 mg/L	4.01	7.00	10.00
initial	temperature (°C)					
	instrument reading					
	Calibrated To		N/A			
	Final Reading					
final	temperature (°C)					
	instrument reading					
	Post Cal Check Pass (yes/no)					

Specific conductivity, ORP[1] and turbidity calibration ([1]check temperature correction)		Specific conductivity calibration	ORP[1] calibration solution (Zobell)	turbidity calibration solutions		
		_____ µs/cm @ 25 °C	_____ mV Ag/AgCl @ 25 °C	#1	#2	#3
				____ NTUs	____ NTUs	____ NTUs
initial	temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Calibrated To					
	Final Reading					
final	Temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Post Cal Check Pass (yes/no)					

initial calibration completed at: _____ (time)	final calibration check completed at: _____ (time)

Comments (DO membrane changed, other equipment issues, etc)

[1]*See Back for Temperature Correction*

ORP (Zobell Solution)

mV	**-5°C**	**0°C**	**5°C**	**7.5°C**	**10°C**	**12.5°C**	**15°C**	**17.5°C**	**20°C**
Ag/AgCl	270.0	263.5	257.0	253.8	250.5	247.3	244.0	240.8	237.5
mV	**22.5°C**	**25°C**	**27.5°C**	**30°C**	**32.5°C**	**35°C**	**40°C**	**45°C**	**50°C**
Ag/AgCl	234.3	231.0	227.8	224.5	221.3	218.0	211.5	205.0	198.5

Post Calibration Criteria

Dissolved Oxygen	± 0.5 mg/L of sat. value, < 0.5 mg/L for the 0 mg/L solution, but not a negative value
Specific Conductance	±5% of standard or ± 10 *µs/cm (whichever is greater)*
pH	± 0.3 pH unit with pH 7 buffer*
ORP	± 10 mv*
Turbidity	± 5% of standard

Note: * Table 8.1, USEPA Region 1 *YSI6-Series Sondes and Data Logger SOP*, January 27, 2016, revision 13.

STANDARD OPERATING PROCEDURE NMI-004

FID/PID/O2-LEL METERS

1.0 INTRODUCTION

A significant number of field activities involve usage of electronic instruments to monitor environmental conditions and for health and safety purposes. It is imperative the instruments are calibrated, used, and maintained properly to obtain accurate data and to insure safe working conditions.

1.1 Objective

This operating procedure provides guidance on the usage, maintenance and calibration of electronic field equipment, owned by the Contractor, or obtained from an equipment rental agency.

These operating procedures may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

1.2 Task-Specific Equipment

- Photoionization detector (PID), with appropriate internal lamp
- Flame Ionization Detector (FID)
- O2 -LEL Meter
- Humidity/dust filters
- Calibration gas and regulator (e.g. Isobutylene), and associated safety data sheets
- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan
- Field book, field data forms and sampling sheets with writing utensils
- Sample containers and sample preservation supplies (e.g. cooler, ice packs or ice)
- Decontamination supplies/equipment
- Tedlar bags for calibration and 4-6 in. of PTFE tubing

2.0 PROCEDURES

- All monitoring equipment will be in proper working order and operated in accordance with the manufacturer's recommendations.
- A copy of the Operating Instructions, Maintenance and Service manual for each instrument used on a project will be kept on site while the equipment is actively used.
- Instruments will be operated only by personnel trained in the proper usage and calibration. In the event certification of training is required, personnel will have documentation of such certification with them on site while using the equipment.
- Field personnel will be responsible for ensuring the equipment is maintained in the field or returned for office or manufacturer maintenance or calibration if warranted. Calibration is discussed in greater detail below.
- Instruments will be operated within the range of conditions such as temperature and humidity specified by the manufacturer unless authorized by the Project Manager and/or Health and Safety supervisor as appropriate.
- Instruments that contain radioactive source material, such as x-ray fluorescence analyzers or moisture-density gauges require specific transportation, handling and usage procedures that are generally associated with a license from the Nuclear Regulatory Commission (NRC) or an NRC-Agreement State. Under no circumstance will transport or operation of such instruments be allowed unless by properly authorized and trained personnel, using the proper personal dosimetry badges or monitoring instruments.

2.1 Calibration

Calibration of an electronic instrument is critical to ensure it is operating properly for its intended use. Such instruments are often sensitive to changes in temperature or humidity, or chemical vapors in the working atmosphere.

Calibration of instruments shall be performed in accordance with the manufacturer's recommendations. This includes the following parameters:

- Frequency
- Use of proper Calibration Gases or Chemical Standards
- Requirements for Factory Calibration

2.1.1 PID and FID-specific Preparation and Calibration

- Turn on instrument and allow to run for at least 15 minutes prior to calibration and use, so that the unit equilibrates to ambient conditions at location of instrument use. The instrument requires time to equilibrate with surrounding conditions, especially if there is a major temperature or humidity difference between where the instrument was stored (building/vehicle) and where it is used (field).

- Calibrate the instruments in accordance with the manufacturer's specifications.

a. At a minimum the instrument shall be calibrated daily at the beginning of each field day.
b. Calibration should be done with isobutylene calibration gas (also known as span gas) using a Tedlar bag.
c. Do not draw gas directly from the calibration gas canister, as the pressure emitted from the canister may harm the instrument. Instead, fill the Tedlar bag by connecting PTFE tubing to the regulator and gas canister.
d. Do not forget to turn off regulator on gas canister. Calibration details should be noted in field book or field forms used.

- Take special precautions when using a PID capable of detecting concentrations to parts per billion (PPB) range and for PIDs using 11.7 electron-volt (eV) lamps, rather than 10.6 eV lamps. This equipment requires additional considerations for calibration and use, such as using a zero filter for calibrating, and understanding the shelf life and sensitive nature of 11.7 eV lamps.

- Determine if a specific correction factor is required for media and anticipated chemical being screened for and apply factor to the unit.

- Filter/moisture traps, whether installed externally on the probe tip or internally within the instrument, should be used for every reading collected to avoid contaminating the instrument with dust, particulates and moisture.

2.1.2 Calibration Gas Safety

Several instruments such as photo-ionization detectors (PID), flame ionization detectors (FID), oxygen meters, explosimeters, and combustible gas indicators require the use of calibration gas contained in compressed gas cylinders. Many of these gases are combustible or explosive. Care shall be taken to minimize the potential for injury from the use of such compressed gases. Transport, handling and storage of cylinders, where necessary, shall be performed in accordance with applicable DOT regulations and site requirements.

Calibration will only be performed in areas free of sources of spark, flame or excessive heat. Smoking will not be allowed in the vicinity of calibration gas usage areas.

2.1.3 Documentation of Calibration

Instrument Calibration activities will be documented on the Instrument Calibration Form.

2.2 Use Considerations

When conducting screening using a instrument, consider the following:

- When collecting readings, take care to avoid uptake of dust, soil, or moisture into the instrument. Probe tip should not come into contact with particulates and moisture, as the introduction of foreign matter to the instrument is the most common reason for instrument fouling and inaccurate readings. When this happens, remove the soil or moisture particles and clean the probe before continuing the process.

- Note background (ambient) readings and moisture content when collecting sample readings. If background readings are detected, actual sample concentrations should be compensated. Excessive moisture should be noted and considered, especially if unexpectedly high screening readings are observed.

- Regularly inspect and replace dust/moisture filters to prevent instrument fouling. Filters should be observed at the start of each day and periodically to see if any dust or moisture is present. If dust, soil, or moisture is observed in the filter, the filter should be replaced. If nothing is observed, the filter can continue to be used. It is recommended that the filter be replaced at least once a week.

- Record the highest reading (the peak) displayed. Readings should peak within 5 seconds of starting the screening and should stabilize within a few seconds. See troubleshooting section below if readings do not stabilize or peak within 10-15 seconds, or if there are other indications that instrument readings may not be accurate.

- Note and record observations of media on which screening is conducted. Are there any odors, staining or other obvious indications of contamination?

- Periodically conduct “bump checks” throughout the day by testing the instrument against the calibration gas, especially after elevated readings are observed and at the end of the day. Use the Tedlar bag unless you were issued a control-flow regulator.

2.3 Troubleshooting and Maintenance

If readings do not stabilize but instead continue to rise (upward creep), or there is any other indication that instrument readings may be erroneous (elevated readings with no other indication of contamination, readings up and down without stabilizing, negative readings below zero, no reading with obvious contamination observed, etc.), consider the following:

- Check dust/moisture filter and replace filter if it appears fouled.
- Complete a full calibration with fresh air and span gas.
- Check the probe tip (inside and out) for presence of particulates or moisture. Clean tip if any foreign matter is observed.
- Conduct a humidity test by cupping the probe tip with a clean hand (free of hand sanitizer or lotion, etc.), allowing air to continue to be drawn into the instrument. If concentrations and humidity readings rise as a result of placing the hand over the tip (introducing hand moisture), readings should be considered inaccurate and further troubleshooting should be conducted.
- Call the equipment rental agency or manufacturer's technical support.
- If using instrument in environments below 20 degrees Fahrenheit, the LCD screen may malfunction due to the cold.
- If using the instrument in direct sunlight on a hot day, the LCD screen may malfunction.
- Instrument units should be maintained by keeping the instrument clean and dry, protecting the unit during inclement weather conditions, clearing the probe tips, and returning the units to the rental agency or manufacturer for yearly maintenance.

2.4 Intrinsically Safe Requirements

Certain work locations may be such that dangerous, ignitable or explosive conditions exist. In such cases, it may be necessary to utilize only equipment that is rated as "Intrinsically Safe." Intrinsically safe instrumentation is designed with limited electrical and thermal energy levels to eliminate the potential for ignition of hazardous mixtures.

For site work requiring operation of monitoring instruments in Class I, Division I locations (as defined by the National Fire Protection Agency (NFPA)) only instrumentation rated as Intrinsically Safe will be used. Such equipment (including all accessories and ancillary equipment) must be rated to conform to Underwriter's Laboratories (UL) Standard 913, for use in a Class I, Division 1 Groups A, B, C, and D locations. It is also recommended the equipment conform with CSA Standard 22.2, No. 157-92.

- Upon completion of the field activities, equipment shall be returned to the possession of the Consultant, Contractor or Rental Agency accompanied by a written summary of any problems encountered with its use or calibration.
- Equipment shall be properly prepared for shipping, including insuring that residual gases (if applicable) are removed from the instrument, and accompanying containers of compressed gases or fluids are properly labeled and sealed.

2.5 Decontamination

Environmental monitoring equipment/instruments will be cleaned prior to and between each use according to appropriate operating procedure (SOP NMI-007) and manufacturer recommendations. After decontamination, the equipment will be wrapped in aluminum foil or placed on clean racks or polyethylene sheeting and placed off the ground until it is used.

2.6 Documentation

Field documentation of instrument use shall be recorded daily field logs included in SOP NMI-008, it is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel.

METER CALIBRATION

Geosyntec consultants
geosyntec.com

Project Name: _____ **Date:** _____ **Recorded By:** _____ **Page** ____ **of** ____

Project Number: _____ **Weather:** _____ **PrimaryActivities:** _____

PIDs

Serial Number		Ambient Air (ppm)	100ppm Isobutylene (ppm)
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		

GEMs

Serial Number		Ambient Air			Calibration Gas			Ambient Air		
		CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									

NOTES:

Personnel Signature: _____ **Date:** _____

Meter Calibration.xl

PID CALIBRATION REPORT
Ambient Air Monitoring Program

Geosyntec consultants
289 Great Road, Acton, MA 01720
Phone: 978-263-9588, Fax: 978-263-9594

Project Name: _____ Date: _____ Page ____ of ____
Project Number: _____ Primary Activities: _____
Field Personnel: _____ _____
_____ _____
Recorded By: _____ _____
Weather (temperature, cloud cover, wind speed/direction, precipitation type): _____

Calibration Gases

Type of Zero Gas (Note: If ambient air is used for zero gas, use charcoal filter on PID inlet tubing.)	Type: Ambient Air / Bottled	Charcoal Filter Used?: Yes / No
Type of Span Gas (ex. isobutylene)		
Span Gas Concentration (ppm)		

Calibration Parameters

Site-Assigned Meter Designation (Mark perimeter monitoring units with corresponding number: 1, 2, or 3)		PID #1	PID #2	PID #3	PID #4 _____	PID #5 _____
Meter Brand (ex. RAE, Photovac, Thermo)						
Meter Model (ex. AreaRAE, MiniRAE 2000, Photovac 2010 or 2020, OVM 580B)						
Meter Serial Number	Manufacturer					
	Rental Company					
Initial Zero Gas Reading (before calibration)	(ppm)					
Final Zero Gas Reading (after calibration)	(ppm)					
Initial Span Gas Reading (before calibration)	(ppm)					
Final Span Gas Reading (after calibration, if needed)	(ppm)					

Comments:

STANDARD OPERATING PROCEDURE NMI-005

INVESTIGATION-DERIVED WASTE HANDLING AND STORAGE

1.0 INTRODUCTION

This procedure applies to the management, handling and characterization of investigation derived waste (IDW) or media including sediment, soils, surface water, groundwater, radioactive waste, decontamination fluids, and personal protective equipment (PPE). Investigative soils and water often cannot be characterized at the time of generation or be considered a listed waste, due to the lack of generator knowledge concerning contaminant source, origin, or timing of contaminant introduction to the subsurface. Consequently, waste sampling and characterization is performed to determine if the wastes have characteristics of hazardous waste (as defined in 40 CFR 261.3 or state regulations), for reuse or disposal purposes. Once the IDW characterization is complete, RCRA regulations apply if the IDW is determined hazardous; if the IDW is determined to be non-hazardous wastes, best management waste handling practices apply. The disposal of excess sediment/soil cuttings, surface water/groundwater or PPE generated from exploration and sampling activities must be assessed on a case by case basis with appropriate planning performed prior to initiation of field activities. Two scenarios typically exist:

1. No Disposal/No Containerization Required - When sufficient site information exists, investigative soils, cuttings, purged surface water or groundwater may be placed back into the exploration or from the area generated. This may be employed when it is believed that the area of concern will require a final remedy involving in-situ treatment, or an off-site disposal removal effort is likely required, or no chemical or contaminant impact is evident as long as the material replacement does not pose a health threat or contaminate new areas.

   Alternatively, no information may be available in the area of activity or investigation, and impacted media/soils are identified. Activities such as new construction and /or maintenance works below grade may encounter environmental conditions that were unknown. Again, it is logistically practical to complete the activity, employ health and safety measures appropriate to the conditions identified, and evaluate the extent and magnitude of the impact. Timely notification to the client would be required to formulate a course of action and collect chemical samples from the area of concern (if warranted). Investigative works may be conducted in areas where it is not known if impacted soils/groundwater exist, and the presence of hazardous constituents is not known. RCRA guidance permits Best Management Practices of keeping media on-Site (reference 2).

2. Disposal Required/Containerization Required – Sometimes existing facility and/or Site information warrants that all materials handled will be contained and disposed of.

   Investigation results may dictate that all IDW be recovered and contained. This approach may be performed to facilitate quick closure/allow access quickly back into the investigative area regardless of environmental impact.

If a known listed hazardous and/or characteristically hazardous waste/contaminated environmental media is being handled, handling must be performed in accordance with RCRA Subtitle C (reference 2).

Similarly, if IDW is radiologically impacted in concentrations greater than background (i.e., 10 CFR 20) then these materials must be handled accordingly as outlined in the Radiation Protection Program and the applicable Health and Safety procedures.

It is expected that the majority of the IDW generated from the pre-design investigation activities at the NMI site will be containerized pursuant to Scenario 2 above.

This SOP is also developed specifically to outline procedures for management of IDW water generated during investigation and testing activities at the NMI site. In many cases, IDW water will be accumulated in a primary (initial) holding tank and potentially in a secondary holding tank(s). During field activities proposed in the Remedial Design Work Plan (RDWP), IDW solids and water will be generated in several ways, including drilling, well development, equipment decontamination, and prolonged groundwater extraction for the evaluation of a pumping remedy for uranium and 1,4-dioxane in bedrock (RDWP Appendix B and Appendix D). The IDW water generated as part of these activities must be accumulated, stored and disposed of in a manner consistent with applicable State and Federal guidance.

The initial generation of water from several IDW sources (e.g., well drilling, decontamination, well development) and accumulation in the primary holding tank are covered in the Appendix B and D Implementation Plan. This SOP covers the management of IDW once it has accumulated in a primary holding tank (e.g., this SOP does not describe procedures for moving water from wells to the primary holding tank or from the decontamination pad to the primary holding tank). This SOP describes water pretreatment and on-Site storage in holding tanks prior to transportation and off-site disposal.

Objective

The objective of this operating procedure is to describe procedures to handle and store IDW which will be generated from investigation activities proposed in the RDWP. Additionally, this SOP outlines the procedures for management of IDW water during the predesign activities proposed in the RDWP. For the purposes of this SOP it has been assumed that the IDW water generated as part of pre-design work will be stored in an primary holding tank, pretreated during transfer to one or more secondary holding tanks connected in series and that pretreated water will be transported for offsite disposal using a tanker truck operated by a licensed carrier. Alterations of these general procedures may be necessary in order to accommodate site specific conditions, analytical results of the IDW water, and access requirements.

Equipment

- Appropriate health and safety equipment (e.g., PPE) per the Health and Safety Plan;

- Solids (soil, sediment) sampling tools and equipment (spoons, trowel, augers, etc.);
- Liquids (surface water, groundwater, etc.) sampling tools and equipment (bailer, pump, etc.);
- Sample glassware and containers;
- Tools to access IDW storage containers (ratchet to open drums);
- Water level indicator or a tape measure to be used for measurements of the water level in the fractionation tank (frac tank) via an access hatch and used to estimate the volume of water in the tank (i.e., using volume tables provided on the frac tanks). Alternatively, a standpipe could be attached to the tank if the tank is on-site for a longer period;
- Alconox, liquinox, or other non-phosphate concentrated laboratory grade soap;
- Deionized Water (for decontamination);
- Holding/frac tank(s) (e.g. Rain-for-Rent or Adler 8,500, 18,000 or 21,000-gallon tank, or similar). Tanks will consist of a primary (initial) and secondary (final) tanks;
- Submersible sump pump (e.g. Gould, Groundfos or similar with a 2-inch outlet) to transfer water from the primary tank, through pretreatment and into the secondary tank;
- Flexible 2-inch hose or lay flat hose with cam lock or similar couplings;
- Various cam lock or similar adapters to connect hose to tanks, pump and filtration equipment;
- Transfer Pump such as a gas or electric powered high-capacity trash pump to transfer water from frac tank(s) into a waste hauler's truck;
- Power supply for pump (i.e., portable generator or electrical grid);
- Pretreatment Equipment (bag filters, chemical dosing, resin or granular activated carbon [GAC] filters, etc.).

2.0 PROCEDURES FOR WASTE HANDLING AND CHARACTERIZATION

The following procedure describes the techniques for characterization of investigation derived waste (IDW) for disposal purposes. IDW may consist of sediment or soil cuttings (sampling, augering, boring, well installation soils, test pit soils), rock core or rock flour (from coring, reaming operations), surface water or groundwater (from well development, purging and sampling activities), personal protective equipment (PPE), and disposal equipment (DE).

Waste Handling Procedure

Solids (Sediment/Soil/Rock Cuttings, other investigative derived solid material)

1. Solids removed from exploration and sampling activities will be contained within an approved container suitable for transportation to the designated consolidation

location or stockpiled in a designated area on poly sheeting and covered securely with poly sheeting until waste determination can be made.

2. Free liquids will be decanted by pouring or pumping prior to consolidating the solid materials. No free liquid, as determined by the "paint filter test" (reference 5), shall be present.
3. Contained solids may be screened for the presence of Volatile Organic Compounds (VOCs), using equipment such as a Photo-Ionization Detector (PID) or Flame-Ionization Detector (FID); this data will be logged for future reference.
4. Solids suspected to be radiologically impacted will be screened by the health physics staff as detailed in the Radiation Protection Program and the relevant Health and Safety Procedures. Radiologically impacted waste will be segregated and stored in a secure location on-site.
5. Small quantity generations (e.g., drill cuttings) can be consolidated in drums or a lined and covered roll off container(s). Representative samples from the containers will be collected for waste characterization purposes and submitted to an environmental laboratory for disposal analysis (see below).
6. Transport and consolidation containers will be labelled with start date of filling/generation, site name, and site contact and generator information. If necessary, the exterior of the container will be cleaned to remove any loose soil/cuttings.
7. Alternatively, it may be practical to collect waste characterization samples as the containers are filled. The waste characterization sampling requirements will be provided in project specific documents with the following established:
    a. volume of soils required for analysis (depending on parameters required),
    b. the number of containers considered representative, the homogenization procedure,
    c. volatile analysis collection procedure (if required), and
    d. preparation handling requirements.

    Typically, at a location where an undetermined site-specific parameter group exists, sampling and analysis may consist of the full RCRA Waste Characterization (ignitability, corrosivity, reactivity, toxicity). At sites/locations where there is historical information and/or generator knowledge which confirms that certain hazardous constituents are absent in the IDW, a subset of the full RCRA waste characterization list can sometimes be used. The amount of waste analysis required will frequently be dictated by the waste receiving facility.

<u>Liquids</u>

1. A relatively flat and stable areas large enough to stage the required number of tanks and pretreatment equipment will be located prior to mobilization. It is assumed that one staging and pretreatment area will be located on the NMI property, likely near the construction trailers, and a second area will be located in the downgradient area, most likely on the Valley Sports Arena property just to the east of the parking lot. The areas should be centrally location ideally near the sources of IDW water and should remain accessible to vehicles that might need to access treatment equipment or holding tanks such as the tanker truck. The IDW accumulation area located on

the Valley Sports Arena property may be secured from public access with a portable chain link fence (or similar) along its perimeter and signs informing the public that the area is off limits if the infrastructure remains for a prolonged period without frequent oversight.

2. Surface water or groundwater generated from well construction development, purging, sampling, etc. activities typically requires disposal and shall be contained within an approved container, suitable for transportation to the designated consolidation location.
3. Temporary containment may include: 55-gallon drums, tanks suitable for temporary storage. Liquids may be consolidated in a 20,000-gallon frac tank(s) located on site. In all cases the containers/tanks used for water storage must be clean before use such that cross-contamination does not occur.
4. Representative samples from the containers will be collected for waste characterization purposes and submitted to laboratory for disposal analysis (see below).
5. Transport and consolidation containers will be labeled with:
    a. start date of filling/generation,
    b. site name, and
    c. site contact and generator information.

    If necessary, the exterior of the container will be wiped, cleaned and dried to remove liquids.
6. The pretreatment of IDW water is not always necessary, but it may be implemented to reduce offsite disposal costs. For example, water generated from groundwater sampling and/or some drilling may be drummed and shipped off-site without pretreatment. The need for pretreatment will be determined based on the expected volume, site logistics and/or composition of the water.

    If pretreatment is used it can include one or several treatment systems. Typical pretreatment equipment includes, but is not limited to, a settling tank/sedimentation basin (i.e., primary holding tank), bag filters and potentially ion exchange resin. Granular activated carbon (GAC) vessels may be needed in some cases and would be included after ion exchange resin. This setup is described in more detail below and an example piping and instrumentation diagram is attached (Figure 1). For set up and operation, and maintenance of treatment equipment, refer to manufacture documentation and individual equipment cut sheets.

    Bedrock groundwater within the NMI property is impacted with uranium, 1,4-dioxane and volatile organic compounds (VOCs) therefore it is anticipated that groundwater generated as part of installation, development and pumping of open bedrock borehole wells BEW-1, BEW-2, BEW-3, and BEW-4 and other wells proposed throughout the site will be pre-treated using filtration, ion exchange resins to remove uranium from the extracted groundwater and possibly GAC to remove potential VOCs. In the downgradient portion of the plume, wells south of RT 62

are not expected to contain uranium at concentrations requiring pre-treatment so pretreatment will entail filtration and potentially GAC to remove VOCs.

Example Pretreatment Description

The primary holding tank where water is accumulated before pretreatment is also expected to serve as a sedimentation tank depending on the solids content of the water. A sedimentation tank is designed to minimize water turbulence so that suspended solids having a specific gravity greater than water begin settling to the base of the tank by gravity. In most cases a typical fractionation tank serving as the initial holding tank can acts as a sufficient sedimentation tank, especially if bag filters are to be used during pretreatment. However, a fractionation tank with internal weir/baffles can also be used. The influent and effluent ports of the primary tank should be spaced far apart (i.e., opposite ends of the tank) and preferably above the tank bottom to minimize the potential for remobilizing solids that have settled to the bottom and maximize solids removal.

The transfer pump and additional storage capacity should be sized to pump water at a flow rate greater than the average rate at which IDW water is being added to the primary storage tank. This will allow for IDW generation activities to continue without interruption. The transfer pump can run continuously, be manually activated, or activated by a control system, such as float switch, depending on the volume being generated and staffing.

Bag filters will be the first step of pretreatment. It is likely that bag filters will be used in parallel with the number and size scaled to handle the desired pumping flow rate. For the purpose of this SOP, it is assumed that the transfer pump and pretreatment apparatus will be designed to handle 20-50 gpm. If pumping through the pretreatment system is continuous or nearly continuous, it will be desirable to have at least trade size #2 bag filter vessels, and it is recommended that a filter bag skid with multiple filters be used (e.g., Rain for Rent BF-200) to have additional capacity.

When GAC and/or ion exchange resin filters are used, there will typically be a pair of vessels sized to the pumping rate and placed in series after the bag filters. If both ion exchange resin and GAC is needed, then ion exchange resin will come first and be followed by GAC.

Ion exchange and GAC treatment process will have vessels oriented in a standard lead-lag configuration which allows for monitoring the breakthrough of contaminants in the first set of vessels by regularly sampling the midfluent between the two vessels. This way the lag vessel will continue to remove contaminants while replacement of the lead GAC or resin is scheduled. After the replacement of the

lead vessel, the order of vessels is switches so that the former lag vessel is moved into the lead position and the monitoring continued.

After pretreatment, the IDW water will be pumped into one or several fractionation tanks depending on the volume being managed (i.e., secondary tanks). Pretreated water from secondary tanks will be sampled for specific parameters required by the disposal facility and await offsite disposal. Hose and pumps that are appropriately sized for the flowrate will be used; most likely these will be 2-inch diameter.

On-Site Storage

Following pretreatment and waste characterization sampling, the IDW water will be stored on-site in one or more secondary holding tanks until it can be hauled offsite. With any storage configuration, the volume of on-site IDW water storage will be tailored to the rate at which it is being generated. The goal is to ensure that enough holding tank capacity is obtained to allow time for pretreatment, waste characterization and off-site disposal without interruption to operations such as pumping during the long-term pumping for the bedrock remedy evaluation. The condition of all tanks and connections should be monitored frequently to ensure that there are no leaks in the IDW storage and transfer set up.

Several possible secondary tank configurations can be used although they may be altered depending on site specific needs, logistics and the required waste characterization frequency. The first configuration is to fill the secondary tanks sequentially and sample each tank after it is filled to capacity. Another option is to plumb the secondary tanks together in series such that they fill evenly and simultaneously, the effluent is homogenized, and a single sample is collected from all the tanks connected in series. A third (hybrid) configuration is to use tanks in series and parallel - for example if six holding tanks are mobilized and staged, three pairs of tanks can be set up and filled in sequence. When the first pair of two tanks is filled and sampled for waste characterization, the effluent is directed to the second pair of tanks and the third pair serves as a backup.

Sequential Holding Tank Configuration

If filling holding tanks sequentially, the effluent from the pretreatment system is connected to the first tank inlet through a valve or by dropping a hose through the top of the tank. Rubber hose appropriately sized to the pumping rate and cam lock fittings are recommended. The water level in the tank should be monitored regularly either using a tape measure or by dropping a water level indicator. The frequency of depth to water measurements will depend on the average pumping rate. A faster pumping rate will call for more monitoring to ensure tank does exceed its maximum capacity and overflow.

Once the first tank or pair tanks is filled, the transfer pump should be turned off, the valve on the inlet line closed and the hose disconnected, or the hose removed from the top of the tank. The hose will be connected to an empty tank or a set of tanks and the transfer pump will be restarted to continue pretreatment and transfer of IDW water from the primary holding tank to allow for IDW-water generation to continue uninterrupted.

Uniform Filling Tank Configuration

Uniformly filling of tanks connect in series is advantageous as it does not require stopping the transfer pump and moving hoses; however, when IDW water is filling all the tanks at once, waste characterization sampling and disposal may not be able to be completed until a large volume of IDW water accumulates.

If plumbing the tanks in series, the holding tanks should be set close together (although far enough for a person to fit in between the tanks for periodic leak inspection). The tanks are typically connected using 3 or 4-inch rubber hose with cam lock connections. The outlet from the first tank should be connected to the second through a valve on each tank and so on for all holding tanks. After all the holding tanks are plumbed together, effluent from the pretreatment system is discharged into the first tank inlet through a valve or by dropping a hose through the top of the tank. Water from the first tank will flow by gravity to the other tanks. Rubber hose appropriately sized to the pumping rate and cam lock fittings are recommended. The water level in the tanks will be checked frequently either visually, or with a water level indicator.

Decontamination

The equipment, including pumps, hoses, transducers, and water levels etc. should be decontaminated prior to deploying and after removing from a well using *SOP NMI-007*. Decontamination between fillings (i.e., switching sources of water) is generally not necessary.

Decontamination Water/Fluids

1. Decontamination-related water and/or fluids will be collected and consolidated with other liquids generated from the investigation activities. Decontamination water will be transported in a similar method as “Liquids” above and stored in a 20,000-gallon frac tank(s).

Personal Protective Equipment (PPE)

1. PPE will be collected in poly bags locally as it is generated and transported for consolidation with the solids in the rolloff box located on the main site. If PPE is

known to be contaminated with RCRA hazardous waste, then it should be disposed of off-Site at a RCRA-Subtitle C facility. Non-hazardous PPE/DE can be disposed on-site within dumpster/municipal trash.

Waste Characterization Procedure

The project specific documents will identify the appropriate sampling strategy frequency and analytes necessary to adequately characterize the contained materials to determine the IDW characteristics and disposal requirements. USEPA SW-846 (reference 4) describes the rationale for sampling plan development and sampling procedures. Generally random sampling and preparation of a composite sample of the media is employed for most IDW. Often multiple representative samples are required to gain valid waste characteristic data to determine the disposal option applicable (if statistics are employed). Typical sampling procedures for IDW are:

Solid Wastes

Grab sampling using pre-cleaned sample spoons, trowels or wooden tongue depressors from bulk piles, lugger boxes, or as drums can be used as drums/roll-off are being filled or as the solids are stockpiled. In some instances, when sufficient media mixing is evident, drum sampling from a random number of drums by accessing only the top solids may be permitted. In other instances where stratification is evident, a sample trowel/hand auger or device to collect from the entire vertical profile is required. Typically, a composite sample(s) from representative areas of the container(s) or stockpile is homogenized and submitted for analysis. Composite samples will also be submitted for radiological analysis. If VOCs are being evaluated, compositing and homogenization is not permitted. Individual grab samples are typically required. The project specific documents and/or requirements of the waste receiving facility will outline the appropriate frequency and procedure for IDW sampling.

Waste Liquids

Depending on the analytical results, waste liquids generated from site investigation activities may either be disposed of off-site, may be appropriate for discharge to an on-site treatment system or may be discharged to the Publicly Owned Treatment Works (POTW) system. Facility sewer discharge permit parameters will be evaluated when disposal to the POTW is being considered.

Prior to offsite disposal, waste characterization samples will be collected from the IDW water in the holding tanks. Grab sampling techniques using pre-cleaned bailers or sampling pumps and equipment is typically employed. Waters in bulk are typically sampled using a bailer or sampling pump. Sample analytes, waste characteristics, and the number of samples for the volume of water will be determined by the waste receiving facility. The waste receiving facility may also prefer to conduct the sampling and analysis themselves. The frac tank(s) will be sampled for a suite of analytes, such as those listed below, for evaluating disposal and treatment options:

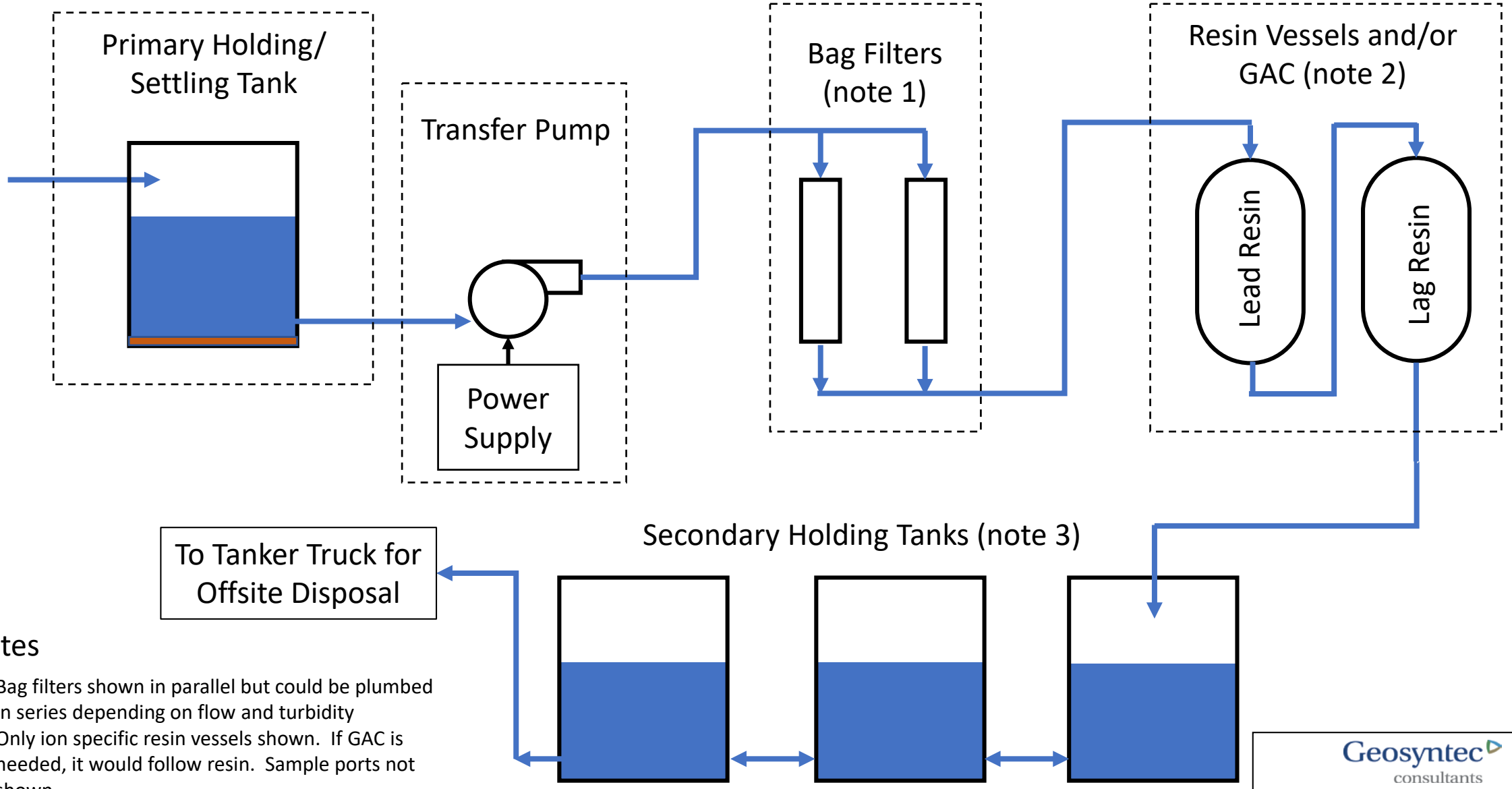
- Volatile organic compounds (VOCs) by USEPA method 8260
- Semivolatile organic compounds (SVOCs) by USEPA method 8270D-SIM
- Total uranium (U235/U238) via USEPA Method 6020A ICP-MS
- Total and dissolved calcium, iron, manganese, magnesium via USEPA Method 6020A ICP-MS
- Bromine, chlorine, fluorine, iodine by USEPA method 300.0
- Total dissolved solids by USEPA Method SM2540C
- Total suspended solids by USEPA Method SM2540D
- Additional cations (aluminum, barium, beryllium, cadmium, cobalt, copper, lead, magnesium, nickel, potassium, silver, sodium, titanium, tin, zinc, and arsenic) via USEPA Method 6020A ICP-MS or similar
- pH by USEPA Method 9040C or SM4500H+-B

Some of the above parameters may be removed or other parameters added based on the disposal facility and familiarity with water from the site (i.e., a vendor may cease to requiring certain parameters for each load if prior results indicate the chemical is not found in site groundwater).

Waste disposal is expected to involve having the disposal/hauling contractor bring tanker trucks to the site and pumping water from the secondary tank into the tanker truck using a trash pump (or similar). Waste profiles and manifests will need to be signed.

Documentation

Field documentation including inventory, sampling and disposal details, and other field observations shall be recorded in daily field logs. It is essential that field data sheets are filled out completely and legibly, signed where required and that the level of documentation is consistent among different personnel.



Notes

1) Bag filters shown in parallel but could be plumbed in series depending on flow and turbidity
2) Only ion specific resin vessels shown. If GAC is needed, it would follow resin. Sample ports not shown.
3) Lines show piping for secondary tanks plumbed in parallel. Plumbing in series is also possible.

Geosyntec consultants
Acton, Massachusetts

Example IDW Water Management Layout
ACTON, MASSACHUSETTS

PROJECT: BR0090 | FIGURE 1

STANDARD OPERATING PROCEDURE NMI-006

DRUM SAMPLING

1.0 INTRODUCTION

Sampling of drums shall be conducted to characterize the contents for off-site disposal. This standard operating procedure (SOP) is directed towards sampling from drums that have been filled with materials that require off-site disposal; however, it could be applied to buried drums encountered during the RD/RA investigations and removal actions. If this procedure is used for buried drums, certain additional health and safety protocols may be warranted and the procedures described herein may be modified to account for worker safety, field conditions and/or condition of the drum(s).

1.1 Equipment

The following equipment and supplies may be used during drum sampling:

- field logbook;
- PID and/or FID;
- radiological screening meters;
- other appropriate health and safety equipment (e.g., radiation meters, O2-LEL, apron, safety-glasses and face mask, gloves, etc.);
- non-sparking drum wrench;
- non-sparking mallet and chisel;
- remotely operated non-sparking punch or other device to open drums suspected of having a volatile or reactive nature;
- stainless steel hand probe, spoon, or spatula (for solids samples);
- syringe for VOC samples;
- stainless steel bowl;
- glass thieving tubes or bailers;
- sample containers;
- decontamination supplies; and
- disposable or digital camera.

2.0 PROCEDURES

2.1 General

Sampling of drums with known and unknown contents may be required during NMI field investigations. The sampling procedure for each circumstance will be the same; however, the preliminary drum identification and opening procedures will differ, as may the required PPE. For drums of investigation derived waste (IDW) stored in a waste accumulation area, the contents and integrity of the drums is known, and sampling is more straightforward. In contrast, if drums are discovered during the RD/RA investigations, a temporary drum staging area will be established for the purpose of staging, sampling and identification of the drum contents. Health and Safety as well as drum sampling approach (and analytical analysis) should be discussed amongst the project team before initiating drum sampling and should be appropriate to the available understanding of drum contents.

Drum sampling will occur according to the following steps, at the minimum:

- determine the scope and objectives of the sampling program;
- assess Site conditions - for example is the drum in a safe location, can it be accessed, are the nearby dangers, is there adequate ventilation, is it in a location where a spill can be contained, etc.;
- evaluation of the methodology and results of any previous sampling and analysis programs that may have been completed nearby;
- determine the appropriate analytical methods for adequate characterization of drum contents and determination of disposal options;
- consider compatibility testing (hazard categorization) for each drum to allow for safe storage and handling and/or to support potential commingling of waste materials for disposal; and
- determine drum identification, preliminary characterization, opening, and sampling techniques.

If multiple drums are found, the number of drums requiring sampling will depend on the results of the investigation (e.g., sampling for drums discovered in an excavation will differ from the number of IDW drums sampled).

3.0 DRUMS WITH KNOWN CONTENTS

When sampling a drum of known contents, the following drum opening, and sampling procedures are recommended but can be modified as needed by field personnel to accommodate specific conditions.

1. Accurately and completely fill out a drum inventory log (SOP NMI-008) during assessment and sampling of the drum. The drum identification number on the log will

key the drum inventory database to the chain of custody, and therefore, to the drum sample database.

2. Photograph the drum to document its condition and any labels or markings. Additionally, note details of markings on the drum log in case photographs are not sufficiently legible.

3. Before opening the drum, segregate the drum as liquid or solid or unstable/reactive, if known. Do this only if the drum can be moved without threat of a rupture (see "Drums with Unknown Contents" below).

4. Before opening the drum, ground it electrically to avoid sparking.

5. Loosen the cover or bung of the drum and scan the drum headspace with a PID and FID. If opening the cover, only crack the cover and place the tip of the instrument inside the drum. Record the measurements on the drum log.

6. Perform similar screening for radiological constituents.

7. If PID, FID, and radiological measurements support the level of PPE worn by the drum sampler, then remove the drum cover and scan the drum with a radiation meter. Record the measurements on the drum log.

8. Material from the drum shall be collected using a stainless-steel hand probe or a stainless-steel spoon (for solids) or a disposable bailer (for liquids). Collection of a hand probe sample is the preferred collection method for drummed solids.

9. For a liquid sample, place the tube or bailer into the center of the drum to collect the sample. Withdraw the sampler and pour liquids directly into the appropriate sample containers. Seal and label containers. If additional volume is required, repeat the process. Return unused liquid to the drum.

10. For a solids sample, advance the hand probe into the center of the drum, as best possible, to collect a core. Collection of a soil core from the drum should be from the 0.5 to 2.5 foot interval below the surface of the material. Withdraw the sampling device from the drum.

11. Gently remove solids from the hand probe, split the acetate liner lengthwise and screen the soil core for VOCs (using a PID and/or FID) and for radiological contamination. Record the measurements in a field log.

12. Select the portion of the drum core with the highest PID/FID reading for VOC analysis (if required), and place soil from this section in the appropriate sample container. Seal and label sample container.

13. Mix the remaining sample thoroughly using a clean stainless steel bowl and spoon. Fill the remaining sample containers (e.g., for metals analysis) and then seal and label the containers. If additional volume is needed to fill the required sample containers, repeat the above sampling steps 10 through 13. Return extra soil to the drum.

14. If radioactive contaminants have been determined to be present, personnel shall survey the external portion of the sample container(s) for loose surface radioactivity and document the survey. If the container(s) are found to be contaminated with loose surface contamination, personnel shall decontaminate the container in accordance with the procedures contained in the Radiation Protection Program (RPP). If decontamination efforts are not successful, sampling personnel shall contact health physics personnel.

15. Immediately after the samples are collected, replace the top of the drum of bung, securing the drum. Then check sample labels for completeness and initiate Chain of Custody procedures. Place samples in coolers for sample shipment.

16. Decontaminate the sampling equipment (per SOP NMI-007).

4.0 DRUMS WITH UNKNOWN CONTENTS

The procedure for sampling a drum of unknown contents is the same as above except that a higher level of PPE and more initial external monitoring may be required. Additionally, if the drum shows evidence of pressurization (i.e., bulging) remote opening techniques may be used and additional health and safety measures may be implemented (e.g., installation of an explosion barrier). If drums appear to be compromised such as leaking, bulging, off-gassing, visible damage (rust holes, bent or crushed), then the sampling team should stop work, and reassess how with the field manager and potentially the project manager how to safely open and sample drums. Extreme caution is required in opening unknown drums.

Prior to handling an unknown drum, the following preliminary classification checklist will be reviewed and each response noted in a field notebook:

1. Does the drum contain markings which would indicate that the contents are potentially explosive?

2. Does the drum exhibit leakage or deterioration (i.e., is it sound, does the drum appear to be empty)?

3. Does the drum exhibit apparent internal pressure?

The results of the preliminary inspection can be used as a guide for which specific procedures should be followed when handling of the drum. The inspection will place each drum in one of three categories: sealed, deteriorated, or drums requiring special handling.

4.1 Sealed Drum Handling

Drums that are sealed, appear sound and intact, and seem to containing material that is not pressurized or potentially explosive, then these drums can be placed in an overpack and transported to the staging area until they can be opened and the contents sampled as described above. Sealed drums which exhibit bulging indicating internal pressure build-up shall be slowly opened in place, if possible, prior to moving the drum to the staging area. Extreme care shall be exercised when working with and adjacent to potentially pressurized drums. Extra shielding and personnel protection shall be put in place when working with such drums. Special precautions shall be taken to limit and confine any leakage from the drum, which may result from the operation. If possible, the drum should be opened remotely. Once depressurized, then the drum shall be overpacked or the contents transferred to a new container prior to moving the drum to the staging area. Should movement of a pressurized drum be unavoidable, handling shall only occur by a grappler and/or sling unit constructed for explosive containment.

4.2 Open and Deteriorated Drum Handling

All open drums will be examined to identify contents. Drums that meet the criteria for being considered empty by Resource Conservation and Recovery Act (RCRA) criteria (i.e., less than one inch of residue) will be decontaminated, crushed, and staged with other debris.

A drum that contains liquids, other than rain water, and exhibits leakage or apparent deterioration such that movement is likely to cause rupture, must have its contents transferred to a new container before the drum is disturbed. Each drum that contains liquids shall be checked with a combustible gas indicator (CGI) for the existence of a potentially explosive atmosphere. If the CGI indicates that the drum atmosphere does not pose an explosion risk, the drum shall also be screened with a photoionization detector (PID) or flame ionization detector (FID) for VOC vapors.

Following the steps described above, drums containing solid or liquid material shall be placed in overpack containers and moved to the staging area for sampling.

4.3 Explosive Material and Special Drum Handling

If encountered, drums or other containers suspected of containing explosive or shock-sensitive waste, and/or laboratory packs, shall require special handling.

It is not anticipated that drums containing explosive or shock sensitive wastes will be handled under this SOP. If drums are encountered that are suspected by visual examination to contain explosive wastes, they shall be handled with extreme caution. Initial handling shall be by a grappler unit or sling unit constructed for explosive containment. Drums shall be placed on pallets prior to transport to a high hazard interim storage area.

If at any time during remedial activities, an explosive, pursuant to provisions of Title 18, U.S. Code, Chapter 40 (Importation, Manufacture, Distribution, and Storage of Explosive Materials,

1975 Explosives List) is identified, it should be secured, and the field manager and the Project Coordinator notified.

Identification of an explosive substance during a remedial action is usually based on the experience of the on-site personnel. Potentially explosive materials are often identified by their physical characteristics (texture, color, density) as well as the way they are packaged or labeled. Most explosives are solids. In some cases, they are packaged in water-tight containers to prevent contact with water, while in other cases they are packaged wet to reduce the risk of explosion.

Prior to handling drums containing explosive wastes, nonessential personnel working in the area shall move to a safe distance. Continuous contact with the support personnel shall be maintained until handling or transporting operations are complete. An audible siren signal system, similar to that employed in conventional blasting operations, is recommended to signify the commencement and completion of explosive waste handling or transporting activities.

If encountered, drums known or suspected of containing discarded laboratory chemicals, reagents or other potentially dangerous material in small volume, or individual containers (lab packs) shall be handled with extreme caution. Until otherwise categorized, they shall be considered explosive or shock sensitive wastes. Initial handling shall be by a grappler and or sling unit constructed for explosive containment. Drums shall be placed on pallets and overpacked, if required, prior to transport to the drum staging area.

Prior to handling or transporting lab packs from the existing drum area, nonessential personnel working in the immediate area shall move to a safe distance. Continuous contact with support personnel shall be maintained until handling or transporting operations are complete. An audible siren signal system, similar to that employed in conventional blasting operations is recommended to signify the commencement and cessation of lab pack handling or transporting activities.

5.0 REFERENCES

de maximis, 2004a. *Quality Assurance Project Plan, Nuclear Metals Inc. Superfund Site*, September 2004.

de maximis, 2004b. *Field Sampling Plan. Nuclear Metals Inc. (NMI) Superfund Site*, Remedial Investigation/Feasibility Study, September 2004, 540 pages.

STANDARD OPERATING PROCEDURE NMI-007

FIELD & HEAVY EQUIPMENT DECONTAMINATION

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in decontamination of field equipment used in the investigation of sites with hazardous and potentially radiological waste. For specific decontamination procedures for equipment that will be used for per - and polyfluoroalkyl substance (PFAS) sampling, please refer to SOP NMI-GW-011- Groundwater Sampling of Monitoring wells for Per- and Polyfluoroalkyl Substances (PFAS).

1.1 Objective

The objective of equipment decontamination is to remove potential contaminants from a sampling device or item of field equipment prior to and between collection of samples for laboratory analysis, and to limit personnel exposure to residual contamination that may be present on used field equipment.

1.2 Equipment

The following equipment may be utilized when decontaminating equipment. Site-specific conditions may warrant the use or deletion of items from this list.

- Alconox or other non-phosphate concentrated laboratory grade soap specifically excluding those containing methanol and hexane;
- Deionized water;
- Pump sprayer;
- Two large plastic wash basins or buckets;
- Two coarse brushes;
- Paper towels or single-use rags;
- Small wire brush;
- Aluminum foil;
- Polyethylene sheeting; and
- Personal protective equipment (gloves, eyewear, apron, Tyvek suites, as needed).

2.0 PROCEDURES

2.1 General

The following procedures should be used for decontaminating field equipment. Procedures will vary with equipment used and potential contaminants present at the site.

2.2 Procedure for Aqueous and Non-Aqueous Sampling Equipment

Soil and sediment sampling equipment, such as grab samplers, split spoon samplers, dredges, shovels, augers, trowels, spoons, bowls, and spatulas will be cleaned using the procedure described below. New, unused core liners should be rinsed with site water at the sample location prior to deployment. Larger sample equipment such as the box corer and devices which employ a sample liner will be decontaminated per Section 2.3. Ground water, soil and sediment sampling equipment, such as bladder pumps, will be cleaned using the following procedure.

The procedure below assumes that large clods of soil have been removed from the equipment using a shovel, trowel or similar tool. Removing clods is best performed at the sampling locations so that soil clods can be collected and placed into the container for other investigative derived waste (e.g., soil drum).

1. Place wash basins (or buckets) in an established decontamination area that has a low permeability liner (e.g., polyethylene sheet) as secondary containment. The decontamination area must be of sufficient size to allow placement of the plastic wash basins in a line and space to allow air drying for equipment.
2. Fill the first wash basin with potable tap water. Add sufficient soap powder or solution to cause suds to form in the basin. Do not use an excessive amount of soap or rinsing the soap residue off the equipment will be difficult.
3. Wash the sampling equipment in the soap solution in the first basin, removing all residues. Use a brush as needed and be sure to wash inside surfaces of equipment as well as exterior surfaces. Allow excess soap to drain off the equipment when finished.
4. Spray and rinse the equipment with deionized water in a second basin.
5. Allow the equipment to completely air dry on clean polyethylene sheeting.
6. Rinse the equipment in the third basin, using deionized water.
7. Allow the equipment to completely air dry on clean polyethylene sheeting.
8. Reassemble equipment, if necessary. Reassembled equipment can wrapped in clean, unused aluminum foil, shiny side out for transport. Equipment used on the same day does not need foil wrapping.
9. Allow spent cleaning solutions in the trays to evaporate into the air. If evaporation is not possible, all spent cleaning solutions shall be drummed for disposal along with any other contaminated fluids generated during the field investigation.

10. All spent cleaning pads (liners, washcloths, towels, etc.) and associated PPE generated during the field investigation shall be drummed for disposal.

11. Record the decontamination procedure in the field logbook or appropriate field form.

Note that if temperature or humidity conditions preclude air drying equipment, equipment can be dried with paper towels or sufficient spares should be available so that no item of sampling equipment need be used more than once. Alternatively, the inability to air dry equipment completely prior to reuse should be noted in the field log.

2.3 Procedure for Oversized Equipment

Oversized equipment, such as submersible pumps, will be cleaned using the following procedure.

1. Fill two clean barrels with tap water.
2. Add enough concentrated soap to one barrel to form a thin layer of soap suds.
3. Immerse the pump in the soap containing barrel and start pump. Circulate the soap solution through the pump and feed discharge into a waste disposal drum. Use a brush to scrub the equipment if necessary, to remove debris.
4. Immerse the pump in the barrel filled with clean tap water and start pump. Circulate the water through the pump and feed discharge into a waste disposal drum. Run the pump until no soap residue is visible in the discharge.
5. Deionized water should then be run through the pump and used to rinse all submersible parts and hoses.
6. Record the decontamination procedure in the field logbook or appropriate field form.

2.4 Procedure for Measuring Equipment

Measuring equipment, such as pressure transducers or water level indicators, will be decontaminated with extra care due to the sensitive nature of this equipment, using the following procedure.

1. Fill two clean basins with tap water.
2. Add enough concentrated soap to one basin to form a thin layer of soap suds.
3. Immerse the device in the soap containing basin and gently agitate. Scrub device using a brush if it is soiled. Do not submerse any electrical connectors or take up reels, only that portion of the device in contact with potentially contaminated water.
4. Immerse the device in the basin containing the rinse water and gently agitate. Do not submerse any electrical connectors or take up reels, only that portion of the device in contact with contaminated water.

5. Spray rinse equipment with deionized water.

6. Allow the equipment to air dry.

7. Record the decontamination procedure in the field logbook or appropriate field form.

2.5 Procedure for Large Heavy Equipment

Because heavy equipment pieces (e.g., ATVs, drill rigs) are much larger than sampling equipment and generally come in less direct contact with sampling aliquots, a modified decontamination procedure is appropriate. The following steps outline the decontamination protocol for heavy equipment:

1. Place the equipment on plastic sheeting large enough to accommodate equipment to be decontaminated and capture rinse water - a decontamination pad may be necessary (see below). The wash pad may consist of a bermed area lined with plastic sheeting with a sump at one corner. A sump pump should be used to remove water from the sump and transfer it to a drum.
    a. A decontamination pad may be constructed that is appropriate for the size and type of equipment being decontaminated for control and containerization of all decontamination fluids. The decontamination pad may contain the following elements, as needed:
        i. an impermeable barrier capable of containing decontamination fluids;
        ii. a low point where fluids will collect and can be pumped into appropriate containers;
        iii. durability to withstand equipment such as vehicle and foot traffic;
        iv. appropriate ancillary equipment such as racks to place decontaminated equipment to drain without further exposure to contaminated fluids; and
        v. labels to alert personnel as to the potential presence of contaminated materials.
2. Remove large clods of soil using a shovel, trowel or other tools. Collect these clods and dispose of them with other investigative derived waste.
3. Use a high-pressure portable washer (i.e., power washer) or high-pressure steam cleaner to remove potentially contaminated material from the equipment.
4. Scrub equipment with detergent (e.g. Alconox) and water using a brush to clean soiled surfaces.
5. Thoroughly rinse all surfaces with potable water.

3.0 WIPE SAMPLING FOR RADIOLOGICAL ACTIVITY

In addition to the decontamination procedures listed above, all sampling equipment, especially if used in areas where soil and groundwater are impacted by uranium, may be subject to wipe sampling following its use for sampling or remediation activities at the Site. The wipe sampling will be directed by the Radiation Safety Officer (RSO).

STANDARD OPERATING PROCEDURE NMI-008

FIELD ACTIVITY FORMS

1.0 INTRODUCTION

1.1 Objective

The objective of this standard operating procedure (SOP) is to guide documentation during field activities. Proper record keeping will be implemented in the field to allow samples to be traced from collection to final disposition. For example, succinct and complete record keeping during drilling and other investigation activities where geology of the subsurface is described will allow accurate interpretation of the geologic units for subsequent work. All information relevant to field operations should be properly documented to ensure that information is recorded, and when needed, activities can be reconstructed from the written records. Several types of field forms will be used for this purpose and should be consistently used by field crews (e.g., field logbooks, daily field record, field data sheets). This document describes recommended procedures for field documentation and provides sample forms for field documentation.

2.0 FIELD DOCUMENTATION

During field sampling events, daily field reports[1] and field data sheets are used to record daily field activities. The purpose of the daily field report is to document events that occur in the field throughout the day. Field data and measured parameters for field sampling activities can be recorded on the specific field forms developed for the field activity (e.g., low-flow sampling). A compilation of common field forms is included as an attachment to this SOP.

Data entry can be made on daily field report forms with consecutively numbered pages using indelible ink for each sampling event; all entries should be signed and dated, and no erasures should be made. All corrections should consist of a single line-out deletion, followed by the sampler's initials and the date. The sampler will sign and date the last page at the end of each day, and a line will be drawn through the remainder of the page.

If field logbooks are used, then each book should be project-specific and information such as the project name, site name and location should be written on the cover of the field logbook. If more than one logbook is used for a site, then the upper right-hand corner of the logbook will be annotated (i.e., 1, 2, 3…) to indicate the number of logbooks. Alternatively, multiple logbooks could be used for different sampling activities (e.g., one logbook for surface water sampling and one for groundwater sampling). It is preferable to not use more than one logbook at one time, although this is sometimes unavoidable. When multiple logbooks are used for a single sampling activity (e.g., 2 or more sampling teams operating simultaneously during a single surface water

1 This SOP uses the terminology daily field report (or daily field form) under the assumption that field staff may complete forms for each day of field work. A field logbook, which is preferred by some staff, can be used as a substitute for a daily field report and the terms should be considered interchangeable in this SOP.

sampling event) logbooks should be annotated alphabetically to indicate which of those books is the primary, secondary, etc. logbook for that sampling activity, followed by the number of the logbook. For example, if surface water sampling requires 3 teams and each have a logbook to record daily activity over the sampling event then the primary book will be labeled "Log Book A-1" and the others as "B-1" and "C-1." When only one team is on site, they will use the primary (A) logbook. Field logbooks will be stored in a secure manner when not in use in the field. Because logbooks can contain a lot of compiled information in a single document, it is sometimes prudent to copy or scan notes from the logbook on a daily or weekly basis to have a back-up.

In addition to the daily field report, supplementary activity-specific field data forms may be used during a field sampling event to record the relevant information (e.g., field calibration forms, groundwater monitoring form). At a minimum, the sampler will record the following information daily in the daily field report or on a field sampling form, as applicable:

- Project name, project location, project number and daily objective;
- Project start date and end date;
- Date and time of entry (24-hour clock);
- Time and duration of daily sampling activities;
- Weather conditions at the beginning of the field work and any changes that occur throughout the day, including the approximate time of the change;
- Name of person making entries and other field personnel, including the times that they are present;
- Onsite visitors, if any, including the times that they are present;
- The name, agency, and telephone number of any field contacts;
- The sample number and analysis code for each sample to be submitted for laboratory analysis;
- All field measurements made, including the time that the measurement was collected;
- The sampling location name, date, water depth (if applicable), and sampling location coordinates;
- Type of sample gear used (e.g., pump type or model, gill net mesh size, size of core barrel);
- The location and description of the work area, including sketches and map references, if appropriate;
- Specific information on each type of sampling activity;
- The sample type (i.e., groundwater, soil, surface sediment), and sample number;

- Cross-references of numbers for duplicate samples;
- A description of the sample (source and appearance, such as soil or sediment type, color, and odor);
- Log of photographs (number taken, photo number on roll or memory card, brief description of photo) taken at the sampling location, if any;
- Variations, if any, from specified sampling protocols and reasons for deviation;
- References to other logbooks used to record information (e.g., field data sheets, health and safety log); and
- The signature of the person making the entry.

Monitoring or sampling equipment information, including installation information, any maintenance performed on each piece of equipment, calibration information, and other observations relating to the operation or condition of the equipment, can be recorded on field forms and/or in daily field report.

The following field sampling forms examples may be used for the applicable field activities:

SOP No.	Task	Field Form
--	All Work	Daily Field Report
NMI-S-001	Surface and Subsurface Soil Sampling using Manual Methods	Sampling Report Form
NMI-S-002	Sediment Sampling	Sampling Report Form
NMI-S-003	Jar Headspace Sampling Procedures	Meter Calibration Form Soil Headspace Measurements
NMI-S-004	Soil and Rock Drilling and Soil Sampling	Boring Construction Log Rock Core Log
NMI-S-005	Test Pitting and Sampling	Test Pit Log
NMI-GW-001	Monitoring Well Integrity Survey	Well Integrity Assessment Form
NMI-GW-002	Monitoring Well Development	Monitoring Well Development and Purging Log
NMI-GW-003	Monitoring Well Installation	Well Construction Log
NMI-GW-008	Direct Push Drive-Point Piezometers	Piezometer Installation Report
NMI-GW-009	Water-Level Measurement Procedures	Water Level Data Form
NMI-GW-010	Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells	Multiparameter Meter Calibration Form Monitoring Well Development and Purging Log
NMI-GW-011	Groundwater Sampling for PFAS	PFAS Sampling Checklist
NMI-GW-016	Packer Testing Procedures	Packer Testing Form
NMI-GW-017	Specific Capacity Testing and Data Reduction	Pump Test Data Sheet

NMI-GW-018	Pump Testing	Pump Test Data Sheet
NMI-GW-019	Slug Testing	Slug Testing Field Form
NMI-A-001	Sub-slab Soil Gas Sampling	Soil Gas Probe Measurements Sub Slab Sample Location Description
NMI-A-002	Indoor Air Sampling	Indoor Air Sample Collection Record MassDEP Indoor Building Survey
NMI-003	Calibration of Field Instruments - ORP, NTU, DO meters	Multiparameter Meter Calibration Log
NMI-004	Calibration of Field Instruments - FID/PID/ O2-LEL meters	Meter Calibration Log PID Calibration Log

3.0 DOCUMENT RETENTION AND MANAGEMENT

The field task managers will be responsible for the management of completed field forms after each day of field work. If possible, completed reports and forms will be converted to an electronic format (pdf) and uploaded to an appropriate location within the *de maximis* online project portal. Following the submittal of the files to the portal, *de maximis* will take responsibility of maintaining the records. In some cases, field records cannot be scanned daily and uploaded, in which case efforts should be made to scan and upload field records as soon as reasonably possible.

4.0 REFERENCED DOCUMENTS

- *de maximis*. 2020. Remedial Design/Remedial Action. Health and Safety Plan (HASP) Nuclear Metals Superfund Site, Concord, Massachusetts.
- *de maximis*. 2020. Remedial Design/Remedial Action. Quality Assurance Project Plan (QAPP) Nuclear Metals Superfund Site, Concord, Massachusetts.

DAILY FIELD REPORT

Geosyntec consultants
289 Great Road
Acton, Massachusetts, 01720
(978)263-9588 Fax (978)263-9594

Project Name: _____ Date: _____ Page ___ of ___

Project Number: _____ Primary Activities: _____

Field Personnel: _____ _____

_____ _____

Recorded By: _____ _____

Weather: _____

Time	Description of activities - **location of work, work performed, equipment & personnel used, incidental information**

HALEY ALDRICH

SAMPLING RECORD

Page ____ of ____

PROJECT ______________________ **H&A FILE NO.** ______________
LOCATION ______________________ **PROJECT MGR** ______________
CLIENT ______________________ **FIELD REP.** ______________
CONTRACTOR ______________________ **DATE** ______________

Weather ______________________ **Temperature** ______________
Ground surface Conditions ☐ Dry ☐ Wet ☐ Damp ☐ Standing Water ☐ Snow (_____in) ☐ Other ______
Comments ______________________

SOIL SAMPLING AND SURFACE WATER SAMPLING INFORMATION

Sample No.	Location	Depth (ft)	Time	Sample Description	Sampling Device	Cleaning Prodedure	Container Type

General Comments: (ie: field filtrations, persons communicated with at site, etc.)

HALEY ALDRICH

SAMPLING RECORD

Page **of**

PROJECT ____________________ **H&A FILE NO.** ____________
LOCATION ____________________ **PROJECT MGR** ____________
CLIENT ____________________ **FIELD REP.** ____________
CONTRACTOR ____________________ **DATE** ____________

Weather ____________________ **Temperature** ____________
Ground surface Conditions ☐ Dry ☐ Wet ☐ Damp ☐ Standing Water ☐ Snow (_____in) ☐ Other ____________
Comments ____________________

SOIL SAMPLING AND SURFACE WATER SAMPLING INFORMATION

Sample No.	Location	Depth (ft)	Time	Sample Description	Sampling Device	Cleaning Prodedure	Container Type

General Comments: (ie: field filtrations, persons communicated with at site, etc.)

METER CALIBRATION

Geosyntec consultants
geosyntec.com

Project Name: _____ **Date:** _____ **Recorded By:** _____ **Page** ____ **of** ____

Project Number: _____ **Weather:** _____ **PrimaryActivities:** _____

PIDs

Serial Number		Ambient Air (ppm)	100ppm Isobutylene (ppm)
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		

GEMs

Serial Number		Ambient Air			Calibration Gas			Ambient Air		
		CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									

NOTES:

Personnel Signature: _____ **Date:** _____

Meter Calibration.xl

SOIL HEADSPACE MEASUREMENTS

Geosyntec consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Borehole ID _____ PID Model Number _____

Project Name _____ PID Serial Number _____

Project Number _____ Date Analyzed _____

Site Location _____ Calibration _____

Field Personnel _____ _____

Recorded By _____ _____

Sample Number	Sample Media	PID Measurements (ppmV)					
		First Reading	Time	10.6/11.7 (eV)	Second Reading	Time	10.6/11.7 (eV)

Boring and Monitoring Well Construction Log

Sheet ____ of ____

Client :	**Project No.**	**Location:**
Geosyntec Inspector:		**Date :**
Weather:	**Borehole Diameter:**	**Drilling Method:**
Drilling Co.	**Rig Type:**	**Driller**
Depth to water :	**Depth to Refusal:**	**Total Depth :**

Geosyntec consultants

engineers | scientists | innovators

Log of Boring

_____

Well Construction	WL	Depth (feet)	Soil Samples	PID	recovery	Sample Description and Boring Notes
		0				
		5				
		10				
		15				
		20				
		25				
		30				
		35				
		40				
		45				
		50				

Notes:

ROCK CORE LOGGING FORM

289 Great Road, Suite 202, Acton, MA 01720
Phone: 978-263-9588

Geosyntec consultants

Project Name:	Logged By:	Boring Location:
Project Number:	Rig Type:	Depth to Weathered Bedrock: Bedrock:
Drilling Contractor / Name:	Bit Type / Size:	Water Input during Drilling
Drilling Method:	Date / Start: Finish: Time:	Casing Size: ID: OD:

Visual	Depth (ft' bgs)	Sample No. (core interval)	Penetration Rate ft/min	Core Breaks (m if Mechanical)			Rock Quality			Rock Description and Comments on Drilling:
				Depth	Type/Dip	Surface Condition	Recovery	Run Length	RQD (%)	

Hardness:
V hard: no scratch
Hard: difficult to scratch
Med hard: easy scratch

Weathering:
v. slightly……1
slightly……2
moderately……3
severely……4
v. severely……5
completely……6

Fracture Frequency:
Extreme: <1"
Moderate: 1-4"
Slightly: 4-8"
Sound: >8"
Joints: close <->

Discontinuities:
Crack
Joint
Shear (slickensides, striations, polishing)
Fault zone: shears or faults

Texture:
Amorphous/aphanitic
Fine grained: barely seen
Med grained: <1/8th"
Coarse grained: 1/8-1/4"
v coarse grained: >1/4"

Color: gray, dk/lt gray, green gray, etc.

Other: water bearing, altered, fractured, brecciated, decomposed, kaolinized.

HALEY ALDRICH

ENVIRONMENTAL TEST PIT LOG

Test Pit No.

Page 1 **of**

PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP**	
CONTRACTOR		**DATE**	
EQUIPMENT		**WEATHER**	

Ground El. _____ ft. **Location** _____ **Groundwater depths/entry rates (in./min.):**

El. Datum _____ **PID Make / Model** _____

Depth (ft.)	Sample ID	PID Reading (ppm.)	Stratum Change Depth (ft.)	USCS Symbol	Visual Identification (Color, GROUP NAME & SYMBOL, % oversized, maximum particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0															

Obstructions:

Remarks:

Bucket Decontamination Metho

Field Tests

Dilatancy:	R - Rapid S - Slow N- None
Toughness:	L - Low M - Medium H - High
Plasticity:	N - Nonplastic L - Low M - Medium H - High
Dry Strength:	N - None L - Low M - Medium H - High V - Very High

Standing water in completed pit:

at depth _____ ft.

measured after _____ hrs. elapsed

Boulders:

Diameter (in.)	Number		Approx. vol. (cu. ft.)
12 to 24		=	
over 24		=	

Test Pit Dimensions (ft.):

Pit Depth _____

Pit Length X Width _____

NOTE: Soil identifications based on visual/manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

J:\forms\final\Frm 3709.xls

WELL INTEGRITY ASSESSMENT FORM

Site Name:_____Well I.D.:_____Date:_____

(For each item, circle the appropriate response or fill in the blank)

Well I.D. Clearly Marked: YES NO

Well Completion: FLUSH MOUNT ABOVE-GRADE
STANDPIPE Lockable Cover: YES NO DAMAGED *(Describe below)*

Lock Present: YES NO ADDED Key Brand/Number:_
Measuring Point Marked: YES NO ADDED
Well Riser Diameter (inches): _____
Well Riser Type: PVC Stainless Steel Other *(Describe)* _____

Surface Condition YES NO *(Describe below)*

Cement Intact:
Curb Box/Well Cover YES NO DAMAGED *(Describe below)*
All Bolts Present: YES NO *(Describe below)* NOT APPLICABLE
Ground Surface Slopes
Away from Well YES NO *(Describe below)*

Well Condition

Well Cap: PVC Slip Cap Pressure-fit Cap None
Well Vent: Slot Cut in Riser Vent Hole in Cap None Not Applicable *(Flush Mount Well)*

Reported Well Riser Stickup (feet): _____*(use negative number if below grade)*

Measured Well Riser Stickup (feet): _____ *(use negative number if below grade)*

Depth to Water (feet from Top of Well Riser): _____ *-or-* DRY

Reported Total Depth (feet below grade): _____

Measured Total Depth (feet below grade): _____

Well Obstructed: YES NO If yes, list depth in feet from Top of Well Riser: _____

Well Bottom: SOFT *(contains sediment)* FIRM *(no sediment)*

Recommendations

Repair Concrete/Surface Completion: YES NO If yes, list date performed:_
Re-Survey Well: YES NO If yes, list date performed:_
Remove Sediment, Redevelop & Re-Measure YES NO If yes, list date performed:_
Replace Well Cap: YES NO If yes, list date performed:_
Replace Bolts: YES NO If yes, list date performed:_
Replace Lock: YES NO If yes, list date performed:_
Other/Miscellaneous Observations:

Inspector(s):_

_____

Photograph of Well (optional):

Date of Photograph: _____

Additional Comments:

MONITORING WELL DEVELOPMENT PURGING & SAMPLING RECORDS

Geosyntec consultants
289 Great Road, Suite 202
Acton, Massachusetts, 01720
(978)263-9588 Fax(978)263-9594

Well ID:_____ Well Diameter:_____ Intake Depth:_____
Project Name:_____ Total Depth of Well:_____
Project Number:_____ Initial Depth to Water:_____ Time:_____
Date:_____ Casing Volume:_____
Recorded By:_____ Depth to Water after Purging:_____ Time:_____
Sample ID:_____ Method of Purging:_____
Duplicate ID:_____ Method of Sampling:_____
Weather:_____ Multi-meter ID:_____ Turbid ID:_____

Time	Depth to water	Pumping rate	Cumulative volume	Temp	pH	Specific conductance	D.O	ORP	Turbidity	Comments
	(ft btoc)	mLpm	L or gals	°F or °C	(units)	(µS / cm)	(mg / L)	(mV)	(NTU)	odor, color, sediment load, well condition, presence of product

Samples collected	Time collected	Container type	Container size	Preservative

Notes: (well condition, nearby activities or changes in land use, odors, problems, deviations from plan, etc.)

Stability according to the United States Environmental Protection Agency - Region 1 requires **three readings spaced at least five minutes apart as follows**[1]:

Parameter	Within
pH:	0.1 unit
Specific Conductivity:	3%
Dissolved Oxygen:	10% or under 0.5mg/L
ORP:	10mV
Turbidity:	10% for values over 5 NTU or 3 readings under 5 NTU
Temperature:	3%

1. EPA. (2017). Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. North Chelmsford, MA.

WELL CONSTRUCTION

Geosyntec consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Well ID _____ Site Location _____

Project Name _____ Field Personnel _____

Project Number _____ Recorded By _____

Permit Number _____

Installation Date(s) _____

Drilling Method _____

Borehole Diameter _____

Drilling Contractor _____

Driller _____

Drilling Fluid _____

Fluid Loss During Drilling _____

Materials Used

Riser Pipe: Diameter 2.0 inches

Construction

- ☐ PVC schedule _____
- ☐ Stainless Steel
- ☐ Other _____

Slotted Area: Length _____

Diameter _____

Slot Size _____

Construction

- ☐ PVC schedule _____
- ☐ Stainless Steel
- ☐ Other _____

Silt Trap Used ☐ Yes ☐ No

Bottom End Cap: ☐ Male ☐ Female ☐ Slip

- ☐ PVC
- ☐ Stainless Steel
- ☐ Other _____

Top Cap: ☐ Male ☐ Female ☐ Slip ☐ J Plug

- ☐ PVC
- ☐ Stainless Steel
- ☐ Other _____

Protective Casing: Length _____ ft/m

Diameter _____

Construction

- ☐ Cast Aluminum
- ☐ Cast Steel
- ☐ Other _____

Casing Installation: Length _____ metres/feet

Diameter _____ cm/inches

Material _____

Sandpack:

Coarse Sand: ___ bags of ___ kg/lb pe r bag Size _____

Fine Sand: ___ bags of ___ kg/lb per bag Size _____

Seal:

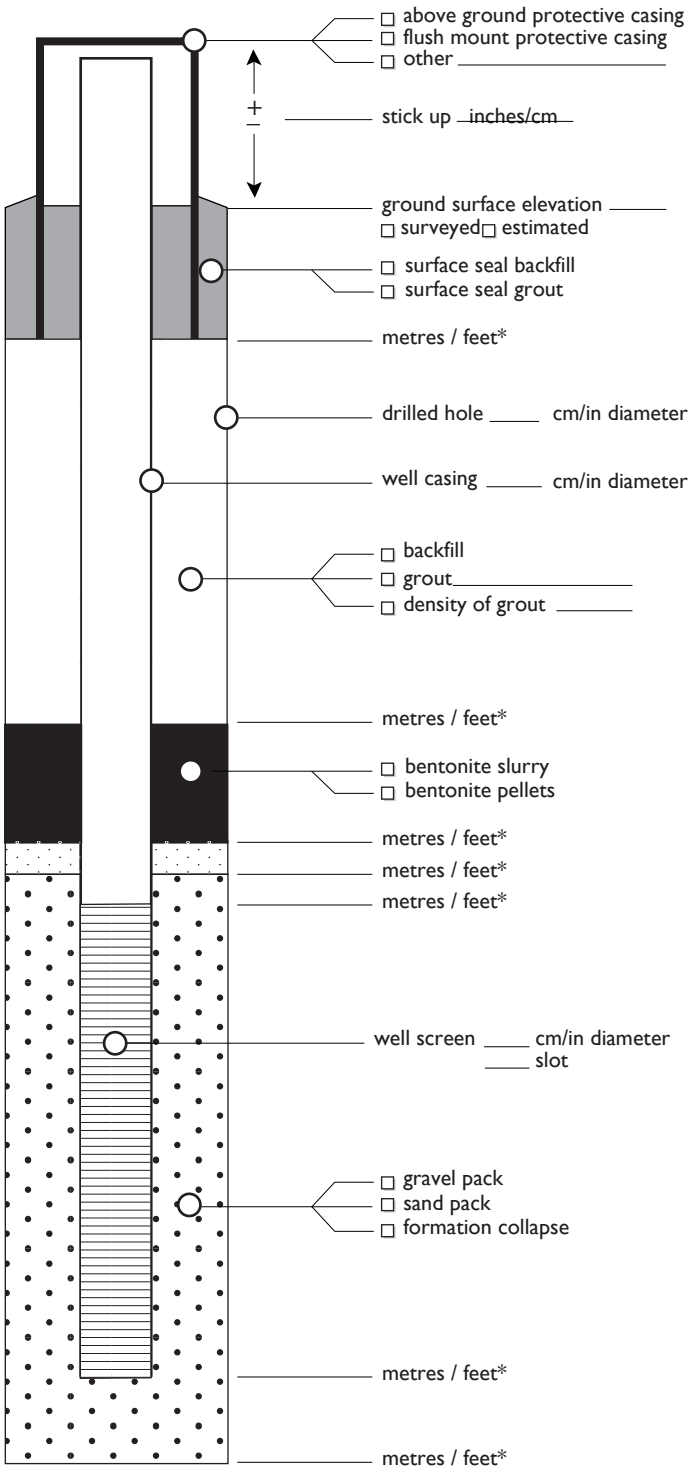
Bentonite Pellets: ___ bags of ___ kg/lb per bag Type _____

Bentonite Slurry: ___ bags of ___ kg/lb per bag Type _____

Grout:

Cement: ___ bags of ___ kg/lb per bag Type _____

Bentonite: ___ bags of ___ kg/lb per bag Type _____



Measuring Point is Top of Well Casing
Unless Otherwise Noted

* Depth Below Ground Surface

PIEZOMETER INSTALLATION REPORT

HALEY ALDRICH

Piezometer No.

Boring No.

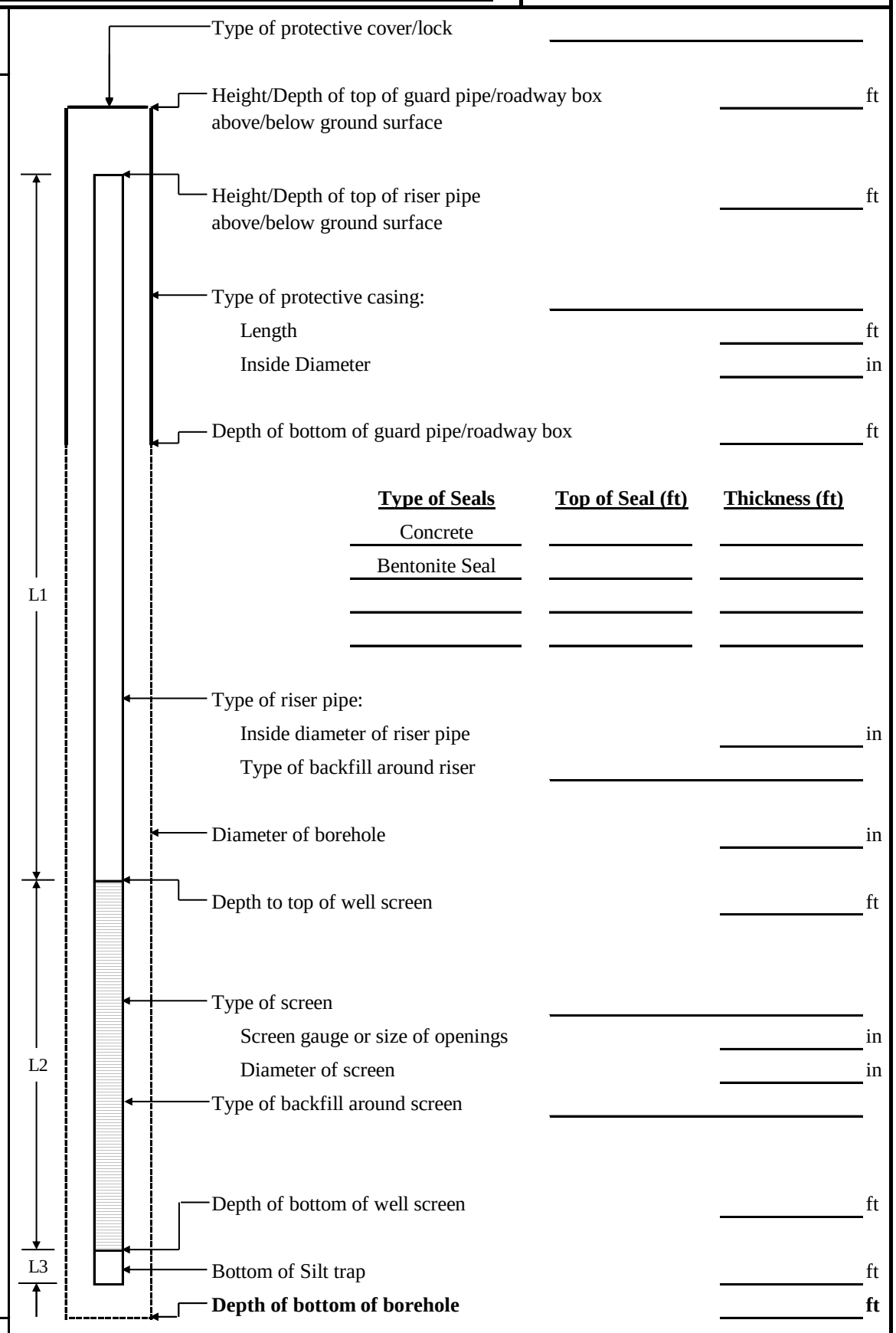
PROJECT		**H&A FILE NO.**	
LOCATION		**PROJECT MGR.**	
CLIENT		**FIELD REP.**	
CONTRACTOR		**DATE INSTALLED**	
DRILLER			

Ground El. _____ ft
El. Datum _____

Location _____

☐ **Guard Pipe**
☐ **Roadway Box**

SOIL/ROCK CONDITIONS	**BOREHOLE BACKFILL**



Type of protective cover/lock _____

Height/Depth of top of guard pipe/roadway box above/below ground surface _____ ft

Height/Depth of top of riser pipe above/below ground surface _____ ft

Type of protective casing: _____

Length _____ ft

Inside Diameter _____ in

Depth of bottom of guard pipe/roadway box _____ ft

Type of Seals	**Top of Seal (ft)**	**Thickness (ft)**
Concrete		
Bentonite Seal		

Type of riser pipe: _____

Inside diameter of riser pipe _____ in

Type of backfill around riser _____

Diameter of borehole _____ in

Depth to top of well screen _____ ft

Type of screen _____

Screen gauge or size of openings _____ in

Diameter of screen _____ in

Type of backfill around screen _____

Depth of bottom of well screen _____ ft

Bottom of Silt trap _____ ft

Depth of bottom of borehole _____ **ft**

(Bottom of Exlporation)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

ft	+	ft	+	ft	=	ft
Riser Pay Length (L1)		Length of screen (L2)		Length of silt trap (L3)		Pay length

COMMENTS: _____

WATER LEVEL DATA

Geosyntec
consultants
289 Great Road
Acton, Massachusetts, 01720
(978) 263-9588 Fax (978) 263-9594

Project Name: _____
Project Number: _____
Date: _____
Field Personnel: _____
_____
Recorded By: _____
Weather: _____

Measuring Instrument:
Steel Tape
Electric Sounder
Other - Type _____
Instrument Serial Number: _____

Well ID	Time	depth to water (metres / feet)			comments odour, color, sediment load, well condition, presence of product
		1st	2nd	3rd	

METER CALIBRATION REPORT

Geosyntec consultants
289 Great Road, Acton, MA 01720
Phone: 978-263-9588, Fax: 978-263-9594

Project Name:		Date:	Page ____ of ____
Project Number:		Primary Activities:	
Field Personnel:			
Recorded By:		Weather:	
Sampler's Initials:			

Meter Summary

Meter	Make/Model (ex. YSI 600XL)	Serial #	Rental Company	Rental Company ID #
Multi-Parameter Probe (pH, DO, ORP, Conductivity)				
Turbidity Meter				

dissolved oxygen (DO) and pH calibration		dissolved oxygen calibration solutions		pH buffer solutions		
		100%	0 mg/L	4.01	7.00	10.00
initial	temperature (°C)					
	instrument reading					
	Calibrated To		N/A			
	Final Reading					
final	temperature (°C)					
	instrument reading					
	Post Cal Check Pass (yes/no)					

Specific conductivity, ORP[1] and turbidity calibration ([1]check temperature correction)		Specific conductivity calibration	ORP[1] calibration solution (Zobell)	turbidity calibration solutions		
		_____ µs/cm @ 25 °C	_____ mV Ag/AgCl @ 25 °C	#1	#2	#3
				____ NTUs	____ NTUs	____ NTUs
initial	temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Calibrated To					
	Final Reading					
final	Temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Post Cal Check Pass (yes/no)					

initial calibration completed at: _____ (time)	final calibration check completed at: _____ (time)

Comments (DO membrane changed, other equipment issues, etc)

[1]*See Back for Temperature Correction*

ORP (Zobell Solution)

mV	**-5°C**	**0°C**	**5°C**	**7.5°C**	**10°C**	**12.5°C**	**15°C**	**17.5°C**	**20°C**
Ag/AgCl	270.0	263.5	257.0	253.8	250.5	247.3	244.0	240.8	237.5
mV	**22.5°C**	**25°C**	**27.5°C**	**30°C**	**32.5°C**	**35°C**	**40°C**	**45°C**	**50°C**
Ag/AgCl	234.3	231.0	227.8	224.5	221.3	218.0	211.5	205.0	198.5

Post Calibration Criteria

Dissolved Oxygen	± 0.5 mg/L of sat. value, < 0.5 mg/L for the 0 mg/L solution, but not a negative value
Specific Conductance	±5% of standard or ± 10 *µs/cm (whichever is greater)*
pH	± 0.3 pH unit with pH 7 buffer*
ORP	± 10 mv*
Turbidity	± 5% of standard

Note: * Table 8.1, USEPA Region 1 *YSI6-Series Sondes and Data Logger SOP*, January 27, 2016, revision 13.

MONITORING WELL DEVELOPMENT PURGING & SAMPLING RECORDS

Geosyntec consultants
289 Great Road, Suite 202
Acton, Massachusetts, 01720
(978)263-9588 Fax(978)263-9594

Well ID:_____ Well Diameter:_____ Intake Depth:_____
Project Name:_____ Total Depth of Well:_____
Project Number:_____ Initial Depth to Water:_____ Time:_____
Date:_____ Casing Volume:_____
Recorded By:_____ Depth to Water after Purging:_____ Time:_____
Sample ID:_____ Method of Purging:_____
Duplicate ID:_____ Method of Sampling:_____
Weather:_____ Multi-meter ID:_____ Turbid ID:_____

Time	Depth to water	Pumping rate	Cumulative volume	Temp	pH	Specific conductance	D.O	ORP	Turbidity	Comments
	(ft btoc)	mLpm	L or gals	°F or °C	(units)	(µS / cm)	(mg / L)	(mV)	(NTU)	odor, color, sediment load, well condition, presence of product

Samples collected	Time collected	Container type	Container size	Preservative

Notes: (well condition, nearby activities or changes in land use, odors, problems, deviations from plan, etc.)

Stability according to the United States Environmental Protection Agency - Region 1 requires **three readings spaced at least five minutes apart as follows**[1]:

Parameter	Within
pH:	0.1 unit
Specific Conductivity:	3%
Dissolved Oxygen:	10% or under 0.5mg/L
ORP:	10mV
Turbidity:	10% for values over 5 NTU or 3 readings under 5 NTU
Temperature:	3%

1. EPA. (2017). Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. North Chelmsford, MA.

Attachment A. Daily Sampling Checklist

Date: _____

Site Name: _____

Weather (temperature/precipitation): _____

Please check all boxes that apply and describe any exceptions in the notes section below along with QA/QC methods used to assess potential sample cross-contamination as a result.

Field Clothing and PPE:

- No water- or stain-resistant boots or clothing (e.g., GORE-TEX®)
- Field boots (or overboots) are made of polyurethane, PVC, rubber, or untreated leather Rain gear are made of polyurethane, PVC, vinyl, wax-coated or rubber
- Clothing has not been recently laundered with a fabric softener No coated HDPE suits (e.g., coated Tyvek® suits)
- Field crew has not used cosmetics, moisturizers, or other related products today
- Field crew has not used sunscreen or insect repellants today, other than products approved as PFAS-free

Field Equipment:

- Sample containers and equipment in direct contact with the sample are made of HDPE, polypropylene, silicone, acetate or stainless steel, not LDPE or glass
- Sample caps are made of HDPE or polypropylene and are not lined with Teflon™ No materials containing Teflon™, Viton™, or fluoropolymers
- No materials containing LDPE in direct contact with the sample (e.g., LDPE tubing, Ziploc® bags)
- No plastic clipboards, binders, or spiral hard cover notebooks No waterproof field books
- No waterproof or felt pens or markers (e.g., certain Sharpie® products) No chemical (blue) ice, unless it is contained in a sealed bag
- No aluminum foil
- No sticky notes (e.g., certain Post-It® products) Decontamination:

Reusable field equipment (e.g., dip sampler) decontaminated prior to reuse

- "PFAS-free" water is on-site for decontamination of field equipment Alconox®, Liquinox® or Luminox® used as decontamination detergent
- Food and Drink:

- No food or drink on-site, except within staging area
- Food in staging area is contained in HDPE or stainless steel container

Notes:

Field Team Leader Name (Print): _____

Field Team Leader Signature: _____ Date/Time: _____

Geosyntec consultants

Straddle Packer Testing Form

Straddle Packer Sample Location (Well Name)	Measuring Point Elevation (ft NGVD)	Static Depth to Water (ft)	Static Groundwater Elevation (ft NGVD)	Test Section Interval (ft bgs)	Test Period	Upper Transducer Reading (ft/PSI)	Middle Transducer Reading (ft/PSI)	Lower Transducer Reading (ft/PSI)	Extraction Rate CIRCLE One (gpm or Lpm)
				to	Pre-inflation				
					Post-inflation				
					Pumping				
Date				to	Pre-inflation				
					Post-inflation				
					Pumping				
				to	Pre-inflation				
					Post-inflation				
					Pumping				
				to	Pre-inflation				
					Post-inflation				
					Pumping				
				to	Pre-inflation				
					Post-inflation				
					Pumping				
Date				to	Pre-inflation				
					Post-inflation				
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					Post-inflation				
					Pumping				
Date				to	Pre-inflation				
					Post-inflation				
					Pumping				
				to	Pre-inflation				
					Post-inflation				
					Pumping				
				to	Pre-inflation				
					Post-inflation				
					Pumping				

Notes:
1. All transducers shall be set to read the static level prior to testing.

PUMP TEST DATA SHEET

Page ______ of ______

Application: _________________ Permit: __________________ Certificate: _________________ Pod_Id: ______________

All water-level measurements must either be in feet and inches, or feet and decimal fractions.

Drawdown Data						Recovery Data					
Date	Time	Time Since Pump Started (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments	Date	Time	Time Since Pump Stopped (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments

PUMP TEST DATA SHEET

Page _____ of ______

Application: ________________ Permit: __________________ Certificate: _________________ Pod_Id: ______________

All water-level measurements must either be in feet and inches, or feet and decimal fractions.

Drawdown Data						Recovery Data					
Date	Time	Time Since Pump Started (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments	Date	Time	Time Since Pump Stopped (minutes)	Depth to Water Below Measuring Pt	Depth to Water Below Land Surface	Comments

SLUG TEST FIELD FORM

Geosyntec consultants

Project Name: _____ Date: _____

Project Number: _____

Field Personnel: _____ Well Name: _____

_____ Well Location: _____

Recorded by: _____ Weather: _____

Expected Water Table Behavior(Rising/Falling):_____

WELL CONSTRUCTION/WATER LEVEL

Reported Well Depth(ft TOR)_____ Date of Last Development_____

Measured Well Depth(ft TOR)_____ Initial Static Water level from TOR(ft)_____

Casing Diameter(in)/Schedule_____ Final Static Water level from TOR(ft)_____

Screen Length(ft) and Slot Size_____ TOR from land surface(ft)_____

Depth to TOP of Screen from TOR(ft)_____ Borehole Diameter(in)_____

Filter Pack Details_____ Annular Seal Details _____

PRESSURE TRANSDUCER INSTALLATION

	Type	Serial Number	Reading in Air	Pressure Units	Log Method	Log Interval	Log Duration
Transducer							

FALLING HEAD TEST DETAILS

Test Number	TEST 01	TEST 02	TEST 03	TEST 04	TEST 05	TEST 06
PT Depth(TOR)						
Water Volume poured into well(mL)						
Initial Displacement(ft H2O)						
WL Equillibrium Time						
Test Start Time						
Test End Time						

TEST ELECTRONIC FILE NAMES

TEST 01	
TEST 02	
TEST 03	
TEST 04	
TEST 05	
TEST 06	

SOIL GAS PROBE MEASUREMENTS

Geosyntec consultants

① Project Name: _____ Probe No.: _____ ☐ Sub-slab probe ☐ Soil gas probe

Date: _____ Project Number: _____ Mini Rae 2000 Serial No.: _____ Lamp: 10.6 / 11.7 eV

Site Location: _____ Landtech GEM 2000 Landfill Gas Meter Serial No. M: _____

Weather: _____ MDG 2002 Helium detector Serial No.: _____

Field Personnel: _____ Tracer Gas: ☐ Helium ☐ Other _____

Recorded By: _____

② Surface Type: ☐ Asphalt ☐ Concrete ☐ Grass ☐ Other_____

Surface Thickness _____ inches/centimeters ☐ Unknown
(i.e., asphalt or concrete)

③ 1 Casing Volume

☐ Sub-slab
<0.1 L

Soil gas probe _____ (L)

④ Initial Vacuum (prior to pumping) _____ in. H_2O

⑤ Shut in test prior to pneumatic test completed,____ in. H_2O held for ___ seconds.

⑥ Start of Pneumatic Test: _____

Elapsed Time (min.)	Pump Flow Rate (LPM)	Well Head Vacuum in. H_2O
	0.1	
	0.2	
	0.5	

⑦ Field tubing blank reading (ppm_v) completed? ☐Yes ☐No PID Reading _____ ppm_v

⑧ Shut in test prior to purging completed? Yes ☐ No ☐

⑨ Purging

Date	Start Time	End Time	Elapsed Time (min.)	Bag Volume (L)	Purge Rate (LPM)	Cumulative Volume (L)	CH_4 (%)	CO_2 (%)	O_2 (%)	Tracer Gas: Shroud (%) Min	Tracer Gas: Shroud (%) Max	Tracer Gas: Sample (ppm_v, %) (circle one)	VOCs by PID (ppm_v)

⑩ Helium concentration in field screened samples is less than 5% of minimum concentration in the shroud? ☐ Yes ☐ No **Note:** 1% helium = 10,000 ppm_v

⑪ Shut in test prior to sample collection completed? Yes ☐ No ☐

⑫ Sample Collection

Date	Time	Sample ID	Summa Canister ID	Flow Controller #	Vacuum Gauge #	Initial Vacuum (in. Hg)	Final Vacuum (in. Hg)

Comments:

SGP measurements - pneumatic testing.ai

SUB-SLAB SAMPLING FORM

Geosyntec consultants

Project Name: _____ Date: _____

Project Number: _____ Address: _____

Field Personnel: _____

Location Description* :

Location Sketch* :

Sub Slab Sampling Location Description.ai

* note floor type, location of probes, walls, fuel tanks, sumps, stored chemicals, stains, etc.

AIR MONITORING FORM

Geosyntec consultants

Site Name _____ Project ID _____

Sampler Name _____

Sample Location: Building _____ Floor _____ Room _____

Sample Type: 6 Liter Summa _____ Weather Conditions _____

Analytical Method (circle one): TO-15 SIM and TO-15 Scan

Sample ID	Canister ID	Regulator ID	Start			End		
			Vacuum (in Hg)	Time	Date	Vacuum (in Hg)	Time	Date

Room Temperature _____

PID Reading _____ (ppm_v)

Other Comments (e.g., PID readings, intermediate vacuum readings)

Sketch of Sample Location (s)

Air Monitoring Form.ai

Indoor Air Quality Building Survey

Date: _____ RTN: _____

Address: _____

_____

Building Contact: _____ Phone: Tel: _____
Cell: _____
Work: _____

Current Occupants:

INITIALS	AGE	SEX (M/F)

Building Construction Characteristics: (Circle or underline appropriate responses)

Single Family	Multiple Family	School	Commercial
Ranch	2-Family		
Raised Ranch	Duplex		
Cape	Apartment House		
Colonial	# of units ____		
Split Level	Condominium		
Colonial	# of units ____		
Mobile Home	Other _____		
Other _____			

General Description of Building Construction Materials:

Wood Brick Stone Metal Other_____

How many occupied stories does the building have? _____

Has the building been weatherized with any of the following?

Insulation Storm Windows Energy-Efficient Windows Other _____

Indoor Air Quality Building Survey, continued

What type of basement does the building have?

Full basement Crawlspace Slab-on-Grade Other _____

What are the characteristics of the basement? Finished Unfinished Other_____

Basement Floor:	Foundation Walls:	Moisture:
Concrete	Poured Concrete	Wet
Dirt	Block	Damp
	Stone	Dry

Is a basement sump present? (Y/N) ____

Does the basement have any of the following characteristics (i.e., preferential pathways into the building) that might permit soil vapor entry?

Cracks Pipes/Utility Conduits Foundation/slab drainage

Sump pumps Other _____

Heating and Ventilation System(s):

What type(s) of heating system are used in this building?

Hot Air Circulation	Heat Pump	Wood Stove
Hot Air Radiation	Unvented Kerosene Heater	Electric Baseboard
Forced Hot Water	Steam Radiation	Other _____

What type(s) of fuel are used in this building?

Natural Gas	Electric	Coal	Other _____
Fuel Oil	Wood	Solar	

What type(s) of mechanical ventilation system are present and/or currently operating in this building?

Central Air Conditioning	Mechanical Fan	Bathroom Ventilation Fan
Kitchen Range Hood	Open Window	Individual Air Conditioning Unit
Air-to-Air Heat Exchange	Other _____	

Indoor Air Quality Building Survey, continued

Sources of Chemical Contaminants:

Potential VOC Source	Check if present in building prior to sampling	Location of Source	Removed 48 hours prior to sampling? (Yes/No/NA)
Paints or paint thinners			
Gas-powered equipment			
Gasoline storage cans			
Cleaning solvents			
Air fresheners			
Oven cleaners			
Carpet/upholstery cleaners			
Hairspray			
Nail polish/polish remover			
Bathroom cleaner			
Appliance cleaner			
Furniture/floor polish			
Moth balls			
Fuel tank			
Wood stove			
Fireplace			
Perfume/colognes			
Hobby supplies (e.g., solvents, paints, lacquers, glues, photographic darkroom chemicals)			
Scented trees, wreaths, potpourri, etc.			
Other			
Other			

☐ YES ☐ NO Do one or more smokers occupy this building on a regular basis?

☐ YES ☐ NO Has anybody smoked in the building in the last 48 hours?

☐ YES ☐ NO Does the building have an attached garage?

☐ YES ☐ NO If so, is the garage used for parking cars

Indoor Air Quality Building Survey, continued

☐ YES ☐ NO Do the occupants of the building frequently have their clothes dry-cleaned?

☐ YES ☐ NO Was there any recent remodeling or painting done in the building?

☐ YES ☐ NO Are there any new pressed wood products in the building (e.g., hardwood plywood, wall paneling, particleboard, fiberboard)?

☐ YES ☐ NO Are there any new upholstery, drapes or other textiles in the building?

☐ YES ☐ NO Has the building interior been treated with any insecticides/pesticides?

If yes, what chemicals are used and how often are they applied?

Outdoor Sources of Contamination/Conditions:

Do any of the occupants apply pesticides/herbicides in the yard or garden? If yes, what chemicals are used and how often are they applied?

Is there any stationary emission source in the vicinity of the building?

Are there any mobile emission sources (e.g., highway, bus stop, high-traffic area) in the vicinity of the building?

Type of ground cover (e.g., grass, pavement, etc.) outside the building: _____

Other Information:

Is there other information about the structural features of the building, habits of its occupants or potential sources of contaminants to the indoor air that may be of significance to the evaluation of the indoor air quality of the building?

Weather Conditions during Sampling:

Outside Temperature (^{o}F): _____

Prevailing wind direction and approximate wind speed: _____

Describe the general weather conditions (e.g., sunny, cloudy, rain): _____

Was there significant precipitation (≥ 0.1 inches) within 12 hours preceding the sampling? _____

METER CALIBRATION REPORT

Geosyntec consultants
289 Great Road, Acton, MA 01720
Phone: 978-263-9588, Fax: 978-263-9594

Project Name:		Date:	Page ____ of ____
Project Number:		Primary Activities:	
Field Personnel:			
Recorded By:		Weather:	
Sampler's Initials:			

Meter Summary

Meter	Make/Model (ex. YSI 600XL)	Serial #	Rental Company	Rental Company ID #
Multi-Parameter Probe (pH, DO, ORP, Conductivity)				
Turbidity Meter				

dissolved oxygen (DO) and pH calibration		dissolved oxygen calibration solutions		pH buffer solutions		
		100%	0 mg/L	4.01	7.00	10.00
initial	temperature (°C)					
	instrument reading					
	Calibrated To		N/A			
	Final Reading					
final	temperature (°C)					
	instrument reading					
	Post Cal Check Pass (yes/no)					

Specific conductivity, ORP[1] and turbidity calibration ([1]check temperature correction)		Specific conductivity calibration	ORP[1] calibration solution (Zobell)	turbidity calibration solutions		
		_____ µs/cm @ 25 °C	_____ mV Ag/AgCl @ 25 °C	#1	#2	#3
				____ NTUs	____ NTUs	____ NTUs
initial	temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Calibrated To					
	Final Reading					
final	Temperature (°C)			N/A	N/A	N/A
	instrument reading					
	Post Cal Check Pass (yes/no)					

initial calibration completed at: _____ (time)	final calibration check completed at: _____ (time)

Comments (DO membrane changed, other equipment issues, etc)

[1]*See Back for Temperature Correction*

ORP (Zobell Solution)

mV	**-5°C**	**0°C**	**5°C**	**7.5°C**	**10°C**	**12.5°C**	**15°C**	**17.5°C**	**20°C**
Ag/AgCl	270.0	263.5	257.0	253.8	250.5	247.3	244.0	240.8	237.5
mV	**22.5°C**	**25°C**	**27.5°C**	**30°C**	**32.5°C**	**35°C**	**40°C**	**45°C**	**50°C**
Ag/AgCl	234.3	231.0	227.8	224.5	221.3	218.0	211.5	205.0	198.5

Post Calibration Criteria

Dissolved Oxygen	± 0.5 mg/L of sat. value, < 0.5 mg/L for the 0 mg/L solution, but not a negative value
Specific Conductance	±5% of standard or ± 10 *µs/cm (whichever is greater)*
pH	± 0.3 pH unit with pH 7 buffer*
ORP	± 10 mv*
Turbidity	± 5% of standard

Note: * Table 8.1, USEPA Region 1 *YSI6-Series Sondes and Data Logger SOP*, January 27, 2016, revision 13.

METER CALIBRATION

Geosyntec consultants
geosyntec.com

Project Name: _____ **Date:** _____ **Recorded By:** _____ **Page** ____ **of** ____

Project Number: _____ **Weather:** _____ **PrimaryActivities:** _____

PIDs

Serial Number		Ambient Air (ppm)	100ppm Isobutylene (ppm)
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		

GEMs

Serial Number		Ambient Air			Calibration Gas			Ambient Air		
		CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									

NOTES:

Personnel Signature: _____ **Date:** _____

Meter Calibration.xl

PID CALIBRATION REPORT
Ambient Air Monitoring Program

Geosyntec consultants
289 Great Road, Acton, MA 01720
Phone: 978-263-9588, Fax: 978-263-9594

Project Name: _____ Date: _____ Page ____ of ____
Project Number: _____ Primary Activities: _____
Field Personnel: _____ _____
_____ _____
Recorded By: _____ _____
Weather (temperature, cloud cover, wind speed/direction, precipitation type): _____

Calibration Gases

Type of Zero Gas (Note: If ambient air is used for zero gas, use charcoal filter on PID inlet tubing.)	Type: Ambient Air / Bottled	Charcoal Filter Used?: Yes / No
Type of Span Gas (ex. isobutylene)		
Span Gas Concentration (ppm)		

Calibration Parameters

Site-Assigned Meter Designation (Mark perimeter monitoring units with corresponding number: 1, 2, or 3)		PID #1	PID #2	PID #3	PID #4 _____	PID #5 _____
Meter Brand (ex. RAE, Photovac, Thermo)						
Meter Model (ex. AreaRAE, MiniRAE 2000, Photovac 2010 or 2020, OVM 580B)						
Meter Serial Number	Manufacturer					
	Rental Company					
Initial Zero Gas Reading (before calibration)	(ppm)					
Final Zero Gas Reading (after calibration)	(ppm)					
Initial Span Gas Reading (before calibration)	(ppm)					
Final Span Gas Reading (after calibration, if needed)	(ppm)					

Comments:

STANDARD OPERATING PROCEDURE NMI-009

GENERAL SURVEY PROCEDURES

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for conducting general surveys of monitoring wells and site features during field investigations at hazardous and non-hazardous waste sites.

1.1 Objective

The objective of conducting surveys is to obtain accurate locations and elevations for incorporation into the preparation of ground water elevation contour maps, site contour maps, and site plans or figures.

1.2 Equipment

The following list of equipment may be utilized during site surveys. Site-specific conditions may warrant addition or deletion of items from this list.

- Theodolite
- Automatic level
- Tripod
- Stadia rod (graduated in 0.01 foot increments)
- Electronic distance meter (EDM)
- DGPS devices (WAAS, Sub-meter, Survey grade)
- DGPS base stations (for use with Survey grade equipment)
- Prisms and targets
- Compass
- Plum-bob
- Folding engineers' ruler (graduated in 0.01 foot increments)
- Steel tape (graduated in 0.01 foot increments)
- Any necessary personal protective equipment (boots, gloves, eyewear, tyvek suits)
- Air monitoring instruments as required for health and safety (photo-ionization detector, particulate meter, etc.)
- Field logbook
- Calculator

- Information about the location and elevation of a local benchmark or datum
- Previous measurement data (if available)
- Surveying nails (PKs)
- Stakes and tacks
- Flagging and/or marking paint
- Permanent markers and/or lumber crayons
- Portable radios or cell phones
- Traffic cones, safety vests
- Hand tools: hammer, chisel, axe, knife, saw, shovel

2.0 PROCEDURES

2.1 Procedures for conducting relative elevation surveys (level loop)

The following procedures should be utilized when performing a relative elevation survey. Procedures may vary depending on the equipment used, features to be surveyed, and contaminants present. Site specific conditions may warrant modifications to these procedures and certain tasks will require a licensed surveying subcontractor. This SOP is intended for use on small areas where only relative elevations are required and can be conducted by qualified personnel who are not licensed surveyors. A comprehensive survey will require more stringent procedures to be established on a task-specific basis.

1. Identify an appropriate benchmark. Set up and level the surveying instruments so that there is a clear line of sight to the local benchmark and objects to be surveyed. If line of sight to all survey points is infeasible, then multiple locations will be needed for instrument set-up. If more than one instrument set-up will be required to complete the survey, identify the approximate instrument locations that will be required to limit the number of set-ups required.

2. Set-up the survey equipment, ensuring that it is level by checking level from multiple directions.

3. Measure the instrument height above the local benchmark elevation (temporary or permanent). Add elevation of the local benchmark and height of the instrument above the local benchmark to determine the elevation of the instrument. Be sure to write this in the logbook. The instrument elevation can be checked if there is another surveyed location within sight.

4. For monitoring well elevation surveys, follow the map or plan of locations in a logical order.

5. Record the condition of the well (protective casing, concrete collar surrounding the protective casing, lock in place etc.).

6. Identify the previous measuring point marking or notch on the riser or casing (if present). Record this location in the field logbook and provide it to the subcontractor or other rod person. BE EXTREMELY CAUTIOUS NOT TO DROP A MARKER (E.G., SHARPIE) DOWN A WELL WHEN MAKING A REFERENCE MARK.

7. Begin the level-loop to the desired locations and record all measurements in the field book (i.e., height from the measuring point to the instrument). Instruct the field personnel (or other) to take measurements of the top of the protective casing, the top of PVC riser at the measuring point notch or marking (if present), and the ground surface to a precision of 0.01 foot at each location, if possible. Shots which are greater than 500 feet in distance should be avoided due to the potential for error. To promote accuracy, the stadia rod should be swayed back and forth slowly by the rod person and the surveyor should record the lowest measurement.

8. Replace the vented cap, lock the well and continue survey at the next location.

9. The loop should be closed at the starting point (benchmark) to an accuracy of +/- 0.1 feet of the original elevation.

2.2 Relative Traverse Surveys

The following procedures should be utilized during the conduct of traverse surveys. Procedures may vary depending on the equipment used and the features to be surveyed. Site specific conditions may warrant modifications to these procedures. This SOP is intended for use by non-registered surveyors and is applicable to use on small areas where only relative locations of site features are required.

1. Establish the traverse loop to be surveyed.

2. Set-up and level the surveying instrument (transit, Theodolite) over a reference stake and center cross-hairs of the optical plumb on a tack in the center of the stake. Set the internal verniers to zero degrees. Conduct a back-sight on an established benchmark.

3. Measure the instrument height above the benchmark elevation, unlock the horizontal vernier and turn the instrument clock-wise (towards a positive angle) to the desired location. Record the measurements in the field book. The prism mounted on a tripod, staff or a stadia rod should be set and held by the rod person in the middle of the object of interest. After all shots are completed at this location, set a stake (hub) or PK nail (if in asphalt or concrete) in the ground at the next desired survey station. Avoid shots which are greater than 500 feet in distance unless an electronic distance meter is being utilized.

4. Set-up and level the instrument over the next station and center the cross-hairs of the optical plumb on a tack in the center of the stake. Repeat steps 2 and 3 except the back sight will be to the former reference station stake instead of a benchmark. The final station should be sighted into the original benchmark. The traverse should close within a ratio of 1:30,000 feet. Horizontal locations should be accurate to within +/- one (1) foot.

2.3 Differential Global Positioning System (DGPS) Surveys

The following procedures should be utilized during the conduct of DGPS surveys. Procedures may vary depending on the equipment used and the features to be surveyed. Site specific conditions may warrant modifications to these procedures. All field personnel (or other) must be trained in the use of the GPS equipment by qualified staff before using this equipment. Specific procedures on the operation and setup of the GPS equipment are described in detail in the operations manuals for each of the instruments. All instruments will be used consistent with the instructions contained within these manuals.

1. The objectives and accuracy requirements should be established and factors that might limit the use of the GPS equipment should be assessed.

2. Select the appropriate model of DGPS for the objectives and accuracy requirements. There are three levels of DGPS equipment: WAAS corrected units (<3 meter accuracy), Sub-meter units (<1 meter accuracy) with both real time and post processing capabilities, and Survey Grade units (<1 foot accuracy). If elevation data are required, survey grade equipment with base station units should be employed with a vertical accuracy within +/- 0.2 feet.

3. Test the GPS equipment prior to going in the field in order to ensure that it works properly and meets the requirements of the field project.

4. Establish features to be collected.

5. Turn on the device and monitor satellite constellation for good signal lock. PDOP and error assessment readings should be consistently monitored before beginning data collection.

6. It is advised to collect at least one location over a site feature with known horizontal and/or vertical control to confirm the equipment is measuring accurately.

7. Collect feature location logging the point name/number in DGPS data logger or field notebook/form.

8. Proceed to the next site feature and continue this operation for all site features.

9. Connect DGPS using to a desktop or laptop computer and download the collected points. If differential correction was not real time when points were collected, then

perform any corrections needed using appropriate software/methods based on the equipment used.

3.0 DECONTAMINATION

The decontamination of equipment used to survey reference elevations on new wells or ground surface elevations is not necessary because the equipment does not come in contact with impacted soils or groundwater. Survey equipment that comes in contact with impacted material (e.g., used to evaluate the depth of excavations) will be decontaminated using procedures listed in SOP NMI-007.

RADIATION SAFETY & CONTROL SERVICES, INC.
STANDARD OPERATING PROCEDURE

CALIBRATION OF RADIATION SURVEY METERS

SOP 2.4

Revision 19

Originator: _____ Date: 7/11/16

Reviewer: _____ Date: 7/11/16

Approval: _____ Date: 7/11/16
RSCS Director / Designee

CALIBRATION OF RADIATION SURVEY METERS

1. OBJECTIVE

This procedure provides guidance for calibrating radiation survey meters.

2. REFERENCES

2.1 ANSI N323AB-2013, American National Standard Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments

2.2 New Hampshire Rules for the Control of Radiation

2.3 RSCS Training and Qualification Manual

2.4 RSCS New Hampshire Radioactive Material License No. 381R

2.5 STID 04-019, Verification of Shepherd Box Calibrator Dose Rate Data

2.6 SOP 2.1.4 Management of Dosimetry Devices

2.7 SOP 2.1.11 Package Receipt and Shipment

2.8 SOP 2.1.2 Restricted Area Access Control

2.9 SOP 2.1.3 Use of Radiological Calibrators

2.10 SOP 2.1.13 Control of Radioactive Material

2.11 SAP 2.4 Calibration Quality Control Review

2.12 SAP 2.5 Instrument Repair Process

2.13 SOP 2.4.39 Calculation of Depleted Uranium Beta Dose Rate Factors for Ion Chambers

2.14 SOP 2.1.16 - Use of the CTI Database for Calibration Lab Processes

3. EQUIPMENT

3.1 NIST-traceable radiation sources: Tech Ops Model 773 Open Beam Source, J. L. Shepherd Model 89 Box Calibrator, Depleted Uranium Slab Source R-052 (S/N CY-11), various button and/or plated disk sources.

3.2 Calibrated radiation survey meter.

3.3 Calibrated electronic pulse generator (Ludlum Model 500 or equivalent).

3.4 Calibrated Digital Timer

4. PRECAUTIONS

4.1 Appropriate dosimetry must be worn in accordance with Reference 2.6 when using sources of radiation.

4.2 When using a beam type calibration source, caution must be taken to minimize exposure of any portion of the body to the direct beam.

4.3 Only individuals that have been trained in accordance with Reference 2.3 are authorized to perform survey meter calibrations using licensed sources of radiation.

4.4 When calibrating equipment with Removable Contamination, protection measures must be taken in accordance with Reference 2.10 to ensure all safety measures are taken for personal protection and cross contamination prevention of the lab area.

5. DISCUSSION

This procedure outlines the general instructions for calibration of radiation survey meters using the Cs-137 gamma calibrators, electronic pulse generators and various check sources for isotopic efficiency calculations. Beta calibrations of ion chambers are addressed per reference 2.13. Neutron survey meters are beyond the scope of this procedure and are calibrated under separate SOP's. In some cases there may be a more instrument specific procedure or vendor manual that contains requirements unique to that instrument. In these cases, the specific procedure or vendor manual should be used. In addition, several instrument models require calibration software provided by the manufacturer. The list of current manufacturer supplied software is maintained by the lab manager, and posted in the calibration lab. These calibration software programs are stored on the "Software" folder on the common drive.

The RSCS Cs-137 calibration sources shall be used by qualified personnel in accordance with Reference 2.9. The person performing the calibration shall control access to the Restricted Area. When applicable, specific ranges of survey meters require electronic calibration using a pulse generator. All calibrations will include at least one scale being checked with a source of radiation or electronic pulse generator, as applicable. The use of a pulse generator shall be noted on the Instrument Follower Sheet and Calibration Certificate.

The calibration curve supplied by the manufacturer (using the inverse square law) shall be used for the beam source. The contribution from scatter may be

ignored provided that the distance from the detector to significant scattering objects is at least twice the distance from the detector to the source, in accordance with Reference 2.1. The CalRite software (developed from the calibration curves provided by the manufacturer) shall be used for the J.L. Shepard Model 89 box calibrator in accordance with Reference 2.5.

6. INSTRUCTIONS

6.1 Prerequisites

6.1.1 ENSURE that all requirements for accessing the Restricted Area are applied in accordance with Reference 2.8.

6.1.2 IF an instrument-specific procedure is available for calibration THEN USE the specific procedure for the instrument.

6.1.3 ENSURE the instruments to be calibrated have sufficient warm-up time as per the manufacturer's recommendations.

6.1.4 ENSURE that acceptable environmental conditions are present in the restricted area per reference 2.1. Acceptable conditions are:

a. Relative humidity: Ambient +/- 10%; not to exceed 75%

b. Ambient temperature: 20-24°C ; 68-75.2° F

c. Atmospheric Pressure: 70-107 kPa (20.67 to 31.6 inches of mercury)

6.1.5 IF acceptable environmental conditions are present, then ENSURE laboratory temperature, humidity and atmospheric pressure have been documented prior to performing calibrations.

6.1.6 IF unacceptable environmental conditions are present, then NOTIFY the Lab Manager and STOP performing calibrations until acceptable conditions are restored.

6.1.7 ENSURE laboratory temperature, humidity, and atmospheric pressure have been documented in the calibration database prior to performing calibrations.

6.1.8 PERFORM electronic pre-checks as required by the manufacturer's specifications.

6.1.9 OBTAIN the copy of the Instrument Follower Sheet generated in the instrument receipt process (Refer to Reference 2.14 for an example Instrument Follower Sheet).

NOTE

The Instrument Follower Sheet may be in either electronic or physical paper form. Any instructions to RECORD something on the Instrument Follower Sheet may be done by physically writing the information on the paper follower and/or by entering the information in the applicable section of the calibration sheet in the electronic calibration database.

6.2 Physical Checks

6.2.1 PERFORM a visual inspection of the exterior of the instrument. RECORD any discrepancies (missing detector cord, wrong detector for meter face, etc.) or damage on the Instrument Follower Sheet

6.2.2 LIST all equipment included with instrument (power cord, detector jigs, etc.) on the Instrument Follower Sheet, if not already noted.

6.2.3 If the instrument belongs to RSCS and is being loaned to a customer, REVIEW customer information and ENSURE calibration is performed in accordance with any special customer requirements.

6.2.4 REVIEW all paperwork accompanying instrument for special customer requirements (customer-noted problems with instrument, specific isotope efficiencies, special calibration frequencies, etc). RECORD any special requirements on the Instrument Follower Sheet.

6.2.5 PERFORM a battery test, as applicable. If the battery test is unsatisfactory, REPLACE batteries and RECORD it on the Instrument Follower Sheet.

6.2.6 VERIFY that the new batteries are within the manufacturer's use by or expiration date indicated on the battery

6.2.7 If it is suspected that there is an internal problem with the instrument (rattling sound noted when handling instrument, indication of water entry, etc.), PERFORM an internal inspection and RECORD results on the Instrument Follower Sheet.

6.2.8 FOR atmospheric ion chambers (i.e. not pressurized), PERFORM a visual inspection of desiccant.

a. IF desiccant is not blue, REPLACE with dried desiccant and record it on the Instrument Follower Sheet.

6.2.9 PERFORM geotropism and mild mechanical agitation checks. RECORD results on the Instrument Follower Sheet.

6.2.10 FOR phosphorous crystal detectors, PERFORM a light leak check. RECORD results on the Instrument Follower Sheet.

6.2.11 PERFORM mechanical zero adjust on instrument, as applicable and RECORD results on the Instrument Follower Sheet.

6.3 DETERMINE if a box to beam evaluation has been performed for the instrument model type in accordance with reference 2.9.

NOTE

This step must be performed prior to making any measurements in the box calibrator.

6.3.1 REVIEW the instrument follower and VERIFY that the statement "Box to Beam Evaluation Performed" is listed in the comments section. IF the box to beam evaluation has been performed, skip to step 6.4.

6.3.2 IF the box to beam comparison has not been verified, PERFORM the following:

a. IRRADIATE instruments using both the box calibrator and the open beam calibrator on the same scale.

b. RECORD the comparison data on Attachment 3.

c. IF the data collected from the box and beam calibrators agree within +/-5%, then ENTER "Box to Beam Comparison Evaluated, correction factor is 1" into the comment section for the model type in the CTI database, and skip to step 6.4.

6.3.3 IF the data collected from the box to beam calibrators do not agree within +/- 5%, then REPEAT box to beam comparison, having another calibration technician perform the comparison.

6.3.4 DETERMINE if table position or attenuator combinations are the cause of the discrepancy, and DOCUMENT any geometry or attenuator effects in the comment section for the model type in the CTI database.

6.3.5 NOTIFY Lab Manager or Operations Manager of repeatable discrepancies outside of +/- 5%.

6.4 "AS FOUND" Determination - Linear Readout Instruments

NOTE

Microprocessor-based instruments that have been proven linear through type-testing and/or acceptance testing may be calibrated as specified in Section 6.6 (Digital Readout Instruments). All other digital instruments are to be calibrated as specified in Section 6.4 (Linear Readout Instruments).

6.4.1 FOR each scale, DETERMINE two points, approximately twenty percent and eighty percent of full scale, and RECORD in the appropriate column on the Instrument Follower Sheet.

6.4.2 DETERMINE the appropriate exposure rate in accordance with Reference 2.9 to provide the desired reading for each calibration point.

a. For the Open Beam source, determine the appropriate number of attenuators and distance.

b. For the Box Calibrator, determine the appropriate source and location within the exposure chamber.

CAUTION

ENSURE THAT DETECTORS ARE ORIENTED PERPENDICULAR TO THE BEAM IN ORDER TO AVOID ANGULAR DEPENDANCE CORRECTIONS.

6.4.3 PLACE the center of the detector probe at the specified location.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

6.4.4 EXPOSE the source to provide the desired radiation exposure level.

6.4.5 RECORD the reading under the applicable "AS FOUND" section of the Instrument Follower Sheet.

6.4.6 RETURN the source to its shielded configuration.

6.4.7 REPEAT steps 6.4.2 through 6.4.6 for the remaining calibration points.

6.4.8 PERFORM an electronic calibration for any instrument range that is below the beam source accuracy limit (typically 100 to 200 µR/hr or µrem/hr). Accuracy diminishes when the distance from the beam source and contribution of scatter is too great.

a. CONNECT the instrument for calibration to a calibrated pulse generator.

b. TURN the instrument and pulse generator ON.

c. RECORD the instrument's high voltage, if applicable onto the Instrument Follower Sheet.

d. SET the pulse generator so that the survey instrument reading matches the lowest measured reading by the beam source.

e. ADJUST the pulse generator to the equivalent of the next point to be measured (e.g., reduce the pulse generator multiplier downward by a factor of 10).

f. ADJUST the survey instrument to the next corresponding point to be measured (e.g., turn the range selector knob downward from x1 to x0.1) and RECORD the "AS-FOUND" value onto the Instrument Follower Sheet.

g. REPEAT steps 6.4.8.d through 6.4.8.f for all remaining calibration points.

6.5 "AS FOUND" Determination - Logarithmic Readout Instruments

6.5.1 For each decade, DETERMINE one point at approximately the midpoint of the decade. For at least one decade, DETERMINE two points at approximately twenty percent and eighty percent of the decade. RECORD the points on the Instrument Follower Sheet.

6.5.2 DETERMINE the appropriate exposure rate in accordance with Reference 2.9 to provide the desired reading for each calibration point.

a. For the Open Beam source, determine the appropriate number of attenuators and distance.

b. For the Box Calibrator, determine the appropriate source, attenuators, and location within the exposure cavity.

CAUTION

ENSURE THAT DETECTORS ARE ORIENTED PERPENDICULAR TO THE BEAM IN ORDER TO AVOID ANGULAR DEPENDANCE CORRECTIONS.

6.5.3 PLACE the center of the detector probe at the specified location.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

6.5.4 EXPOSE the source to provide the desired radiation exposure level.

6.5.5 RECORD the reading under the applicable "AS FOUND" section of the Instrument Follower Sheet.

6.5.6 RETURN the source to its shielded configuration.

6.5.7 REPEAT steps 6.5.2 through 6.5.6 for the remaining calibration points.

6.6 "AS FOUND" Determination – Digital Readout Instruments

NOTE

This Section only applies to digital instruments that are microprocessor-based and have been proven linear through type-testing and/or acceptance testing. All other digital instruments are to be calibrated as specified in Section 6.4 (Linear Readout Instruments).

6.6.1 FOR each scale or decade, DETERMINE one point (typically at fifty percent of the scale or decade), and RECORD in the appropriate column on the Instrument Follower Sheet.

6.6.2 DETERMINE the appropriate exposure rate in accordance with Reference 2.9 to provide the desired reading for each calibration point.

a. For the Open Beam source, determine the appropriate number of attenuators and distance.

b. For the Box Calibrator, determine the appropriate source and location within the exposure chamber.

CAUTION

ENSURE THAT DETECTORS ARE ORIENTED PERPENDICULAR TO THE BEAM IN ORDER TO AVOID ANGULAR DEPENDANCE CORRECTIONS.

6.6.3 PLACE the center of the detector probe at the specified location.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

6.6.4 EXPOSE the source to provide the desired radiation exposure level.

6.6.5 RECORD the reading under the applicable "AS FOUND" section of the Instrument Follower Sheet.

6.6.6 RETURN the source to its shielded configuration.

6.6.7 REPEAT steps 6.6.2 through 6.6.6 for the remaining calibration points.

6.6.8 PERFORM an electronic calibration for any instrument range that is below the beam source accuracy limit (typically 100 to 200 µR/hr or µrem/hr). Accuracy diminishes when the distance from the beam source and contribution of scatter is too great.

a. CONNECT the instrument for calibration to a calibrated pulse generator.

b. TURN the instrument and pulse generator ON.

c. RECORD the instrument’s high voltage, if applicable onto the Instrument Follower Sheet.

d. SET the pulse generator so that the survey instrument reading matches the lowest measured reading by the beam source.

e. ADJUST the pulse generator to the equivalent of the next point to be measured (e.g., reduce the pulse generator multiplier downward by a factor of 10).

f. ADJUST the survey instrument to the next corresponding point to be measured (e.g., turn the range selector knob downward from x1 to x0.1) and RECORD the “AS-FOUND” value onto the Instrument Follower Sheet.

g. REPEAT steps 6.6.8.d through 6.6.8.f for all remaining calibration points.

6.7 "AS FOUND" Determination – Integrating Instruments

NOTE

A large number of digital instruments have integration capabilities in addition to exposure/dose rate readout. This section outlines the steps for verifying the accuracy of the integration feature.

6.7.1 DETERMINE the dose rate range of the instrument.

6.7.2 CALCULATE two points that are at approximately twenty percent and eighty percent of the dose rate range.

6.7.3 CALCULATE the Target Doses for each Dose Rate that would be obtained with a one minute exposure time, and RECORD the Target Dose in the appropriate column on the Instrument Follower Sheet.

NOTE

Other exposure times may be used, if desired. However, one minute should be the minimum amount of time used. This will help to ensure a statistically valid reading and will minimize potential variability in the length of time from source exposure to starting the timer.

6.7.4 DETERMINE the appropriate distance and attenuator combinations in accordance with Reference 2.9 to provide the desired dose rate for each calibration point.

a. For the Open Beam source, determine the appropriate number of attenuators and distance.

b. For the Box Calibrator, determine the appropriate source and location within the exposure chamber.

CAUTION

ENSURE THAT DETECTORS ARE ORIENTED PERPENDICULAR TO THE BEAM IN ORDER TO AVOID ANGULAR DEPENDANCE CORRECTIONS.

6.7.5 PLACE the center of the detector probe at the specified location.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

6.7.6 EXPOSE the source for the determined amount of time to provide the desired dose level.

6.7.7 RECORD the reading under the applicable "AS FOUND" section of the Instrument Follower Sheet.

6.7.8 RETURN the source to its shielded configuration.

6.7.9 REPEAT steps 6.7.4 through 6.7.8 for the remaining calibration points.

6.8 Electronic Calibrations of Count Rate Instruments

6.8.1 PERFORM an electronic calibration for count rate instruments.

a. CONNECT the instrument for calibration to a calibrated pulse generator.

b. TURN the instrument and pulse generator ON.

c. RECORD the instrument’s high voltage, if applicable onto the Instrument Follower Sheet.

d. PULSE the instrument at 20% and 80% of full scale and RECORD the “As-Found” values onto the Instrument Follower Sheet.

e. ADJUST instrument response as necessary so that the lower point is within 15% and the upper point is within 10% of pulsed value.

NOTE

Reference 2.1 does not provide +/- acceptance criteria for count rate instruments. In the absence of specific criteria, these type of calibrations will continue to use the criteria specified above from the previous version of the ANSI standard (ANSI N323A-1997).

f. RECORD the “As-Left” values onto the Instrument Follower Sheet.

g. REPEAT for all instrument scales.

h. PERFORM the precision check as applicable in section 6.14. RECORD the results onto the Instrument Follower Sheet.

6.9 Acceptable Accuracy Check Tolerances for all Instrument types other than count rate instruments.

For instrument readings between background and 1.0 mR/hour = +/- 30%

For instrument readings between 1.0 mR/hour and 100 mR/hr = +/-20%

For instrument readings between 100 mR/hour and 1000 mR/hr = +/- 10%

NOTE

Although the ANSI standard specifies the variable tolerance ranges discussed above, it is an RSCS goal to achieve As-Left readings within +/- 10% when possible. The CTI database is hard coded with all calibration templates for survey instruments set with a tolerance of +/- 10%. If a less restrictive tolerance is necessary for the instrument to pass calibration, individual instrument followers can be edited to change the % tolerance as needed.

6.10 Accuracy Check and Calibration - Linear Readout Instruments

NOTE

Microprocessor-based instruments that have been proven linear through type-testing and/or acceptance testing may be calibrated as specified in Section 6.5 (Digital Readout Instruments). All other digital instruments are to be calibrated as specified in Section 6.4 (Linear Readout Instruments).

NOTE

If adjustment potentiometers are provided for each scale, adjustments are to be made according to the manufacturer's specifications or at twenty percent or eighty percent of full scale for each scale. If only one adjustment potentiometer is provided, adjustments are to be made at the point(s) specified by the manufacturer or at twenty percent or eighty percent of full scale for the middle scale.

6.10.1 PERFORM the following steps for each scale:

a. PLACE the center of the detector probe at the specified location, as determined in Section 6.4.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

b. EXPOSE the source to provide the desired radiation exposure level.

NOTE

The following steps are not meant to preclude instrument adjustment to achieve tighter tolerances if desired and reasonably achievable.

c. RETURN the source to its shielded configuration.

d. If the reading is within $\pm$10% of the Known Exposure Rate, RECORD the reading in the "AS LEFT" column.

e. IF the reading is greater than $\pm$10% of the Known Exposure Rate, ADJUST the instrument using the manufacturer’s specifications.

f. REPEAT Steps 6.10.1.a through 6.10.1.e until the response is within 10 % of the Known Exposure Rate or the applicable +/- % specified in Step 6.9, if +/- 10% cannot be achieved.

g. REPEAT Steps 6.10.1.a through 6.10.1.f for each point chosen.

6.10.2 If the instrument fails the accuracy check and cannot be adjusted to within specifications, CONTACT the customer to determine if the instrument should be repaired or returned as Failed Calibration.

6.11 Accuracy Check and Calibration - Logarithmic Readout Instruments

NOTE

The instrument should be adjusted according to the manufacturer's specifications, or at one point near the midpoint of each decade with two points being calibrated on at least one of the decades.

6.11.1 PERFORM the following steps for each scale:

a. PLACE the center of the detector probe at the specified location, as determined in Section 6.5.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

b. EXPOSE the source to provide the desired radiation exposure level.

NOTE

The following steps are not meant to preclude instrument adjustment to achieve tighter tolerances if desired and reasonably achievable

c. If the reading is within $\pm$10% of the Known Exposure Rate, RECORD the reading in the "AS LEFT" column.

d. RETURN the source to its shielded configuration.

e. IF the reading is greater than ±10% of the Known Exposure Rate, ADJUST the instrument using the manufacturer's specifications.

f. REPEAT Steps 6.11.1.a through 6.11.1.e until the response is within 10 % of the Known Exposure Rate or the applicable +/- % specified in Step 6.9, if +/- 10% cannot be achieved.

g. REPEAT Steps 6.11.1.a through 6.11.1.f for each point chosen.

6.11.2 If the instrument fails the accuracy check and cannot be adjusted to within specifications, CONTACT the customer to determine if the instrument should be repaired or returned as Failed Calibration.

6.12 Accuracy Check and Calibration - Digital Readout Instruments

NOTE

The instrument should be adjusted according to the manufacturer's specifications, or at one point near the midpoint of each decade. Many digital instruments require special software that will specify pre-determined calibration points. Often this will include separate point(s) for determining a Calibration Constant and another for determining detector dead time. If applicable, the manufacturer's calibration process should be followed and may be incorporated into a separate, instrument-specific, RSCS Standard Operating Procedure.

6.12.1 PERFORM the following steps for each calibration point:

a. PLACE the center of the detector probe at the specified location, as determined in Section 6.6.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

b. EXPOSE the source to provide the desired radiation exposure level.

NOTE

The following steps are not meant to preclude instrument adjustment to achieve tighter tolerances if desired and reasonably achievable

c. If the reading is within ±10% of the Known Exposure Rate, RECORD the reading in the "AS LEFT" column.

d. RETURN the source to its shielded configuration.

e. IF the reading is greater than +10% of the Known Exposure Rate, ADJUST the instrument using the manufacturer's specifications.

f. REPEAT Steps 6.12.1.a through 6.12.1.e until the response is within 10 % of the Known Exposure Rate or the applicable +/- % specified in Step 6.9, if +/- 10% cannot be achieved.

g. REPEAT Steps 6.12.1.a through 6.12.1.f for each point chosen.

h. .If the instrument fails the accuracy check and cannot be adjusted to within specifications, CONTACT the customer to determine if the instrument should be repaired or returned as Failed Calibration.

6.13 Integration Mode Accuracy Check Determination – Integrating Instruments

6.13.1 DETERMINE the dose rate range of the instrument.

6.13.2 CALCULATE two points that are at approximately twenty percent and eighty percent of the dose rate range.

6.13.3 CALCULATE the Target Doses for each Dose Rate that would be obtained with a one minute exposure time, and RECORD the Target Dose in the appropriate column on the Instrument Follower Sheet.

NOTE

Other exposure times may be used, if desired. However, one minute should be the minimum amount of time used. This will help to ensure a statistically valid reading and will minimize potential variability in the length of time from source exposure to starting the timer.

6.13.4 DETERMINE the appropriate distance and attenuator combinations in accordance with Reference 2.9 to provide the desired dose rate for each calibration point.

a. For the Open Beam source, determine the appropriate number of attenuators and distance.

b. For the Box Calibrator, determine the appropriate source and location within the exposure chamber.

CAUTION

ENSURE THAT DETECTORS ARE ORIENTED PERPENDICULAR TO THE BEAM IN ORDER TO AVOID ANGULAR DEPENDANCE CORRECTIONS.

6.13.5 PLACE the center of the detector probe at the specified location.

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

6.13.6 EXPOSE the source for the determined time to provide the desired dose level.

6.13.7 RETURN the source to its shielded configuration.

6.13.8 If the reading is within +/- 10% of the Known Dose, RECORD the reading in the "AS LEFT" column.

6.13.9 If the reading is greater than $\pm$10% of the Known Dose, ADJUST the instrument and REPEAT Steps 6.13.4 through 6.13.7 until the response is within acceptable +/- % of the Known Dose based on the corresponding dose rate used for the integration as specified in Step 6.9.

NOTE

Typically, the only way to adjust the integration mode will be by adjustment of the corresponding dose rate range. If this is the case it will be necessary to repeat As-Left readings for those ranges as well.

6.13.10RECORD the reading in the "AS LEFT" column.

6.13.11 If the instrument fails the integration mode accuracy check and cannot be adjusted to within specifications, CONTACT the customer to determine if the instrument should be repaired or returned as Failed Calibration.

6.14 Precision Check

CAUTION

MINIMIZE EXPOSURE OF ANY PORTION OF THE BODY TO THE DIRECT BEAM.

6.14.1 EXPOSE the instrument to a radiation field (or a pulse generator, if applicable) three times under identical conditions. RECORD the results on the Instrument Follower Sheet.

6.14.2 The CTI Database determines the mean value for the three readings taken and shows acceptance in GREEN and unsatisfactory readings in RED.

6.14.3 If any reading deviates by more than ±10% from the mean (RED), RECORD as "UNSAT" on the Instrument Follower Sheet and INITIATE actions to correct the problem.

6.15 Efficiencies and Source Checks

6.15.1 DETERMINE detector efficiencies for each desired isotope as follows:

a. PLACE detector in a repeatable standard geometry

b. COLLECT and RECORD a background count

c. OBTAIN the appropriate NIST traceable source in accordance with Reference 2.10

d. EXPOSE detector at contact or as directed by the client and RECORD gross count rate. RECORD actual geometry used on the Instrument Follower Sheet.

e. CALCULATE and RECORD the detector efficiency for the isotope:

$$Eff = \frac{GrossCountRate - BackgroundCountRate}{SourceDecayRate}$$

6.15.2 For instruments with an attached check source, DETERMINE a source response.

a. PLACE detector on contact (window open if applicable) with source

b. RECORD the average instrument response

c. CALCULATE and RECORD a band of ±20% of the average response.

6.16 Documentation

NOTE

Calibrations performed and documented by a trainee must be counter signed by the qualified individual providing the training.

6.16.1 REVIEW customer information and ENSURE all customer documentation requirements are met.

6.16.2 INDICATE on the Instrument Follower, which source or combination of sources, were used for the calibration (Open Beam and/or Box Calibrator).

6.16.3 COMPLETE Attachment 1, Survey Meter Calibration Certificate.

6.16.4 IF an instrument's As Found values exceeded 20% of the Known value:

a. ENSURE the calibration certificate includes the exceeded 20% AS Found data for customer notification.

b. NOTIFY customers that have requested immediate or alternative notification methods for exceeded 20% AS Found data.

6.16.5 RECORD in the comment section any of the following, as applicable or requested by customers:

NOTE: Some comments are automated by the Instrument Follower Sheet

a. The instrument scale could not be calibrated to within ±10%, and if so that the scale was within the acceptable ± X% of the known values based on ANSI Standards.

b. A pulse generator was used on a particular scale

c. "AS FOUND" readings greater than ±20% of known values

d. Calibrated or Not Calibrated in mR/hr

e. Any other comments as necessary

6.16.6 IF the instrument passed calibration, AFFIX a Calibration sticker, and Efficiency/Source Response Sticker as applicable (Attachment 2) to the instrument.

6.16.7 If the Instrument has any use restrictions in accordance with reference 2.1 (ex. not calibrated in mR/hr, not calibrated above x mR/hr, etc.), APPLY limited use stickers describing the condition(s) and ENSURE that the limitations are noted on the calibration certificate.

6.16.8 If the meter failed calibration and the customer requests repair then PROCESS the instrument in accordance with reference 2.12.

6.16.9 If the meter failed calibration and the customer requests instrument return:

a. AFFIX a Failed Calibration sticker (Attachment 2) to the meter

b. COMPLETE Attachment 1, Meter Calibration Certificate as a Failed Calibration

c. RETURN the meter to the customer.

6.17 Final Verifications

6.17.1 ENSURE that all applicable sections of the Instrument Follower Sheet are completed for all instruments calibrated.

6.17.2 ENSURE instrument is turned off.

6.17.3 ENSURE that the source is returned to its shielded configuration and verified with a calibrated survey meter.

6.17.4 ENSURE that the Restricted Area is secured.

6.17.5 PERFORM a Calibration Quality Review in accordance with Reference 2.11 (Quality Assurance Manager, Lab Manager or Designee).

7. FORMS AND ATTACHMENTS

7.1 Attachment 1 – Example Survey Meter Calibration Certificate.

7.2 Attachment 2 - Example of Calibration / Failure Stickers

7.3 Attachment 3 – Box to Beam Comparison Form

8. SUMMARY OF CHANGES

8.1 SOP 2.4 Revision 6, effective date 5/17/99.

Revision 6 changed the procedure to the new SOP format, corrected typographical errors, made slight modifications in grammar, and added a precautions section. Several steps in the procedure that were redundant (and hence confusing) were replaced by referencing the applicable section where the step was initially performed.

In addition, this revision removed the section on the Yankee Atomic characterization for the box calibrator. This characterization was performed on a specific Eberline box calibrator which is no longer available.

8.2 SOP 2.4 Revision 7, effective date 2/21/03.

Step 6.5.1, d and e, changed accuracy to reflect a $\pm$15% value on lower and $\pm$ 10% on upper end of scale per ANSI standard.

Step 6.6.1 d + e; 6.3.4 + 5;and 6.8.2 changed Plus or minus to $\pm$.

Changed Attachment 2 to reflect 15% and 10% criteria.

Changed the calibration sticker to the current version.

8.3 SOP 2.4 Revision 8, effective date 10/10/03.

Changed Attachment 1, 2 and 3 to reflect the new Follower, Calibration Sheet and Calibration Stickers.

8.4 SOP 2.4 Revision 09, effective date 3/10/05.

Added section 6.2 to perform physical inspections of instruments, and section 6.8 to perform efficiencies and determine check source responses.

Edited model of referenced box calibrator to J. L. Shepherd Model 89.

Performed minor editorial changes.

8.5 SOP 2.4 Revision 10, effective date 7/8/05.

Added step to note customer comments included with shipping documents

Added section for customer notification of out of tolerance As Found condition or emergent repair needs

Added Quality Review section.

8.6 SOP 2.4 Revision 11, effective date 12/9/05.

Added a protected Note to section 6.3 per CR 05-025 requiring that detectors be placed perpendicular to the radiation beam in order to avoid angular dependence corrections.

8.7 SOP 2.4 Revision 12, effective date 2/2/06.

Made several editorial/rewording changes

Renumbered several paragraphs

Updated Reference section

Removed Instrument Follower from Attachments, added reference to use Instrument Follower from SOP 1.4

Added Note prior to Step 6.4

Added Protected Caution Box prior to Step 6.4.3 and 6.5.3

Added Note prior to Step 6.11.1

Revised failed calibrations in Step 6.11.

Removed Out Of Service Tag Attachment

Removed Daily Quality Assurance Check steps and added reference to SAP 2.4

Added Step 6.13.2, Ensure instrument is turned off

8.8 SOP 2.4 Revision 13, effective date 1/31/07.

Added notes to verify customer calibration and documentation requirements are met prior to loaning RSCS equipment

Added Step 6.11.4 to cover limited use calibration situations

8.9 SOP 2/4 Revision 14, effective date 11/28/07.

Added the word “Calibrated” to 3.3 in reference to the electronic pulser equipment

Replaced Reference 2.4 in section 6.1.5 to Attachment 4 and added a follower sheet example titled Attachment 4 to the end of the SOP.

Added 6.3.8 to include electronic pulse of low points of instruments

Added 6.6 Electronic calibrations of count rate meters

Made several editorial/rewording changes to sections 6.5 through 6.10

8.10 SOP 2.4 Revision 15, effective date 4/9/10.

Added steps 6.1.4 to 6.1.6 to specify required environmental conditions per reference 2.1 and actions to perform if environmental conditions outside of acceptable ranges.

8.11 SOP 2.4 Revision 16, effective date 9/13/2010

Added a Precaution (Section 4) to include Removeable Contaminated instrument calibration safety procedures reference

Revised document to specify electronic and follower sheet

Added Reference 2.12 – SAP 2.5 Instrument Repair Process and revised the text for instruments in need of repair

Revised Attachment 1 to reflect current certificate format

Revised Attachment 3 to reflect the revised follower sheet

Added step 6.7 with instructions on when and how to perform a box to beam comparison.

8.12 SOP 2.4 Revision 17, effective date 6/12/2012

Added reference 2.13 SOP 2.4.39 Calculation of Depleted Uranium Beta Dose Rate Factors for Ion Chambers.

Added guidance to section 4 “Discussion” on use of reference 2.13 for performing beta calibrations of ion chambers.

Added guidance to section 4 “Discussion” on the use of manufacturer supplied calibration software.

8.13 SOP 2.4, Revision 18, effective date June 5, 2015

Added a calibrated electronic timer to the Equipment List in Section 3

Fixed incorrect Reference Number in Precautions Section, Step 4.4

Added the inches of mercury equivalents to the kPa atmospheric pressure specified in Step 6.1.4.c

Revised Steps 6.1.5 and 6.1.7 to include atmospheric pressure

Added Steps 6.5 and 6.11 for Digital Instruments

Added Steps 6.6 and 6.12 for Integrating Instruments

Revised Note Box at the beginning of Step 6.3 that pointed to incorrect procedure steps

Updated Attachment 1 and 2 to remove Calibration Technology reference and replaced with RSCS, Inc.

8.14 SOP 2.4, Revision 19, effective on date of front-cover signature.

The primary focus of this revision is to update the procedure to reflect the changes needed for RSCS calibrations to comply with the latest ANSI Standard (ANSI N323AB-2013) and for ISO/IEC 17025:2005 compliance for the calibration laboratory. All RSCS calibration SOP's are being revised/developed concurrent to this revision for simultaneous adoption.

Changed Reference 2.1 to ANSI N323AB-2013

Added Reference 2.14

Added Step 6.2.6 to require checking the expiration date of replacement batteries.

Removed the words "paper" and "electronic" from all procedural steps that called for recording information specifically on a paper or electronic version of the Instrument Follower. Added a Note Box after Step 6.1.9 to indicate that the Instrument Follower Sheet may be either an electronic or paper form. These steps were too prescriptive and changing them will also enable RSCS to move to a paperless system in the future, if desired.

Moved the Section for Box to Beam Comparison to Step 6.3 and added a Note Box to indicate that step needs to be performed prior to making any measurements in the Box Calibrator. Renumbered subsequent procedure steps, as needed.

Added Step 6.9 that references the new ANSI Standard +/- % acceptable accuracy check tolerances to be used for all Instrument types based on the exposure rate range.

Replaced the +/- % acceptable accuracy check instructions found in Steps 6.10, 6.11, 6.12 and 6.13 with new instructions that refer to Step 6.9 for acceptable tolerances.

Added Step 6.16.2 to indicate on the Follower which source or sources were used for the calibration.

Replaced Attachment 1with a new example Calibration Certificate that references the new ANSI standard.

Removed Attachment 3 - Example Instrument Follower Sheet and pointed to Reference 2.14 for an example follower in Step 6.1.10.

Renumbered Attachment 4 to Attachment 3.

Attachment 1
(Example Survey Meter Calibration Certificate)

RSCS
Radiation Safety & Control Services

Calibration Certificate
ID Number: 47609101434-1

Customer: Joan Ervey
Radiation Safety & Control Services, Inc.
91 Portsmouth Avenue
Stratham, NH 03885

Instrument
Ludlum Model 2-001R

Serial Number
47609

Probe Model
Ludlum 44-6

Serial Number
68769

Precision Check

Test 1	Test 2	Test 3	Mean	Results
4.10 mR/hr	4.10 mR/hr	4.10 mR/hr	4.10 mR/hr	Satisfactory

Accuracy Check

Range	Target Value	As Found	As Left
X10	40 mR/Hr	42 mR/Hr	40 mR/Hr
X10	10 mR/Hr	12 mR/Hr	11 mR/Hr
X1	4 mR/Hr	4.3 mR/Hr	4.1 mR/Hr
X1	1 mR/Hr	1.2 mR/Hr	1.1 mR/Hr
X0.1	0.4 mR/Hr	0.47 mR/Hr #	0.4 mR/Hr #
X0.1	0.1 mR/Hr	0.12 mR/Hr #	0.11 mR/Hr #

Readings with * indicate ranges where As-Found readings are >20% of Target value. Readings with ** indicate As-left readings are >10.00% of Target value
Readings with # indicate ranges where pulser was used.

MTE Instrument Type	Model	CalDueDate
Pulser	Ludlum 500-4 SN: 98756	07/09/2016

Outer Physical Check: *Pass*
Internal Check: *Pass*
Geotropism Check: *Pass*
Mechanical Zero: *Pass*
Tap Test: *Pass*

Electronics Checks	As Found	As Left
High Voltage	898 Volts	898 Volts

Comments: Source Check Acceptance Ranges (On Contact):
44-6 Pr (SN68769) = 0.2 to 0.3 mR/hr
(On Contact with open window using Source #5345) Geometry: Detector Perpendicular To Source

Calibrated by: QA Review:

Calibration Date: 07/06/2016
Expires: 07/06/2017

Atmospheric Conditions - Temperature: 74°F Humidity: 42% Barometric Pressure: 29.69"hg

This calibration was performed by RSCS using one or more of the following NIST Traceable radiation sources:
Tech Ops Model 773 Cs-137 Beam Calibrator (S/N 5-1110), characterized using Eurados Model A6 (S/N 185) and Keithley Electrometer Model 617 (S/N 0547677) in accordance with methods specified in RSCS TSD 11-000, with estimated uncertainty of 6.0%.
J.L. Shepherd and Associates Model 89 Cs-137 Box Calibrator (S/N 9141), characterized using Eurados, Model A6 (S/N 185), A3 (S/N 197), A12 (S/N XA091124), and Keithley Electrometer Model 617 (S/N 0547677) in accordance with methods specified in RSCS TSD 11-001, with estimated uncertainty of 2.7%.
RSCS Neutron Calibrator, AmBe Source Model NUMEC-AM-31 (S/N Am-470), characterized using Far West Technologies Model FWAD-1 "HAWK" TEPC (S/N 021) in accordance with the methods specified in RSCS TSD 13-002, with estimated uncertainty of 9.4%
Unless otherwise stated, calibrations performed in conformance to the following documents: ANSI N323AB-2013; RSCS New Hampshire Radioactive Material License Number 361R.
RSCS calibration services are performed in accordance with the RSCS Radiation Protection Program Manual and Standard Operating Procedures.
Calibration Laboratory is operated in accordance with ANSI/NCSL Z540-1-1994
This calibration certificate shall not be reproduced except in full without the express written consent of RSCS, Inc.

Radiation Safety and Control Services, Inc.
91 Portsmouth Ave. Stratham, NH 03885
1-800-525-0339 (603) 778-2871 Fax (603) 778-6879 www.radsafety.com

Page 1 of 1

Attachment 2
(Example Calibration Stickers)

RSCS, Inc.
1-800-525-8339
S/N: XXXX

09/10/2014	09/10/2014	MTN
Cal Date	Due Date	By

RSCS Inc. 1-800-525-8339
10 06 2014 10 06 2014 MTN
Cal Date Due Date By
S/N
xxxxxxx

RSCS, Inc.
1-800-525-8339

Failed Calibration

Attachment 3

EXAMPLE BOX CALIBRATOR TO BEAM COMPARISON FORM

Instrument Model #	Serial #	Box Reading	Beam Reading	Date	Initial

RADIATION SAFETY & CONTROL SERVICES, INC.
STANDARD OPERATING PROCEDURE

RSCS
Radiation Safety & Control Services

OPERATION OF RADIOLOGICAL INSTRUMENTATION

SOP 2.7.4

Revision 00

Originator: _____ Date: 9/13/10

Reviewer: _____ Date: 9/13/10

Approval: _____ Date: 9/13/10
RSCS Director / Designee

OPERATION OF RADIOLOGICAL INSTRUMENTATION

1. OBJECTIVE

1.1 The objective of this procedure is to provide guidance in performing radiation surveys along with performing and analyzing contamination surveys.

2. REFERENCES

2.1 RSCS Radiation Protection Program (RPP)

2.2 New Hampshire Rules for the Control of Radiation (NHRCR) He-P 4022, Surveys and Monitoring.

2.3 American National Standards Institute, ANSI N.323A – "Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments".

2.4 NRC Regulatory Guide 8.21, Health Physics Surveys for By-Product Material at NRC-Licensed Processing and Manufacturing Plants.

3. EQUIPMENT

3.1 Calibrated radiation and contamination survey meters capable of detecting radiation type, energy, and levels in the range of interest

3.2 Smears material

3.3 Calibrated analytical laboratory system, capable of detecting activity in the range of interest

3.4 Radioactive Material Labels or Tags

4. PRECAUTIONS

Ensure that personnel performing surveys have appropriate training and qualifications per reference 2.1.

5. DISCUSSION

Radiological surveys consist of evaluating radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a

physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Surveys are performed to verify that exposure rates and contamination levels are as expected. Surveys are conducted at intervals specified in Reference 2.4. Routine radiation and contamination surveys are also performed to further ensure that no measurable contamination or radiation levels in excess of regulatory limits exist in the areas in question. This procedure establishes the correct protocol for performing radiation and contamination surveys.

Radiological surveys shall be performed to:

- Assess radiological conditions
- Provide information to personnel of the radiological conditions in their work areas
- Ensure areas are properly posted in accordance with applicable limits and to alert personnel to radiological hazards present
- Ensure personnel exposure to radiation is maintained ALARA
- Ensure items and materials unconditionally released from a Radiological Controlled Area are free of licensed radioactive materials in accordance with applicable NRC or State rules.

6. INSTRUCTIONS

6.1 Radiation Surveys

Perform the following steps:

6.1.1 SELECT an appropriate radiation survey.

6.1.2 INSPECT the instrument for physical damage.

6.1.3 CHECK the calibration sticker to ensure that the meter has a current calibration.

6.1.4 PERFORM a battery check, and if applicable, REPLACE batteries.

6.1.5 PERFORM an operability test using a check source and compare readings obtained with those found at the time of instrument calibration.

a. IF the operability test is within +/- 20% of expected reading, CONTINUE to 6.1.6.

b. IF the operability test is > +/- 20% of the expected reading, REMOVE the instrument from service and tag it out for calibration and or repair.

6.1.6 MOVE the selector switch to the lowest scale and OBSERVE the background radiation level as applicable.

6.1.7 INSPECT the area to be surveyed and SKETCH the area to be surveyed on a survey form (reference Attachment A) or equivalent.

6.1.8 PERFORM a radiation survey holding the meter at waist level.

6.1.9 IF exposure rates are above normal anticipated rates CONTACT the Radiation Safety Officer (RSO) or appropriate personnel.

6.1.10 DOCUMENT radiation survey on the Survey Form

a. RECORD radiation levels on the survey form in units of mR/hr.

b. ENSURE that the survey date, instrument serial number, calibration due date, and signature or initials of surveyor are recorded on the survey form

c. RECORD any applicable comments such as special notes pertaining to the reason for survey or other special radiological hazards or conditions.

6.1.11 SUBMIT completed survey documentation to the RSO or designee for review.

6.2 Contamination Surveys

6.2.1 Direct Measurements Contamination Surveys

a. SELECT a calibrated rate meter with a pancake probe or large area detector.

b. NOTE the surface area of the detector (15 cm^2 for pancake, 100 cm^2 for large area detector).

c. PERFORM a battery check, and if applicable, REPLACE batteries.

d. PERFORM an operability test using a check source and compare readings obtained with those found at the time of instrument calibration.

1. IF the operability test is within +/- 20% of expected reading, CONTINUE to step e.

2. IF the operability test is > +/- 20% of the expected reading, REMOVE the instrument from service and tag it out for calibration and or repair.

e. MOVE the selector switch to the lowest scale and OBSERVE the background cpm level as applicable.

f. FRISK areas paying particular attention to areas with a potential for contamination.

g. IF the survey indicates activity above background or higher than anticipated CONTACT the RSO or designee.

h. DOCUMENT survey results by area on the survey form.

1. NUMBER the direct-measured locations indicating results in dpm/100 cm^2 in the appropriate section on the form.

2. ANNOTATE frisked locations by their number in a square on the survey form with the units of dpm above background.

6.2.2 Smear Surveys for Removable Contamination

a. ACQUIRE a sufficient number of smears, suitable for the area to be assessed. COMPLETE required data on smear folder as appropriate.

b. SMEAR the area in question (100 cm^2)/smear paying attention to the areas of potential contamination.

c. ANALYZE smears in accordance with section 6.3.

d. DOCUMENT the smear results on a survey form.

1. NUMBER smears indicating results in the appropriate section on the form in units of dpm per 100 cm^2.

2. ANNOTATE smear locations by their number in a circle on the survey form.

e. ENSURE that smears are analyzed with counting parameters sufficient to meet the removable contamination limit.

f. SUBMIT completed survey documentation to the RSO or designee for review.

g. IF activity is detected above the limit, LABEL and/or POST, then CONTACT the RSO or designee.

6.3 Smear Sample Analysis

6.3.1 ENSURE that the scaler calibration due date has not expired.

6.3.2 VERIFY that the electronic settings of the scaler are in accordance with the most recent calibration data.

6.4 Performance of System Background

NOTE

This section need not be performed if previously completed within the last 12 hours.

6.4.1 ENSURE that the sample counting chamber has an appropriate blank or is empty and that any requisite shielding is in place.

6.4.2 PERFORM a background count for at least 10 minutes.

6.4.3 SELECT the appropriate sample count time.

6.4.4 CALCULATE the Critical Level, Lc, as follows:

$$L_c(cpm) = \frac{1.645\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{t_s}$$

where Rb = background count rate (c/m)
ts = sample count time (min)
tb = background count time (min)

6.4.5 DETERMINE the energy emission(s) of the sample to be analyzed.

6.4.6 CALCULATE the system MDA as follows:

$$MDA(dpm) = \frac{3 + 3.29\sqrt{R_b t_s\left(1 + \frac{t_s}{t_b}\right)}}{eff * t_s}$$

where Rb = background count rate (c/m)
ts = sample count time (min)
tb = background count time (min)
eff = counting efficiency (c/d)

6.4.7 ENSURE that the system count time is sufficient to achieve an MDA that is specified by the customer or regulations (whichever is more restrictive). REFER to Table 1 for guidance.

6.4.8 ANNOATE the Lc and MDA values on the appropriate paperwork.

6.5 Performance of System Quality Control Check

NOTE

This section need not be performed if previously completed within the last 12 hours.

6.5.1 PLACE the appropriate QC source in the standard counting configuration.

6.5.2 COUNT the QC source for the interval indicated on the most recent calibration.

6.5.3 RECORD the QC source count and count time in the system log book.

6.5.4 ENSURE the QC value is within the acceptance range established during system calibration.

6.5.5 REPEAT steps 6.5.1 to 6.5.4 if the QC source result is outside the acceptance range. RECALIBRATE or TAG the system as out of service if second attempt is outside the acceptance range.

7. ATTACHMENTS AND TABLES

7.1 Attachment A -- Radiological Survey Form

7.2 Table 1 – Guidance for MDA Requirements

8. SUMMARY OF CHANGES

8.1 SOP 2.10.6 Revision 00, effective date 6/18/07, new procedure.

8.2 SOP 2.7.4 Revision 00, effective on date of front cover signature.

Formerly SOP 2.10.6 with minor formatting changes.

Attachment A

Radiological Survey

Date:	Facility:	
By:	Location:	Comments: Readings in mR/hr. "( )" indicates shielded readings.
Reviewed by (RSO/Assistant RSO)	Date	

#	Instrument	Serial Number	Cal Due Date	Bkgd

Surface Contamination Measurements (results in dpm/100cm^2 unless otherwise noted)

#	ccpm	Results	Inst #	#	ccpm	Results	Inst #	#	ccpm	Results	Inst #

Table 1

Guidance for MDA Requirements

Type of Sample	**Minimum Detectable Activity**		**Reference**
	β, γ	α	
Leak Test	0.005 μCi	0.005 μCi	10CFR 34.25, Specific License Conditions
Removable Contamination-Free Release of Individual Items	1000 dpm	20 dpm	I&E Circular 81-07
Removable Contamination-Shipping	2200 dpm	220 dpm	49CFR173.443
Air Sampling	Isotope Specific 0.3 DAC For Posting Purposes (may be lower for some applications)		10CFR20.1003
Decommissioning	Isotope Specific		Draft NUREG-11549, MARSSIM, and License decommission requirements

RADIATION SAFETY & CONTROL SERVICES, INC.
STANDARD OPERATING PROCEDURE

GAMMA WALKOVER SURVEY WITH THE LUDLUM 2241-2 SURVEY METER AND 44-10 DETECTOR

SOP 2.7.18

Revision 01

Originator: _____ Date: 06/02/17

Reviewer: _____ Date: 06/02/17

Approval: _____ Date: 06/02/17
RSCS Director

GAMMA WALKOVER SURVEY WITH THE LUDLUM 2241-2 SURVEY METER AND 44-10 DETECTOR

1. OBJECTIVE

This procedure details the use of the Ludlum 2241-2 Survey Meter with the 44-10 NaI detector (or equivalent) and provides direction on how to perform gamma walkover surveys.

2. REFERENCES

2.1 Instruction Manual for the Ludlum Model 2241-2 Survey Meter

3. EQUIPMENT

3.1 Ludlum Model 2241-2 Survey Meter.

3.2 Ludlum Model 44-10, NaI detector, or equivalent.

3.3 Approved response check source.

3.4 Field computer with USB port.

3.5 Ludlum Model 2241-2 Logger software.

3.6 USB/Serial Port Adapter, Gigaware USB-A to Serial Cable (RS232), or equivalent

4. DISCUSSION

This procedure applies to surveys performed over all surfaces including soils, concrete and asphalt. This procedure is not intended to quantify radioactivity on or near the surface, but to identify localized areas that are outliers relative to the remainder of the area. Areas identified as outliers will require follow-up investigation to determine specific radionuclides and quantification of activity.

5. PRECAUTIONS

5.1 The meter and the detector or calibrated as a pair, do not use if the detector does not match up with the meter as depicted on the calibration sheet.

5.2 The meter must be in the off position when changing out batteries or connecting the meter to the probe or the computer.

6. INSTRUCTIONS

6.1 Equipment Set Up

6.1.1 Setting up the Ludlum 2241-2 Survey Meter

> **NOTE**
>
> Refer to Figures 1 and 2 for Ludlum 2241-2 survey meter external and internal controls. The initial setup steps are for first time use in the field. Subsequent uses will not require performing steps marked “initial setup only", unless changes to the instrumentation have occurred, or problems are encountered.

a. Verify that the Ludlum 2241-2 survey meter with 44-10 detector are within calibration (one year). The meter and detector are calibrated as a pair. Ensure that the appropriate meter and detector are paired as indicated on the calibration sheet.

b. Battery installation (initial set up only)

1. Ensure the OFF/RATEMETER/SCALER switch is in the OFF position.

2. Open the battery lid and install 2 “D” size batteries. Note the (+) and (-) polarity marks inside the battery door and install accordingly.

6.1.2 Operational Check

a. Connect the 44-10 NaI detector to the Model 2241-2 with the coax cable provided.

b. Place the detector switch in the appropriate position. Refer to the calibration sheet to identify the detector setup for the data logging mode. The calibration includes 2 detector setups, identified as detectors 1 and 2. Identify the setup that identifies alert and alarm settings in kC/m (which is typically detector 2, the count rate data logging mode). Place the detector selection switch by lifting and moving the switch to the desired detector. The switch is designed such that it must be lifted before it can be moved to prevent inadvertent movement during operation.

c. Turn the OFF/RATEMETER/SCALER switch (Figure 1) to the RATEMETER position. Note that the display goes through an initialization sequence. The display will initially show all "8"s with decimal points. Note that the display will include a low battery icon in the lower left corner during normal operations if the batteries have reached the minimum battery voltage. If the icon is displayed, replace the batteries in accordance with Section 6.1.1, (b).

d. In the RATEMETER position, the display will start displaying a C/m (or kC/m) value that will display for 2 seconds alternating with “DUP” for 2 seconds, indicating that the meter is in the data logging mode. If the alternating pattern is not occurring, change the internal setting as follows:

1. Turn the meter to OFF

2. Remove the case

3. Place the Function Switch (Figure 2), a 16 position rotary switch, to position “D”. This is accomplished by rotating the switch such that "D" is in the 12:00 position.

4. Replace the case, turn the meter to the RATEMETER position.

6.1.3 Daily Source Check

a. A daily source check shall be performed prior to use of the Ludlum 2241-2 ratemeter / scaler with 44-10 detector.

b. Source checks shall be performed with a gamma button source (e.g. Cs-137) or another source as approved by the Project Manager. The location of the check source as placed on the detector shall be marked, or a jig utilized, to allow for reproducibility of geometry on subsequent days.

c. Source checks shall be obtained with the Ludlum 2241-2 in the RATEMETER mode. Upon placing the source on the detector, an alarm can be anticipated. Pushing the RESET button will silence the alarm. The count rate, in kcpm, will be displayed for 2 seconds, followed by the DUP display. The process will repeat, allowing for ease of noting the count rate value.

d. The initial baseline value shall be determined by obtaining at least 5 count rate values. The average of the 5 values will be used as the baseline value. The initial baseline values shall be recorded on Attachment A with "initial" in the comment field.

e. Record the baseline average value and source serial # at the top of Attachment A. Calculate and record the +/- 20% acceptance values on Attachment A.

f. The value obtained from the daily source checks shall be recorded on Attachment A and verified to be within the acceptance criteria.

g. Failure of the daily source check requires notification and approval of the Project Manager prior to use in the field.

6.2 Computer Set Up

NOTE

The computer must have the connector cable software installed. The Ludlum 2241-2 must be in the SCALER mode.

The computer must contain Ludlum Model 224x Logger software, Version 1.1.0, or later. Software is downloadable from the Ludlum website, www.Ludlums.com.

The software will scroll through all the computer Comm Ports until the one to which the Ludlum 2241-2 is connected is found. If the number of the Comm Port is noted when the “select Comm Port” screen disappears, subsequent openings of the Ludlum software can proceed by selecting “Manual” and then entering the number associated with the Comm Port.

If screen settings are not correct, notify Project Manager.

6.2.1 Prior to opening the Ludlum software, create a file structure in the computer directory. Each file should contain the building number and the survey unit number, or other identifier to associate and group data taken in specific areas.

6.2.2 Right click on the Ludlum icon and select “run as administrator.” A data screen will appear with a “Select Comm Port” Screen.

6.2.3 Attach the Ludlum 2241-2 to the computer using the RS232 to USB connector cable.

6.2.4 Select “Automatic” and hit “OK”.

6.2.5 Following recognition of the instrument, the computer screen should display the following:

a. "Scaler" 2 seconds

b. "Data Dump" in AUTO

c. "Number of Samples to log CONTINUOUS.

6.3 Performance of Gamma Walkover Survey

NOTE

Refer to figure 3 for scan pattern example. Avoid "swinging" the detector to minimize variability in detector to ground distance. Move the detector from side to side while moving your arm in the same plane.

The data will be obtained as total counts in a 2 second interval, followed by a 2 second window to transfer the data to the computer. During the transfer time, no data is being recorded by the Ludlum 2241-2.

Survey data will be stored as comma delimited (.csv), which can be opened from the Excel program.

6.3.1 Surveys will be performed by walking in lines or “strips”. The pattern to be walked must be planned and recorded on a strip map. Avoid long strips, since locating small areas of elevated readings will require correlating the data point location from the data string with the approximate location along the strip. Shorter strips provide better correlation

6.3.2 Surveys will be performed by walking each planned strip at a speed of approximately ½ meter per second (known as a wedding march pace) while moving the detector in a serpentine fashion of 1 to 1.5 meters at approximately 4 inches from the ground.

6.3.3 To start each strip, hit “Start Logging” on the Model 2241 Logger screen on the computer.

6.3.4 At the end of each strip, hit "Stop Logging".

6.3.5 Hit "Save". The computer directory will appear. Select the file location established for the specific survey being performed. Name the file with the specific strip number for the strip just completed, as follows. The default file name will appear as YYYYMMDD. Append a "-" and a sequential number (i.e. -1, -2, etc.) for each strip on a given date. Save the data to the computer.

6.3.6 Each subsequent strip will start with “Start Logging” followed by a screen that will ask if the data is to be appended to the previous strip. Select “No”, unless the survey is a continuation of the previous strip.

6.3.7 Upon completion of surveys, return computer and strip maps to the post processor for data processing.

6.4 Instrumentation Acceptance Criteria

6.4.1 Acceptance occurs when instrument source checks fall within the +/- 20 % acceptance range.

7. DOCUMENT CONTROL

7.1 All survey results should be documented on an appropriate survey form as directed by project supervision.

8. FIGURES AND ATTACHMENTS

8.1 Figure 1 - Ludlum Model 2241-2 Detector Face

8.2 Figure 2 – Ludlum Model 2241-2 Function Switch

8.3 Figure 3 – Scan Pattern Example

8.4 Attachment A – Daily Source Check Form

9. SUMMARY OF CHANGES

9.1 Revision 01, add “or equivalent” to allow equivalent 2” x 2” NaI detectors (e.g. Eberline SSPA-3) to be utilized with this procedure.

Figure 1

Ludlum Model 2241-2 Detector Face

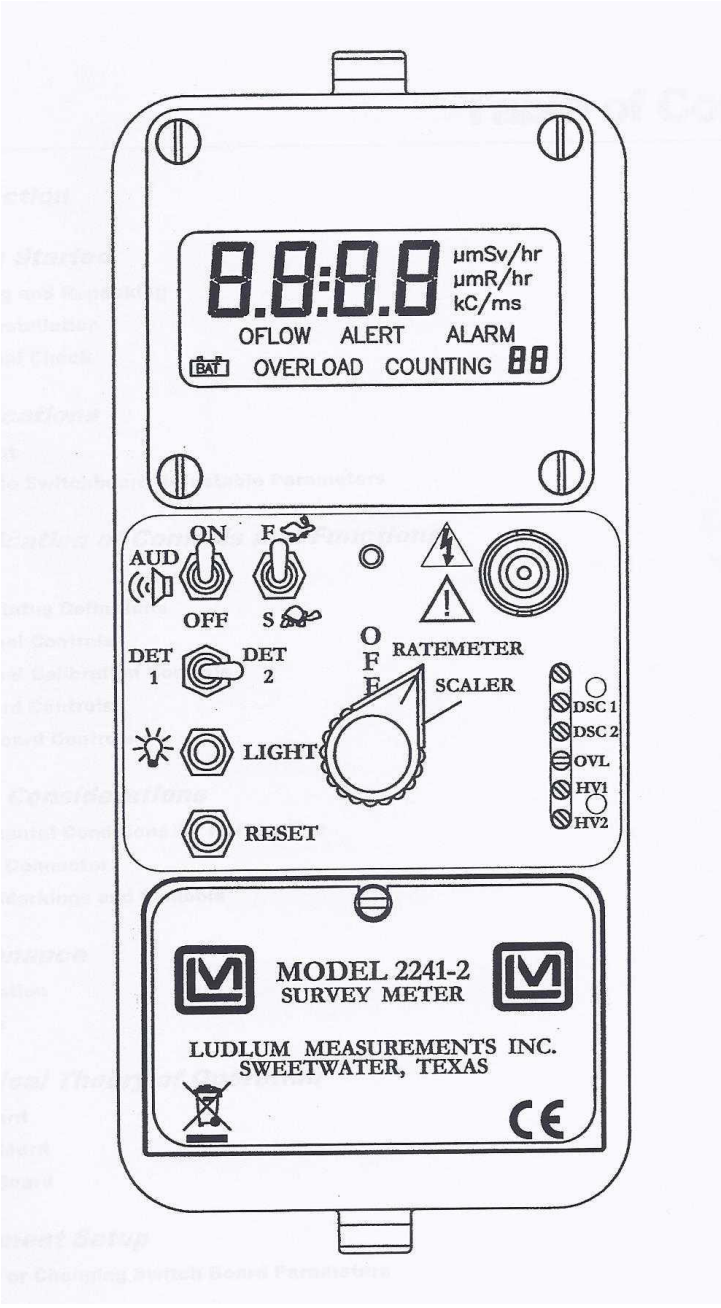


Figure 2

Ludlum Model 2241-2 Function Switch

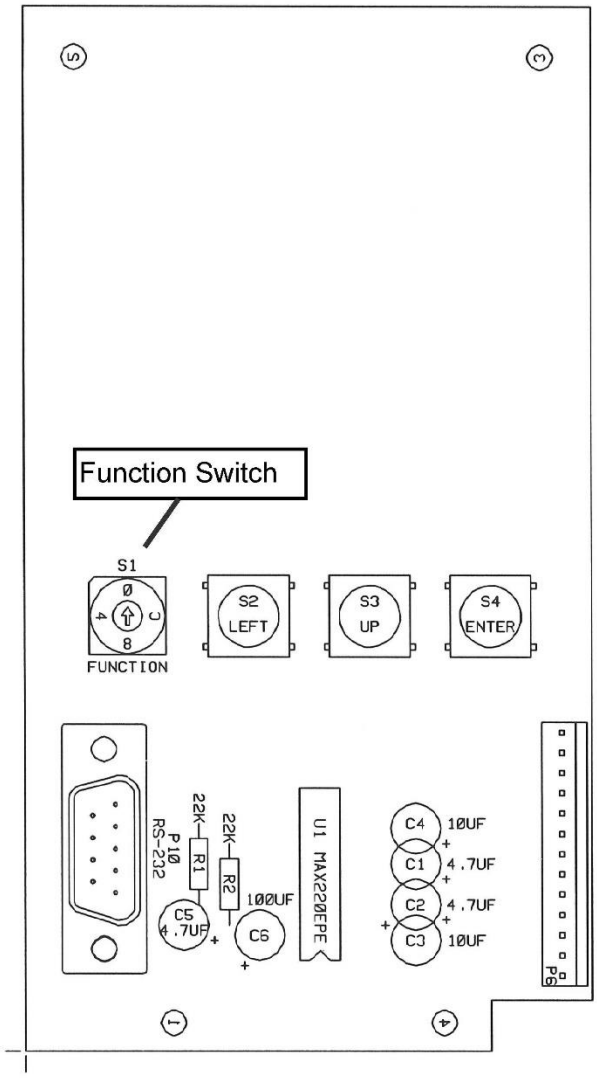
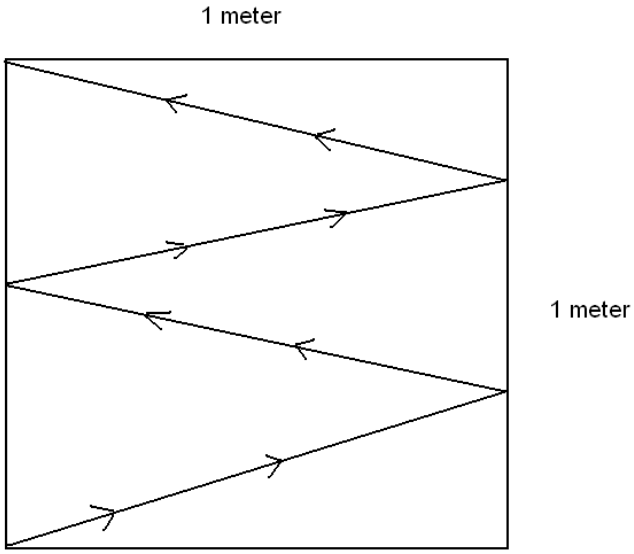


Figure 3

Scan Pattern example



at a speed of approximately ½ meter per second

Attachment A

Daily Source Check Form

Instrument S/N: _____ **Probe S/N:** _____

Baseline Average: _____ **cpm** **Source S/N:** _____

Acceptance Criteria: _____ **(-20%) cpm to** _____ **(+20%) cpm**

Date	Response (cpm)	Acceptable (Y/N)	Comment	Technician Initials

RADIATION SAFETY & CONTROL SERVICES, INC.
STANDARD OPERATING PROCEDURE

RSCS
Radiation Safety & Control Services

OPERATION OF THE THERMO SCIENTIFIC RADEYE SX

SOP 2.7.21

Revision 00

Originator: _____ Date: July 11, 2019

Reviewer: _____ Date: July 11, 2019

Approval: _____ Date: 7/11/19
RSCS Director

OPERATION OF THE THERMO SCIENTIFIC RADEYE SX

1. OBJECTIVE

This procedure provides instructions for operating the Thermo Scientific RadEye SX multi-purpose meter for external scintillation probes. Although the meter has other capabilities, this procedure only addresses its use as a scaler / ratemeter.

2. REFERENCES

2.1 Operating Instructions for the Thermo Scientific RadEye SX for external Scintillation Detectors.

2.2 SOP 2.1.13 Control of Radioactive Material

3. EQUIPMENT

3.1 RadEye SX Meter

3.2 Scintillation Probe

3.2.1 Dual phosphor α/β probe

3.2.2 NaI (Tl) scintillation detector

3.2.3 Other scintillation detectors

3.3 Radioactive check source

4. PRECAUTIONS

4.1 Ensure the meter is turned off prior to connecting or disconnecting a probe, otherwise a shock hazard may be present.

4.2 Prior to use, verify that the instrument is within its annual calibration.

4.3 Do not use this instrument if error messages appear on the screen.

4.4 This instrument must not be used in an explosive atmosphere.

5. DISCUSSION

RSCS is commissioned to perform radiological surveys, including contamination surveys at various facilities to determine radiological conditions. These surveys are typically performed either in support of the operation of the facility, or support of conditional/un-conditional release of the facility. This instrument is used to perform surface contamination measurements or gamma scans, depending on the probe selected. Care must be taken to ensure the instrumentation is operating correctly and that Quality Checks are performed. The attached "Forms" may be electronically reproduced and modified if the original intent of the Form is not compromised.

6. INSTRUCTIONS

Figure 1 - RadEye SX Meter

6.1 Basic Operation

6.1.1 CONNECT the probe to the MHV connector on top of the meter.

6.1.2 PRESS AND HOLD the “On / Screen” button for at least one second. The meter will beep, and the start screen will be displayed for 2 seconds.

6.1.3 CONFIRM that the probe displayed on the screen is correct.

CAUTION

Selecting the incorrect probe serial number / type may result in the improper HV being applied to the probe, possibly resulting in damage to the probe.

6.1.4 ACCEPT the selection by pressing the “Left Arrow” button if the probe serial number displayed is correct.

6.1.5 IF an incorrect probe serial number is displayed, THEN SELECT “Change” by pressing the “Right Arrow” button to open the probe selection menu.

6.1.6 PRESS the “Up Arrow” or “Down Arrow” buttons to SCROLL through the display of the other probe serial numbers.

6.1.7 HIGHLIGHT the correct probe serial number and PRESS the “Left Arrow” button to select the probe. A checkmark will appear next to the selected probe and the meter will initialize that probe automatically within 10 seconds and bring you to the measurement screen.

6.1.8 IF an error was made or measurements are complete, THEN TURN OFF the unit by pressing the “Left Arrow” button three times with a 1 second pause between presses.

6.2 Setting the Operation Mode

6.2.1 TURN ON the unit as per step 6.1.2.

6.2.2 PRESS the “Menu” button to display the menu options.

6.2.3 USE the “Up Arrow” or “Down Arrow” buttons to SCROLL to the “Operation mode” selection and PRESS the “Left Arrow” button to select the operation mode.

6.2.4 Selecting Ratemeter Mode from Operation Mode Screen

a. USE the “Up Arrow” or “Down Arrow” to SCROLL to “Ratemeter ADF” and SELECT using the “Left Arrow” button.

b. PRESS the “Right Arrow” once to exit the “Operation Mode” and revert to the “Main Menu.

c. USE the “Up Arrow” or “Down Arrow” to SCROLL to “Measuring unit” and SELECT using the “Left Arrow” button.

d. USE the “Up Arrow” or “Down Arrow” to SCROLL to the appropriate units, normally “cpm” and SELECT using the “Left Arrow” button.

e. IF unsure about appropriate units, THEN ASK the survey supervisor.

f. PRESS the “Right Arrow” button twice to exit to the measurement screen or wait 15 seconds for a timeout.

6.2.5 Selecting Scaler Mode from Operation Mode Screen

a. USE the “Up Arrow” or “Down Arrow” to SCROLL to “Scaler” and SELECT using the “Left Arrow” button.

b. PRESS the “Right Arrow” key once to exit the “Operation mode” and revert to “Main menu”.

c. USE the “Up Arrow” or “Down Arrow” to SCROLL to “Scaler parameter” and SELECT using the “Left Arrow” button.

d. USE the “Up Arrow” or “Down Arrow” to SCROLL to “Preset TimeMode” and SELECT using the “Left Arrow” button.

e. USE the “Up Arrow” or “Down Arrow” to SCROLL to “Set Time/Count”, SELECT using the “Left Arrow” button and SET the required time, typically 60 seconds.

f. IF unsure about required count time, THEN ASK the survey supervisor.

g. PRESS the “Right Arrow” button twice to exit to the measurement screen or wait 15 seconds for a timeout.

h. PRESS the “Up Arrow” button to initiate the count. PRESS the “Up Arrow button again to interrupt a count. PRESS the “Up Arrow” again to reset the count.

i. LOG the reading and PRESS the “Up Arrow” button to begin the next count once the count is complete.

6.2.6 Quality Control

a. PERFORM a QC response check at the beginning of every day / shift.

NOTE

The QC response check consists of a 1-minute background measurement (in scaler mode) and a 1-minute check source measurement. Check sources shall be obtained, transported and used in accordance with reference 2.2.

1. CONSULT with the survey supervisor for the acceptance criteria established at the beginning of the project.

2. RECORD the result of the QC measurement on Attachment A, “Daily Response Check Form”.

3. VERIFY that the net result of the QC measurement falls within the acceptance criteria.

4. IF the QC measurement falls outside of the acceptance criteria, THEN CONSULT with the survey supervisor for instructions on how to proceed.

7. FORMS AND ATTACHMENTS

7.1 Attachment A, Daily Response Check Form

8. SUMMARY OF CHANGES

8.1 SOP 2.7.21, Revision 00. Effective on date of front cover signature.

Initial Issue

ATTACHMENT A
DAILY RESPONSE CHECK FORM

Instrument Serial # _____ **Probe Serial #** _____

HV Setting _____ **Volts** **Radiation Type** _____

Acceptance Criteria: _____ **to** _____ **cpm on Source Serial #** _____

Date	In Cal? (Y/N)	Response (net cpm)	Acceptable (Y/N)	Comments	Technician Initials

RADIATION SAFETY & CONTROL SERVICES, INC.
STANDARD OPERATING PROCEDURE

RSCS
Radiation Safety & Control Services

PERFORMANCE AND DOCUMENTATION OF RADIOLOGICAL SURVEYS

SOP 3.4.1

Revision 00

Originator: _____ Date: 6/18/13

Reviewer: _____ Date: 6/18/13

Approval: _____ Date: 6/19/13
RSCS Director

PERFORMANCE AND DOCUMENTATION OF RADIOLOGICAL SURVEYS

1. OBJECTIVE

1.1 This procedure provides guidance in methods and techniques for performing and documenting radiation, contamination, and hot particle surveys along with analyzing contamination surveys.

2. REFERENCES

2.1 SOP 3.4, “Radiological Survey and Posting Program”

3. EQUIPMENT

3.1 Calibrated radiological survey instrumentation capable of detecting the range of interest for the type of radioactivity being surveyed

3.2 Cloth smears or approved equivalent

3.3 Tacky rollers or masslin

3.4 Calibrated analytical counting equipment capable of detecting a Minimum Detectable Activity (MDA) that is specified by the customer or regulations (whichever is more restrictive) on a standard cloth smear. Refer to Attachment A for guidance.

4. DISCUSSION

4.1 Radiation and Contamination surveys shall be conducted to evaluate and identify the extent of radiation hazards that may be present.

4.2 Health Physics supervision shall be notified if radiological conditions change to unexpected values or if conditions change that will affect the posting of an area.

5. PRECAUTIONS

5.1 Radiological survey instrument will have a current legible calibration sticker and a calibration certificate stating it passed calibration with a NIST- traceable radiation source.

5.2 Instruments being used shall be QC source/response checked prior to initial use on the date of use.

5.3 When an instrument is in a continuous use, a battery check should be performed periodically to ensure its proper ability to function.

6. INSTRUCTIONS

6.1 Survey Preparation

6.1.1 OBTAIN if available, information on radiological conditions of the area to be surveyed as applicable.

6.1.2 SELECT appropriate survey instrument.

6.1.3 INSPECT the instrument for physical damage.

6.1.4 CHECK the calibration sticker to ensure that the meter has a current calibration.

6.1.5 PERFORM a battery check, and if applicable, REPLACE batteries.

NOTE

Performance of system quality control check need not be performed if previously completed within the last 12 hours.

The QC acceptance range for an instrument will normally be established during system calibration at ± 20% of the average QC source counts, unless directed otherwise by the RSO/D

6.1.6 PERFORM Pre-operational checks as follows:

a. PLACE the appropriate QC source in the standard counting configuration;

b. COUNT the QC source for the interval indicated on the most recent calibration;

c. RECORD the QC source count and count time on appropriate form;

d. ENSURE the QC value is within the acceptance range established during system calibration;

e. REPEAT steps 6.1.6.a to 6.1.6.b if the QC source result is outside the acceptance range. TAG the system as out of service and notify RPS/D for further instructions if second attempt is outside the acceptance range.

6.2 Gamma Survey

6.2.1 PERFORM a general area radiation survey holding the meter at waist level.

6.2.2 When performing dose rates, document the following in accordance with section 6.9, as necessary:

- General Area
- Contact
- 30 cm
- Dose gradients

6.3 Beta Surveys

NOTE

Beta surveys are typically performed when the presence of beta radiation is known or suspected (e.g., breach and/or maintenance of radioactive systems, valve yokes and packing glands, etc.).

Beta attenuation surveys are typically performed using the slide provided on the meter as the attenuator. In lieu of the closed window reading other attenuators may be used e.g., Plastics, PC's, Gloves etc. as requested by RPS/D.

6.3.1 OBTAIN the difference between open and closed window readings then multiply by the beta correction factor to determine beta dose rate as follows:

a. [OW-CW] x [BCF] = beta dose rate

Where: OW = Open Window, CW = Closed Window, BCF = Beta Correction Factor

6.3.2 REFER to section 6.9 and DOCUMENT results.

6.4 Smear Contamination Survey

6.4.1 ACQUIRE a sufficient number of smears, suitable for the area to be assessed. COMPLETE required data on smear folder as appropriate.

6.4.2 SMEAR the area in question:

a. Paying attention to the areas of potential contamination;

b. Surveying a representative area or portion of the item(s) accessible surface(s) e.g., 100 cm^2 or equivalent (entire surface for items < 100 cm^2).

6.4.3 VERIFY a system background has been performed on the counting equipment within the past 12 hours, if not, go to section 6.8 for performance of system background before continuing.

6.4.4 COUNT all smears for beta-gamma activity.

6.4.5 COUNT smears for alpha activity as directed by the RPS/D.

6.4.6 ENSURE that smears are analyzed with counting parameters sufficient to meet the removable contamination limit.

6.4.7 REFER to section 6.9 and DOCUMENT results.

NOTE

Large Area Smears are typically performed to provide a qualitative evaluation method to determine detectable contamination.

6.5 Large Area Smear Survey (LAS)

6.5.1 WIPE the area of interest.

6.5.2 SURVEY the collection medium.

a. Minimize distance between probe and medium being monitored

b. Move the probe slowly

6.5.3 IF positive response is detected in a non-contaminated area, PERFORM additional survey(s) to quantify the extent of the contamination.

6.5.4 REFER to section 6.9 and DOCUMENT results

6.6 Removable Hot Particle Survey

6.6.1 PERFORM Hot Particle surveys on systems and areas where the potential for Hot Particles exist.

6.6.2 PERFORM hot particle contamination surveys with masslin swipes, sticky rollers, tape or other collection media.

6.6.3 SURVEY the collection medium.

a. Minimize distance between probe and medium being monitored

b. Move the probe slowly

NOTE

Various techniques can be used to isolate Hot Particles e.g., collimator, shrouded probe, etc.

6.6.4 IF discrete particle(s) greater than 20,000 ccpm are identified, PERFORM the following, otherwise REFER to section 6.9 and DOCUMENT results:

a. If possible, ISOLATE suspected hot particle (s)

b. NOTIFY the RPS/D for further analytical requirements

6.6.5 REFER to section 6.9 and DOCUMENT results.

6.7 Direct Hot Particle Survey

6.7.1 SCAN the area(s) of interest with an appropriate instrument (e.g., frisker, RO-2).

6.7.2 LOCATE area of high activity.

6.7.3 ISOLATE, if possible, suspected hot particle(s).

6.7.4 If a hot particle is detected notify the RPS/D and refer to section 6.9 and document results.

6.8 Sample Counting System Setup and Use

NOTE

Performance of system background need not be performed if previously completed within the last 12 hours.

6.8.1 ENSURE that the sample counting chamber has an appropriate blank or is empty and that any requisite shielding is in place.

6.8.2 PERFORM a background count for at least 10 minutes.

6.8.3 SELECT the appropriate sample count time.

6.8.4 CALCULATE the Critical Level, L_c, as follows:

$$L_c\,(cpm) = \frac{1.645\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{t_s}$$

Where
R_b = background count rate (c/m)
t_s = sample count time (min)
t_b = background count time (min)

6.8.5 DETERMINE the energy emission(s) of the sample to be analyzed.

6.8.6 CALCULATE the system MDA as follows:

$$MDA\,(dpm) = \frac{3 + 3.29\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{eff * t_s}$$

Where
R_b = background count rate (c/m)
t_s = sample count time (min)
t_b = background count time (min)
eff = counting efficiency (c/d)

6.8.7 ENSURE that the system count time is sufficient to achieve an MDA that is specified by the customer or regulations (whichever is more restrictive). REFER to Attachment A for guidance.

6.8.8 ANNOTATE the L_c and MDA values on the appropriate paperwork

6.8.9 COUNT samples for the determined sample count time

6.8.10 ANNOTATE samples as containing positive activity if results are equal to or exceed the Critical Level, L_c.

a. DOCUMENT the reported activity of results equal or exceed the Critical Level

b. RECORD the sample results as “not detectable” (ND) or “less than Critical Level”, ($<L_c$) if results are less than the Critical Level

6.9 Survey Documentation

6.9.1 DOCUMENT the following information on survey forms:

- Date, time, and location of the survey;
- Surveyors name and signature;
- Radiological information, which may include contact and general area dose rates, fixed and smearable contamination, air samples, large area smears and direct hot particle results;
- MDA and L_c of counting instruments, when applicable;
- Signature of a qualified reviewer;

- RWP's used, if applicable;
- Total DAC Fraction, when applicable;
- The purpose of the survey;
- The Instrument model/serial numbers and the calibration due dates.

6.9.2 REFER to Attachment B for an example "Survey Record Form".

6.9.3 REFER to Attachment C for an example "Survey Record Smear Continuation Form".

7. FORMS AND ATTACHMENTS

7.1 Attachment A - Guidance for MDA Requirements

7.2 Attachment B - Example Survey Record Form

7.3 Attachment C - Example Survey Record Smear Continuation Form

8. SUMMARY OF CHANGES

8.1 Initial issue

Attachment A

Guidance for MDA Requirements

Activity	**Removable Contamination**
Leak Testing	0.005 µCi βγ 0.005 µCi α
Shipping	$\frac{2{,}200\ \text{dpm}}{100\ \text{cm}^2}$ βγ $\frac{220\ \text{dpm}}{100\ \text{cm}^2}$ α
Air Sampling – Isotopic Specific	<0.3 DAC for posting purposes
Radionuclide	**Activity Concentration**
U-natural, U-235, U-238 and associated decay products	$\frac{1{,}000\ \text{dpm}}{100\ \text{cm}^2}$
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	$\frac{20\ \text{dpm}}{100\ \text{cm}^2}$
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	$\frac{200\ \text{dpm}}{100\ \text{cm}^2}$
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission except Sr-90 and others noted above).	$\frac{1{,}000\ \text{dpm}}{100\ \text{cm}^2}$

Attachment B

Radiological Survey Record Form

Date:	Location:
By:	Survey Number:

_____
Reviewed by (RPS/Designee) / Date

#	Instrument	Serial Number	Cal Due Date

Comments: Readings are in mRem/hr unless otherwise noted
= waist level dose rates
* = contact dose rates
(#) = smear locations
Mda = _____dpm
L_c= _____ cpm
Frisker Background = ____cpm

Surface Contamination Measurements (results in dpm/100cm^2 unless otherwise noted)

#	CCPM	Results	Inst #	#	CCPM	Results	Inst #	#	CCPM	Results	Inst #

Attachment C

Radiological Survey Record (Smear Continuation Sheet)

Date:	Location:
By:	Survey Number:

________________________________ Reviewed by (RPS/Designee) / Date	Comments: Mda = ___________ dpm. L_c = _____________cpm.

#	Instrument	Serial Number	Cal Due Date

Surface Contamination Measurements (results in dpm/100cm^2 unless otherwise noted)

#	CCPM	Results	Inst #	#	CCPM	Results	Inst #	#	CCPM	Results	Inst #

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

CONDUCT OF RADIOLOGICAL WORK

PROCEDURE NO: HP-NMI-01

Revision 2

October 2018

Table of Contents

A. Overview

This procedure describes the methods to be used to perform radiological work safely and within regulatory compliance. Because the procedure contains requirements and general guidance, careful reading and understanding is required.

1. Requirements contain the word "shall" or "will."

2. Guidance statements contain the word "should," or some other non-definitive term, and verbatim compliance with guidance statements is not always required. Compliance with the principles they address is required. In any event, "should" statements shall be performed as written unless directed by Health Physics Staff or Radiation Safety Officer (RSO) to the contrary.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

1. NRC 10 CFR 20, Standards For Protection Against Radiation

2. NRC Regulatory Guide 1.86

3. Health and Safety Plan – Appendix A, Radiation Protection Program

D. General Rules

1. Individuals involved in radiological work shall perform work in accordance with applicable procedures and radiological work permits (RWPs).

2. Physical hazards to life or limb take precedence over radiological protection concerns. If implementation of any procedural or RWP requirement will jeopardize the health or safety of a worker, then work shall be suspended and the RSO and the Project Health and Safety Officer (HSO) contacted for resolution.

E. Access to Restricted Areas and Radiologically Controlled Areas

1. The following people may enter a Restricted Area without an escort:

    a. Individuals trained in accordance with the NMI Radiation Protection Program.

b. Training shall be repeated annually for personnel performing work covered by RWP (a 60 grace period may be used for scheduling purposes).

2. Individuals not meeting the above requirements may enter the restricted area for non-invasive activities (tours, inspection, etc.) under the following conditions:

   a. At no time may a visitor enter a radiologically controlled area without express permission of the RSO.

   b. The individual is briefed on the radiological conditions in the area.

   c. The individual shall be issued a direct reading dosimeter. Groups may be issued one dosimeter for each five member group, as long as the group stays together.

   d. The Health Physics Technician (HP) or Project Manager in charge of the work is notified.

   e. The individual shall be escorted by an individual meeting the requirements of Section E.1. above 100% of the time he/she is in the restricted area.

   f. Visitor entry shall be controlled and documented.

3. Regulatory oversight personnel employed by the EPA, NRC or applicable Agreement State are qualified to enter the restricted area without escort; however, every reasonable effort shall be made to provide a qualified escort.

4. Only qualified radiological workers or HPs may enter posted airborne radioactivity areas.

F. Radiological Protection Coverage

1. The following activities shall be performed only by qualified and properly trained Health Physics Staff:

   a. Radiological surveys

   b. Radioactive material shipment/receipt surveys

   c. Labeling radioactive material upon receipt

   d. Radiological sample analysis

   e. Instrument response checks

f. Instrument repair/troubleshooting (except battery or cord replacement)

g. Instrument calibration (unless performed by outside vendor)

h. Air sample collection

i. Posting or de-posting of radiological areas

j. Unconditional release surveys of equipment/materials

k. Any other task as specified by RWP or other implementing procedure

2. The following activities may be performed by radiological workers:

a. Decontamination, dismantling and sampling

b. Opening containers of radioactive material

c. Pumping radioactive liquids

d. Entry into a posted Contamination Area

e. Directly handling uncontained radioactive material

f. Processing of radioactive waste

g. Any other task as specified by RWP or other implementing procedure

G. Performance of Work

1. Contamination Control

Every reasonable precaution shall be taken to prevent the spread of contamination.

a. Maintain good housekeeping.

b. All boundaries and signs shall be observed.

c. Personal Protective Equipment (PPE) prescribed by RWP shall be worn.

d. Minimize the amount of material that is taken into potentially contaminated areas.

e. Sleeve or wrap items as necessary to prevent them from becoming contaminated.

f. Use fixative agents, containments and/or negative ventilation as necessary to control the spread of contamination.

g. All items removed from a contaminated area shall be surveyed or controlled as radioactive material.

h. Remove PPE or monitor for contamination at the boundary or as indicated on RWP.

i. Hoses, power cords, etc. should be secured at the point at which they cross a contamination area boundary.

j. Keep containers of radioactive material closed to the extent practicable.

k. Promptly clean up spills, even in contamination areas and notify HP if any radioactive material has been spilled.

2. Radiation exposure

a. Workers shall not loiter in radiation areas or radiologically controlled areas.

b. Perform as much work as possible outside of radiation areas and radiologically controlled areas.

c. Specific methods of maintaining radiation exposure as low as reasonably achievable (ALARA) should be included in RWPs. Workers shall obey those instructions.

d. Individuals shall wear required dosimetry as specified in procedures or RWPs.

e. Radioactive material should be stored such that radiation dose rate at the restricted area boundary does not exceed 0.5 mrem/hour. Contact health physics before storing radioactive material adjacent to the restricted area boundary.

3. Airborne radioactivity control

a. Obey all instructions listed above for contamination control.

b. Brooms should not be used in contamination areas or airborne radioactivity areas.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

DEFINITIONS

PROCEDURE NO: HP-NMI-02

October 2018

Absorbed dose	The energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).
Activity	The rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the becquerel (Bq).
Adult	An individual 18 or more years of age.
Airborne radioactive material	Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.
Airborne radioactivity area	A room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of radioactive material, exist in concentrations— (1) In excess of the derived air concentrations (DACs) specified in appendix B, to §§ 20.1001–20.2401, or (2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.
Air-purifying respirator	A respirator with an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element.
Annual limit on intake **(ALI)**	The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue. (ALI values for intake by ingestion and by inhalation of selected radionuclides are given in table 1, columns 1 and 2, of appendix B to §§ 20.1001–20.2401).

Assigned protection factor (APF)	The expected workplace level of respiratory protection that would be provided by a properly functioning respirator or a class of respirators to properly fitted and trained users. Operationally, the inhaled concentration can be estimated by dividing the ambient airborne concentration by the APF.
Atmosphere-supplying respirator	A respirator that supplies the respirator user with breathing air from a source independent of the ambient atmosphere, and includes supplied-air respirators (SARs) and self-contained breathing apparatus (SCBA) units.
Background radiation	Radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the site.
Bequerel (Bq)	A unit of radioactivity equal to 1 disintegration per second (dps).
Bioassay **(radiobioassay)**	The determination of isotopes, quantities, concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body (in vitro counting).
Byproduct material	(1) Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear material; and (2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute ‘‘byproduct material’’ within this definition.

***Class* (or *lung class* or *inhalation class*)**	A classification scheme for inhaled material according to its rate of clearance from the pulmonary region of the lung. Materials are classified as D, W, or Y, which applies to a range of clearance half-times: for Class D (Days), of less than 10 days, for Class W (Weeks), from 10 to 100 days, and for Class Y (Years), greater than 100 days.
Collective dose	The sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation.
***Committed dose equivalent* (HT,50)**	The dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.
***Committed effective dose equivalent* (HE,50)**	The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.
Constraint (dose constraint)	A value above which specified actions are required. Also referred to as an administrative limit.
Controlled area	An area, outside of a restricted area but inside the site boundary, access to which can be limited for any reason.
Critical Group	The group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.
Curie (Ci)	A unit of radioactivity equal to 3.7×10^{10} Bq or 2.22×10^{12} disintegrations per minute.
Declared pregnant woman	A woman who has voluntarily informed the RSO, in writing, of her pregnancy and the estimated date of conception. The declaration remains in effect until the declared pregnant woman withdraws the declaration in writing or is no longer pregnant.

Decommission	To remove a facility or site safely from service and reduce residual radioactivity to a level that permits— (1) Release of the property for unrestricted use and termination of the license; or (2) Release of the property under restricted conditions and the termination of the license.
Deep-dose equivalent **(Hd),**	The dose which applies to external whole-body exposure, it is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm2).
Demand respirator	An atmosphere-supplying respirator that admits breathing air to the facepiece only when a negative pressure is created inside the facepiece by inhalation.
Derived air concentration **(DAC)**	The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI. DAC values are given in table 1, column 3, of appendix B to §§ 20.1001–20.2401.
Derived air concentration-hour **(DAC hour)**	The product of the concentration of radioactive material in air (expressed as a fraction or multiple of the derived air concentration for each radionuclide) and the time of exposure to that radionuclide, in hours. A RPP may take 2,000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems (0.05 Sv). A single DAC hour can also be expressed as 2.5 mrems (0.025 mSv).
Distinguishable from background	Means that the detectable concentration of a radionuclide is statistically different from the background concentration of that radionuclide in the vicinity of the site or, in the case of structures, in similar materials using adequate measurement technology, survey, and statistical techniques.
Dose **or** ***radiation dose***	A generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

***Dose equivalent* (HT)**	The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).
Dosimetry processor	An individual or organization that processes and evaluates individual monitoring devices for radiation dose. Must be NVLAP accredited.
dpm	One atomic nuclear disintegration per minute.
DPW	Declared pregnant woman.
***Effective dose equivalent* (HE)**	The sum of the products of the dose equivalent to the organ or tissue (HT) and the weighting factors (W_T) applicable to each of the body organs or tissues that are irradiated.
Embryo/fetus	The developing human organism from conception until the time of birth.
Entrance or access point	Any location through which an individual could gain access to an area where fixed or removable radioactive materials are present, or where a dose potential above permissible doses to members of the public exist. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.
Exposure	Being exposed to energy from ionizing radiation or to radioactive material.
External dose	The portion of the dose equivalent received from radiation sources outside the body.
Extremity	Hand, elbow, arm below the elbow; foot, knee, or leg below the knee.
Fetal dosimeter	A dosimeter (usually a TLD) that is assigned to a declared pregnant woman and is worn on the abdomen to monitor deep dose equivalent (DDE) to the embryo/fetus.

Fit factor	A quantitative estimate of the fit of a particular respirator to a specific individual, and typically estimates the ratio of the concentration of a substance in ambient air to its concentration inside the respirator when worn.
Fit test	The use of a protocol to qualitatively or quantitatively evaluate the fit of a respirator on an individual.
Generally applicable environmental radiation standards	Standards issued by the Environmental Protection Agency (EPA), as amended, that impose limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.
Gray(Gy)	A unit of absorbed dose. One gray equals 100 rad.
High radiation area	An area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or 30 centimeters from any surface that the radiation penetrates.
Individual	Any human being.
Individual monitoring	(1) The assessment of dose equivalent by the use of devices designed to be worn by an individual; (2) The assessment of committed effective dose equivalent by bioassay (see *Bioassay*) or by determination of the time-weighted air concentrations to which an individual has been exposed, i.e., DAC-hours; or (3) The assessment of dose equivalent by the use of survey data.
Individual monitoring devices	Devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescence dosimeters (TLDs), pocket ionization chambers, and personal (‘‘lapel’’) air sampling devices.
Internal dose	The portion of the dose equivalent received from radioactive material taken into the body.

Lens dose equivalent (LDE)	Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm2).
***Limits* (dose limits)**	The permissible upper bounds of radiation doses.
Member of the public	Any individual except when that individual is receiving an occupational dose. The dose to a member of the public, either real or theoretical is not to exceed 100 mrem/yr.
Minor	An individual less than 18 years of age.
***Monitoring* (radiation monitoring, radiation protection monitoring)**	The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.
Negative pressure respirator (tight fitting)	A respirator in which the air pressure inside the facepiece is negative during inhalation with respect to the ambient air pressure outside the respirator.
Nonstochastic effect	Health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).
NRC	Nuclear Regulatory Commission or its duly authorized representatives.
Occupational dose	The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation or to radioactive material from sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive, from voluntary participation in medical research programs, or as a member of the public.

Planned special exposure	An infrequent exposure to radiation, separate from and in addition to the annual dose limits.
Positive pressure respirator	A respirator in which the pressure inside the respiratory inlet covering exceeds the ambient air pressure outside the respirator.
Powered air-purifying respirator (PAPR)	An air-purifying respirator that uses a blower to force the ambient air through air-purifying elements to the inlet covering.
Pressure demand respirator	A positive pressure atmosphere-supplying respirator that admits breathing air to the facepiece when the positive pressure is reduced inside the facepiece by inhalation.
Primary dosimeter	The whole body TLD that is issued to an employee for an entire routine wear period.
Quality Factor (Q)	The modifying factor (listed in tables 1004(b).1 and 1004(b).2 of § 20.1004) that is used to derive dose equivalent from absorbed dose.
Rad	A unit of absorbed dose equivalent to 100 ergs per gram of material.
***Radiation* (ionizing radiation)**	Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high- speed protons, and other particles capable of producing ions. Radiation, as used in this part, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.
Radiation area	An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Radiologically controlled area (RCA)	Any radiation area, high radiation area, very high radiation area, contamination area, airborne radioactivity area, or radioactive material area; or any area that contains one or more of those areas and is posted as a radiologically controlled area for ease of entry and exit control.
Reference man	A hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.
Rem	A unit of dose equivalent. On rem is equivalent to absorbed dose in rads times the applicable quality factor.
Removable contamination	Radioactive material deposited on a surface that can be removed by wiping with a dry filter paper.
Residual radioactivity	Means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the site's control. This includes radioactivity from all sources used but excludes background radiation. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.
Respiratory protective device	An apparatus, such as a respirator, used to reduce the individual's intake of airborne radioactive materials.
Restricted area	An area, access to which is limited for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.
RSO	Radiation Safety Officer. The RSO is the individual primarily responsible to the regulatory agency for compliance with radiation protection regulations.

Sanitary sewerage	A system of public sewers for carrying off waste water and refuse, but excluding sewage treatment facilities, septic tanks, and leach fields owned or operated by the site.
Secondary dosimeter	A dosimeter that is used to supplement the reading from the primary dosimeter; or a second dosimeter that is used to estimate exposure. Readings from the secondary dosimeter are not used to report record dose unless they are deemed to be more accurate than the readings from the primary dosimeter.
Self-contained breathing apparatus (SCBA)	An atmosphere-supplying respirator for which the breathing air source is designed to be carried by the user.
Shallow-dose equivalent **(HS)**	Applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2) averaged over an area of 1 square centimeter.
Sievert	A unit of dose equivalent equal to 100 rem.
Site boundary	That line beyond which the land or property is not owned, leased, or otherwise controlled by the site.
Source material	(1) Uranium or thorium or any combination of uranium and thorium in any physical or chemical form; or (2) Ores that contain, by weight, one twentieth of 1 percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.
Stochastic effects	Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.
Supplied-air respirator (SAR) **or** ***airline respirator***	An atmosphere-supplying respirator for which the source of breathing air is not designed to be carried by the user.

Survey	An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.
Tight-fitting facepiece	A respiratory inlet covering that forms a complete seal with the face.
TLD	Thermoluminescent dosimeter.
Total contamination	The sum of the fixed contamination and the removable contamination present on a surface.
Total Effective Dose Equivalent **(TEDE)**	The sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).
U.S. DOT	United States Department of Transportation.
Unrestricted area	An area, access to which is neither limited nor controlled for purposes of radiological controls.
Uranium fuel cycle	The operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel to the extent that these activities directly support the production of electrical power for public use. Uranium fuel cycle does not include mining operations, operations at waste disposal sites, transportation of radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and byproduct materials from the cycle.

User seal check (fit check)	An action conducted by the respirator user to determine if the respirator is properly seated to the face. Examples include negative pressure check, positive pressure check, irritant smoke check, or isoamyl acetate check.
Week	7 consecutive days starting on Sunday.
***Weighting factor* wT,**	For an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly
Whole body	For purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.
Year	The period of time beginning in January used to determine compliance with the provisions of this part.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Radiological Safety Training

PROCEDURE NO: HP-NMI-03

October 2018

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Lesson 1: Radiological Fundamentals

Terminal Objective:

Given various radiological concepts, the participant will be able to define the fundamentals of radiation, radioactive material, and radioactive contamination in accordance with the approved lesson materials.

Enabling Objectives:

The participant will be able to select the correct response from a group of responses to verify his/her ability to:

E01: **IDENTIFY** the three basic particles of an atom.
E02: **DEFINE** radioactive material, radioactivity, radioactive decay/disintegration, radioactive half-life and radioactive contamination.
E03: **IDENTIFY** the units used to measure radioactivity and contamination.
E04: **DEFINE** ionization and ionizing radiation.
E05: **DISTINGUISH** between ionizing radiation and non-ionizing radiation.
E06: **IDENTIFY** the four basic types of ionizing radiation and the following for each type:
   a. Physical characteristics
   b. Range
   c. Shielding
   d. Biological hazard(s)
E07: **IDENTIFY** the units used to measure radiation exposure or dose.
E08: **CONVERT** rem to millirem and millirem to rem.

Overview

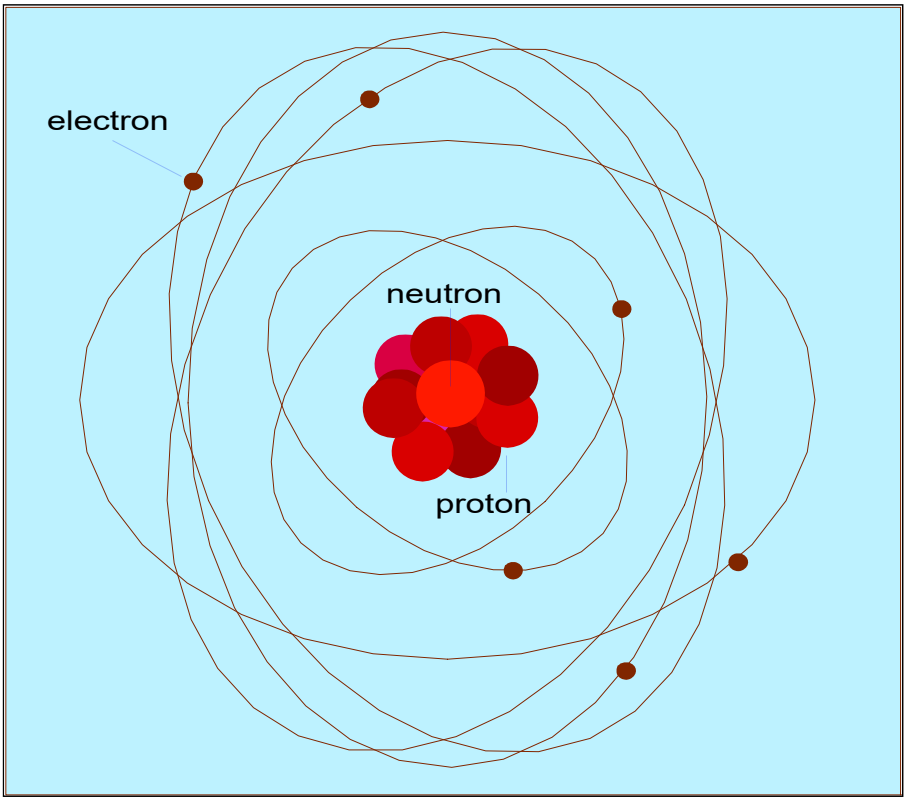
Nuclear science is truly a product of the 20th century. This module will discuss several nuclear science topics at a basic level appropriate for the radiological worker. These concepts are necessary for the worker to understand the nature of radiation and its potential effect on health. The topics covered include basic particles of the atom, types of radiation, and the definition of units used to measure radiation.

This module introduces the worker to basic radiological fundamentals and terms that are common in working with radioactive materials. After learning the fundamentals of radiation, radioactive material, and radioactive contamination, the worker will build from the basic to the more in-depth concepts presented in the other modules.

E01: Identify the three basic particles of an atom.

Atomic Structure

All matter consists of elements or a combination of elements. An element is a substance that cannot be split into anything simpler by ordinary chemical of physical means. The basic unit of an element is the atom. The atom is the smallest part of an element that still retains the properties of the element. The three basic particles of the atom are protons, neutrons, and electrons. The central portion of the atom is the nucleus. The nucleus consists of protons and neutrons. Electrons orbit the nucleus similar to the way planets orbit our sun.



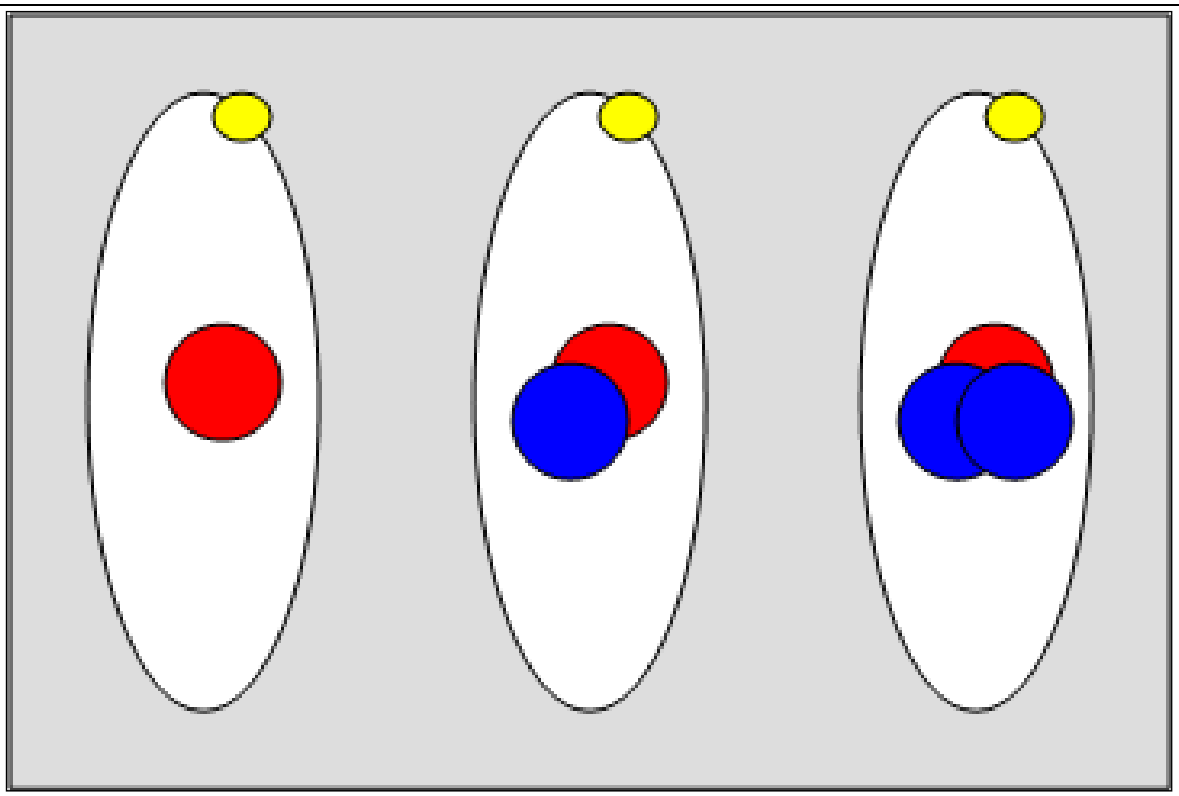
Protons

- Protons are located in the nucleus of the atom.
- Protons have a positive electrical charge.
- The number of protons in the nucleus determines the element.

Neutrons

- Neutrons are located in the nucleus of the atom.
- Neutrons have no electrical charge.
- The number of neutrons determines the nuclear stability.
- Atoms that have the same number of protons but different numbers of neutrons are called isotopes.
- Isotopes have the same chemical properties; however, the nuclear properties can be quite different.

The following depicts three of the isotopes of hydrogen:



Hydrogen Hydrogen (Deuterium) Hydrogen (Tritium)

NOTE: The common notation for describing isotopes is to list the atomic symbol for an element followed by its atomic weight. The atomic weight is the sum of protons and neutrons. For example, tritium has 1 proton and 2 neutrons, and is denoted as H-3. Additionally a superscript can also be used before the atomic symbol, again using tritium; ^{3}H.

Electrons

Electrons are in orbit around the nucleus of an atom.
Electrons have a negative electrical charge.
The number of electrons (compared to the number of protons) determines the electrical charge of the atom.

Charge of the atom

- *No charge (neutral)*
  If the number of electrons equals the number of protons, the atom is electrically neutral. The atom does not have a net electrical charge.

- *Positive charge (+)*
  If there are more protons than electrons, the atom is positively charged.

- *Negative charge (-)*
  If there are more electrons than protons, the atom is negatively charged.

- *Ion*
  An atom with any electrical charge whether positive or negative, is called an ion.

Basic Particles Summary

Particle	Location	Charge	Comments
Protons	Nucleus	+ positive	Number of protons determines the element. If the number of protons changes, the element changes.
Neutrons	Nucleus	No Charge	Number of neutrons determines nuclear stability. Different numbers of neutrons produce different isotopes of the element.
Electrons	Orbit nucleus	- negative	The number of electrons determines the electrical charge of the atom.

Stable and unstable atoms

Only certain combinations of neutrons and protons result in stable atoms. The unstable atom will try to become stable by giving off excess energy. Nuclear radiation is energy (particles or rays) emitted from the nucleus of unstable atoms. These unstable atoms are known as radioactive atoms.

E02:	Define radioactive material, radioactivity, radioactive decay/disintegrations, radioactive half-life and radioactive contamination.
E03:	Identify the units of measure used for radioactivity and contamination

Definitions

- **Radioactive material** is any material that contains radioactive atoms (unstable atoms that emit radiation.)
- **Radioactivity** is the process that takes place in the nucleus of radioactive atoms that cause the atoms to release energy. This is done by emitting radiation. This process is referred to as **radioactive decay**. A **disintegration** is a single atom undergoing radioactive decay.

Radioactivity and Contamination Units of Measure

Radioactivity is measured in the number of disintegrations radioactive material undergoes in a certain period of time.

- Disintegrations per minute (dpm)
- Disintegrations per second (dps)
- Curie (Ci)
  One curie equals:
  2,200,000,000,000 disintegrations per minute (2.2×10^{12} dpm)
  37,000,000,000 disintegrations per second (3.7×10^{10} dps)
  1,000,000 microcuries
- Microcurie (μCi)
  One microcurie equals:
  2,200,000 disintegrations per minute (2.2×10^{6} dpm)
  37,000 disintegrations per second (3.7×10^{4} dps)

Radioactive contamination is radioactive material that is uncontained and in an unwanted place. (There are certain places where radioactive material is intended to be.)

Contamination is measured per unit area or volume.

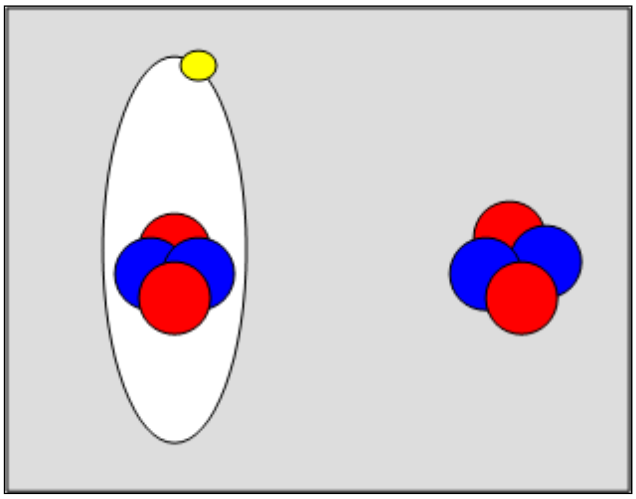
- dpm/100cm^2
- µCi/ml
- µCi/g

Radioactive half-life is the time it takes for one half of the radioactive atoms present to decay.

E04: Define Ionization

Ionization

An **Ion** is an atom with an electrical charge**. Ionization** is the process that occurs when a neutral atom loses an electron. Electrons will be removed from an atom if enough energy is supplied. The remaining atom has a positive (+) charge. The ionized atoms may affect chemical processes in cells. These ionization events may affect the cell's ability to function normally.



The positively charged atom and the negatively charged electron are called and "ion pair." Ionization should not be confused with radiation. Ions (or ion pairs) produced as a result of the interaction of radiation with an atom allow the detection of radiation.

E05: Distinguish between ionizing radiation and non-ionizing radiation

Ionizing radiation

Ionizing radiation is radiation that has enough energy to cause ionization (produce ions). Some devices also can cause ionization. Examples of devices that emit ionizing radiation are X-ray machines, accelerators, and fluoroscopes.

Note: It is important to note that exposure to ionizing radiation does not result in contamination of the worker. Radiation is a type of energy, and contamination is radioactive material that is uncontained and in an unwanted place.

Non-ionizing radiation

Electromagnetic radiation that doesn't have enough energy to ionize an atom is called "non-ionizing radiation."

Examples of non-ionizing radiation

- radar waves
- microwaves
- visible light

E06: Identify the four basic types of ionizing radiation and the following for each type

1. Physical characteristics
2. Range
3. Shielding
4. Biological hazard(s)

Four Basic Types of Ionizing Radiation

The four basic types of ionizing radiation of concern are alpha particles, beta particles, gamma or X-rays, and neutrons. The following tables summarize the pertinent information about the four radiations or emissions of interest.

Alpha Particles

Physical Characteristics	+2 charge Large mass (2 protons, 2 neutrons, 0 electrons) Largest of the four types
Method of ionization	Strips electrons from the atoms
Range	Very short (about 1-2 inches in air)
Shielding	Few inches of air Sheet of paper Dead layer of skin (outer layer)
Biological Hazards	No external hazard (dead layer of skin will stop alpha particles) Internally, the source of alpha radiation is in close contact with body tissue. It can deposit large amounts of energy in a small amount of body tissue.

Beta Particles

Physical Characteristics	Small mass Smallest of the three types which have mass -1 charge, known as B- or +1 charge, known as B+
Method of Ionization	Strips electrons from atom
Range	Short distance in air (one inch for tritium to 20 feet for phosphorous-32 or strontium-90) depending on initial energy
Shielding	Plastic Glass Safety glasses
Biological Hazard	Internal hazard (this is due to short range) Externally, may be hazardous to skin and eyes

Gamma Rays/X-rays

Physical Characteristics	No mass No charge Electromagnetic wave or photon Gamma rays differ from X rays primarily because of where they are formed. Gamma rays originate in the nucleus while X-rays are generated from particles interacting with electrons.

Method of Ionization	Transfers energy to the electrons of the atom.
Range	Range in air is very far Depending on its energy, a gamma may travel several hundred feet. Very high penetrating power since it has no mass and no charge.
Shielding	Lead Concrete Water
Biological Hazard	Whole body exposure. The hazard may be external and/or internal. This depends on whether the source is inside or outside the body.

Neutrons

Physical Characteristics	No charge. Has mass. $^1/_4$ of alpha and 2000 times that of beta
Method of Ionization	Transfers energy to the nucleus of the atom (indirect ionization)
Range	Range in air is very far Depending on the energy, neutrons may travel up to several hundred feet. High penetrating power due to lack of charge (difficult to stop)
Shielding	Water Concrete Plastic (high hydrogen content)
Biological Hazard	Whole body exposure The hazard is generally external

E07: Identify the units used to measure radiation exposure or dose.

Units of Measure for Radiation

Roentgen (R)

- Is a unit for measuring external exposure.
- Defined only for effect on air.
- Applies only to gamma and X-rays.
- Does not relate biological effects of radiation to the human body.
- Infrequently used in today's work environments.

Rad (Radiation absorbed dose)

- A unit for measuring absorbed dose in any material.
- Is defined for any material.
- Applies to all types of radiation.
- Does not take into account the potential effect that different types of radiation have on the body.

Quality Factor

The Quality Factor (QF) is used as a multiplier to reflect the relative amount of biological damage caused by the same amount of energy deposited in cells by the different types of ionizing radiation. Rem = rad x QF.

Quality Factors:

- Gamma/X-ray = 1
- Beta = 1
- Alpha = 20
- Neutron = 2-11 (depending on the energy)

Rem (Roentgen equivalent man)

- A unit for measuring dose equivalence.
- Is the most commonly used unit.
- Pertains to the human body.
- Takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation.

Radiation Dose and Dose Rate

Radiation dose rate is the dose per time.
Example

1. Radiation dose rate = dose/time.
2. Radiation dose equivalent rate = mrem/hr
3. Radiation absorbed dose rate = mrad/hr.

Radiation Units

Roentgen (R)	Rad (Radiation Absorbed Dose)	Rem (Roentgen Equivalent Man)
Unit for measuring exposure.	Unit for measuring absorbed dose in any material.	Unit for measuring dose equivalence (most commonly used unit).
Defined only for effect on air.	Defined for any material.	Pertains to human body.
Applies only to gamma and X-ray radiation.	Applies to all types of radiation.	Applies to all types of radiation.
Does not relate biological effects of radiation to the human body.	Does not take into account the potential effect that different types of radiation have on the body.	Takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation. Equal doses of different types of radiation (as measured in rad) can cause different levels of damage to the body (measured in rem).

E08: Convert rem to millirem and millirem to rem.

By now you have heard the term rem and millirem. What does the term "milli" mean? A milli is equal to one thousandth of a part. It takes 1,000 millirem to equal on rem. Consequently, 0.001 rem equals one millirem.

To convert rem to millirem, multiply the number of rem by 1000.

Example: 5 rem * 1000 millirem/rem = 5000 millirem (or mrem)
0.5 rem * 1000 millirem/rem = 500 mrem

To convert millirem to rem, divide the number of millirem by 1000.

Example: 3000 millirem / 1000millirem/rem = 3 rem
300 millirem / 1000 millirem/rem = 0.3 rem

Lesson 2: Biological Effects

Terminal Objective

The participant will be able to identify natural and manmade sources of radiation and the biological risks associated with radiation dose in accordance with lesson materials.

Enabling objectives:

E01: **IDENTIFY** the major sources of natural background and manmade radiation.
E02: **IDENTIFY** the average annual dose to the general population from natural background and manmade sources of radiation.
E03: **STATE** the method by which radiation causes damage to cells.
E04: **IDENTIFY** the possible effects of radiation of cells.
E05: **DEFINE** the terms "acute dose" and "chronic dose."
E06: **STATE** examples of chronic radiation dose.
E07: **DEFINE** the terms "somatic effect", "genetic effect" and "heritable effect."
E08: **STATE** the potential effects associated with prenatal radiation dose.
E09: **COMPARE** the biological risks from chronic radiation doses to health risks experienced by workers in industry and daily life.

Overview

The fact that ionizing radiation produces biological damage has been known for many years. We have gained most of our knowledge of these effects since World War II. In this module, we will discuss the potential for biological effects and risks due to ionizing radiation and put these potential risks into perspective when compared to other occupations and daily activities. With this information, it is hoped that employees will develop a healthy respect for radiation rather that fear or disregard.

We know more about the biological effects of ionizing radiation than most other environmental factors. Rather than just being able to base our information on animal studies, we have a large body of information available regarding exposures to humans. There are four major groups of people that have been exposed to significant levels of radiation.

The first group includes early radiation workers, such as radiologists. These workers received large doses of radiation before the biological effects were recognized. Since that time, standards have been developed to protect workers.

The second group is the more than 150,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki. Some of these survivors received doses estimated to be in excess of 50,000 mrem.

The third group of individuals is patients who have undergone radiation therapy for cancer and other diseases.

The fourth group is uranium mine workers.

Sources of Radiation

We live in a radioactive world and always have. In fact, the majority of us will be exposed to more ionizing radiation from natural background radiation than from our jobs.

E01: Identify the major sources of natural background and manmade radiation.

Natural Sources

Several sources of radiation occur naturally. The radiation emitted from these sources is identical to the radiation that results from manmade sources.

The four major sources of naturally occurring radiation exposures are:

- Cosmic radiation
- Sources in the earth's crust, also referred to as terrestrial radiation
- Sources in the human body, also referred to as internal sources
- Radon – a colorless, odorless gas emanating from radioactive elements in the earth's crust.

Cosmic Radiation (total average dose ~ 28 mrem/yr)

Cosmic radiation comes from the sun and outer space. It consists of positively charged particles and gamma radiation. At sea level, the average annual cosmic radiation dose is about 26 mrem. At higher elevations, the amount of atmosphere shielding cosmic rays decreases; therefore, the dose increases.

Sources in Earth's Crust (terrestrial) (total average dose ~ 28 mrem/yr)

There are natural sources of radiation in the ground (i.e., rocks and soil). Some of the contributors to terrestrial sources are the natural radioactive elements radium, uranium, and thorium. Many areas have elevated levels of terrestrial radiation due to increased concentrations of uranium or thorium in the soil.

Internal (total average dose ~ 40 mrem/yr)

The food we eat and the water we drink contains trace amounts of natural radioactive materials. These naturally occurring radioactive materials deposit in our bodies and cause internal exposure to radiation. Some naturally occurring radioactive isotopes include Sodium-24 (Na-24), Carbon-14 (C-14), Argon-41(Ar-41), and Potassium-40 (K-40). Most of our internal exposure comes from K-40.

Radon (total average dose ~ 200 mrem/yr)

Radon comes from the radioactive decay of uranium, which is naturally present in the soil. Radon is a gas. It can travel through the soil and enter through building foundation cracks. The greatest concentrations of indoor radon are found in basements. Radon emits alpha particles. It presents a hazard only when taken into the body (e.g., when inhaled).

Manmade Sources

The difference between manmade sources of radiation and naturally occurring sources is the origin of the source. The four top sources of manmade radiation exposures are:

- Tobacco products
- Medical radiation
- Building materials
- Domestic water supply

Tobacco products (average dose ~ 1300 mrem/yr)

Medical radiation sources (total average dose ~ 54 mrem/yr)

- X-rays (total average dose ~ 40 mrem/yr)
- X-rays are similar to gamma rays; however, they originate outside the nucleus.
- A typical radiation dose from a chest X-ray is about 10 mrem.
- Diagnosis and therapy (total average dose ~ 14 mrem/yr)
- In addition to X-rays, radioactive materials and radioactive sources are used in medicine for diagnosis and therapy.
- Building materials (total average dose ~ 7 mrem/yr)

Domestic water supply (total average dose ~ 5 mrem/yr)

Other minor contributors

Other contributors to dose include consumer products, industrial sources, and atmospheric testing of nuclear weapons.

• Ra-226, Pb-210	Luminous dials and gun sights.
• Po-210, Ra-226, Th-232	Tobacco products
• U, Pb, Po	Coal fired boilers
• U, Th	Masonry products
• K-40, U	Dentures
• Th	Rose-colored glasses
• U	Some pottery

E02: Identify the average annual dose to the general population from natural background and manmade sources of radiation.

Average Annual Dose

The average annual total effective dose equivalent to the general population (non-smokers) from naturally occurring and man-made sources is about 620 mrem.

E03: State the method by which radiation causes damage to cells.

Effects of Radiation on Cells

The human body is made up of many organ systems. Each system is made up of organs. Organs are made up of tissues. Specialized cells make up tissues. Ionizing radiation can potentially affect the normal function of cells.

Biological effects begin with the ionization of atoms. **The method by which radiation causes damage to human cells is by ionization of atoms in the cells.** Atoms make up the cells that make up the tissues of the body. Any potential radiation damage begins with damage to atoms.

A cell is made up of two principal parts, the body of the cell and the nucleus. The nucleus is like the brain of the cell. When ionizing radiation hits a cell, it may strike a vital part of the cell like the nucleus or a less vital part of the cell, like the cytoplasm.

Cell sensitivity

Some cells are more sensitive than others to environmental factors such as viruses, toxins, and ionizing radiation.

Actively dividing and non-specialized cells

- Cells in our bodies that are actively dividing are more sensitive to ionizing radiation

Cells that are rapidly dividing include blood-forming cells, the cells that line our intestinal tract, hair follicles, and cells that form sperm.
Less actively dividing and more specialized cells

- Cells that divide at a slower rate or are more specialized (such as brain cells or muscle cells) are not as sensitive to damage by ionizing radiation.

E04: Identify the possible effects of radiation on cells

Possible Effects of Radiation on Cells

Several things can happen when a cell is exposed to ionizing radiation. The following are

possible effects of radiation on cells.

- There is no interaction and therefore no damage
- Cells repair the damage and operate normally
- Cells are damaged and operate abnormally
- Cells die as a result of the damage

The body of most cells is made up primarily of water. When ionizing radiation hits a cell, it is most likely to interact with the water in the cell. One of the byproducts of radiation-induced ionization of water is hydrogen peroxide. Hydrogen peroxide can damage cell structures.

Ionizing radiation can also hit the nucleus of the cell. The nucleus contains the vital parts of the cell, such as chromosomes. The chromosomes determine cell function. When chromosomes duplicate themselves, the chromosomes transfer their information to new cells. Radiation may cause a change in the chromosome that does not affect the cell.

Damage to chromosomes and other cell structures can be repaired. In fact, our bodies repair a very large number of chromosome breaks every day.

Cell damage may not be repaired or may be incompletely repaired. In that case, the cell may not be able to function properly. It is possible that a chromosome in the cell nucleus could be

damaged but not be repaired correctly. If the cell continues to reproduce, this is called a mutation and may result in cancer.

At any given moment, thousands of our cells die and are replaced by normal functioning cells. However, the radiation damage to a cell may be so extensive that the cell dies prematurely.

E05: Define the terms "acute dose" and "chronic dose."

Acute and Chronic Radiation Dose

Potential biological effects depend on the type of radiation, how much and how fast a radiation dose is received. Radiation doses can be grouped into two categories: acute and chronic dose.

Acute Radiation Doses

High doses of radiation received in a short period of time are called **acute** doses. The body's cell repair mechanisms are not as effective for damage caused by an acute dose.

After an acute dose, damaged cells will be replaced by new cells and the body will repair itself, although this may take a number of months. Only in extreme cases, such as with the Chernobyl firefighters (500 rem), would the dose be so high as to make recovery unlikely.

X-ray Machines

It is possible that radiation exposure may be limited to a part of the body, such as the hands. There have been accidents, particularly with X-ray machines, in which individuals have exposed their fingers to part of the intense radiation beam. In some of these cases, individuals have received doses of millions of mrem to their fingers, and some individuals have lost their finger or fingers. It is important for individuals who work with X-ray or similar equipment to be trained in the safe use of this equipment.

Radiation Therapy

Radiation therapy patients receive high doses of radiation in a short period of time, but generally only to a small portion of the body (not a whole body dose). The skin and limited tissue of these patients may receive significant doses, but doses to the region of a tumor are many times higher.

Ionizing radiation is used to treat cancer in these patients because cancer cells are rapidly dividing and therefore sensitive to ionizing radiation. Some of the side effects of people undergoing radiation therapy are hair loss, nausea, and tiredness.

Probability of a Large Acute Dose

What is important to understand is that it takes a large acute dose of radiation before any physical effect is seen. These acute doses have occurred in Hiroshima/Nagasaki, and in a few radiation accidents, including Chernobyl. The possibility of a radiological worker receiving a large acute dose of ionizing radiation on the job is extremely low. Typically, radioactive materials are handled in small quantities that do not produce a large amount of radiation. Where there is a potential for larger exposures, many safety features are required.

E06: State examples of chronic radiation dose.

Chronic Radiation Doses

A chronic radiation dose is typically small dose exposures received repeatedly over a long period of time. Examples of chronic doses are the doses we receive from natural background every day of our lives and the doses received as a result of occupational exposures. The body's cell repair mechanisms are better able to repair a chronic dose than an acute dose. The body has time to repair damage because a smaller percentage of the cells need repair at any given time. The body also has time to replace dead or non-functioning cells with new, healthy cells.

Biological Effects of Radiation Exposure

EO7: Define the terms "somatic effect," "genetic effect," and "heritable effect"

Somatic Effects

Somatic effects refer to the effects radiation has on the individual receiving the dose. Somatic effects can best be described in terms of prompt and delayed effects as discussed below.

Prompt Effects

Although rare in the nuclear industry, large doses are typically acute radiation doses representing serious overexposures. The biological effects of large acute doses are as follows:

Prompt Biological Effects

Dose (rem)	Effect
0-25	None detectable through symptoms or routine blood tests.
25-100	Changes in blood.
100-300	Nausea, anorexia.
300-600	Diarrhea, hemorrhage, and possible death

Delayed Effects

Delayed effects may result from either a single large acute overexposure or from continuing low-level chronic exposure. Cancer in its various forms is the most important potential delayed effect of radiation exposure. Other effects noted include cataracts, life shortening and, for individuals exposed in the womb, lower IQ test scores.

Genetic Effects

Genetic effects refer to mutations due to radiation damage to the DNA of a cell.

Heritable Effect

A heritable effect is a physical mutation or trait that is passed on to offspring. In the case of heritable effects, the parent has experienced damage to some genetic material in the reproductive cells and has passed the damaged genetic material onto offspring.
Heritable effects from radiation have never been observed in humans but are considered possible. They have been observed in studies of plants and animals. Heritable effects have not been found in the 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki (these are children who were conceived after the atom bomb -- i.e., heritable effects). Studies have followed these children, their children, and their grandchildren.

Factors affecting biological damage due to exposure to radiation

- Total dose
  In general, the greater the dose, the greater the potential for biological effects.
- Dose rate (how fast)
  The faster the dose is delivered, the less time the body has to repair itself.
- Type of radiation
  For example, internally deposited alpha emitters are more damaging than beta or gamma emitters for the same energy deposited.
- Area of the body that receives a dose
  In general, the larger the area of the body that receives a dose, the greater the biological effect. Extremities are less sensitive than blood forming and other critical

organs. That is why the annual dose limit for extremities is higher than for a whole body dose that irradiates internal organs.

- Cell sensitivity
  The most sensitive cells are those that are rapidly dividing. Examples include blood cells, hair follicles, and the cells lining the gastrointestinal tract.
- Individual sensitivity
  Some individuals are more sensitive to environmental factors such as ionizing radiation. The developing embryo/fetus is the most sensitive, and children are more sensitive than adults are. In general, the human body becomes relatively less sensitive to ionizing radiation with increasing age. The exception is that elderly people are more sensitive than middle-aged adults due to the inability to repair damage as quickly (less efficient cell repair mechanisms).

E08: State the potential effects associated with prenatal radiation dose.

Prenatal Radiation Exposure

Although no effects were seen in Japanese children conceived after the atomic bomb, there were effects seen in some children who were in the womb when exposed to the atomic bomb radiation at Hiroshima and Nagasaki. Some of these children were born with a slightly smaller head size, lower average birth weight, and increased incidence of mental retardation. Some later showed lower IQ test scores and slower scholastic development, smaller physical size, and increased incidence of behavioral problems.

Sensitivity o*f* the Fetus

Embryo/fetal cells are rapidly dividing, which makes them sensitive to many environmental factors including ionizing radiation. The embryo/fetus is most susceptible to developing adverse health effects if exposed during the time period of 8 - 15 weeks after conception.

Factors for Potential Effects Associated with Prenatal Exposures

Many chemical and physical (environmental) factors are suspected *of* causing or known to have caused damage to a fetus, especially early in the pregnancy. Radiation, alcohol consumption, exposure to lead, and heat, such as from hot tubs, are only a few such factors.

E09: Compare the biological risks from chronic radiation doses to health risks experienced by workers in industry and daily life.

Risks in Perspective

Current radiation protection standards and practices are based on the premise that any radiation dose, no matter how small, can result in health effects such as cancer. Further, it is assumed that these effects are produced in direct proportion to the dose received (i.e., doubling the radiation dose results in a doubling of the risk of the effect). These two assumptions lead to a dose-response relationship, often referred to as the linear, no-threshold model, for limiting health effects at very low radiation dose levels.

However, it should be noted that this is a conservative assumption made in the absence of more conclusive evidence. Health effects (primarily cancer) have been observed in humans only at doses in excess of 10 rem delivered at high dose rates. Below this dose, estimation of adverse health effects is speculative. Risk estimates that are used to predict health effects in exposed individuals or populations are based on epidemiological studies of well-defined populations (e.g., the Japanese survivors of the atomic bombings in 1945 and medical patients) exposed to relatively high doses delivered at high dose rates. It is generally accepted that studies have not demonstrated adverse health effects in individuals exposed to small doses (less than 10 rem) delivered over a period of many years.

Risk from exposures to ionizing radiation

No increases in cancer have been observed in individuals who receive a dose of ionizing radiation at occupational levels. The possibility of cancer induction cannot be dismissed even though an increase in cancers has not been observed. Risk estimates have been derived from studies of individuals who have been exposed to high levels of radiation.

The risk of cancer induction from radiation exposure can be put into perspective. This can be done by comparing it to the normal rate of cancer death in today's society. The current rate of cancer death among Americans is about 20 percent. Taken from a personal perspective, each of us has about 20 chances in 100 of dying of cancer.

A radiological worker who receives 25,000 mrem over a working life increases his/her risk of cancer by 1 percent, or has about 21 chances in 100 of dying of cancer. A 25,000 mrem dose is a fairly large dose over the course of a working lifetime. The average annual dose to workers is less than 100 mrem, which leads to a working lifetime dose (40 years assumed) of no more than approximately 4,000 mrem.

Comparison of risks

The following table compares the estimated days of life expectancy lost as a result of

exposure to radiation and other health risks.

The following information is intended to put the potential risk of radiation into perspective when compared to other occupations and daily activities.

Estimated Loss of Life Expectancy from Health Risks

Smoking 20 cigarettes a day	6 years
Overweight (by 15%)	2 years
Alcohol consumption (U.S. average)	1 year
Agricultural accidents	320 days
Construction accidents	227 days
Accidents	207 days
Occupational radiation dose (1 rem/y), from age 18 to 65 (47 rem total)	51 days
Natural hazards (earthquakes, lightning, flood)	7 days
Local radiation	6 days

The estimates in the table indicate that the health risks from occupational radiation doses are smaller than the risks associated with normal day-to-day activities that we have grown to accept.

Acceptance of a risk:

Acceptance or rejection is a personal matter.

Acceptance or rejection should be based on an informed judgment.

Most scientific groups who have studied them generally consider the risks associated with occupational radiation doses acceptable as compared to other occupational risks. There are some scientific groups who claim that the risk is too high. DOE continues to fund and review worker health studies to address these concerns.

SUMMARY

In summary, the estimated risk associated with occupation radiation dose is similar to other routine occupational risks and much less than some risks widely accepted in society. National and international scientific groups consider the risk of work in a radiation environment within the normal occupational risk tolerance. However, acceptance of risk is an individual matter and is best made with accurate information. A radiological worker should understand the risk of working in a nuclear environment in relation to the risks of daily life and the risks presented by work in other professions.

The intent of this module is to give you the facts about radiation exposure risks and provide you with an opportunity to ask questions about radiation risk. It is hoped that understanding radiation risk and risk in general will help you to develop an informed and healthy respect for radiation, and that your understanding will eliminate excessive fear of or indifference to radiation.

Lesson 3: Radiation Limits and Administrative Control Levels

Terminal Objective:

The participant will be able to identify applicable State/Federal dose limits and NMI RPP administrative control levels in accordance with the lesson material.

Enabling Objectives:

EO1: **STATE** the purposes of administrative control levels.
EO2: **IDENTIFY** the State/Federal radiation limits and recommended administrative control level.
EO3: **STATE** the actions a female worker should perform *to* declare her pregnancy.
EO4: **IDENTIFY** the employee's responsibilities concerning radiation *dose* limits.

Overview

Historical Dose Limits:

1934	60 Rem/yr
1936	30 Rem/yr: 100 mrem/day
1950	15 Rem/yr: 50 mrem/day: 300 mrem/wk
1957	5 Rem/yr: 50 mrem/day: 300 mrem/wk

This module will address State/Federal dose limits and administrative control levels. State/Federal limits and administrative control levels have been established for the purpose of restricting occupational radiation exposures to levels of acceptable risk.

Radiation Dose Equivalent Limits & Administrative Control Levels

Basis for State/Federal dose limits

State/Federal has established radiation dose equivalent limits for general workers. These limits are based on guidance from national and international scientific groups and government agencies, such as:

- International Commission on Radiological Protection (ICRP)
- National Council on Radiation Protection and Measurements (NCRP)
- U.S. Environmental Protection Agency (EPA)

The radiation protection standards for all workers are described in 105 CMR 120.000, "Standards for Protection Against Radiation." These regulations apply to State/Federal, their contractors, and persons utilizing or working in facilities and include dose equivalent limits.

E01: State the purposes of administrative control levels

Facility Administrative Control levels for General Employees

The administrative control levels for workers are lower than the State/Federal limits and are set to:

Ensure the State/Federal limits and control levels are not exceeded.

Help reduce individual and total worker population radiation dose (collective dose).

E02: Identify the State/Federal radiation dose limits and recommended administrative control levels.

Dose Equivalent Limits and Controls

	State/Federal Dose Equivalent Limit (Federal) rem/yr	Dose Equivalent Limit (Administrative)rem/yr
Whole body	5	2
Lens of the eye	15	6
Extremity	50	20
Skin & other organs	50	20
Declared pregnant worker	0.5/gestation period	0.5/gestation period
Member of the public	0.1	0.1

NOTE:

1) The chart is based on limits and control levels for routine conditions. The limits and control levels are also based on the sum *of* internal and external dose. External dose is from sources outside the body. Internal dose is from sources inside the body.

2) The internal dose reported in a given calendar year is actually the projected dose the individual will receive over the next 50 years from intakes in that calendar year. Radioactive material may be inhaled, ingested, or absorbed through the skin or open wound.

Whole Body

The whole body extends from the top of the head down to just below the elbow and just below the knee. This is the location of most of the blood-producing and vital organs.

Limit and control levels

The State/Federal whole body dose equivalent limit is based on the sum of internal and external dose. The State/Federal radiation dose equivalent limit during routine conditions is 5 rem/year. Because the objective is to maintain personnel radiation dose well below the regulatory limits, the NMI RPP recommends an administrative control level during routine conditions of 2 rem/year.

Lens of the eye

State/Federal radiation dose equivalent limit for lens of the eye is 15 rem/year.

Extremities

Extremities include the hands and arms below the elbow, and the feet and legs below the knees.

Limit and control level

Extremities can withstand a much larger dose than the whole body because there are no major blood-producing organs located here. The State/Federal radiation dose equivalent limit for extremities is 50 rem/year.

Skin and other organs

The State/Federal radiation dose equivalent limit for skin and other organs is 50 rem/year.

E03: State the actions a female worker should perform to declare her pregnancy.

Declared Pregnant Worker: Embryo/fetus

After a female worker voluntarily notifies her employer in writing that she is pregnant, she is considered a declared pregnant worker. For the purposes of radiological protection of the fetus/embryo, State/Federal regulations contain a special limit for dose to the fetus/embryo. In addition, the State/Federal regulations recommend that the employer provide the option of a mutually agreeable assignment of work tasks, with no loss of pay or promotional

opportunity, such that further occupational radiation exposure is unlikely. This declaration may be revoked, in writing, at anytime by the declared pregnant worker.

State/Federal limit

For a declared pregnant worker who continues working as a radiological worker, the following radiation dose limit will apply. The dose equivalent limit for the embryo/fetus (during the entire gestation period) is 0.5 rem (500 mrem).

Measures must be taken to avoid substantial variation above the uniform exposure rate necessary to meet the 0.5 rem (500 mrem) limit for the gestation period. The State/Federal regulations recommend that efforts be made to avoid exceeding 50 mrem/month to the embryo/fetus of the declared pregnant worker. If the dose equivalent to the embryo/fetus is determined to have already exceeded 0.5 rem (500 mrem) when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

Members of the Public

State/Federal radiation dose equivalent limit is 0.1 rem (100 mrem/year.)

E04: Identify the employee's responsibilities concerning radiation dose limits.

Worker Responsibilities Regarding Dose Limits

It is each employee's responsibility to comply with State/Federal dose limits and administrative control levels. If you suspect that dose limits or administrative control levels are being approached or exceeded, you should notify your supervisor immediately.

Lesson 4: ALARA Program

Terminal Objective:

The participant will be able to identify the techniques for minimizing exposure to radiation and radioactive material in accordance with lesson materials.

Enabling Objectives:

E01: **STATE** the ALARA concept.
E02: **STATE** the NMI Site's policy for the ALARA program.
E03: **IDENTIFY** the responsibilities of Management, the Health Physics organization (HP) and the Radiological Worker in the ALARA Program.
E04: **IDENTIFY** the methods for reducing external and internal radiation dose.
E05: **STATE** the pathways by which radioactive material can enter the body.
E06: **IDENTIFY** methods a radiological worker can use to minimize radioactive waste.

Overview

State/Federal regulations establish dose limits and employers set administrative control levels for general employees. However, radiological workers and their management strive to keep radiation dose well below these limits. Radiological workers should always try to maintain their radiation dose As Low As Reasonably Achievable (ALARA).

This module is designed to inform the student of the concept of ALARA (As Low As Reasonably Achievable). This module discusses radiation hazards. Methods for reducing both external and internal doses from radiation and radioactive material are also discussed.

E01: State the ALARA concept.

ALARA Program

ALARA stands for As Low As Reasonably Achievable. ALARA is an approach to radiation safety that strives to manage and control doses (both individual and collective) to the work force and the general public to as low as is reasonable taking into account social, technical, economic, practical, and public policy considerations.

ALARA Concept

Because some risk, however small, exists from any radiation dose, all doses should be kept ALARA. ALARA includes reducing both internal and external radiation dose. The ALARA concept is an integral part of all site activities that involve the use of sources of ionizing radiation. ALARA is the responsibility of all employees.

E02: State the policy for the ALARA program.

NMI Management Policy for the ALARA Program

Personal radiation exposure shall be maintained As Low As Reasonably Achievable. Radiation exposure to the work force, public and the environment shall be controlled such that radiation doses are well below regulatory limits.

There is no radiation exposure without an overall benefit.

E03: Identify the responsibilities of Management, the Health Physics Organization (HP) and the Radiological Worker in the ALARA Program.

Responsibilities for the ALARA Program

The individual radiological worker is ultimately responsible for maintaining his/her radiation dose ALARA. However, management and Health Physics personnel also play an important role in the ALARA program. The following are some of the responsibilities of the three groups:

Management

- Create and support review and approval committees
- Investigate unusual exposure events
- Review personnel exposure data for workload plans
- Provide tools, equipment, and other materials
- Establish training requirements
- Encourage ALARA suggestions to reduce exposures

Health Physics (HP)

- Implement the ALARA program
- Provide radiological information
- Specify protective measures

- Provide an interface point
- Maintain and provide records of exposure
- Maintain calibrated instrumentation
- Evaluate need for temporary shielding

Radiological Workers

Each radiological worker is expected to demonstrate responsibility and accountability. This is accomplished through an informed, disciplined, and cautious attitude toward radiation and radioactivity.

- Comply with the requirements of work documents
- Know the radiological conditions in the work area
- Know previous exposure history
- Know exposure limits
- Participate in pre-and post-job meetings
- Use exposure reduction techniques
- Report radiological hazards to supervision or Health Physics personnel

E04: Identify methods for reducing external and internal radiation dose.

External and Internal Radiation Dose Reduction

Engineering controls should be the primary method to control exposure (e.g., enclosed hoods). Administrative controls are the next method to control exposures (e.g., postings). Personnel Protective equipment is the last method (e.g., respirators).

External Radiation Dose Reduction

Basic protective measures used to minimize external dose include:

- Minimizing time in areas with an external dose hazard
- Maximizing the distance from a source of radiation
- Using shielding whenever possible
- Reducing the amount of radioactive material (source reduction)

Methods for minimizing time

- Reducing the time spent in a field of radiation will lower the dose received by the workers.
- Plan and discuss the task thoroughly prior to entering the area.
- Use only the number of workers actually required to do the job.
- Have all necessary tools present before entering the area.
- Use mock-ups and practice runs that duplicate work conditions.
- Take the most direct route to the job site if possible and practical.
- Never loiter in an area controlled for radiological purposes.
- Work efficiently and swiftly.
- Do the job right the first time.
- Perform as much work outside the area as possible.
- When practical, remove parts or components to areas with lower dose rates to perform work.

Do not exceed stay times. In some cases, the Health Physics personnel may limit the amount of time a worker may stay in an area due to various reasons. This is known as "stay time." If you have been assigned a stay time, do not exceed this time.

Methods for maximizing distance from sources of radiation.

The worker should stay as far away as possible from the source of radiation.

- Stay as far away from radiation sources as practical given the task assignment. For point sources (such as valves and hot spots), the dose rate follows a principle called the inverse square law. This law states that if you double the distance, the dose rate falls to 1/4 of the original dose rate. If you triple the distance, the dose rate falls to 1/9 of the original dose rate.
- Be familiar with radiological conditions in the area.
- During work delays, move to lower dose rate areas.
- Use remote handling devices when possible.

Proper uses of shielding

Shielding reduces the amount of radiation dose to the worker. Different materials shield a worker from the different types of radiation.

Take advantage of permanent shielding, such as non-radiological equipment/structures.

- Use shielded containments when available.
- Wear safety glasses/goggles to protect your eyes from beta radiation, when applicable.
- Temporary shielding (e.g., lead or concrete blocks) can only be installed when proper procedures are used.
- Temporary shielding will be marked or labeled with wording such as "Temporary Shielding - Do Not Remove Without Permission from Health Physics."
- Once temporary shielding is installed, it cannot be removed without proper authorization.
- When evaluating the use of shielding, the estimated dose saved is compared to the estimated dose incurred during shield installation and removal.

Source Reduction

Source reduction is another method of reducing radiation doses. Source reduction often involves procedures such as flushing radioactive systems, decontamination, and removal of contaminated items. This is done to reduce the amount of radioactive materials present in/on a system because these materials can add to radiation levels in an area.

E05: State the pathways by which radioactive material can enter the body.

Internal Radiation Dose Reduction

Internal dose is a result of radioactive materials being taken into the body. Radioactive material can enter the body through one or more of the following pathways:

- Inhalation
- Ingestion
- Absorption through the skin.
- Absorption through wounds
- Injection through contaminated sharp objects

Reducing the potential for radioactive materials to enter the body is important. As previously stated, install or use engineering controls followed by administrative controls as the primary

methods to control internal exposure. PPE is the last choice for controlling internal exposure. In addition, the following are methods the worker can use.

- Wear respirators properly when required.
- Respirators should only be used by personnel qualified to wear them.
- Report all wounds or cuts (including scratches and scabs) to the appropriate facility specific organization before entering any area controlled for radiological purposes.
- Comply with the requirements of the controlling work documents.
- Do not eat, drink, smoke, or chew in Radioactive Materials Areas, Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas, as dispersible radioactive materials may be present.
- Do not apply cosmetics or OTC medicinal aids including but not limited to, lip stick, lip balm, cough drops, eye drops, throat sprays.
- Notify Health Physics personnel first if a potential inhalation of radioactive material has occurred. If an employee is suspected of being involved in a potential inhalation, nose and mouth swabs may be taken by a Health Physics Technician.

E06: Identify methods a radiological worker can use to minimize radioactive waste.

Radioactive Waste Minimization

One of the potential consequences of working with radioactive materials is the generation of radioactive waste. This radioactive waste must be properly disposed. Examples of radioactive waste include:

- Paper
- Gloves
- Glassware
- Rags
- Brooms
- Mops

The ALARA concept also applies to minimizing radioactive waste. This will reduce personnel exposure associated with the handling, packaging, storing, and disposing of radioactive waste. This will also reduce the resultant costs. It is very important for each radiological worker to minimize the amount of radioactive waste generated.

The following information identifies methods to minimize radioactive waste:

1) Minimize the materials used for radiological work.

   - Take only the tools and materials you need for the job into areas controlled for radiological purposes. Use only the materials required to clean the area. An excessive amount of bags, rags, and solvent adds to radioactive waste. This is especially important for contamination areas.
   - Unpack equipment and tools in a clean area. This will help to avoid bringing unnecessary material to the job site. This material can become radioactive waste if it is contaminated.
   - Use tools and equipment that are identified for radiological work when possible. Sleeve, or otherwise protect with a covering such as plastic, clean materials brought into contaminated areas.

2) Separate radioactive waste from non-radioactive waste.

   - Place radioactive waste in the containers identified for radioactive waste. Do not place radioactive waste in non-radioactive waste containers.
   - Do not throw non-radioactive waste, or radioactive material that may be reused, into radioactive waste containers.

3) Separate compactable material from non-compactable material.

4) Minimize the amount of mixed waste generated. Mixed waste is waste that contains both radioactive and hazardous materials.

5) Use good housekeeping techniques.

Lesson 5: PERSONNEL MONITORING PROGRAMS

Terminal Objective:

The participant will be able to identify the purpose, types, and worker responsibilities for each personnel monitoring program in accordance with lesson material.

Enabling Objectives:

EO1: **STATE** the purpose and worker responsibilities for each of the external dosimeter devices.
EO2: **STATE** the purpose and worker responsibilities for each type of internal monitoring method.
EO3: **STATE** the methods for obtaining radiation dose records.
EO4: **IDENTIFY** worker responsibilities for reporting radiation dose received from other sites and from medical application.

Overview

External exposure results from radiation that comes from radioactive material outside of the body. A "personnel dosimeter" is a device used to measure external dose. Internal dose is radiation that comes from radioactive material within the body. The whole body counter, chest/lung counter, and bioassay sampling are methods for measuring internal dose. Personnel monitoring for radiation dose involves assessing exposure due to external sources and internal sources. The various types of personnel monitoring devices and the employee's responsibilities concerning each will be discussed.

E01: State the purpose and worker responsibilities for each of the external dosimeter devices.

External Dosimetry

A personnel dosimeter is a device used to measure radiation dose. Different types of external dosimeters may be used. Health Physics personnel determine which type(s) are needed. The following information identifies the different types used at this facility.

Type	Purpose
TLD—Thermoluminescent Dosimetry	**Beta, Gamma, X-ray, Neutrons**
DRD - Direct Reading Dosimetry **SRD - Self-Reading Dosimetry** **ED - Electronic Dosimetry**	**Gamma and X-ray**
Special TLD's: Finger Rings **Pregnancy badges**	**Gamma and Beta**

Worker responsibilities for external dosimetry include the following:

- Wear dosimeters when required.
- Health Physics personnel identify the requirements.
- Check signs and radiological work permits (RWPs) for the requirements.
- Wear dosimeters properly.
- Primary dosimeters should be worn on the chest area. This area is on or between the neck and the waist. Health Physics procedures or work authorizations may also identify proper placement.
- Supplemental dosimeters are worn in accordance with site policy. This includes pocket, electronic dosimeters, extremity dosimetry, or multiple dosimeter sets.

Take proper actions if dosimeter is lost, damaged, contaminated, or off-scale. If in an area controlled for radiological purposes, take the following actions:

- Place work activities in a safe condition.
- Alert others.
- Immediately exit the area.
- Notify Health Physics personnel.

Store the dosimeter in the proper storage location. Return dosimeters for processing as directed. Personnel that fail to return dosimeters may be restricted from continued radiological work.

E02: State the purpose and worker responsibilities for each type of internal monitoring method.

Internal Monitoring

Whole body counters, chest counters, and/or bioassay samples may be used to monitor radioactive material in the human body. In some cases, the locations of radioactive material may be determined. An internal dose estimate may be performed based on these measurements.

Types of internal monitoring.

- Whole Body Counter - Gamma
- Chest/Lung Counters - Low Energy Gamma
- Bioassay - Alpha, Beta, Gamma

Worker responsibilities:

- Comply with monitoring schedules!

E03: State the methods for obtaining radiation dose records.

Methods for Obtaining Radiation Dose Records

Individuals who are monitored for exposure have the right to request reports of that exposure as follows:

- Individuals may submit a written request for a report on an annual basis. Detailed information concerning any individual's dose shall be made available to the individual upon request of that individual.
- Upon the request from an individual terminating employment, records of radiation dose shall be provided by the facility within 90 days. If requested, a written estimate of radiation exposure received by the terminating employee shall be provided at the time of termination.

E04: Identify worker responsibilities for reporting radiation dose received from other sites and from medical applications.

Notify Health Physics personnel prior to and following any radiation dose received at another facility so that dose records can be updated. You must also notify Health Physics of medical radioactive applications. This does not include routine medical and dental X-rays. This does include therapeutic and diagnostic radio-pharmaceuticals.

Lesson 6: Radiological Access Controls and Postings

Terminal Objective

The participant will be able to identify the purposes of a radiological work permit, list the information found on a radiological work permit, describe radiological postings, and list the requirements for entering, working in and exiting radiological areas.

Enabling Objectives

EO1: **STATE** the purpose of and information found on Radiological Work Plans (RWPs).

EO2: **IDENTIFY** the worker's responsibilities in using Radiological Work Plans.

EO3: **IDENTIFY** the colors and symbol used on radiological postings.

EO4: **STATE** the radiological and disciplinary consequences of disregarding radiological postings, signs and labels.

EO5: **DEFINE** the areas controlled for radiological purposes.

EO6: **IDENTIFY** the minimum or recommended requirements for entering, working in and exiting:

- Radiation Areas
- High Radiation Areas
- Very High Radiation Areas
- Radiography Areas
- Radioactive Material Areas
- Contamination Areas
- High Contamination Areas
- Airborne Radioactivity Areas

EO7: **STATE** the administrative and physical controls for access to HRA or VHRA.

Overview

Radiological Work Plans (RWP) used to control access into areas controlled for radiological purposes will be addressed. In addition, radiological requirements for working in these areas will be presented.

The previous modules discussed some important radiological topics from a theoretical perspective. The current module will discuss the application of this theory to control radiological work in a safe but efficient manner.

EO1: State the purpose of and information found on Radiological Work Plans (RWPs)

Radiological Work Plans (RWPs)

RWPs may be used to establish radiological controls for entry into areas controlled for radiological purposes. They serve to:

- Inform workers of area radiological conditions.
- Inform workers of entry requirements.
- Provide a record relating radiation doses to specific work activities.

The type of RWP used will depend on the radiological conditions in the area.

General Radiological Work Plans
This should be used to control routine or repetitive minor work activities such as tours and inspections or activities in areas with well-characterized, stable (unchanging) and predictable radiological conditions. General RWPs remain valid for the duration of the activity up to 1 year.

Job-specific Radiological Work Plans
This should be used to control work activities that are not routine or repetitive. The operation or work is performed in areas with unstable radiological conditions or where the conditions are subject to change. Job Specific RWPs are valid for the duration of a particular job.

An alternate formal mechanism, such as written procedures, work plan or other written authorization, may be used in lieu of an RWP. The alternate method should include the elements of an RWP.

Information found on the RWP

- Description of work.
- Work area radiological conditions. This information may also be determined from area radiological survey maps/diagrams or the radiological posting for that area.
- Dosimetry requirements
- Pre-job briefing requirements. Pre-job briefings generally consist of discussions among workers and supervisor(s) concerning various radiological aspects of the job. The purpose of the briefings should be to discuss radiological exposure and appropriate actions for unplanned situations.
- Required level of training for entry
- Protective clothing/equipment requirements
- Health Physics coverage requirements and stay time controls, as applicable

- Limiting radiological condition that may void the permit
- Special dose or contamination reduction considerations
- Special personnel frisking considerations
- Technical work document to be used, as applicable
- Date of issue and expiration
- Authorizing signatures and unique identifying designation or number

E02: Identify the worker's responsibilities in using Radiological Work Plans.

Responsibilities of the worker when using an RWP

- Workers must read and comply with the RWP requirements. Workers must acknowledge they have read, understood, and agreed to comply with the RWP prior to entering the area and after any revision to the RWP. This is done by signature or through electronic means.
- Health Physics personnel or a supervisor should be contacted prior to work if the RWP appears to be incorrect or is difficult to understand.
- Do not make substitutions for specified requirements.
- Report to Health Physics personnel if radiological controls are not adequate or are not being followed.

At any time, if there are questions or concerns regarding understanding of any of the information or "requirements specified in a RWP including the radiological conditions in your work area or you believe that the information on the RWP may be incorrect, STOP and ask your supervisor or appropriate HP personnel for direction and/or clarification.

YOU ARE RESPONSIBLE FOR UNDERSTANDING AND COMPLYING WITH RADIATION WORK PERMITS.

Radiological Postings

Radiological postings are used to:

- Alert personnel to the presence of radiation and radioactive materials.
- Aid in minimizing personnel dose.
- Prevent the spread of contamination.

In addition, the TN SRPARs specify requirements for personnel entry controls for High Radiation and Very High Radiation Areas.

E03: Identify the colors and symbol used on radiological postings

Posting Requirements

Areas and materials controlled for radiological purposes will be designated with a magenta or black standard three-bladed radiological warning symbol (trefoil) on a yellow background. Fixed barriers such as walls, rope, tape, or chain will designate the boundaries of posted areas. Where possible, the barriers will be yellow and magenta in color. The barriers should be placed to clearly mark the boundary of the radiological areas. Entrance points to radiologically controlled areas should have signs or postings stating the entry requirements, such as "TLD REQUIRED FOR ENTRY" or "RWP REQUIRED FOR ENTRY."

In some cases, more than one radiological condition may be present. The area shall be posted to include all of the radiological conditions that are present. In areas of ongoing work activities, the dose rate and contamination levels (or ranges of each) may be included in postings. The posting will be placed where it is clearly visible to personnel.

Worker Responsibilities

Before entering an area controlled for radiological purposes, read all of the signs. Since radiological conditions can change, the signs will also be changed to reflect the new conditions. A sign or posting that you saw one day might be replaced with a new one the next day.

Obey any posted, written or oral requirements including "Exit," "Evacuate," "Hold Point," or "Stop Work Orders." These requirements may be included in RWPs and work procedures, and may come from Health Physics personnel at the job site. Hold points are specific times noted in a procedure, work permit, etc., where work must stop for Health Physics or other evaluations.

Stop Work Orders are usually a result of:

- Inadequate radiological controls
- Failure to implement radiological controls
- Radiological hold point not being observed
- Changing or unexpected conditions

Report unusual conditions such as leaks, spills, or alarming area monitors to the Health Physics personnel. Be aware of changing radiological conditions. Be aware that others' activities may change the radiological conditions in your area. If any type of material used to identify a radiological hazard is found outside an area controlled for radiological purposes, it

should be reported to Health Physics personnel immediately.

E04: State the radiological and disciplinary consequences of disregarding radiological postings, signs, and labels.

Consequences of Disregarding Radiological Postings

It is each worker's responsibility to read and comply with all the information identified on radiological postings, signs, and labels. Disregarding any of these or removing/relocating them without permission can lead to:

- Unnecessary or excessive radiation dose
- Personnel contamination
- Disciplinary actions such as formal reprimand, suspension, or even termination

Areas Controlled for Radiological Purposes

The level of training a radiological worker has successfully completed determines the types of areas he/she can enter.

E05: DEFINE the areas controlled for radiological purposes.
E06: IDENTIFY the minimum or recommended requirements for entering, working in, and exiting.

- **Radiation Areas**
- **High Radiation Areas**
- **Very High Radiation areas**
- **Radiography Areas**
- **Radioactive Material Areas**
- **Contamination Areas**
- **Airborne Contamination Areas**

Radiation Areas (RAs)

RAs are any areas accessible to individuals in which radiation levels could result in an individual's receiving a deep dose equivalent in excess of 5 mrem/hr and less than or equal to 100 mrem/hr. This is established based on dose rates at 30 cm from the source of radiation.

Posting Requirements:

"CAUTION, RADIATION AREA"

Additionally, the posting may state:

"RWP AND TLD REQUIRED FOR ENTRY" **"RADIOLOGICAL WORKER TRAINING REQUIRED FOR ENTRY"**

Minimum requirements for unescorted entry should be:

- Radiological Worker Training.
- Personnel dosimeter.
- Worker's signature on the RWP, as applicable.

Minimum requirements for working in an RA

- Don't loiter in the area.
- Follow proper emergency response to abnormal situations.
- Avoid hot spots.

Hot spots are localized sources of radiation or radioactive material normally within facility piping or equipment. The radiation levels of hot spots exceed the general area radiation level by more than a factor of 5 and are greater than 100 mrem per hour on contact.

Posting (optional):

"Caution, Hot Spot"

Minimum requirements for exiting a RA:

- Observe posted exit requirements
- Sign-out on RWP or equivalent, as applicable

E07: State the administrative and physical controls for access to HRA or VHRA

High Radiation Areas (HRAs)
A High Radiation Area is any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem/hr (100 mrem/hr at 30 centimeters from the radiation source or from any surface that the radiation penetrates but less than or equal to 500 rad in one hour at a distance of 1m from the radiation source.

Posting Requirements:

"CAUTION" or "DANGER", "HIGH RADIATION AREA"

Additionally, the posting may state:

"RWP, TLD, SUPPLEMENTAL DOSIMETER", AND "RADIOLOGICAL WORKER TRAINING REQUIRED FOR ENTRY"

Unescorted entry into this area requires RW Training.

Very High Radiation Areas (VHRAs)
A Very High Radiation Area is any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

Very High Radiation Areas will be posted with a standard radiation symbol colored magenta (or black) on a yellow background, reading:

"GRAVE DANGER VERY HIGH RADIATION AREA"

Additionally the posting may state:

"SPECIAL CONTROLS REQUIRED FOR ENTRY"

Some HRAs and VHRAs only exist when machinery is energized, such as radiation producing devices. For example, a posting could be:

"High Radiation Area When Warning Light is On"

"Controlled Area When Warning Light is Off"

Minimum requirements for entering HRAs

- Radiological Worker Training.
- Worker signature on the appropriate Radiological Work Permit (RWP).
- Personnel and supplemental dosimeter.
- Survey meter(s) or dose rate indicating device available at the work area (may be required for certain jobs).
- Access control.
- A radiation survey prior to first entry.
- Notification of operations personnel.
- Administrative Control Levels (ACLs).
- Procedure review

Additional requirements can exist where dose rates are greater than 1 rem in an hour at 30 cm from the source or from any surface that the radiation penetrates. These should include:

Administrative Controls

- Determination of worker's current dose.
- Pre-job briefing, as applicable.
- Review and determination by the RSO regarding the level of Health Physics personnel coverage.

Physical Controls

- No controls shall be established in an HRA or VHRA that would prevent rapid evacuation of personnel.
- Access Points secured by control devices that energizes a visible or audible alarm

required by 105 CMR 120.

- A control device that prevents entry or upon entry causes the radiation level to be reduced below that level defining an HRA.
- An automatic device that prevents use or operation of the radiation source.
- Continuous direct or electronic surveillance.
- Additional measures to ensure personnel are not able to gain unauthorized or inadvertent access to Very High Radiation Areas.

Minimum requirements for working in HRAs - same as those for Radiation Area

Minimum requirements for exiting HRAs - same as those for Radiation Area

Access to VHRAs
Due to the extremely high dose rates in a VHRA, personnel access to these areas needs to be strictly monitored and controlled. Additional training would be required, as well as enhanced monitoring.

Consequences of violations of HRAs or VHRAs

- Excessive and unplanned personnel exposure
- Disciplinary action

Radiography Area
Radiography is a source of radiation exposure. Radiography is a technique to inspect welds and other equipment similar to taking X-rays. Radiography sources produce extremely high dose rates. Signs, barriers and announcements will warn workers of radiography operations. Stay as far away as practical during radiography operations

"CAUTION, RADIOGRAPHY, KEEP OUT"

Radioactive Materials Area (RMA)
RMA means any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in TN SRPAR's 1200-2. Radioactive materials may consist of equipment, components, or materials that have been exposed to contamination or have been activated. Sealed or unsealed radioactive sources are also included. Radioactive material may be stored in drums, boxes, etc., and will be marked appropriately.

Posting Requirements:

"CAUTION, RADIOACTIVE MATERIAL(S)"

Additionally the posting may state:

"RADWORKER TRAINING REQUIRED FOR ENTRY"
"TLD REQUIRED FOR ENTRY"

Exceptions to posting requirements

Any radiological area may be exempted from the posting requirements for periods of less than eight (8) continuous hours when placed under continuous observation and control of a Health Physics Technician. This individual must be knowledgeable of, and empowered to implement, required access and exposure control measures.

The following areas may be exempted from the radioactive material area posting requirements:

- Areas posted Radiation Area, High Radiation Area, Very High Radiation Area, Airborne Radioactivity Area, Contamination Area, or High Contamination Area.
- Areas in which each item or container of radioactive material is clearly and adequately labeled in accordance with 105 CMR 120 such that individuals entering the area are made aware of the hazard.
- The radioactive material consists solely of structures or installed components which have been activated.
- Areas containing only packages received from radioactive material transportation labeled and in a non-degraded condition need not be posted in accordance with 105 CMR 120 until the packages are surveyed.

Minimum requirements for unescorted entry should include:

Radiological Worker Training.
For entry into Radioactive Material Areas where whole body dose rates exceed 5 mrem/hour, the Radiation Area entry requirements will apply.

For entry into Radioactive Material Areas where removable contamination levels exceed the specified State/Federal limits, the Contamination Area entry requirements will apply.

Minimum requirements for exiting an RMA

- Follow egress instructions

Contamination Area

A Contamination Area is an area where removable contamination levels are, or are likely to be, greater than the limits specified in US NRC Reg. Guide 1.86, but do not exceed 100 times these levels.

Posting requirements include:

"CAUTION CONTAMINATION AREA"

Additionally, the posting may state:

"RWP AND RADIOLOGICAL WORKER (RW) TRAINING OR RW TRAINED ESCORT REQUIRED FOR ENTRY"

Unescorted entry requires RW training

High Contamination Area

A High Contamination Area is an area where contamination levels are, or are likely to be, greater than 100 times the Contamination Area limits. Posting requirements include:

"DANGER or CAUTION, HIGH CONTAMINATION AREA"

Additionally, the posting may state:

"RWP AND RADIOLOGICAL WORKER (RW) TRAINING REQUIRED FOR ENTRY"

Unescorted entry into this area requires RW training.

Airborne Radioactivity Area is an area where airborne radioactivity exceeds specified limits. Posting requirements include:

"CAUTION OR DANGER, AIRBORNE RADIOACTIVITY AREA:

Additionally the posting may state:

"RWP AND RADIOLOGICAL WORKER (RW) TRAINING REQUIRED FOR ENTRY"

Unescorted entry into this area requires RW training.

Minimum Requirements for Entering Contamination, High Contamination, and Airborne Radioactivity Areas without an Escort

- Radiological Worker training.
- Personnel dosimetry, as appropriate.
- Protective clothing and respiratory protection as specified in the RWP.
- Workers signature on the RWP, as applicable.
- Pre-job briefings, as applicable.

Minimum Requirements for Working in Contamination, High Contamination, and Airborne Radioactivity Areas

- Avoid unnecessary contact with contaminated surfaces.
- Secure equipment (lines, hoses, cables, etc.,) to prevent them from crossing in and

out of contamination areas.
- When possible, wrap or sleeve materials, equipment, and hoses.
- Place contaminated materials in appropriate containers when finished.
- Do not touch exposed skin surfaces. High levels of skin contamination can cause a significant skin dose. It may also lead to internal contamination with radioactive material.
- Avoid stirring contamination as it could become airborne.
- Do not smoke, eat, drink, or chew. Do not put anything in your mouth.
- Exit immediately if a wound occurs or if your protective clothing is compromised (e.g., becomes wet, torn, or otherwise compromised.)

Minimum Requirements for Exiting Contamination, High Contamination, and Airborne Radioactivity Areas

- Exit only at step-off pad.
- Remove protective clothing carefully. Follow posted instructions.
- Frisk or be frisked for contamination when exiting a contaminated area at the location provided by the Health Physics personnel. If personnel contamination is found, stay in the area, notify the Health Physics Technician, and minimize the potential for cross contamination (e.g., place a glove over a contaminated hand.)
- Survey all personal equipment prior to removal from the area.
- Ensure all tools and equipment have been surveyed prior to removal from the area.
- Observe RWP and control point guidelines.
- Use proper techniques to remove protective clothing.
- Do not smoke, eat, drink, or chew.
- Do not put anything in your mouth.

Lesson 7: Radiological Emergencies

Terminal Objective:

The participant will be able to identify the appropriate responses to a radiological emergency or alarm in accordance with approved lesson materials.

Enabling Objectives

E01: **State** the purpose and types of emergency alarms.
E02: **Identify** the correct responses to emergencies and alarms
E03: **State** the possible consequences of disregarding radiological alarms.
E04: **State** the site administrative emergency radiation dose guidelines.

Overview

- Monitoring systems are used to warn personnel when off-normal radiological conditions exist.
- Radiological workers must become familiar with these alarms and know the response to each. These responses will help to minimize exposure and personal contamination during off-normal conditions.
- This module discusses off-normal and emergency situations and the appropriate response to each. Radiological alarms associated with monitoring equipment will also be discussed.

E01: State the purpose and types of emergency alarms.
E02: Identify the correct responses to emergencies and alarms.

Emergency Alarms and Responses
Equipment that monitors radiation dose rates and airborne contamination levels is placed throughout radiological facilities. It is essential for radiological workers to recognize the equipment and the associated alarms and know the appropriate response.

Area Radiation Monitors (ARM)

Appropriate response

- Stop work activities -- Perform shutdown operations of equipment which can be done without delay
- Alert others
- Immediately exit -- proceed through the appropriate exit point without frisking
- Assemble in designated area
- Notify Health Physics personnel and facility supervision

Airborne Contamination Monitors / Continuous Air Monitors (CAMs)

Appropriate response

- Stop work activities -- Perform shutdown operations of equipment which can be done without delay
- Alert others
- Immediately exit to dress-out area -- proceed to the appropriate exit point.
- Doff anti-C and frisk if area is not airborne -- Doff anti-C clothing and frisk if the airborne contamination is not affecting the dress-out area - no elevated background.
- Notify Health Physics personnel and facility supervision

E03: State the possible consequences of disregarding radiological alarms.

Disregard for Radiological Alarms

Disregarding any of these radiological alarms may lead to:

- Possible excessive radiation dose
- Unnecessary spread of contamination.
- Unnecessary personal contamination.
- Disciplinary action

Radiological Emergency Situations

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. If an emergency arises during

radiological work, response actions may be necessary to ensure personnel safety.
Personnel injuries in areas controlled for radiological purposes.

Minor injuries

- If a minor injury occurs inside a radiological area, leave the area immediately.
- Follow normal exit procedures
- Notify Health Physics personnel so that the injury can be surveyed
- You may then report to the medical department or another area for treatment.

Actions may be completed in conjunction with each other.

Serious injuries

- The major consideration in the event of a serious injury in a radiological area is the immediate health of the individual rather than routine exiting procedures.
- In the event of a major injury, worker health takes precedence over contamination control.
- Every effort is made to control contamination, but the health and safety of the individual should not be jeopardized

Situations that require immediate exit from an area controlled for radiological purpose

- Lost or damaged dosimetry
- Off-scale DRDs or DRD reading 75% of full scale
- Torn anti-C clothing
- Radiological conditions have changed
- Radiation or CAM alarm
- At the direction of HP

An accidental breach of a radioactive system or spill of radioactive material. For radioactive spills involving highly toxic chemicals, workers should immediately exit the area without attempting to stop or secure the spill. They should then promptly notify Industrial Hygiene or the Hazardous Material team and Health Physics personnel.

For radiological spills - general response:

- Stop or secure the operation causing the spill, if it can be done safely
- Warn others in the area and notify Health Physics personnel
- Isolate the spill area, if possible
- Minimize individual exposure and contamination
- Secure unfiltered ventilation (fan, open windows, etc.)

For radiological spills - See and Flee response:

See the spill

Flee the spill area while warning others in the area to flee also. Avoid contact with the spill. Assist in ensuring that non-emergency personnel do not enter the vicinity of the spill.

Notify Supervisor or Health Physics personnel.

Considerations in Rescue and Recovery Operations
In extremely rare cases, emergency exposure to high levels of radiation may be necessary.

This is done to rescue personnel or protect major property. Rescue and recovery operations that involve radiological hazards can be very complex.

The type of response to these operations is generally left up to the official in charge of the emergency situation. The official's judgment is guided by many variables that include determining the risk versus the benefit of an action and deciding how best to implement the action.

No individual shall be required to perform a rescue action that might involve substantial personal risk. All personnel selected to provide emergency response shall be trained commensurate with the hazards in the area and required controls. They shall be briefed beforehand on the known or anticipated hazards to which they shall be subjected.

E04: State the site administrative emergency radiation dose guidelines

- The risk of injury to those individuals involved in rescue and recovery operations shall be minimized.
- Operating management shall weigh actual and potential risks to rescue and recover individuals against the benefits to be gained.
- Rescue action that might involve substantial personal risk shall be performed by volunteers.

Guidelines for Control of Emergency Exposures

Dose limit (Whole body)	Activity performed	Conditions
5 rem **10 rem** **< 25 rem**	All activities Protecting major property. Lifesaving or protection of large populations.	 Where lower dose limit is not practicable
> 25 rem	Lifesaving or protection of large populations.	Only on a voluntary bases to personnel fully aware of the risks involved

Lesson 8: Radioactive Contamination Control

Terminal Objective:

The participant will be able to identify the different types of radioactive contamination and identify the methods used to control the spread of radioactive contamination in accordance with lesson material.

Enabling Objectives

E01: **Define** fixed, removable and airborne contamination.
E02: **State** sources of radioactive contamination.
E03: **Identify** methods used to control radioactive contamination.
E04: **Identify** the proper use of protective clothing.
E05: **Identify** the purpose of personnel contamination monitors.
E06: **Identify** the normal methods used for decontamination.

Overview

Contamination control is one of the important aspects of radiological protection. Using proper contamination control practices helps to ensure a safe working environment. It is important for all employees to recognize potential sources of contamination and to use appropriate contamination control methods.

This module is designed to inform the worker about radioactive contamination and discuss methods used to control the spread of contamination.

Radioactive Contamination

Radioactive material is material that contains radioactive atoms. When radioactive material is properly contained, it still emits radiation and may be an external dose hazard, but it is not a contamination hazard. When radioactive material escapes its container, it is then referred to as radioactive contamination.

Note: Radiation is energy; contamination is a material.

Note: Radiation is the energy released from radioactive material – whether the material is in a wanted place or in an unwanted place (contamination)

E01: Define fixed, removable, and airborne contamination

Types of Contamination

Radioactive contamination can be fixed, removable, or airborne. Fixed contamination is contamination that cannot be easily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, etc.). Over time it may "weep," leach, or otherwise become loose or removable.

Removable contamination is contamination that can easily be removed from surfaces. Any object that comes in contact with it may become contaminated. It may be transferred by casual contact, wiping, brushing, or washing. Air movement across removable contamination could cause the contamination to become airborne.

Airborne contamination is contamination suspended in air.

Types of Radioactive Contamination

Types	Definitions
Fixed Contamination	Cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, etc.). Over time, may become loose or removable.
Removable Contamination	May be transferred by casual contact. Any object that makes contact with it may in turn become contaminated. Air movement across removable contamination may cause the contamination to become airborne.
Airborne Contamination	Airborne contamination is contamination suspended in the air.

Radioactive Contamination

Radiological work is required in areas and in systems that are contaminated by design (e.g., maintenance of valves in radioactive fluid systems). Regardless of the precautions taken, radioactive material can sometimes contaminate objects, areas, and people.

E02: State sources of radioactive contamination.

Sources of radioactive contamination
The following are some sources of radioactive contamination.

- Leaks or breaks in radioactive fluid systems.
- Leaks or breaks in air-handling systems for radioactive areas.
- Airborne contamination depositing on surfaces.
- Leaks or tears in radioactive material containers such as barrels, plastic bags or boxes.

Another common cause of contamination is sloppy work practices. These may lead to contamination of tools, equipment, and workers. Examples include:

- Opening radioactive systems without proper controls.
- Poor housekeeping in contaminated areas.
- Excessive motion or movement in areas of higher contamination.
- Improper usage of step-off pads and change areas.
- Violation of contamination control ropes and boundaries.

Hot Particles
Small, sometimes microscopic pieces of highly radioactive material may escape containment. These pieces are known as "hot particles." Hot particles may be present when contaminated systems leak or are opened. These particles may also be present when machining, cutting, or grinding is performed on highly radioactive materials. Hot particles can cause a high, localized radiation dose in a short period of time if they remain in contact with skin.

Indicators of Possible Contamination:
Radiological workers should be aware of potential radioactive contamination problems. Potential contamination problems should be reported to the Radiological Controls Organization.

Examples include:

- Leaks, spills, or standing water that is possibly from a radioactive fluid system.
- Damaged or leaking radioactive material containers.
- Open radioactive systems with no observable controls.
- Dust/dirt accumulations in radioactive contamination areas.
- Torn or damaged tents, glove bags or containments on radioactive systems.

E03: Identify methods used to control radioactive contamination.

Contamination Control Methods

Every radiological worker should perform work in such a manner as to minimize the generation of radioactive contamination and confine the spread of radioactive contamination to the smallest area possible. By controlling contamination, the worker minimizes the potential for internal exposure, and personnel contamination can be minimized. Examples of methods used to control the spread of radioactive contamination follow.

Administrative Controls

A sound maintenance program can prevent many radioactive material releases. The following list summarizes some of the ways to prevent spills and contamination spreading from occurring:

- Establish a solid routine maintenance program for operating systems to minimize failures and leaks that lead to contamination.
- Repair leaks as soon as identified to prevent a more serious problem.
- Establish adequate work controls before starting jobs.
- During pre-job briefings, discuss measures that will help reduce or prevent contamination spread. The agreed upon measures should be implemented by workers at the job site.
- Change protective gear (e.g., gloves) as necessary (typically as directed by Health Physics personnel) to prevent cross contamination.
- Stage areas to prevent contamination spread from work activities.
- Cover work area to minimize cleanup afterward.
- Cover piping/equipment below a work area to prevent dripping contamination onto cleaner areas.
- Cap contaminated pipes or systems when not in use.
- Prepare tools and equipment to prevent contamination.
- Bag or sleeve hoses and lines to prevent contamination.
- Cover/tape tools or equipment used during the job to minimize decontamination.
- Minimize the equipment and tools taken into and out of contamination areas.
- Use good housekeeping practices; clean up during and after jobs. "Good Housekeeping" is a prime factor in an effective contamination control program. Each radiological worker should keep his/her work area neat and clean to control the spread of contamination.
- Do not violate contamination area ropes or barricades.
- Use change areas and step-off pads as directed.

- Frisk materials out of contamination areas as directed by site procedures.
- Remove items from the contamination area using site procedures.
- Be alert for potential violations to contamination control procedures.
- Ensure ventilation systems are operating as designed (i.e., no unauthorized modifications).
- Radiological workers should always ensure that the proper entry, exit, and equipment control procedures are used to avoid the spread of contamination. Comply with procedures!

Engineering controls

Ventilation

Systems and temporary spot ventilation (e.g., temporary enclosures with HEPA filters) are designed to maintain airflow from areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas). A slight negative pressure is maintained on buildings/rooms/enclosures where potential contamination exists. High efficiency particulate air (HEPA) filters are used to remove radioactive particles from the air.

Containment Devices

Permanent and temporary containments are used for contamination control. Examples include vessels, pipes, cells, glovebags, gloveboxes, tents, huts, and plastic coverings.

Personal Protective Measures

Sometimes engineering controls are not sufficient to control contamination. Personnel protective measures, such as protective clothing and respiratory equipment, will be used at this point.

E04: Identify the proper use of protective clothing.

Protective clothing

Protective clothing is required for entering areas containing contamination and airborne radioactivity levels above specified limits to prevent personnel contamination. The amount and type of protective clothing required is dependent on work area radiological conditions and nature of the job. Personal effects such as watches, rings, jewelry, etc., should not be worn.

Full protective clothing generally consists of:

- Coveralls
- Cotton liners / latex or nitrile gloves
- Rubber gloves
- Booties (reusable or disposable)
- Rubber Shoe covers/ overshoes / totes
- Hood (possibly a respirator)

NOTE: Cotton glove liners may be worn inside rubber gloves for comfort (When included in RWP requirements) , but should not be worn alone or considered as a layer of protection against contamination.

Proper use of Protective Clothing

Inspect protective clothing for rips, tears, or holes prior to use. If you find damaged protective clothing, discard properly. Supplemental and multiple dosimeters should be worn as prescribed by the Radiological Control Organization. After donning protective clothing, proceed directly from the dress-out area to the work area. Avoid getting coveralls wet. Wet coveralls provide a means for contamination to reach the skin/clothing. Contact Health Physics personnel if clothing becomes ripped, wet, or otherwise compromised.

Respiratory Protection Equipment

This is used to limit the inhalation of radioactive materials. Respirator use and respiratory training are usually required for Airborne Radioactivity Areas.

This training course DOES NOT qualify a worker to wear respiratory protection equipment.

E05: Identify the purpose of personnel contamination monitors.

Contamination Monitoring Equipment

Purpose

Contamination monitoring equipment is used to detect radioactive contamination on personnel and equipment.

Types and Uses

- Hand Held Contamination Monitor / Count Rate Meter (CRM) / Frisker:
- Verify instrument is in service, has proper calibration, has been source checked, is set to proper scale (usually the X1 setting).

- Instruments provide both an audible response and have a visual indication of the count rate.
- Note background count rate at frisking station.
- Background for an alpha monitor should be $\leq$ 5 cpm, and, for a beta/gamma monitor < or equal to 300 cpm.
- Frisk hands before picking up the probe.
- Hold probe approximately half inch from surface being surveyed for beta/gamma and quarter inch for alpha.
- Move probe slowly over surface, approximately 1-2 inches per second.
- Perform frisk as required by posted instructions.

The whole body survey should take at least 2-3 minutes. If the beta-gamma and alpha instruments are separate then the time is 4-6 minutes. Carefully return the probe to holder. The probe should be placed on the side or face up to allow the next person to monitor. Monitor hands last. If the count rate increases during frisking, you may be contaminated. Move probe away from area of possible contamination to allow monitor to return to background counting, return probe to area and pause for 5-10 seconds over the area to provide adequate time for instrument response. If rate increase persists, notify Health Physics.

Personnel Contamination Monitor (PCMs)

PCMs are installed at the exits of certain radiological areas and are designed to make whole body contamination monitoring faster, easier and more effective. PCMs check your entire body for contamination (one side at a time).

The PCM-IB operates using 15 detectors. The PCM-2 operates by using 34 detectors.

Instructions are posted at each monitor that inform the user of the proper steps to follow when using the monitor. If an alarm sounds and or red lights illuminate indicating contamination, follow the posted instructions.

The PCMs are usually preferred over hand-held monitors for performance of monitoring.

Appropriate action if contamination is indicated:

- Remain in the area.
- Notify Health Physics personnel.
- Minimize cross-contamination (e.g., put a glove on a contaminated hand).

E06: Identify the normal methods used for decontamination

Decontamination

Decontamination is the removal of radioactive materials from locations where it is not wanted. If removable contamination is discovered, decontamination is the normal means of control.

Personnel Decontamination

Personnel decontamination is normally accomplished using mild soap and lukewarm water per Health Physics Organization instructions. More aggressive decontamination techniques are performed under the supervision of the Radiation Safety Officer.

Equipment and Area Decontamination

Equipment and area decontamination is the removal of radioactive materials from tools, equipment, floors, and other surfaces in the work area.

In some situations, decontamination is not possible.

Economic considerations: Cost of time and labor to decontaminate the location may outweigh the hazards of the contamination present.

Radiological conditions: Radiation dose rates or other radiological conditions may present hazards which exceed the benefits of decontamination. The decontamination activity may not be ALARA. Decontamination may increase the personnel doses instead of saving personnel doses.

Hazardous conditions: The physical or chemical conditions in the area may prevent entry for decontamination purposes.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIOLOGICAL SURVEYS

PROCEDURE NO: HP-NMI-05

Revision 1

October 2018

Table of Contents

A. Overview

This procedure describes the methods to be used to ensure contamination surveys are performed in accordance with requirements and standard industry practice.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. This procedure is applicable to all personnel and other contractors who are trained to perform contamination surveys in the course of their duties.

C. References

1. NRC 10 CFR 20, Standards For Protection Against Radiation

D. Contamination Survey Program

1. Contamination surveys shall be performed as directed by the RSO to:

    a. Document radiological conditions;

    b. Detect changes in radiological conditions;

    c. Detect the gradual buildup of radioactive material; and

    d. Identify and control potential sources of individual exposure to radiation and/or radioactive material.

2. Instruments and equipment used for contamination surveys shall be:

    a. Periodically maintained and calibrated in accordance with the manufacturers or applicable operating procedure requirements;

    b. Appropriate for the types, levels, and energies of the radiation encountered; and

    c. Appropriate for existing environmental conditions.

E. Direct Surveys for Total Contamination:

1. Preparation

    a. Ensure the instrument chosen is appropriate for the survey being performed.

    b. Inspect the instrument to ensure it is calibrated and in good condition.

    c. Perform instrument response checks and background determination.

    d. Turn the instrument ON.

    e. Perform a battery check if applicable.

    f. Audible response should be ON if applicable.

    g. Meter response (if applicable) should be set to SLOW, if applicable, for most surveys.

2. Performance of survey

    a. Review the previous survey of the area, if available.

    b. Observe the meter reading and note background.

    c. For beta-gamma surveys, hold the detector face within ½ inch of the surface being surveyed. For alpha surveys, hold the detector face within ¼ inch of the surface.

    d. Slowly scan the surface at a rate of 2 inches per second or less.

    e. Listen to the audible response. If an increase in count rate is detected, locate the area of highest contamination and record results.

    f. Keep the probe stationary and perform a measured count over the designated time interval with instruments with this capability.

F. Surveys for Removable Contamination

a. Perform instrument response checks and background determination.

b. Review the previous survey of the area, if available.

CAUTION: Gloves should be worn when collecting smears on potentially contaminated surfaces.

c. Collect a sufficient number of dry smears to adequately characterize the area.

i. If total contamination was measured, pay particular attention to those areas showing higher levels of total contamination.

ii. The area smeared should be approximately 100 cm^2.

d. Analyze the smear and record results.

2. Large Area Wipes

a. Large Area Wipes (LAWs) are used to check large areas that are expected to be clean for the presence of removable contamination.

b. A LAW can be of nearly any size, but should normally be limited to less then 20 m^2.

c. If detectable contamination is found on a LAW, it should be followed up with smears, as appropriate, to quantify contamination levels.

G. Performance of Dose Rate Surveys:

1. Preparation

a. Ensure the instrument chosen is appropriate for the survey being performed.

b. Inspect the instrument to ensure it is calibrated and in good condition.

c. Turn the instrument ON.

d. Perform a battery check if applicable.

e. Audible response should be ON if applicable.

f. Meter response (if applicable) should be set to SLOW for most surveys. FAST response should be used in radiation areas and other locations where minimization of exposure to the individual performing the survey is critical.

g. Ensure beta window is closed unless specifically taking beta readings.

2. Performance of general area survey

a. Review the previous survey of the area.

b. Turn the meter to the highest scale and enter the area.

c. Turn the selector switch to lower scale until a reading is obtained.

d. Holding the meter approximately waist high, move meter side to side while slowly walking around area.

e. Record readings in various locations.

f. Take readings near floor, over head, and on contact with surfaces to fully characterize the area.

3. Documentation of surveys

   a. The following information is the minimum required on radiation survey documentation:

      i. Date and time of survey

      ii. Name of surveyor

      iii. Location

      iv. Purpose of survey

      v. Instrument(s) used, calibration due date

      vi. Readings obtained

      vii. Signature of individual performing the survey

      viii. Signature of reviewer

   b. Radiation units

      i. Numbers appearing on the survey are assumed to be general area, in μR/hr, unless otherwise specified.

      ii. Contact readings should be noted by presence of a *.

H. Documentation of surveys

1. Conversion of units

   Convert cpm to dpm/100 cm^2 as follows:

$$dpm/100cm^2 = \frac{C_g - C_b}{e_i}$$, where

C_g = Gross counts per minute obtained while counting sample
C_s = Background counts per minute
e_i = 4π detector efficiency for the type and energy of radiation being measured

a. Direct surveys:

$$dpm/100cm^2 = \frac{C_g - C_b}{e_i\left(\frac{A}{100}\right)}$$, where:

C_g = Gross counts per minute obtained while counting sample
C_s = Background counts per minute
e_i = 4π efficiency of the detector for the type and energy of radiation being measured
A = Active area of the detector window

i. The "active area" is the area of the window, including portions that are covered by protective screen. This is the area used when the instrument is calibrated. The "open area" is the portion of the detector window that is not covered by protective screen. Unless specifically directed otherwise, the "active area" should be used.

ii. Direct surveys should be corrected to 100 cm^2.

b. Direct surveys in accordance with MARSSIM protocol:

$$dpm/100cm^2 = \frac{C_g - C_b}{e_t\left(\frac{A}{100}\right)}$$, where:

C_g = Gross counts per minute obtained while counting sample
C_s = Background counts per minute
E_t = The product of the 2π efficiency of the detector for the type and energy of radiation being measured and the assigned surface efficiency (See NOTE below)
A = Active area of the detector window

NOTE: The 2π efficiency shall be used if available. In the event the 2π efficiency is not available, estimate the total efficiency (Et) as:

$$E_t = 4\pi \cdot 2 \cdot assigned\ surface\ efficienc$$

i. Recommended values of assigned surface efficiency may be used are:

- 0.5 for beta emitters having E_{max} ≥400 keV
- 0.25 for beta emitters with E_{max} <400 keV and alpha emitters

ii. The "active area" is the area of the window, including portions that are covered by protective screen. This is the area used when the instrument is calibrated. The "open area" is the portion of the detector window that is not covered by protective screen. Unless specifically directed otherwise, the "active area" should be used.

iii. Direct surveys should be corrected to 100 cm^2.

2. The following information is the minimum required on radiation survey documentation:

   a. Date and time of survey

   b. Name of surveyor(s)

   c. Location and purpose

   d. Instrument(s) used, calibration due date, efficiency, background

   e. Contamination levels

   f. Signature of individual performing the survey

   g. Signature of reviewer

3. Contamination units

   a. Final results for direct surveys and smears should be recorded as "dpm/100 cm^2."

   b. LAWs should be recorded as "net cpm/LAW."

   c. Values less than the background value or MDA should be recorded as "<MDA"

I. Routine Survey Requirements

The RSO or designee shall develop a routine survey schedule.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

PERSONNEL MONITORING AND DECONTAMINATION

PROCEDURE NO: HP-NMI-06

Rev. 1

October 2018

Table of Contents

A. Overview

This procedure describes the requirements for monitoring of personnel for contamination and immediate actions in the event personnel contamination is suspected or confirmed. Initial personnel decontamination is also discussed.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. This procedure is applicable to all personnel and other contractors who are trained to use perform contamination surveys in the course of their duties.

C. References

1. NRC 10 CFR 20, Standards For Protection Against Radiation

2. NRC Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors.

3. HP-NMI-05, Radiological Surveys

D. Personnel Contamination Monitoring Requirements

1. In the event of a personal injury or other emergency, do not perform any steps below if it will delay first aid or emergency response.

2. Personnel exiting areas having the potential for removable contamination shall be monitored as appropriate for contamination prior to entering unrestricted areas. Such monitoring is required to:

    a. Detect and prevent the spread of contamination

    b. Avoid unnecessary radiation dose to the skin

    c. Detect possible intake of radioactive material.

3. The following minimum requirements shall be implemented:

a. Personnel who perform invasive work under a specific RWP in a Contamination Area, Airborne Radioactivity Area, or Radioactive Material Area where dispersible forms of radioactive material are present shall perform a whole body frisk.

    i. If background radiation levels preclude monitoring at the boundary, it is permissible to monitor the hands, feet, and face upon exit. The individual shall then proceed directly to the nearest monitoring station for whole body monitoring.

    ii. If another similarly posted area will be immediately entered, it is permissible to monitor the hands, feet, and face upon each exit. Upon final exit, the individual shall perform a whole body frisk.

E. Monitoring Instructions

1. Hand-held contamination monitors (friskers)

    a. These instruments shall be response checked daily when in use.

    b. Alarming instruments should be set to alarm at twice background.

    c. Inspect the instrument. Ensure it is calibrated, turned on, and shows no obvious signs of damage.

    d. Ensure the scale selector switch is set to the lowest scale.

    e. Ensure the audible response is turned ON. If there is a volume control, turn the volume all the way up.

    f. Frisk hand prior to picking up the probe.

    g. Maintain a distance of less than ½ inch (beta & gamma) or less than ¼ inch (alpha) while frisking.

    h. Moving the probe at a speed of less than 2 inches per second, monitor the whole body. Pay particular attention to the hands, feet, face, chest, abdomen, back, knees, and thighs.

    i. Listen to the audible response. If an increased count rate is noted, stop and locate the source of contamination.

        i. If none is found, continue with frisking.

ii. If contamination is found, STOP and notify Health Physics personnel.

F. Initial Response to Personnel Contamination

1. An individual shall be considered contaminated if:

    a. Contamination above the limits contained in NRC Regulatory Guide 1.86 is detected on the skin, hair, or personal clothing.

    b. Any contamination above background should be removed to the extent practicable for ALARA purposes. If contamination above background is detected contact the RSO to determine if further decontamination efforts are warranted.

CAUTION: Decontamination or removal of clothing that may raise modesty concerns should be done only by an individual of the same gender. In any event, such activities should never be performed by a single individual. Always contact supervisory or management personnel prior to clothing removal or skin decontamination of a sensitive nature.

NOTE: The steps below are generic in nature. The RSO, HP Supervisor, or Project RSO may authorize alternative methods to remove contamination based on the specific situation.

    c. If contaminated clothing is detected:

        i. Attempt to remove the contamination using tape or by wiping, as appropriate.

        ii. If contamination cannot be removed, then carefully remove the contaminated clothing so as not to spread contamination. Retain the clothing for analysis, if requested by RSO.

    d. If skin contamination is detected:

        i. Attempt to remove with tape or by wiping.

        ii. Use damp cloths or absorbent paper. Do not scrub or rub aggressively, as that may cause the contamination to become embedded in the pores of the skin.

        iii. If wiping is unsuccessful, attempt to remove the contamination using warm soapy water and a soft brush. Do not attempt more than once.

iv. If skin irritation or reddening develops, stop decontamination efforts and notify the RSO.

e. If contaminated hair is detected:

i. Attempt to remove by washing, or

ii. If the individual has given permission, carefully cut off the contaminated hair.

f. Do not attempt to decontaminate a contaminated wound that requires medical attention. Qualified medical personnel shall be consulted.

G. Follow-up Actions for Personnel Contamination

1. If the initial contamination reading was greater than 10,000 cpm, then forward to RSO for initial skin dose assessment.

2. If not already known, investigate the source of the contamination.

a. Interview the individual.

b. Perform contamination surveys of the work area and other areas that may have been traversed.

c. Document the personnel contamination using Attachment 1.

3. If a contaminated individual cannot be decontaminated to background levels, notify the RSO. The RSO shall:

a. Investigate the possibility of inhaled or ingested radioactive material;

b. Consult medical personnel when skin doses exceed 1 rem; or

c. Authorize the individual to leave the site, with specific instructions.

d. If a contaminated individual is authorized to leave the site:

i. Discuss the matter with the individual

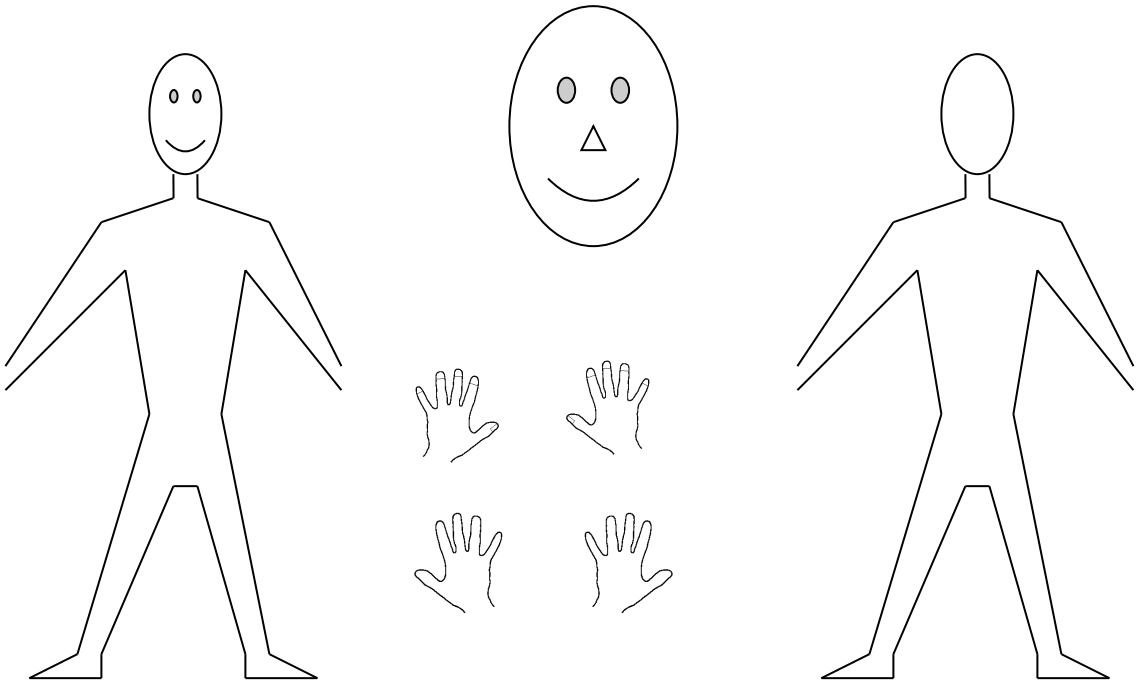
ii. Sign a written authorization with instructions. Give a copy to the individual and file the other. Ensure the individual signs the file copy indicating he/she understands the requirements.

H. Attachments

1. Attachment 1: Personnel Contamination Event

Attachment 1: Personnel Contamination Event

Date & Time of Event:			**Individual Affected:**			**SSN:**	
Type of Contamination:	☐ **Skin** ☐ **Personal clothing** ☐ **Hair** ☐ **Company-issued clothing**						
Location of Event:							
RWP:		**Job/Task:**					
Describe the Event (use additional sheets as necessary)**:**							
Contaminated Area:		**Initial dpm/100 cm^2:**		**First Decon:**		**Second Decon**	
Contaminated Area:		**Initial dpm/100 cm^2:**		**First Decon:**		**Second Decon**	
Contaminated Area:		**Initial dpm/100 cm^2:**		**First Decon:**		**Second Decon**	
Indicate location(s) and level of contamination (before decontamination) below:							



Additional Information:	
Instructions to Affected Individual:	
Individual Sign/Date:	**HP Sign/Date:**
RSO: Skin dose assessment required? ☐ **Yes** ☐ **No**	**RSO Sign/Date:**

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIOLOGICAL POSTING AND LABELING

PROCEDURE NO: HP-NMI-07

Rev. 1

October 2018

Table of Contents

A. Overview

The purpose of this procedure is to provide instruction for the posting of radiological areas, equipment, and material. This procedure also identifies the requirements for documenting and inspecting these posted areas.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

1. Health and Safety Plan – Appendix A, Radiation Protection Program

2. NRC 10 CFR 20, Standards For Protection Against Radiation

3. HP-NMI-02, Definitions

D. Postings

1. The standard radiation symbol depicted in Attachment 4 shall be used for posting and labeling. The symbol shall use the colors magenta, purple, or black on yellow background.

2. Use results from radiological surveys as the basis for all radiological posting, labeling, and access control measures. For areas not routinely accessed and the radiological conditions could have changed, surveys should be performed prior to personnel entry.

3. RSO may authorize the use of radiological data from existing surveys in lieu of a new survey.

4. Routine survey data shall be used as a means to verify the adequacy of existing controls.

5. All signs, labels, rope, tape, chain, ribbon, etc., used as visual indicators of the presence of radiological hazards shall be in accordance with Attachments 1 through 6.

E. Physical Controls

1. Using current radiological survey data, compare measured or estimated radiological conditions to posting criteria in Attachment 1 and 4; and determine the type of postings appropriate for the area and the hazards involved.

2. Determine if barriers are required for access control to the area.

3. Identify locations at which barriers will be required and potential access/egress points to establish access control. Guidance located in Attachments 3.

4. Determine if collection containers for used protective clothing and equipment are needed.

5. Obtain materials required to establish and post access/egress point.

6. Access/egress area shall have sufficient room for location of collection containers, if required.

7. Consider the numbers of personnel that will be entering or leaving the area.

8. Place stanchions, rope, tape, chain, ribbon, etc., to establish the physical boundaries of the area.

9. Post with entry requirements (Attachment 4).

10. Place step-off pads outside of barrier at access/egress point, if necessary.

11. Create a movable barrier such as a rope, chain, ribbon, etc., across access/egress point if no door/barrier exists.

    WARNING: DO NOT establish any control that would prevent the rapid exit of personnel from the area under emergency conditions.

12. It is not necessary to post sections of boundaries that consist of permanent structural barriers (i.e., walls, buildings, structures, etc.).

13. Place a sufficient number of signs/labels, etc., to clearly indicate to personnel the conditions within the barriers. As a minimum, place a sign at each access point and at least one sign on each side of bounded area where personnel could likely enter.

14. If postings or barricades must be moved to facilitate the removal or transfer of equipment or material, move the posting or barricade and:

    a. Replace the moved posting/barricade with temporary posting/barricade, such as rope or tape with a sign.

    b. Return permanent posting/barricades when removal or transfer process is complete.

       NOTE: Areas may be accepted from the temporary posting/barricade requirements for periods of less than 8 hours when placed under continuous observation and control of Health Physics Staff.

15. Notify RSO if areas for which controls have been established are new or if area posting and/or access control requirements have changed.

16. Verify, by radiological survey, that radiological conditions at new or relocated boundaries are adequate for the affected area.

F. Labeling

1. Ensure that each container of radioactive material bears a durable, clearly visible label bearing the radiation symbol and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL."

2. The label must also provide sufficient information (such as the radionuclide(s) present, an estimate of the quantity of radioactivity, the date for which the activity is estimated, radiation levels, etc) to permit individuals handling or using the containers, or working in the vicinity of the containers, to take precautions to avoid or minimize exposures (See Attachment 5).

3. Labeled containers should be stored in posted Radioactive Materials Areas or be under the surveillance of a qualified Radiation Worker.

4. Refer to Attachment 2 for additional labeling guidance.

G. Exceptions to Labeling Requirements

1. Containers holding radioactive material in quantities less than the quantities listed in Appendix C to 10 CFR 20 do not require labels.

2. Containers holding radioactive material in concentrations less than those specified in Table 3 of Appendix B to 10 CFR 20 do not require labels.

3. Containers attended by an individual that takes the precautions necessary to prevent the exposure of individuals in excess of the established limits do not require labels.

4. Containers in transport and packaged and labeled in accordance with U.S. DOT regulations.

NOTE: "In transport" means the containers are loaded or being loaded onto a vehicle in preparation for shipment, are en route, are temporarily unloaded for purposes of consolidating loads on vehicles ("transship"), or have been unloaded and have not yet been surveyed upon receipt.

Attachment 1

Required Postings

Radiological Condition	Required Posting
An area, access to which is limited for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials	Restricted Area
Any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.	Radiation Area RWP Required For Entry
Any room, enclosure or operating area where there exists loose surface contamination at levels between 200 dpm/100cm^2 and 20,000 dpm/100cm^2.	Contamination Area RWP Required For Entry
Any Soil contamination is radioactive material mixed within media (e.g. soil) at levels exceeding natural background. Contamination in these areas may be well below the levels required for Contamination Area posting but require marking to prevent events involving spreading contamination. In the event soil contamination exceeds the limits for Contamination Area, it will be posted as such and appropriate access-control measures will apply.	Soils Contamination Area
Any room, enclosure or operating area where there exists loose surface contamination at levels greater than 20,000 dpm/100cm^2.	High Contamination Area RWP Required For Entry
A room, enclosure, or area in which airborne radioactive materials exist in concentrations: (1) In excess of the derived air concentrations (DACs) specified in appendix B, to 10 CFR 20.1001 - 20.2401, or (2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours. (e.g. >25% DAC) NOTE: The RSO shall be notified prior to the posting of "Airborne Radioactivity Area"	Airborne Radioactivity Area RWP Required For Entry
If not otherwise posted, any room, enclosure, open area, or surface where there exists fixed contamination at levels equal to or greater than 1,000 dpm/100cm^2	Radioactive Material(s)

Attachment 1

Required Postings

Any room, open area or enclosure in which radioactive material is used or stored. Each room, area or enclosure in which there is used or stored an amount of radioactive material exceeding 10 times the quantity of such material specified in Appendix C to Part 20 shall be posted.	Radioactive Material(s)

Attachment 2

General Guidance - Postings And Labels

1. Only approved postings, labels, signs and symbols shall be used for posting and labeling of Radiological Areas and Radioactive Materials.

2. Radiological Areas shall be clearly and conspicuously posted.

3. Postings and labels shall be securely affixed and located such that they can be expected to remain in place under normal environmental conditions in the posted location.

4. Posting shall be completed prior to commencement of work, maintained current and updated periodically when changes in radiological conditions occur, and shall be removed as soon as possible when no longer valid.

5. Boundary posting shall be placed on sides of radiological areas that are likely to be entered by personnel. (It is not necessary to post solid walls if the other side contains a radiological area.)

6. Each area boundary shall be posted with area conditions if personnel could encounter that barrier in their pathway through the work area. At least one sign should be visible from any normal avenue of approach.

7. Postings shall be mounted on chains, ropes, stanchions, walls, doors, fences, or other durable structures.

8. Signs shall not be placed such that they will be blocked from view during normal operations.

9. Inserts, when used on postings, shall contain pertinent information about the requirements for entry into the area or about the radiological area.

10. Posting may be used to reflect potential or intermittent radiological conditions.

11. An area in a posted radiation/contamination area in which the level of radiation/contamination is significantly greater than the adjacent area, should have additional postings.

Attachment 2

General Guidance - Postings And Labels

12. Equipment that is internally contaminated or potentially contaminated in an area that is not otherwise posted, shall be labeled (e.g., “Caution: Internal Contamination” or “Potential Internal Contamination”).

13. Containers of Radioactive Materials shall be clearly labeled “Caution Radioactive Material”. A sufficient number of labels shall be used such that the container’s contents can be clearly identified.

Attachment 3

Establishing Physical Access Controls

1. The number of access and egress points for an area requiring posting shall be kept to a minimum.

2. Area boundaries shall be clearly identified with rope, tape, chain, ribbon, etc., if existing structural barriers cannot be used. Structural boundaries shall be used as much as possible.

3. It is not necessary to erect physical barriers to identify the boundaries of areas that are not accessible to personnel.

4. Appropriate signs shall be placed intermittently along the boundary of an area (e.g., fences, barricades, ropes, tapes, etc.) At least one sign shall be placed on each side of an area boundary, and a sign should be visible from any normal avenue of approach. Rope, tape, chain, ribbon, or similar barrier material used to designate radiological areas shall be yellow and magenta in color.

5. Radiological postings and barriers **SHALL NOT** be placed in a manner that interferes with the operation of emergency exits.

6. Rope, chain, or ribbon shall not be attached to operating handles, valves or operating components.

7. Access/egress points shall not be in locations offering threats to worker safety.

8. Frisking stations shall be located as close as possible to egress points from Contamination and Airborne Radioactivity Areas.

Attachment 4

Radiological Postings

Examples of radiological postings and signage are provided to achieve uniformity and consistency for posting areas with known or potential radiological conditions.

Standard Radiological Sign:

Radiation Area - shall be posted with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIATION AREA" as a minimum.

Airborne Radioactivity Area - shall be posted with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, AIRBORNE RADIOACTIVITY AREA" or "DANGER, AIRBORNE RADIOACTIVITY AREA" as a minimum.

Contamination Area - shall be posted with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, CONTAMINATION AREA" as a minimum.

Soils Contamination Area - shall be posted with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, SOILS CONTAMINATION AREA" as a minimum.

Radioactive material rooms or areas in which there is used or stored an amount of radioactive material exceeding 10 times the quantity of such material specified in Appendix C to 10 CFR part 20 - shall be posted with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIOACTIVE MATERIAL(S)" or "DANGER, RADIOACTIVE MATERIAL(S)" as a minimum.

Attachment 4

Radiological Postings

Fixed Contamination – If not otherwise posted, areas or surfaces with fixed contamination shall be conspicuously posted with a sign and/or label bearing the radiation symbol and the words “CAUTION, RADIOACTIVE MATERIAL(S)" or "DANGER, RADIOACTIVE MATERIAL(S)" as a minimum.

Attachment 5

Radioactive Material Label

Radioactive Material Label (example)

CAUTION

RADIOACTIVE MATERIAL

==========

DESCRIPTION OF MATERIAL:

_____ Gross Weight (lbs)

NUCLIDE DATA

_____ pCi/g U-238

_____ pCi/g _____ (other)

==========

SPECIAL INSTRUCTIONS

_____ _____

BY DATE

==========

Attachment 6

Ranking Of Radiological Posting Based on Hazard

RESTRICTED AREA

RADIOACTIVE MATERIAL(S)

SOILS CONTAMINATION AREA

CONTAMINATION AREA

HIGH CONTAMINATION AREA

AIRBORNE RADIOACTIVITY AREA

RADIATION AREA

VERY HIGH RADIATION AREA

CONTACT HEALTH PHYSICS PRIOR TO ENTRY

NOTIFY HEALTH PHYSICS BEFORE REMOVING ANY MATERIAL FROM THIS AREA

EATING, DRINKING, CHEWING, SMOKING PROHIBITED

KEEP OUT

NOT AN ENTRANCE

EXIT AT SOP ONLY

RWP REQUIRED FOR ENTRY

FRISK REQUIRED UPON EXIT

NOTE: This is not intended to be all-inclusive. Special conditions may require specific inserts not listed here. The above inserts are intended to be used for routine postings; additional posting may be used as necessary.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIATION EXPOSURE LIMITS & MONITORING

PROCEDURE NO: HP-NMI-08

Revision 3

October 2018

Table of Contents

A. Overview

This procedure contains the limits for personnel exposure to ionizing radiation and guidance for issuing, retrieving, and changing external dosimeters.

External dosimeters are the primary means of measuring personnel radiation exposure from external sources. External dosimeters are rugged under most conditions but are susceptible to damage if handled, packaged, stored, or shipped improperly. Proper wear is essential to obtaining readings that accurately reflect the dose equivalent received.

Federal and state regulations require that the dose to an embryo/fetus during the entire pregnancy, from occupational exposure to a declared pregnant woman (DPW), does not exceed 0.5 rem. The dose to the embryo/fetus is the sum of the deep dose equivalent (DDE) to the declared pregnant woman and the dose to the embryo/fetus from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman.

This procedure describes the methods for ensuring doses to the embryo/fetus are maintained below the limits described above and ALARA. This procedure also provides instructions for declaring pregnancy and withdrawing declaration of pregnancy, and monitoring requirements for the DPW and embryo/fetus.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. This program is applicable to all site personnel and other contractors who require external monitoring, may perform radiological work, handle radioactive material, make entries into radiological areas, or prepare radiological work documents.

C. References

1. NRC 10 CFR 20, Standards For Protection Against Radiation

2. ICRP 54, Individual Monitoring for Intake of Radionuclides by Workers: Design and Interpretation

3. ICRP 78, Individual Monitoring for Internal Exposure of Workers

4. NUREG 1400, Air Sampling in the Workplace
5. NRC Regulatory Guide 8.7, Instructions for Recording and Reporting Occupational Radiation Exposure Data
6. NRC Regulatory Guide 8.25, Air Sampling in the Workplace
7. NRC Regulatory Guide 8.34, Monitoring Criteria and Methods to Calculate Occupational Exposures
8. Health and Safety Plan – Appendix A, Radiation Protection Program
9. NRC Regulatory Guide 8.13, Instruction Concerning Prenatal Radiation Exposure
10. NRC Regulatory Guide 8.36, Radiation Dose to the Embryo/Fetus
11. HP-NMI-17, Employee In/Out Processing

D. Dose Limits

1. Legal exposure limits

   The following exposure limits SHALL NOT be exceeded in any calendar year:

   a. 5000 mrem total effective dose equivalent (TEDE)

   b. 15,000 mrem lens of the eye dose equivalent (LDE)

   c. 50,000 mrem shallow dose equivalent to the extremities (SDE-ME) or to the skin (SDE-SK)

   d. 5000 mrem committed effective dose equivalent (CEDE)

   e. 50,000 mrem committed dose equivalent (CDE)

2. Administrative Limits

   The following Administrative Limits shall not be exceeded without prior written authorization from the Radiation Safety Officer and de maximis management:

   a. 2000 mrem TEDE

   b. 6000 mrem LDE

   c. 20,000 mrem SDE

d. 2000 mrem CEDE

e. 20,000 mrem CDE

3. Dose to an Embryo/Fetus of a Declared Pregnant Woman

   a. Total Effective Dose Equivalent (TEDE) - <500 mrem over entire pregnancy

   b. TEDE should not vary substantially above 50 mrem in any month

4. New employees

   a. IF the employee has indicated no monitoring was performed during the current calendar year, THEN the limits in b., above apply.

   b. IF the employee has indicated monitoring was performed during the current calendar year, THEN the following limits are in effect until record dose has been received:

      i. Radiological workers are limited to 500 mrem TEDE for the remainder of the calendar year.

   c. Once record dose information for the current calendar year has been received, the limits in b., above shall apply, with the following additional controls:

      i. Current year record or estimated dose from previous employer(s) shall be subtracted from the legal dose limits in Section a., above.

5. In the event of an emergency threatening loss of life or major property damage, site employees may voluntarily take necessary actions in response to the emergency without regard to the dose limits stated above. Such decision rests solely with the individual. Total dose should not exceed 25 Rem EDE for life-saving operations.

6. The radiation dose in any unrestricted area shall not exceed 0.5 mrem/hr.

E. Determination of Monitoring Requirements

1. External Monitoring shall comply with Attachment 1 – External Monitoring Guide and the following:

   a. Individuals having the potential to receive occupational radiation exposure in excess of 500 mrem in a calendar year from external sources shall be issued an external dosimeter.

b. Individuals having the potential to receive a dose to the extremities in excess of 5,000 mrem shall be issued extremity external dosimeter.

c. Multiple whole body monitoring

Multiple whole body external dosimeters shall be issued to individuals if:

i. The dose rate at 30 cm from the source exceeds 100 mrem/hour

ii. The dose rate to various parts of the whole body varies by more than 50%, and

iii. The individual's dose to the whole body is expected to exceed 300 mrem in a day.

NOTE: If multiple whole-body dosimetry is worn, the individual's routine external dosimeter shall be removed and a separate whole body external dosimeter issued as part of the multi-badge pack.

2. Internal monitoring

a. Routine monitoring shall comply with Attachment 2 – Internal Monitoring Guide and the following:

i. Individuals qualified as radiological workers shall be monitored prior to initial work in the RCA (baseline sample upon hire or qualification).

ii. Radiological workers likely to receive intakes resulting in >100 mrem CEDE shall be monitored at a frequency no less than semiannually

iii. Individuals who directly handle unpackaged radioactive material or who open packages of radioactive material shall be monitored no less frequently than annually.

iv. Any individual expected to receive an intake greater than 0.05 ALI in a calendar year shall be monitored no less frequently than quarterly.

v. Individuals shall have a baseline bioassay on file prior to wearing a respirator for protection from internal radiation exposure.

vi. Individuals monitored under this bioassay program shall be asked to submit a bioassay upon termination.

b. Special monitoring

Special bioassay samples may be required under the following conditions:

i. Any individual who is exposed to airborne radioactive materials in any combination of concentration and time as to potentially deliver a dose equal to or greater than 1.0 mrem. Credit can be given for respiratory protection (APF) when calculating the potential dose.

ii. Detection of contamination on the nose or mouth;

iii. Detection of skin contamination on the chest, back, or abdomen and decontamination attempts have no affect (evidence of internally-deposited radioactivity);

iv. Individuals using respiratory protection for the purpose of limiting intake of radioactive materials and the respirator fails;

v. As directed by the RSO; and

vi. As required by a Radiological Work Permit.

vii. Any individual who has undergone a nuclear medicine procedure involving ingestion/injection of radionuclides are required to notify the RSO as soon as practical after the procedure.

c. Internal monitoring methods

i. Internal monitoring is normally performed by urine bioassay. The chemical form of uranium present in some areas of the site is best monitored by in vivo lung counting, fecal and then urine bioassay techniques. Representative air monitoring will provide the best estimate for internal exposures at the NMI site. A combination of urine bioassay results and representative air monitoring will be used to estimate internal doses of workers. Additionally, in vivo lung counting may also assist with internal dose estimates.

F. Declaration of Pregnancy

1. Privacy

a. Declaration of pregnancy is strictly voluntary

b. Management shall not impose reduced exposure limits on a woman known or thought to be pregnant unless she specifically declares her pregnancy in writing.

c. Management shall not order or recommend a woman thought to be pregnant to declare her pregnancy.

2. Declaration

a. Obtain Attachment 3 - Declaration of Pregnancy, from your direct supervisor.

b. Complete Attachment 3 and forward it to your direct supervisor.

c. Within one working day, the supervisor shall:

i. forward the declaration of pregnancy to the Health Physics Staff;

ii. verbally notify the RSO of the pregnancy declaration.

d. The RSO or designee shall contact the DPW.

i. Evaluate current occupation dose history and work assignments.

ii. Answer any questions the DPW may have regarding radiation exposure to the embryo/fetus.

iii. Provide the DPW with a copy of NRC Regulatory Guide 8.13.

iv. Discuss reassignment to work involving reduced radiation exposure.

v. Assign radiation exposure limits.

vi. Sign the Declaration of Pregnancy

e. Dosimetry shall

i. Exchange the DPW's dosimetry. The DPW's whole body dosimetry shall be exchanged monthly.

ii. Issue a bioassay to the DPW with instructions to return it within 72 hours (or the next work day if longer than 48 hours).

iii. Issue a fetal dosimeter to be worn on the abdomen. Fetal dosimeter shall be exchanged monthly.

3. General Requirements

    a. Dose limits

    Dose to embryo/fetus shall not exceed 500 mrem during the entire gestation period, and shall be ALARA, and should be essentially uniform from month to month during the gestation period. The RSO shall complete Attachment 4 – Embryo/Fetus Dose Limit Calculation for the DPW.

    The DPW's occupational radiation exposure from the time of declaration until an estimate of dose received thus far in the pregnancy is completed shall be limited to 10 mrem.

    b. Dose to embryo/fetus shall not exceed 500 mrem during the entire gestation period.

        i. Using the information from Attachment 3, estimate the DPW's occupational exposure thus far in the pregnancy.

        ii. If at the time of declaration the DPW's occupational exposure already exceeds 450 mrem for the gestation period, then:

        - Remove the DPW from work involving handling or use of radioactive materials;
        - Restrict the DPW from entering and RCA or radioactive material area;
        - Limit the occupational exposure for the remainder of the gestation period to 50 mrem.

    c. The dose to the embryo/fetus should not exceed 50 mrem in any one month.

4. A DPW shall not enter a posted Airborne Radioactivity Area, Radiation Area, High Radiation Area, or Very High Radiation Area.

5. A DPW shall not perform tasks where radioactive contamination could be dispersed during the course of work.

6. Withdrawal of Declaration of Pregnancy

    a. Declaration of pregnancy shall remain in effect until either:

        i. The individual is no longer pregnant, or

ii. The individual voluntarily withdraws her pregnancy declaration in writing.

b. To withdraw a pregnancy declaration:

i. Obtain the original pregnancy declaration from dosimetry

ii. Complete the bottom portion and sign

iii. Give the completed form to the direct supervisor.

G. External Dosimeter Handling and Storage

1. External Dosimeter Packaging

a. External dosimeters

b. Upon receipt, unpack external dosimeters

i. Perform inventory against packing list to ensure all External dosimeters are accounted for.

ii. Ensure each monitored individual has an external dosimeter. If each monitored individual does not have an external dosimeter, contact the RSO.

iii. Ensure there is a Control external dosimeter in the package, if necessary.

iv. Visually inspect External dosimeters for obvious signs of damage.

v. Retain the packing list for return shipment

c. To send external dosimeters back to the vendor for processing:

i. Check off each external dosimeter against the original packing list and place the external dosimeters in the package.

ii. If any spare external dosimeter were issued during the wear period, write the name of the individual to whom issued in the appropriate line on the packing list.

iii. Attach a tag or label reading, “Not used” to each external dosimeter that was issued to an individual but not worn.

iv. Ensure all spare external dosimeter and Control badges are included in the package.

v. Mark the outside of the package, "Dosimetry devices – Do not x-ray."

vi. Send the package of external dosimeters back to the vendor by any appropriate means.

d. External Dosimeter Storage

External dosimeters and their associated control external dosimeter shall be stored as follows:

i. In a segregated area such as a file cabinet drawer dedicated to external dosimeter storage

ii. Away from sources of radiation.

iii. External dosimeter storage should be locked if necessary to prevent unauthorized access.

iv. Control external dosimeters shall be stored away from any ionizing radiation (excluding natural sources), heat sources and light sources.

H. External Dosimeter Issue and Exchange

1. Issue

CAUTION: Never issue an external dosimeter to anyone other than the individual to whom it has been assigned.

When possible, external dosimeters should be issued to new employees by contacting the dosimetry vendor and providing the necessary information. The vendor can usually ship the new external dosimeter the next business day. If this is not possible, then issue an available spare external dosimeter

a. Ensure the individual has received initial training in accordance with the NMI RPP.

b. Ensure the individual has submitted a baseline bioassay, if required.

c. Complete the information as required by HP-NMI-017, Employee In/Out Processing.

d. Issue the external dosimeter and holder.

2. Exchange

a. External dosimeters should be exchanged on the first day of the new wear period.

b. No individual shall wear external dosimeters from more than one wear period simultaneously.

c. Once all external dosimeters from the previous wear period have been collected, they shall be packaged and shipped with the control EXTERNAL DOSIMETER(S).

d. External dosimeters shall be promptly returned to the vendor to avoid fading and associated sources of error/inaccuracy.

I. External Dosimeter Wear and Usage

1. External dosimeter shall be worn on the portion of the whole body expected to receive the highest dose.

a. Unless instructed otherwise by the RSO or Project RSO, the external dosimeter shall be worn between the neck and the waist, on the front of the body. The beta window shall face away from the body.

b. If PPE clothing is worn, the external dosimeter should be worn inside the PPE clothing to protect against contamination.

c. If applicable, do not tamper with the Mylar beta window.

2. Extremity external dosimeters (finger rings) shall be worn as follows:

a. Each ring shall be worn on the extremity matching the identifier on the ring.

b. The ring shall be worn with the chip on the inside of the finger, so that the dose received when small objects are handled is accurately recorded.

J. Lost or Damaged External Dosimeters

1. Exit the radiologically controlled area and immediately notify the work supervisor, RSO, or Project RSO, , if any of the following occur:

a. The dosimeter is lost;

b. The dosimeter is visibly damaged;

c. The dosimeter is contaminated.

2. Complete Attachment 5, "*Lost or Damaged Dosimeter Report*"

3. The RSO shall determine whether or not an exposure investigation is required

4. The RSO shall authorize re-entry.

5. The RSO may authorize use of a secondary dosimeter (DRD) in the event of a lost external dosimeter at a remote job location.

   a. Entry to a high radiation area or very high radiation area is not permitted;

   b. The expected whole body dose from external sources is expected to be less than 25 mrem during the time the individual does not have an external dosimeter;

   c. An investigation indicates the individual's estimated total effective dose equivalent for the calendar year is less than 400 mrem;

   d. Extremity dosimetry is not required;

   e. Work area radiation surveys are performed and documented;

   f. External dosimeters shall be replaced by the next work shift;

   g. Any dose recorded on the secondary dosimeter while the external dosimeter was lost shall be added to the individual's Record dose.

K. Secondary Dosimetry

1. Secondary dosimeters shall be worn as required by the applicable RWP.

2. Secondary dosimeters shall be worn adjacent to the whole body external dosimeter.

3. Secondary dosimeters shall be calibrated at a frequency no longer than annually.

4. When worn, the reading shall be recorded on each entry to and exit from the radiologically controlled area.

5. If the secondary dosimeter is dropped, lost, or damaged:

   a. Notify coworkers and supervisor and exit the work area.

b. Report to and/or RSO.

c. Complete Attachment 5.

d. The RSO shall authorize reentry.

L. Attachments

1. Attachment 1 – External monitoring guide
2. Attachment 2 – Internal monitoring guide
3. Attachment 3 – Declaration of Pregnancy
4. Attachment 4 – Embryo/Fetus Dose Limit Calculation
5. Attachment 5 – Lost or Damaged Dosimeter Report

Attachment 1

External Monitoring Guide

	None	EXTERNAL DOSIMETER (WB, β-γ)	Finger Ring	WB Neutron	Multiple WB	DRD	Alarming High Rad Area
Office workers, no RW training	X						
Visitors to field office	X						
Visitors to a Restricted Area						X	
Potential whole body dose >500 mrem/year		X					
Potential dose to extremities >5 rem/year		X	X		X		

Attachment 2

Internal Monitoring Guide

As an appendix to this procedure, the contents of this form and the bioassay requirements contained herein may be changed at the discretion of the RSO.

	None	Annual	Semiannually	One Day post-exposure	3 Days post-exposure
Office workers, no RW training	**X**				
Routinely enter restricted area (40+ hours/year)	**X**				
HP project personnel		**U/A**	**U/A**		
Frequent work in Contaminated Areas			**U/A**		
Use respiratory protection			**U/A**		
>0.1 DAC for 8 hours (unprotected DAC)			**U/A**		
Instantaneous >10 DAC-HR or CAM alarm			**U/A**	**U/A**	
Facial contamination				**Contact RSO**	
Respiratory failure				**Contact RSO**	

Key:
U = Urine A = Alpha Spec P = Isotopic Pu
F = Fecal

Attachment 3

Declaration of Pregnancy

Worker Name		Badge Number	Social Security Number
Work Location	Work Phone Number	Job Title	Employer/Supervisor's Name

DECLARATION I am voluntarily declaring that I am pregnant, for the purpose of lowering the dose received by my embryo/fetus. I realize that my job assignment or responsibilities may change due to work restrictions imposed to ensure that the embryo/fetus radiological dose is maintained within limits specified in 10 CFR 20.1208. I will cooperate with any supplemental radiological monitoring and dose evaluations that may be required to ensure compliance with the regulations mentioned above. The work restrictions may also apply during the entire gestation time or until I make a formal withdrawal of my pregnancy declaration. I understand that submitting this Pregnancy Declaration Form will in no way affect my pay, benefits, seniority, or potential for promotion. I am aware that counseling is available for worker concerns regarding the hazards of radiation to the embryo/fetus. At my request, I will be provided access to a designated contact who will counsel me on radiation risks during pregnancy.

☐ YES, COUNSELING IS REQUESTED* ☐ NO COUNSELING REQUESTED

*If counseling was requested, attach pertinent information that was discussed.

Estimated Conception Date	Estimated Delivery Date
Worker Signature	Date
SUPERVISOR (or Manager) (Sign/Date):	
RSO/RPM (Sign/Date):	
Dosimetry (Sign/Date):	

Withdrawal of Declaration of Pregnancy

I am voluntarily withdrawing my previous declaration of pregnancy that was executed on (date) _____. I understand that, as a result of signing and submitting this form, any work restrictions that have been imposed as a result of the previously submitted Declaration of Pregnancy will be lifted.

Worker (Signature/Date):
RSO/RPM (Sign/Date):
Dosimetry (Sign/Date):

Attachment 4

Embryo/Fetus Dose Limit Calculation

Declared Pregnant Worker Name:	Badge Number:	Social Security Number:

EXTERNAL DOSE TRACKING

Estimated monthly dose to the embryo/fetus from conception to declaration date (mrem):

Month Number	Calendar Month/Year	Monthly External Dose (mrem)	Monthly Internal Dose (mrem), if required, or N/A	Initials	Date	Cumulative External Dose (mrem)

Total Embryo/Fetus External Dose (mrem) :

INTERNAL DOSE TRACKING

Initials Date Dose (mrem)

Estimated embryo/fetus dose equivalent prior to initial bioassay (from previous bioassays)	
a. Has the Declared Pregnant Woman been removed from all work having potential for internal exposure?	If YES, the internal exposure monitoring is not required. If NO, answer b. and c.
b. Nature of work involving potential internal exposure, and radionuclides present:	
c. Required bioassay frequency and analyses:	

RSO Signature/Date:

Embryo/Fetus Dose Equivalent During Entire Gestation Period (mrem) :

TOTAL EMBRYO/FETUS DOSE (mrem): ***combine internal and external***

Prepared By (name and signature) Date

Dosimetry Manager or Designee (name and signature) Date

Attachment 5

Lost / Damaged / Misplaced Dosimeter Report

Employee Name:_____ SSN:_____

Date / Time of Occurrence:_____

Work Area:_____ RWP Number:_____

Describe events surrounding the loss/damage, and actions taken when discovered (Use additional sheets is necessary):

Employee Signature:_____

Supervisor Signature:_____

Forward this form to RSO immediately upon completion.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

SEALED SOURCE ACCOUNTABILITY AND LEAK CHECKS

PROCEDURE NO: HP-NMI-09

October 2018

Table of Contents

A. Overview

The purpose of this procedure is to provide guidance and instruction for the performance of leak checks and accountability for non-exempt radioactive sources.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

1. Health and Safety Plan – Appendix A, Radiation Protection Program

2. NRC 10 CFR 20, Standards For Protection Against Radiation

3. HP-NMI-05, Radiological Surveys

4. HP-NMI-02, Definitions

D. General Requirements

1. This procedure does not apply to sources which are generally licensed, such as those in smoke detectors, or exempt sources. Radiation control instruments and their attached exempt sources may be subject to the requirements specified in instrument specific operating procedure. Check sources should be inventoried every (6) months.

2. Sources may be brought on-site and controlled by other licensees (e.g., density gauges, Independent Verification Survey (IVS) contractor's check sources, etc.) These sources do not need to be placed in the Radiation Protection Program Inventory, but should be leak checked upon arrival and departure. These sources shall be stored in locked areas when not in use.

3. When performing leak checks on electroplated sources or sources with a thin/fragile covering:

    a. DO NOT smear the active electroplated surface or the thin/fragile covering. This may damage the source and give a false indication that the source is leaking.

b. DO smear the holder or case of electroplated sources or sources with thin/fragile covering.

4. If a source is inaccessible, smear the point where contamination would leak from the device if the source were leaking.

5. Sources shall be stored in locked areas when not in use.

6. Sealed sources in detector cells containing licensed material shall not be opened or removed from the source holder.

7. Do not touch the active area of plated sources with bare hands.

8. Inventory each non-exempt sealed source every six (6) months.

9. Leak check each sealed source containing beta gamma emitting material at intervals not to exceed six (6) months.

10. Leak check sources designed for the purpose of primarily emitting alpha particles at intervals not to exceed six (6) months.

11. Leak-check all new sources prior to placing them in service.

12. Sealed sources need not be tested if they contain only hydrogen-3; or they contain only a radioactive gas; or the half-life of the isotope is 30 days or less; or they contain not more than 100 microcuries of beta- and/or gamma-emitting material or not more than 10 microcuries of alpha-emitting material.

13. Source leak checks shall be capable of detecting the presence 0.005 microcuries (11,100 dpm, 185 becquerels) of radioactive material on the sample media (smear material). A smear shall be taken from the sealed source or from the surfaces of the device in which the sealed source is permanently or semi-permanently mounted or stored on which one might expect contamination to accumulate.

E. Source Receipt

1. Upon receipt of a new source, use a unique source identification number or assign one, as necessary.

2. Add the source information to the Source Inventory Log and complete the Source Leak Check and Inventory Record (Attachment 1).

3. If no leak check paperwork accompanied the source, perform a leak check, and document the survey in accordance with HP-NMI-05.

4. Attach the leak check and inventory survey results to Attachment 1.

F. Leak Check

1. Prior to leak checking new or unfamiliar radioactive sources determine how the source is used and decide which surfaces need to be surveyed. If there is a question on how to conduct a source leak check for a particular source, contact the RSO for guidance.

2. Using a dry smear, gently wipe the accessible area of the source and/or source container and place smear in a clean envelope.

3. Count the smear on the appropriate alpha or beta radiation counter and complete the Radiological Survey Form per HP-NMI-05.

4. Conducting leak checks on plated sources or sources with thin or fragile coverings:

   CAUTION: DO NOT SWIPE THE ACTIVE SURFACE OF THE SOURCE. THIS MAY DAMAGE THE SOURCE OR GIVE A FALSE INDICATION THAT THE SOURCE IS LEAKING.

   a. Perform a survey for removable surface contamination on surfaces, such as the non-active area around the source and/or the inside of the source storage container.

G. Leak Check Results

1. If source leak check results are greater than or equal to 0.005 microcuries, (11,100 dpm) perform the following actions:

   a. Immediately contain the source and restrict access to source storage/use locations until area surveys are completed.

   b. Notify the RSO.

   c. Conduct contamination surveys in source storage, use, and transit locations to identify the potential spread of contamination.

   d. The RSO will determine follow-up corrective actions.

2. If source leak check results exceed the removable contamination limits listed in Health and Safety Plan – Appendix F, Radiation Protection Program, but are below 0.005 microcuries (11,100 dpm), perform the following actions:

    a. Remove source from use and restrict access to source storage/use locations until area surveys are completed.

    b. Conduct contamination surveys in source storage, use, and transit locations to identify the potential spread of contamination.

    c. Notify the RSO.

H. Source Accountability

1. Inventory new sources by recording the appropriate information on Attachment 1.

2. When a new source is received retain copies of the shipping papers and manufacturer-supplied documents (e.g., leak test results and calibration certificates).

3. During the inventory of both active and stored sources, pay particular attention to whether the:

    a. Source is present and the source ID # matches the ID # on the source storage container.

    b. Source appears free of any damage.

    c. Source is properly posted/labeled.

    d. Source is properly stowed and the storage device (locker, drawer, cabinet, etc.) is properly posted/labeled and locked.

4. Non-exempt sources and devices containing radioactive material shall be inventoried every 6 months.

5. Update the source inventory on Attachment 1.

6. When a source is removed from service record the date on the Source Inventory Log and remove the Source Leak Check and Inventory Record from the active section of the master source logbook and place it in inactive section.

7. If the source is disposed of, indicate the disposal in the location column of the inventory record.

Attachment 1

Source Check and Inventory Record

Source ID #	Source Serial #	Type[1.]	Isotope(s)	Activity	Leak Check Date	Inventory Date

[1.] Alpha, Beta, Gamma, etc.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIOLOGICAL AIR SAMPLING

PROCEDURE NO: HP-NMI-10

Rev. 1

October 2018

Table of Contents

A. Overview

This procedure describes the methods to be used to ensure requirements of the air sampling program are met.

Air samples are required to be collected if worker intakes are likely to result in a committed effective dose equivalent of 100 mrem or if airborne concentrations are expected to be >25% of the DAC. Air samples are also required if respiratory protection is worn to reduce worker intakes of radioactive materials, and to verify the effectiveness of engineering controls.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. This procedure is applicable to all site personnel, radiological control personnel and other contractors performing work in radiological areas.

4. This procedure does not apply to effluent monitoring.

C. References

1. 10 CFR 20, Standards For Protection Against Radiation
2. 29 CFR 1910.134
3. NUREG 1400, Air Sampling in the Workplace
4. NRC Regulatory Guide 8.25, Air Sampling in the Workplace

D. Air Monitoring Program

1. The Air Monitoring Program, including individuals and areas, shall be performed, as appropriate, to:

    a. Document radiological conditions;

    b. Detect changes in radiological conditions;

    c. Detect the gradual buildup of radioactive material; and

d. Identify and control potential sources of individual exposure to radiation and/or radioactive material.

2. Instruments and equipment used for air monitoring shall be:

   a. Maintained and calibrated as specified in the device's operating procedure;

   b. Appropriate for the types, levels, and energies of the radiation encountered; and

   c. Appropriate for existing environmental conditions.

3. Air monitoring shall be performed:

   a. Where an individual is likely to receive an intake of 0.1 ALI in a calendar year;

   b. When the average work area airborne radioactivity concentration is likely to exceed 0.25 DAC;

   c. When the use of respiratory protection is designated by the RWP

4. Air samples that are representative of the breathing zone air shall be collected:

   a. Airborne radioactivity concentration is likely to exceed 40 DAC-hours in a workweek; and

   b. When respiratory protection is prescribed by RWP to limit intake of radioactive material

5. Continuous air monitoring:

   Should be provided if there is a potential for intakes to exceed 40 DAC-hours in one day (credit may be taken for respiratory protection).

6. In locations where no effluent stack monitoring system is installed or operational, perimeter air monitoring shall be performed to measure the airborne radioactivity concentration at the Restricted Areas boundary. Perimeter air samples shall be collected outside the work area but either at or inside of the Restricted Area boundary whenever dispersible radioactive material is being directly handled.

E. Detection Limits

1. For breathing zone and work area air samples, a minimum detectable activity (MDA) of 1 DAC-hr For perimeter air samples, a MDA of 5E-14 uCi/ml.

2. To demonstrate the applicable MDA is met, do one of the following:

    a. Calculate the collection volume required using Attachment 1, then select the appropriate instrument(s) and run times.

    b. When collection volume will not be adequate to meet the desired MDA, consider using the guidance of Attachment 2 (derived from NUREG 1400) to achieve a weighted MDA based on multiple samples.

3. If an air sample should be collected and the required MDA cannot be met contact the RSO for guidance.

F. Determination of Derived Air Concentration

1. Derived Air Concentration (DAC) shall be determined for each air sample, and the results of the air sample shall be compared to the DAC.

2. The DAC value may be derived as follows:

    a. For a single radionuclide, choose the DAC for that radionuclide.

    b. For a mixture, use one of the following:

        i. Choose the radionuclide with the most limiting DAC, and use it; or

        ii. Determine the Effective DAC (DAC_{eff}) from the mixture as follows:

- Determine the fractional abundance (f_n) of each radionuclide present.

- Calculate effective DAC

$$DAC_{eff} = \frac{1}{\frac{f_1}{DAC_1} + \frac{f_2}{DAC_2} + \frac{f_3}{DAC_3} + \ldots \frac{f_n}{DAC_n}}$$

G. Placement Of Air Monitoring Equipment

1. Place air sampling equipment in the vicinity of workers to provide an indication of the airborne radioactivity concentrations to which workers are exposed.

2. Real-time monitors (CAMs) should be placed in a position for providing early warning of a significant release of airborne radioactivity. For example:

    a. Next to a containment structure that is being used to prevent release of airborne radioactivity;

    b. In clean areas adjacent to work areas where a significant potential for release exists.

3. Place boundary and perimeter air samples such that air currents will carry radioactivity to the air sampler.

4. Breathing Zone/Lapel Samplers should be located close to the worker's head as practical (preferably within 6 inches) to the workers mouth and nose.

H. Sample Collection And Analysis

1. Determine the appropriate sampler to collect the required volume. Refer to Attachments 1 and 2 as necessary.

2. Ensure air samples are collected and filter media changed at the appropriate times. Following are guidelines for changing filter media:

    a. High-volume air samplers should be changed after each sample. Sample collection time should not exceed 30 minutes or the motor may be damaged.

    b. Low-volume air samplers should be changed daily unless longer run times are necessary to meet the required MDA. In no case shall they run longer than a week.

    c. Boundary and perimeter air samplers should be changed weekly.

    d. Personal air monitor samples should be changed at the end of each shift. However, they may be collected for up to five days if needed to achieve the required MDA.

CAUTION: Store individual air samples in envelope, plastic bag, or similar holder to prevent cross-contamination. Air samples are potentially radioactive material and shall be handled and controlled accordingly.

3. Air samples should be held for approximately 24 hours prior to final counting. Samples may be counted earlier if data is required sooner with the understanding that Radon could be present. Count and record results.

a. IF Air sample indicates >0.1 DAC, THEN allow to decay a total of at least 72 hours and count again. Use another Air Sample Data sheet to record the second count

b. IF first count indicates <0.1 DAC, then proceed to Step 4.

4. Record results and forward to Supervisor for review.
5. Notify Supervisor or Project RSO, as appropriate, of air samples indicating >0.1 DAC on final analysis.

I. Records

Air sample records shall be filed and maintained in accordance with the applicable requirements.

Attachment 1

Air Sample Volume Requirements to Achieve Desired MDA

$$MDA = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E \cdot V}$$, therefore

$$V = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E \cdot Desired\ MDA}$$

For Alpha sampling:

Radionuclide	DAC (uCi/ml)	B_r (cpm)	t_b (min)	t_s (min)	E	Required V (ml)
U-235/U-238	2E-11	0.1	10	1	.15	7.0E5
U-234	2E-11	0.1	10	1	.15	7.0E5

Attachment 2

Determination of Time-Weighted MDC

Regulatory Guide 8.25, Section 6.3: "The 10 CFR Part 20 monitoring criteria (i.e., 10 percent of the limit) do not establish required levels of detection sensitivity (lower level of detection, minimum detectable activity, minimum detectable concentration, etc.). For example, lapel samplers may not be able to detect uranium concentrations of 10 percent of the DAC, but lapel samplers are still acceptable for measuring the uranium intake of workers. The monitoring criteria should not be considered requirements on the sensitivity of a particular measurement because when the results of multiple measurements are summed, the sum will have a greater statistical power than the individual measurements. However, to achieve the greater statistical power, the staff should record all numerical values measured, even values below "minimum detectable amounts" and values that are negative because the measured count rate is below the background. Results should not be recorded as "below MDA" or similar statements."

NUREG 1400, Appendix A.2 provides guidance, as shown in Equation 2 for using time-weighted average MDC's to detect small intakes over an extended period of time.

$$\overline{MDC} = \left(\frac{\sum_{i=1}^{n} T_{s,i}}{\sum_{i=1}^{n} (E_i F_i K_i T_{s.i}^2} \right) \left(\frac{2.71}{\sum_{i=1}^{n} T_{g,i}} \right) + 3.29 \sqrt{\frac{\sum_{i=1}^{n} \frac{R_{b,i} \left(\frac{1}{T_{b,i}} + \frac{1}{T_{g,i}} \right)}{E_i^2 F_i^2 K_i^2}}{\left(\sum_{i=1}^{n} T_{s,i} \right)^2}}$$

Below is an illustration of the effect of time-weighted average MDC.

BKG count time	**Gross count time**	**Sample collection run time**	**BKG count rate**	**Gross count rate**	**Sampler flow rate**	**Filter Efficiency**	**Counting Efficiency**	**Concentration**	**Minimum detectable concentration**	**Time-weighted Minimum detectable concentration**
min	min	min	cpm	cpm	ml/min			uCi/ml	uCi/ml	uCi/ml
T_b	**T_g**	**T_s**	**R_b**	**R_g**	**F**	**E**	**K**	**C**	**MDC**	**MDC_w**
10	1	10080	35	63	5000	0.95	0.25	1.1E-12	8.7E-13	1.
10	1	240	38	38	5000	0.95	0.25	0.0E+00	3.8E-11	
10	1	520	52	51	5000	0.95	0.25	-7.3E-13	2.0E-11	
10	1	60	29	40	5000	0.95	0.26	6.7E-11	1.3E-10	
10	1	120	41	39	5000	0.95	0.26	-6.1E-12	7.5E-11	
5	1	480	37	51	5000	0.95	0.26	1.1E-11	1.9E-11	
10	2	600	44	50	5000	0.95	0.26	3.6E-12	1.1E-11	
10	1	240	40	36	5000	0.95	0.26	-6.1E-12	3.7E-11	

Attachment 3
Air Sample Data Sheet

Location:		RWP #		Date Sample Collection Ended:	
Sample Type (circle one):	GA BZ Boundary Perimeter	Reason for Sample, or Client Processed:			
Sampler Model #		Serial #		Cal. Due Date:	
Start Date/Time:		Start Flow Rate:	lpm		
End Date/Time:		End Flow Rate:	lpm		
Run Time:	min.	Ave. Flow Rate:	lpm	RCT Signature	
Volume (V) Run Time x Ave Flow Rate x 1000:			ml		

Counting Instrument(s)								
ALPHA	Inst. Model #		Serial#		Cal Due:		4 π Efficiency (E)	
BKG cpm (B_r)		BKB Count time, min (t_b)		Sample count time, min (t_s)				
BETA					Cal Due:		4 π Efficiency (E)	
BKG cpm (B_r)		BKB Count time, min (t_b)		Sample count time, min (t_s)				

$$MDA = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E \cdot V}$$

		Count Results (Date/Time):		**MDA**
Alpha DAC:	(μCi/ml)	Alpha Air Sample Results:	(μCi/ml)	(μCi/ml)
Beta DAC:	(μCi/ml)	Beta Air Sample Results:	(μCi/ml)	(μCi/ml)
		Total DAC Fraction		

Respiratory Protection Worn? Y N		Type		Assigned Protection Factor	
Remarks:					
RCT Signature:		Review/Date:			

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIOLOGICAL WORK PERMITS

PROCEDURE NO: HP-NMI-11

Rev. 1

October 2018

Table of Contents

A. Overview

This procedure describes the Radiological Work Permit (RWP) program and the method of generating, using, terminating, and revising RWPs.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. Where contract documents/procedures address radiological controls programs specific to the associated work task, the contents of this procedure should be used to minimize personnel exposures and prevent release of radioactivity to the environment.

4. This program is applicable to all site personnel and other contractors who may perform radiological work, handle radioactive material, make entries into radiological areas, or prepare radiological work documents.

5. This document does NOT apply to work that is conducted at customer-operated sites or under the customer's radiation protection program.

C. References

1. 10 CFR 20, Standards for Protection Against Radiation

D. Types of RWPs

1. General RWPs

    a. Written to cover routine jobs where the radiological conditions are known to be relatively constant and contact with dispersible forms of radioactivity are unlikely.

        i. No entry to an airborne radioactivity area.

        ii. Work area radiation dose rates are less than 5 mrem per hour.

iii. Removable contamination levels are generally less than 10 times the Regulatory Guide 1.86 limits (10,000 dpm/100cm^2 for removable and 50,000 dpm/100cm^2 total contamination.

b. General RWPs may be written for up to one year.

c. Individuals entering on a General RWP shall sign the RWP review sheet indicating they have read and understand the requirements of the RWP.

2. Specific RWPs

a. Specific RWPs are written to cover specific jobs, work in areas exceeding conditions in 4. b. through d. above, and entry to areas having the potential for changing radiological conditions.

b. Specific RWPs are normally good for the duration of a specific job and should expire at that time.

c. Individuals using a Specific RWP shall be briefed on the requirements of the RWP by the Health Physics Staff and shall sign the RWP briefing log.

d. Individuals using a Specific RWP shall sign in and out each entry and exit.

E. RWP Requirements

1. A radiological work permit (RWP) shall govern entry to any Radiologically Controlled Area (RCA).

2. RWPs are prepared by the Health Physics group with input from the individuals doing the work.

3. RWP Content

RWPs shall contain at least the following information:

a. Location(s) of work

b. Job description

c. Unique serial number

d. Expected radiological conditions

e. Effective dates/times of the RWP

f. PPE and dosimetry requirements

g. Limiting conditions

h. Special instructions

4. RWPs are not active and shall not be used until approved by the RSO.

F. Initiation, Approval, Revision

1. The job supervisor shall review the work to be done and determine whether or not the work is covered by an existing RWP. If a new RWP is needed, initiate one.

    a. Contact Health Physics regarding the work to be done.

    b. A formal RWP Request is not required due to the small scope of most jobs. The scope of the work, hazards, radiological conditions, and methods of completion shall be discussed between the job supervisor, workers, and Health Physics Staff.

    c. Health Physics Staff shall complete Attachment 2.

    d. Assign RWP number using the next available number in the RWP Log, Attachment 1. RWP numbering shall be in the format "YY- ###," where

        i. YY is the 2-digit current year;

        ii. ### is the 3-digit sequential number. The first RWP written in a calendar year will have the number 001.

    e. Forward the RWP to the job supervisor and SSO for review and comment.

    f. Resolve comments and write final copy of RWP.

    g. The individual preparing the RWP shall sign as "preparer."

    h. At least one other signature is needed for approval. Individuals authorized to approve RWPs shall be designated by the RSO.

2. RWP Use

    a. The original RWP containing original signatures shall be filed.

    b. A working copy shall be posted or otherwise available in the work area.

c. Workers shall sign a RWP Brief Sheet, Attachment 3, at least once for each RWP they use, indicating they have read the RWP and understand its requirements and limitations.

d. Workers using a general RWP should be familiar with the stated requirements.

e. Workers using a specific RWP shall log in and out each entry and exit, Attachment 4.

3. RWP Revision and Extension

a. Field changes may be made by lining out and adding text in ink.

i. Approval is by the same level of approval as the original RWP.

ii. Notify the job supervisor and the RSO by phone call or email within two working days of any field changes made to RWPs.

iii. A field change shall not be made if adhering to the change will result in violation of any procedure or regulatory requirement.

iv. Field changes are good for no more than 30 days, after which the RWP shall be revised or terminated.

b. An RWP may be revised as necessary to extend the termination date, or make any necessary changes.

i. RWP revisions shall have the same level of approval as the original.

ii. Before using a revised RWP, ensure the working copies of the previous revision are removed from the work area.

iii. Notify the RSO within one working day of any revisions.

iv. If applicable, the RSO shall notify affected employees and Health Physics Staff that may be using that RWP of the revision.

4. RWP Termination

a. When an RWP has expired or is no longer needed, it shall be terminated.

i. Pull all working copies.

ii. Write or stamp on the RWP "Terminated."

iii. Compile the following records associated with the RWP into one file:

- Correspondence applicable to initiation, approval, or field changes
- All revisions
- Surveys used as basis for stated radiological conditions on the RWP
- RWP briefing sheets
- RWP log-in sheets (for Specific RWPs).

G. Attachments

Attachment 1 – RWP Log

Attachment 2 – Radiological Work Permit

Attachment 3 – RWP Briefing Acknowledgement

Attachment 4 – RWP Entry/Exit Log

Attachment 1 – Radiation Work Permit Log

RWP No.	General or Specific	Work Areas	Issue Date	Expiration Date	Remarks

Attachment 2 – Radiological Work Permit

NMI Site - Radiological Work Permit			
Type:	☐ General ☐ Specific		
RWP No.:	NMI-001	Revision:	0
Issue Date:		Expiration Date:	

TASK INFORMTION	
Area(s):	
Work Area/Description of Work:	
Task Description:	

ALARA
Radionuclide(s) of Concern:

HP Staff Coverage Level	**Air Monitoring Requirements**	**Personnel Frisking Requirements**
☐ None ☐ Initial ☐ Intermittent ☐ Continuous ☐ Daily Briefing Required	☐ None ☐ Work Area ☐ CAM ☐ High Volume ☐ Low Volume ☐ Personal BZ	☐ Whole Body ☐ Hand and Foot

Contamination Levels			
Total: 10,000 to 1million dpm/100cm^2	Removable: 0 to 3,000 dpm/100cm^2	Dose Rates: BKG to 140 uR/hr	Airborne Levels: <10% DAC

Dosimetry Requirement:
External: ☐ Whole Body ☐ DRD ☐ NA ☐ Other
Internal: ☐ Baseline Bioassay ☐ Routine Bioassay ☐ Special Bioassay ☐ NA

Personal Protective Equipment		
☐ Disposable Coveralls (specify) ☐ Double Coveralls ☐ With Hood/Boots ☐ Tape Hands/Feet ☐ Disposable Lab Coat* ☐ Disposable//Reusable Shoe Covers ☐ Inner Glove (nitrile or equivalent) ☐ Outer Glove (Specify)	☐ Hard Hat ☐ Safety Glasses ☐ Safety Shoes ☐ Hearing Protection	☐ Dust Mask Respirator (N-95/P-100) ☐ Half-Face APR (specify cartridge) ☐ Full-Face APR (specify cartridge) ☐ PAPR Helmeted (specify cartridge) ☐ PAPR Hooded (specify cartridge) ☐ Full-Face Supplied Air ☐ Helmeted Supplied Air ☐ Hooded Supplied Air

Special Requirements/Instructions:

Personnel Instructions:
Prepared By/Date:
Approved By/Date:

Attachment 3

Radiological Work Permit Briefing Acknowledgement

RWP#________________ Rev. #_____

NAME	SIGNATURE	DATE	TIME

Attachment 4

Radiological Work Permit Entry/Exit Record

RWP #_____ Rev.#____

EMPLOYEE NAME	INITIALS	DATE	TIME IN / DOSE IN	TIME OUT / DOSE OUT	TIME IN / DOSE IN	TIME OUT / DOSE OUT

Log in and out each entry and exit when using Specific RWP. IF a DRD is required, record reading at entry and exit. If a DRD is not required, enter "NA."

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIOACTIVE MATERIAL RECEIPT AND SHIPMENT

PROCEDURE NO: HP-NMI-12

Rev. 3

October 2018

Table of Contents

A. Overview

The purpose of this procedure is to provide the general instructions for receiving radioactive sources and shipping radioactive samples, unless otherwise authorized by the RSO, or designee.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

1. Health and Safety Plan – Appendix A, Radiation Protection Program

2. 10 CFR 20, Standards for Protection Against Radiation

3. 49 CFR 171, General Information, Regulations, and Definitions

4. 49 CFR 172, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans

5. 49 CFR 173, Shippers – General Requirements for Shipments and Packages

6. 49 CFR 177, Carriage by Public Highway

7. International Air Transport Association (IATA) Dangerous Goods Regulation (Most Current Edition)

8. United Nations International Civil Aviation Organization (UN/ICAO)

9. HP-NMI-02, Definitions

D. General Requirements

In general, this procedure covers the requirements for receipt of radioactive material sources and shipment of analytical samples for fixed base laboratory analysis. Most sample shipments made from the Site will be categorized as limited quantity, Low Specific Activity (LSA), or exempt from regulation. Personnel shall

comply with this procedure when packing, marking, labeling and shipping environmental and waste samples to ensure that all shipments are in compliance with the above regulations and guidance.

Environmental samples shipped by ground transport shall be regulated by Department of Transportation (DOT) regulations. Refer to 49 CFR and/or the RSO/designee for further classification information. Only personnel with current training in compliance with DOT shipping regulations to the extent that their duties demand may perform the tasks outlined in this procedure.

Environmental samples shipped by air transport shall also comply with the requirements of the IATA Dangerous Goods Regulations (DGR) and carrier specific requirements.

The procedures contained in this document are to be used by personnel when packing, marking, labeling, and shipping environmental samples and dangerous goods by air transport.

The steps in this procedure do not have to be followed sequentially and in many cases they can be performed simultaneously. Some shipments may not require the completion of all steps as the categorization of material determines the packaging, labeling, manifesting and transport requirements.

Personnel performing tasks specified by this procedure must have received DOT function specific training (49 CFR 172) for ground transport and additional IATA function specific training for air transport.

E. Receipt of Radioactive Materials

1. Radioactive material (RAM) received should be radiologically surveyed within 3 hours after receipt at the site or the next working day if received on a non-work day such as a holiday or Saturday.

2. All RAM received shall be placed in a secure area not accessible to members of the public or non-radiation safety trained project personnel.

3. If it appears that package integrity has been compromised during transport, notify the RSO/designee for any special survey instructions.

    a. The external surface monitoring shall be completed as soon as practicable following receipt of the package, but not later than the 24 hours specified above.

b. Immediately notify the RSO/designee if the contamination survey results are in excess of 2,200 dpm/100cm^2 βand γ, or 220 dpm/100cm^2 α.

4. Document all incoming surveys as required by HP-NMI-05 Radiological Surveys.

F. Shipment of Radioactive Materials

1. General Shipping Requirements

   a. Shipments of RAM packages shall be made only by workers with 49 CFR 172 DOT function specific training and IATA function specific training for air transport.

   b. The RSO or designee will be responsible for reviewing shipping documentation for transport of radioactive samples.

   c. Special hazardous materials shipping requirements apply materials with additional hazards (liquids, combustibles, corrosives, etc). Contact the RSO/designee for special instructions.

   d. Verification that receivers have a current radioactive material license(s) for the nuclides in the shipment is required.

   e. Notify the receiving facility that a radioactive materials shipment will be coming. An advance copy of the shipping documentation may be required.

2. Shipment Preparation

   a. Pick an appropriate shipping container for the radioactive material to be shipped. Considerations will include the size and weight of the material, its physical form, the design specifications of the package, and any consignee requirements.

   b. Inspect the shipping container prior to loading for any physical defects that would impair container integrity. These would include punctures, holes, tears or other significant structural damage.

   c. Inspect the container's closure devices and lids for any defect that would impair proper operation.

   d. Load the radioactive material into the container carefully as not to damage the package integrity. Load only the material selected to be placed in that container and document items in the shipment.

e. When loading radioactive samples the following procedure must be followed:

   i. Begin by cleaning the cooler with a liquid soap, Simple Green® or Alconox® are acceptable. Survey the cooler for both total and removable contamination to make sure that there is not any radioactive contamination inside the cooler

   ii. If using a sample cooler, make certain that the spigot is carefully caulked shut and taped to prevent the caulk "cork" from coming out.

   iii. Use plastic jars and bottles whenever it is acceptable. However, some analytical methods will not allow the use of plastic. Use glass containers only when absolutely necessary. Glass containers must be wrapped individually in bubble wrap.

   iv. Insure that the primary container is securely sealed by tightening the lid/cap and placing tape around the neck to make sure the cap cannot vibrate off.

   v. If warranted, place a "Radioactive" or trefoil sticker on each individual container.

   vi. Place each individual sample jar/container into its own plastic bag such as Ziploc® or equivalent. This will contain the material in case of breakage as well as maintain the legibility of the label.

   vii. At this stage you should randomly select a group of samples to survey for removable radioactive contamination.

   viii. Line the cooler with a large 3 or 6 mil plastic inner liner bag. All samples and ice are required to be placed into the inner liner.

   ix. If shipping the samples under ice, as in most cases, you will need to place absorbent pads in the bottom of the 3 or 6 mil plastic bag, which should be in the cooler at this time. Note: Vermiculite contains high amount of NORM (Naturally Occurring Radioactive Material). This can interfere with surveys due to false positives. This is why absorbent pads are the preferred material for liquid absorption.

x. Begin loading the radioactive samples on top of the absorbent pads. Make a complete layer across the cooler.

xi. Place another layer of absorbent pads across the top of the samples.

xii. Prepare the ice by double bagging the ice in Zip-Lock type bags in manageable portions.

xiii. Make a layer of ice bags across the top of the absorbent pads.

xiv. Place another layer of absorbent pads on top of the ice bags.

xv. If necessary place a second layer of samples on top of the absorbent pads.

xvi. Cover the second layer with more absorbent pads.

xvii. Place a final layer of ice bags on top of the absorbent pads.

xviii. Seal the 3 or 6 mil plastic bag with a "J hook" style knot and duct tape.

xix. Place the chain of custody in a plastic bag and place it on top of the cooler contents.

xx. Survey the cooler one final time to make sure that there is no removable contamination present on the outside of the bag or cooler.

xxi. Fill any void spaces in the cooler with bubble wrap or packaging peanuts to prevent the samples from shifting during transport. Seal the cooler lid perimeter using clear packing or duct tape. Band the right and left side of the cooler by going over the top of the cooler and down and under the bottom with industrial strength strapping tape or equivalent. A minimum of two full wraps around both the left and right sides of the cooler. This will effectively "band" the lid to the cooler body and prevent the lid from coming open during transit.

xxii. Place custody seals over the front and back lid so that if the lid is opened the seal will be broken. Cover the custody seal with clear packing tape.

xxiii. Finally, take exposure readings on contact with the cooler and at a distance of 1 meter from the side with the highest reading.

f. If loading hazardous or regulated materials into the container as well as radioactive material, obtain any additional loading and labeling instructions necessary from the RSO or designee.

g. If loading liquids in a container, ensure that the inner package contains enough absorbent material to absorb twice the amount of liquid in the package. Ensure any inner packages are secure to minimize the chance of breakage.

3. Post Loading Steps

a. Ensure that the contents are within any parameters established by the RSO/ designee.

b. If the contents contain moisture, add enough absorbent material to absorb any free-standing water that could be generated during transport.

c. Survey the package for radiation and contamination levels.

d. Weigh the container.

e. Label and mark the container as specified by the RSO designee.

- For limited quantity of radioactive material shipments, the outside of the container will be legibly marked “Radioactive” if no inner packages were thus marked.

- The outside of the container will also be marked with the package ID letters/number, gross package weight and its unit of measurement, and the designated UN shipping number.

- For LSA or SCO shipments, in addition to the above markings, mark the exterior of the package with the words “Radioactive LSA” or “Radioactive SCO “ instead of the word “Radioactive” as appropriate.

- If the Package contains a Reportable Quantity of a hazardous substance, mark “RQ” on the package exterior.

Store in a designated Shipping Area.

G. Ground Shipment Paperwork

1. Only DOT trained personnel may certify by signature on the manifest and/or Bill of Lading that the shipment is classified, described, packaged, marked and labeled and are in proper condition for ground transportation according to DOT regulations.

2. Ensure that the shipment is within the consignee's radioactive material license limits.

3. Prepare the Bill of Lading

4. The following information is required on shipping papers (and bill of lading):

    a. If both hazardous and non hazardous materials are listed on the same papers, the hazardous materials must be listed first (or in a different color) and must be identified by an "X" in the column captioned "HM".

    b. Emergency response phone number.

    c. Proper shipping name, hazard class, and identification number (e.g., Radioactive Material, 7, UN2910).

    d. The words "RADIOACTIVE MATERIAL"

    e. The name of each radionuclide.

    f. Physical and chemical form.

    g. Activity levels.

    h. Category of label applied to each container.

    i. Transport index.

    j. Type of shipping container.

    k. Shipper certification.

    l. Emergency response information.

5. The radiation exposure rate and contamination levels required by 49 CFR 173.441 and 173.443 have been met and documented.

6. Ensure for each package that it meets the package limits for the radionuclide(s) being shipped as specified in 49 CFR for the class of shipment being used.

7. Have another qualified individual review the paperwork for accuracy and completeness.

8. If requested by consignee, send a copy of any requested shipping papers to the consignee for approval prior to shipment. An advance copy of the manifest may be included with this paperwork.

9. File all shipping documents so that they can be easily retrievable by the RSO/designee.

H. Excepted Package Shipment Paperwork

1. Only IATA trained personnel may certify by signature on the air waybill that the shipment is classified, described, packaged, marked and labeled and are in proper condition for air transport according to IATA regulations.

2. Ensure that the shipment is within the consignee's radioactive material license limits.

3. Prepare the Airway Bill

    a. Include Proper Shipping Name and UN Identification Number

    b. Sign and Date

4. Affix the IATA Radioactive Materials - Excepted Package Label (Attachment 1)

5. The radiation exposure rate and contamination levels required by the IATA DGR have been met and documented.

6. Ensure for each package that it meets the package limits for the radionuclide(s) being shipped as specified in IATA DGR Section 10.4.

7. Have another qualified individual review the paperwork for accuracy and completeness.

8. If requested by consignee, send a copy of any requested paperwork to the consignee for approval prior to shipment.

I. Empty Radioactive Materials Package Requirements

1. Empty radioactive materials packages must be prepared for shipment in accordance with 49 CFR 173.428.

2. Survey the interior non-fixed contamination and the external radiation and non-fixed contamination levels to ensure the package conforms to the limits set forth in 49 CFR 173.428.

3. Empty radioactive materials packages do not require shipping papers, and marking.

4. Empty radioactive materials packages must display “empty” labels and the proper shipping name found in 49 CFR 172.101 (i.e., UN-2908).

J. Emergency Response to Transportation Accidents

1. It is the responsibility of consignor or designee to implement the requirements of 49CFR 171.15 upon notification of an accident.

K. Records

1. The following records shall be maintained by the RSO/designee:

    a. Shipping papers

    b. Carrier's documentation

    c. Shipper's radiological survey form

    d. Bill of Lading/Air Waybill

    e. Certification documentation (if required)

2. For radioactive material received, the following records shall be maintained by the RSO/ designee for a minimum period of 375 days:

    a. Shipping paper

    b. Carrier's documentation

    c. Analytical results (if available)

    d. Incoming radiological survey data

Attachment 1
IATA Radioactive Material — Excepted Package Label

(74 x 105mm ~3x4inches)

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

ENVIRONMENTAL MONITORING

PROCEDURE NO: HP-NMI-13

Rev. 2

October 2018

Table of Contents

A. Overview

The purpose of this procedure is to provide guidance and instruction for environmental monitoring.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

1. Health and Safety Plan – Appendix A, Radiation Protection Program

2. 10 CFR 20, Standards For Protection Against Radiation

3. Regulatory Guide 4.15, Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment, July 2007

4. Regulatory Guide 4.20, Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees Other Than Power Reactors, December 1996

5. Regulatory Guide 8.37, ALARA Levels for Effluents from Materials Facilities, July 1993

6. HP-NMI-02, Definitions

D. General Requirements

1. The Site environmental monitoring program includes:

    a. Monitoring of dose rates at the Site Boundary to determine worse-case external doses to members of the general public.

    b. Monitoring at the Site Boundary when performing activities that have the potential to release airborne radioactive materials to determine worse-case internal doses to members of the general public.

    c. Guidance and instruction for the review and documentation of monitoring and sampling activities.

2. This procedure serves as a complement to the Site Management and Security Plan which outlines a comprehensive perimeter monitoring program that includes both radiological as well as chemical contaminants.

3. Samples should be collected in accordance with FSP & QAPP

4. ALARA goals for effluents are 20% of the 10 CFR 20 Appendix B values.

5. Investigation Levels for effluents are 50% of the 10 CFR 20 Appendix B values.

E. Environmental Monitoring

1. Environmental monitoring may be performed to:

    a. Monitor doses to members of the general public from radiation/radioactive material.

    b. Monitor radiological releases to the environment.

    c. Identify increases in the radioactive content of soils and waters through the collection and analysis of on and off site environmental samples.

2. Environmental Monitoring shall be performed until the Radiation Safety Officer, with concurrence from the Project Coordinator and Site Operations Manager, has determined the radiological contaminant levels at the site or the site activities can no longer generate effluents or dose rates that would result in a total effective dose equivalent to a member of the public in excess of 0.1 mSv (100 mrem).

3. Environmental monitoring shall be conducted to meet the limits established in:

    a. 10 CFR Part 20.1302, “Compliance With Dose Limits For Individual Members of The Public” and

    b. 10 CFR Part 20.2003, “Disposal By Release Into Sanitary Sewerage.”

4. As site conditions change (e.g., a building or structure is vacated or the building’s operational status changes), evaluations/assessments shall be performed by the RSO to determine if a change in the environmental monitoring/sampling requirements is necessary.

F. Environmental ALARA

1. Normal site operations, as well as decontamination and decommissioning activities, shall be conducted in a manner that ensures exposure to individuals and the environment is as low as reasonable achievable (ALARA).

2. This Project is committed to reducing unnecessary exposure to members of the public and minimizing radiological releases to the environment.

3. Activities at the NMI Site shall use sound, commonly accepted practices in conjunction with established procedures, engineering controls, and process controls to achieve the environmental ALARA goals established.

4. The RSO shall perform an annual review of the content and implementation of the Environmental Monitoring Program. This review shall include an analysis of trends in release concentrations and environmental monitoring data.

G. Soil Monitoring

1. Soil monitoring shall be performed twice a year in spring and fall, or as directed by the RSO.

2. Samples should be obtained from representative locations as directed by the RSO.

3. Soil samples will be shipped to an approved off site facility for analysis.

4. Soil and sediment samples should be analyzed utilizing gamma spectroscopy. Samples shall be analyzed to meet an *a priori* minimum detectable activity (MDA) of 0.1 pCi/g for U-238.

5. Water samples may be analyzed for gross alpha/beta activity, gamma isotopic activity or alpha isotopic activity.

6. Current sampling results should be compared to previous sampling periods to identify trends in contamination levels.

7. Calculate the mean and standard deviation for the sample results from each location and determine the +/- 2 sigma values.

8. Samples with activity greater than 2 sigma above or below the mean shall be identified and the RSO notified.

H. Airborne Effluent Monitoring

1. Airborne effluent monitoring shall be conducted anytime activities are being performed that could result in a release to the environment that could potentially exceed the limit(s) specified in 10 CFR 20 Appendix B, or as required by the RSO.

2. Samples shall be counted to meet an lower limit of detection (LLD) value of Uranium (Gross α): $\leq 5 \times 10^{-14}$ uCi/ml.

3. The RSO shall be notified of air sample results with an activity greater than the LLD values specified above.

4. When used for effluent monitoring, sample pump flow meters shall be calibrated at least annually.

I. Boundary Dose Monitoring

1. External dose monitoring shall be accomplished through the use of Dosimeters.

    a. The dosimetry used shall be certified by a NVLAP accredited vendor as acceptable for environmental monitoring.

    b. Dosimetry shall be capable of accurately measuring the radiation energies present and be able to measure an accumulated dose of 10 mrem over a period of one-quarter year of gamma radiation.

    c. Dosimetry shall be used to monitor any site area accessible to members of the general public where they could remain for an extended period of time. By extension, a location that would provide a more conservative (i.e. higher reading) may be chosen at a site fence line and used as a surrogate measure of the potential exposure to a member of the public.

2. Environmental dosimetry should be placed in a plastic bag or equivalent for weather protection.

    a. A small slit should be placed in the bottom corner of the bag to allow condensation to drain out.

    b. A hole may be made in the top of the bag above the seal so the bag may be secured to structures at the designated locations.

3. Dosimetry should be placed approximately 1 meter above the ground level.

4. Dosimetry should be oriented such that the front face of the Dosimetry is facing outward when placed against a solid object.

5. Dosimetry shall be changed out quarterly.

    a. Quarters start on the first day of Jan., Apr., July, and Oct.

    b. A leeway period of +/- two weeks is acceptable for the quarterly dosimetry change.

6. A background dosimetry shall be placed at the site background monitoring location at the same time monitoring dosimetry are changed.

7. A control dosimetry shall be kept in an area designated by the RSO (*e.g.*, Administrative trailers).

8. Dosimetry should be placed at the locations as directed by the RSO.

J. DOSIMETRY Documentation

1. The RSO shall review radiological surveys and planned work activities to determine boundary dose monitoring requirements.

2. Based on the monitoring requirements, a map should be developed to identify the number and locations of the dosimetry.

3. Dosimetry information shall be recorded on the Environmental Dosimetry Record sheet (Attachment 1).

4. The individual hanging the dosimetry shall record the dosimetry number, date hung, time hung, and initial the entries on the Environmental dosimetry Record sheet.

    a. The Environmental Dosimetry Record will be placed in the designated active Environmental Dosimetry file.

    b. When dosimetry is pulled, the individual shall record the date pulled, time pulled, and initial the entries on the same Environmental Dosimetry Record sheet the dosimetry were issued under.

    c. The Environmental Dosimetry Record and Dosimetry shall be given to the RSO.

5. The RSO (or designee) will ensure the dosimetry are properly packaged and delivered to the vendor for processing.

6. When the dose report is received, the RSO (or designee) shall review the report and enter the following information on the Environmental Dosimetry Record:

    a. The total dose adjusted for the monitoring quarter.

    b. A corrected total quarterly dose will be calculated by subtracting the background dose from the environmental monitors.

7. Background corrections may be performed by the Dosimetry vendor. If the vendor performs this task, enter "vendor corrected" in the total dose column and enter the vendor reported dose in the corrected dose column.

8. The RSO shall review and sign the Dosimetry Report (NOTE: any total quarterly dose >10 mrem above background should be investigated).

9. The RSO shall perform a final review and sign the Environmental Dosimetry Report. The Dosimetry Report and the Environmental Dosimetry Record shall be placed in the completed Environmental Dosimetry file.

K. Environmental Monitoring Results Evaluation

1. Environmental monitoring sample results should be reviewed and evaluated against previous sampling results.

2. Quality assurance aspects of environmental monitoring and sampling, along with the review and evaluation of sampling results, should be consistent with the Field Sampling Plan & Quality Assurance Project Plan (FSP & QAPP).

ENVIRONMENTAL DOSIMETRY RECORD

Location	DOSIMETRY #	Date Hung	Time Hung	Hung By	Date Pulled	Time Pulled	Pulled By	Average Dose *	Quarterly Dose **	Total Dose ***

Person(s) placing DOSIMETRYs _____ _____ _____ _____
Signature Initials Signature Initials

Person(s) removing DOSIMETRYs _____ _____ _____ _____
Signature Initials Signature Initials

* Average Dose = average of 4 zones from each DOSIMETRY
*** Total Dose = Quarterly dose adjusted for background
**** Background DOSIMETRY Location
All Dose is reported in mrem. Attach Map of DOSIMETRY Locations.

Prepared By: _____ Date: _____ Reviewed By: _____ Date:_____

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

EXPOSURE INVESTIGATION

PROCEDURE NO: HP-NMI-14

Rev. 2

October 2018

Table of Contents

A. Overview

This procedure contains guidance for performing radiation exposure investigations. Investigations may be required in the event of lost or damaged dosimetry, primary-secondary dosimetry mismatch, unanticipated dosimeter read results, or exposure to unexpected radiological conditions without proper monitoring.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. This program is applicable to all personnel and other contractors who require external monitoring in accordance with HP-NMI-08, Radiation Exposure Limits and Monitoring.

C. References

1. 10 CFR 20, Standards For Protection Against Radiation

2. NRC Regulatory Guide 8.7, Instructions for Recording and Reporting Occupational Radiation Exposure Data

3. NRC Regulatory Guide 8.34, Monitoring Criteria and Methods to Calculate Occupational Exposures

4. HP-NMI-08, Radiation Exposure Limits and Monitoring

D. Triggers for Exposure Investigations

a. Lost, misplaced or damaged dosimeter or secondary dosimeter; or

b. Contaminated dosimetry; or

c. DOSIMETER-DRD mismatch:

i. The dosimeter and DRD readings for the same time period differed by more than 30% of the dosimeter reading; and

ii. The dosimeter reading was at least 100 mrem; or

d. Skin contamination in excess of 10,000 cpm; or

e. Exceedance of administrative limits

f. Abnormal exposure survey results/work conditions

g. As directed by the RSO

E. Conducting the investigation

1. The Health Physics Staff will be responsible for performing a preliminary investigation to approximate the individual's year-to-date exposure, including the time period in question, i.e. quarterly. The individual whose dose is being investigated shall not be permitted to enter the restricted area unless the preliminary investigation has been documented and reviewed by the RSO and indicates:

    a. The individual's total effective dose equivalent (TEDE) could not have exceeded 500 mrem for the calendar year.

    b. The shallow dose equivalent (SDE) or eye dose equivalent (LDE) could not have exceeded 1000 mrem for the calendar year, and

2. If the investigation is the result of lost or damaged dosimetry, then complete Attachment 1.

3. Perform the following, as applicable:

    a. Interview the individual and coworkers

    b. measure radiation dose rates in the work area

    c. measure contamination levels in the work area

    d. measure airborne radioactivity concentration in the work area

    e. Review previous representative surveys of the work area and surrounding areas.

    f. Determine the dose to other workers in the area based on DRD readings, if worn.

g. Consider having dosimeters of co-workers read.

h. Estimate dose rates from the source to approximate dose field

4. Estimate the individual's dose

   a. IF the individual lost his/her dosimeter, then:

      i. If the DRD reading is consistent with what would be expected for the work area, then record that dose as the RECORD dose.

      ii. If a DRD was worn but the reading is suspect, then record the DRD reading as ESTIMATED dose and continue the investigation.

      iii. If no DRD was worn, or was lost or damaged, or if the DRD reading is suspect, then continue the investigation.

   b. Analyze the data collected in 2 above.

   c. Estimate exposure.

   d. Document all information and exposure estimate on Attachment 2. Attach supporting documentation as necessary to make a complete record.

   e. If the exposure investigation was the result of a lost or damaged dosimeter, then attach Attachment 1 to Attachment 2.

   f. The RSO shall approve all dose estimates.

   g. Review the dose estimate with the individual. Once the individual and his/her supervisor sign Attachment 2, then enter dose as RECORD dose in employee's dosimetry file.

F. Records

1. All records associated with exposure investigations shall be filed in the individual's permanent file.

G. Attachments

1. Attachment 1, Lost/Damaged Dosimeter Report

2. Attachment 2, Exposure Investigation

Attachment 1

Lost / Damaged / Misplaced Dosimeter Report

Employee Name:_____ SSN:_____

Date / Time of Occurrence:_____

Work Area:_____ RWP Number:_____

Describe events surrounding the loss/damage, and actions taken when discovered (Use additional sheets is necessary):

Employee Signature:_____

Supervisor Signature:_____

Forward this form to RSO immediately upon completion.

Attachment 2
External Exposure Investigation

Employee Name	**SSN**	**Date/Time of Occurrence**
Work Area		**RWP Number**

Reason for investigation

☐ Lost/damaged DOSIMETER ☐ Lost/damaged DRD ☐ Contaminated dosimetry
☐ Skin contamination > 10,000 cpm ☐ DOSIMETER-DRD mismatch
☐ Improper use of dosimetry ☐ Directed by the RSO

Description of task and events surrounding occurrence (refer to Attachments as necessary):

DRD Reading	**Radiation Levels**	**Contamination Levels:**
mrem	**AVG:**	**AVG:**
	MAX:	**MAX:**

Coworkers/comparable doses:

Basis for Assigned Dose:

Dose Assignment All doses in mrem

Monitoring Period: ☐ RECORD Dose ☐ ESTIMATED Dose

DDE		LDE		SDE(Sk)		SDE(ME)	
UL		UR		LL		LR	
CDE		CEDE		TEDE		TODE	

Performed by (sign/date):	**Individual (sign/date):**
Supervisor (sign/date):	**RSO Approval (sign/date):**

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

PORTABLE INSTRUMENT CALIBRATION
AND RESPONSE CHECKS

PROCEDURE NO: HP-NMI-15

Rev. 2

October 2018

Table of Contents

A. Overview

Portable instruments will be calibrated at set frequencies, usually annual intervals or as prescribed by the manufacturer. Procedures must be in place to periodically check instruments ensuring that they respond to radiation and will give accurate readings when used in the field. This procedure provides general instructions for the performance of response checks on portable instruments.

B. Applicability

1. This procedure applies to portable handheld instruments having internal or external probes and bench-top or semi-portable instruments such as scalers. It does not apply to stationary lab equipment or other non-portable instrumentation.

2. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

3. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

4. This procedure is applicable to all personnel and other contractors who perform instrument response checks in the course of their duties.

C. References

1. 10 CFR 20, Standards For Protection Against Radiation

2. NUREG 1575, Multi-Agency Radiation Survey and Site Investigation Manual

3. NUREG 1507, Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions

4. ISO-7503.1, Evaluation of Surface Contamination – Part 1: Beta emitters (maximum beta energy greater than 0.15 MeV) and alpha emitters

5. ANSI N323A-1997, Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments

D. General Requirements

1. Portable instruments shall be calibrated annually or more frequently if required by manufacturer. Instruments shall be inspected before daily use to verify calibration date.

CAUTION: Ensure the appropriate efficiency and geometry are being used for each survey application in accordance with the manufacturers requirement and applicable operational procedure for the instrument. MARSSIM surveys and other unique instrument applications may require specialized calibration (2π and 4π efficiencies).

2. Contamination instruments used for work area monitoring and unconditional release surveys shall have efficiency determined using 4π activity geometry; in the absence of 4π efficiency, the 2π efficiency shall be used with modifications described in NUREG 1507.

3. Instruments used for final status release surveys in accordance with MARSSIM should have efficiency determined using the 2π emission geometry.

4. Instruments shall be calibrated using similar geometry and energy to that expected to be encountered in the field. For contamination instruments used in various field locations, efficiencies should be determined for a variety of radionuclides. As a general rule, request the following:

    a. Both 2π and 4π efficiencies for Tc-99 for probes used to measure surface beta contamination

    b. Both 2π and 4π efficiencies for Th-230 or Pu-239 for probes used to measure surface alpha contamination

    c. Both 2π and 4π efficiencies for I-129, Cs-137, or Co-60 for probes used to measure surface gamma contamination

    d. Dose rate instruments should be calibrated using Cs-137.

5. Portable instruments shall be response checked daily when in continuous use.

6. Portable instruments that are not in continuous use shall be response checked prior to each day's use.

7. The source and geometry used for daily response checks shall be the same source used for initial setup.

E. Initial Setup and Response Check

NOTE: Use of a source jig is recommended to ensure an identical geometry is maintained through initial setup and subsequent response checks on portable instruments. Ensure instruments and detectors are paired correctly and calibration is current.

1. Initial set-up/operability checks of contamination monitoring instruments (Attachment A)

    a. Perform physical inspection of the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, switches, and high voltage.

    b. Count background:

        i. For scalers, count background for at least 1 minute or longer based on the required MDC. Obtain 10 background measurements and record results.

        ii. For ratemeters, record average background reading in cpm.

    c. Count source

        i. For scalers, count source for at least 1 minute or longer based on the required MDC. Obtain 10 gross counts and record rate in cpm.

        ii. For ratemeters, place source under detector window and allow meter to stabilize. Record gross count rate in cpm.

    d. Subtract background reading from gross count rate and record total net counts and net count rate (CPM)

    e. Calculate allowable response range (±20% of the net count rate) in cpm.

2. Initial setup of dose rate instruments (Attachment C)

    a. Perform physical inspection of the instrument, detector, and cables for signs of obvious damage; check batteries, mechanical zero, electrical zero, and switches.

    b. Place source a measured distance from the instrument. Measure the dose rate from the source; allow the meter to stabilize, and record the dose rate reading.

Calculate the allowable response range (±20% for each multiplier setting) and record results in the appropriate blocks.

F. Routine Response Checks

NOTE: Some instruments are affected by ambient temperature and pressure. Reasonable effort should be made to perform response checks under conditions approximating normal indoor room environment.

1. Frequency

    a. Daily when in continuous use (used or likely to be used every day);

    b. Prior to use if not used every day.

    c. Response checks shall be performed if the operability of the instrument is suspect.

2. Contamination instrument response check (Attachment B)

    a. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, switches, and high voltage; allow sufficient purge time for gas-flow detectors in accordance with instrument operating instructions.

    b. Count background:

        i. For scalers, perform a 1-minute background count and record results

        ii. For ratemeters, observe and record average background reading.

        iii. Assure background is in the acceptable range.

    c. Count source

        i. For scalers, perform a 1-minute source count. Record net counts.

        ii. For ratemeters, place source under detector window and allow meter to stabilize. Record net count rate, check appropriate status (S/U), and initial form.

    d. Assess results of response check.

i. If response check falls within allowable response range, AND if physical checks in a. above are satisfactory, then the instrument is ready for use.

ii. If response check result is outside of allowable response range OR if the physical checks performed in a. above are unsatisfactory:

- Notify supervisor
- Check batteries, Mylar, cord, gas flow and pressure, and range selector switch and adjust as necessary. Cords, Mylar, and batteries may be replaced in the field if necessary. Re-test the instrument. If the response check falls within the allowable range, then the instrument is ready to use.
- If the instrument still does not fall within the allowable range, then tag instrument out of service. Investigate all surveys performed with the instrument since the last satisfactory response check.

3. Dose rate instrument response check (Attachment D)

a. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, switches, and electrical zero.

i. Measure the dose rate from the source; allow the meter to stabilize, and record the dose rate reading check appropriate status (S/U), and initial form.

b. Assess results of response check.

i. If response check falls within allowable response range, AND if physical checks in a. above are satisfactory, then the instrument is ready for use.

ii. If response check result is outside of allowable response range OR if the physical checks performed in a. above are unsatisfactory:

- Check batteries, Mylar, cord and range selector switch and adjust as necessary. Cords, Mylar, and batteries may be replaced in the field if necessary. Re-test the instrument. If the response check falls within the allowable range, then the instrument is ready to use.

- If the instrument still does not fall within the allowable range, then tag instrument out of service. Investigate all surveys performed with the instrument since the last satisfactory response check.

G. Minimum Detectable Activity

1. Often MDA will be calculated in the field each day due to changing conditions. When background levels are expected to remain fairly constant, MDA that is determined during instrument setup may be used for a longer period of time.

2. Calculate MDA using the following equation:

$$MDA = \frac{3 + 3.29\sqrt{B_R \cdot t_S \cdot \left(1 + \frac{t_S}{t_B}\right)}}{t_S \cdot E_{TOT} \cdot \frac{A}{100}}$$

Where

B_R	=	Background count rate (cpm)
t_S	=	Sample count time (minutes)
t_B	=	Background count time (minutes)
E_{TOT}	=	Total efficiency
A	=	Detector active window area (A=100 on instruments used to count smears cm^2)

- For instruments used for counting smears, work area monitoring, and unconditional release surveys, E_{TOT} is equal to the 4-pi efficiency determined during instrument calibration.
- For instruments used for direct surface contamination measurements during final status surveys in accordance with MARSSIM, E_{TOT} is the product of the 2-pi instrument efficiency determined during calibration times the surface efficiency determined in accordance with ISO-7503.1.

H. Records

1. Calibration certificates shall be maintained on file.

2. Response check forms shall be maintained on file.

I. Attachments

1. Attachment A: Contamination Instrument Initial Setup Log

2. Attachment B: Contamination Instrument Response Check Log
3. Attachment C: Dose Rate Instrument Setup and Response Check Log
4. Attachment D: Dose Rate Instrument Daily Response Check Log

Attachment A

Contamination Instrument Initial Setup Log

Instrument Model	Instrument Serial Number	Calibration Due Date
Detector Model	**Detector Serial Number**	**Detector Area (cm2)**
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**
Calibrated Efficiency (4pi)	**Project Efficiency (4pi)**	**High Voltage**

Background Count Time (tB)	
	minute(s)

Background Counts	
Count #	**Background Count Rate**
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
BKG CPM	

Source Count Time (tS)	
	minute(s)

Source Counts		
Count #	**Gross Source Count Rate**	**Net Count Rate**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Source Mean		
Source Reproducibility (+/- 20%)		

Measurement MDC	
	dpm/100cm^2

$$MDA = \frac{3 + 3.29\sqrt{B_R \cdot t_S (1 + \frac{t_S}{t_B})}}{t_S * E_{tot} * \frac{A}{100}}.$$

Performed By: _____ **Date:** _____

Reviewed By: _____ **Date:** _____

Attachment B
Contamination Instrument Response Check Log

Instrument Model	Instrument Serial Number	Calibration Due Date	Project Efficiency
Detector Model	**Detector Serial Number**	**Detector Area**	**High Voltage**
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to

Date	Time	Type	Background	Gross Count Rate	Net Count Rate	SAT/UNSAT	Comments	Initials
		α						
		β						
		γ						
		α						
		β						
		γ						
		α						
		β						
		γ						
		α						
		β						
		γ						

Reviewed By: Date:

Attachment C

Dose Rate Instrument Initial Setup Log

Instrument Model		**Serial Number**		**Date Setup**	
Detector Model		**Serial Number**		**Source Isotope:**	
Calibration Date		**Calibration Due Date**		**Source ID:**	

Before proceeding, ensure the following are satisfactory. Initial block below.				
Cord OK?	**BATT Check**	**Mechanical ZERO**	**Elec. ZERO**	**All Switches**

Record the initial response check readings and range selector switch position for the ranges checked. ***Fill in the blank for the range multiplier setting***			
Range Selector _____ Geometry	**Range Selector _____ Geometry**	**Range Selector _____ Geometry**	**Range Selector _____ Geometry**
Reading	**Reading**	**Reading**	**Reading**
Allowable range (+/- 20%)	**Allowable range (+/- 20%)**	**Allowable range (+/- 20%)**	**Allowable range (+/- 20%)**

Performed by (Sign/Date):_____

Reviewed by (Sign/Date):_____

Attachment D

Dose Rate Instrument Daily Response Check Log

Instrument Model_____ Serial No_____

Date	Time	Physical Check (S/U)	Scale _____ Reading	Scale _____ Reading	Scale _____ Reading	Scale _____ Reading	Status (S/U)	Initials
Allowable Response Range								

Performed by (Sign/Date):_____

Reviewed by (Sign/Date):_____

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

LUDLUM Model 3 OPERATION

PROCEDURE NO: HP-NMI-16

Rev. 3

October 2018

Table of Contents

A. Overview

This procedure describes source checking and use of the Ludlum Model 3 ratemeter/scaler instruments with 44-9 probe.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

3. This procedure is applicable to all health physics personnel that perform radiological surveys.

C. Precautions

The Ludlum Model 3 will not be used to perform release surveys for materials and equipment for unrestricted release from radiological areas.

D. Preparation

1 Perform a visual check of the meter and probe for damage such as scratches or holes in the probe detector window, frayed cord, excessive meter damage, meter face cracked, etc.

2 Check to see if that the calibration is valid by observing the dates on the calibration sticker on the instrument. If past “calibration due” date, notify RSO or designee.

3. Turn the selector knob so that it points to the “BAT” label and verify that the reading is in the “BAT OK” region of the meter movement. If the reading is out of this region then replace the batteries and perform this check again. If the meter still does not reach the “BAT OK” region, then notify RSO or designee.

E. Procedure

Instrument Source Check

CAUTION: The following steps must be performed prior to initial use of the instrument for the day.

1. Initially place the RESP toggle switch to “S” position for source checking.

2. Position the probe face away from any source of radiation.

3. Turn the ratemeter switch to the "X1" position.

4. Place the DIGITAL timer control knob to "1" if applicable.

5. Press the COUNT button located in the handle to initiate a one minute count (if applicable). Record average background in cpm if timer is not present.

6. Record the background count on Instrument Source Check Form (Attachment 1).

   Note: If background has not been established yet, then use background established during calibration recognizing that there may be some variation from local site background. Typically, readings within 20% of the background are acceptable.

7. Place the probe face directly over the check source.

8. Adjust the RATEMETER knob to the appropriate scale for the check source being used so the counts are registered without overloading the meter movement. Place the DIGITAL timer control knob to "1" if applicable.

9. Press the COUNT button located in the handle to initiate a one minute count. Record average source rate in cpm if timer is not present.

10. Record the check source reading on the Instrument Source Check Form (Attach 1).

    Note: If the instrument meets all of the preceding criteria, proceed to the next step.

    Note: If the instrument does not meet all the preceding criteria, note on Instrument Source Check Form (Attachment 1), notify the RSO or designee of the faults and choose another survey instrument.

Scanning Surface Measurement Meter Use

1 Position the response (RESP) toggle switch in the, slow "S" position.

2 Hold the probe approximately 1/8" from the surface and scan the surface slowly at a rate of approximately 1-2 inches per second.

3 If there is audible indication of elevated contamination levels during scanning, locate maximum area of contamination.

a. *If the audible indication continues, hold the probe in that position for an additional 15 seconds to confirm the presence of surface contamination by noting the readout.*

b. *If surface contamination is confirmed, perform a 1-minute scaler count and record the reading in dpm/100cm^2 on survey sheet.*

Determine the activity per 100cm^2 as follows:

a. *Divide total counts by count length to get gross counts per minute (gcpm).*

b. *Take the gcpm value and subtract the background for net counts per minute (ncpm).*

c. *Multiply the net counts per minute times 100 divided by the active counting area of probe being used to get ncpm/100cm^2.*

d. *Determine the average activity per 100cm^2 by dividing the net cpm/100cm^2 by the detection efficiency of the instrument.*

$$\frac{\text{Total Counts}}{\text{Count Length}} = \text{Gross Counts per Minute (gcpm)}$$

gcpm – Background Counts per Minute (bcpm) = Net Counts per Minute (ncpm)

$$\text{ncpm} \times \frac{15\ \text{cm}^2}{\text{active counting area of probe}} = \text{ncpm/100cm}^2$$

$$\frac{\text{ncpm/100cm}^2}{\text{Instrument Efficiency (eff.)}} = \text{Activity/100cm}^2$$

Contamination Instrument Response Check Log

Instrument Model	Instrument Serial Number	Calibration Due Date	Project Efficiency
Detector Model	**Detector Serial Number**	**Detector Area**	**High Voltage**
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to

Date	Time	Type	Background	Gross Count Rate	Net Count Rate (CPM)	SAT/UNSAT	Comments	Initials
		α						
		β						
		γ						
		α						
		β						
		γ						
		α						
		β						
		γ						
		α						
		β						
		γ						

Reviewed By: Date:

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

EMPLOYEE IN/OUT PROCESSING

PROCEDURE NO: HP-NMI-17

Revision 2

October 2018

Table of Contents

A. Overview

This program was developed to provide NMI Site personnel and other contractors with a document containing the necessary requirements and guidelines to successfully process employees in and out during hire and termination.

Several radiation protection functions – determination of prior dose, baseline bioassay, ensuring training requirements are met – need to begin during a new employee's first few days on the job. This procedure contains instructions on completing those tasks so the employee is able to work safely with radioactive materials.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

1. 10 CFR 20, Standards For Protection Against Radiation

2. 29 CFR 1910.134

3. NRC Regulatory Guide 8.13, Instruction Concerning Prenatal Radiation Exposure

D. New Hire In-processing

1. Training

    a. The hiring manager shall complete Attachment 1.

        i. Send original to RSO or designee

        ii. Give copy to employee.

    b. Schedule the employee for any required training that has not yet been completed.

    c. If the individual is female:

i. Brief her and her supervisor on the requirements of HP-NMI-08 as it pertains to Declaration of Pregnancy;

ii. Provide her with a copy of NRC Regulatory Guide 8.13

d. Training received from any other facilities shall be evaluated on a case-by-case basis.

2. Dosimetry

a. The employee shall complete Attachment 3, Exposure History Form.

b. The employee shall sign the bottom of Enclosure 4, Request for Monitoring Results.

c. If the worker will be radiological worker under the NMI Radiation Protection Program, the employee's direct supervisor shall:

i. Complete Enclosure 5 and forward to Dosimetry.

ii. Issue bioassay containers if needed as specified by HP-NMI-05, Internal Monitoring.

d. Dosimetry shall create a dosimetry file for the individual

e. When previous dose history is obtained, generate NRC Form 4 (or equivalent). Sign and retain in employee's file.

E. Terminated Employee Out-processing

1. Internal Dosimetry

a. Issue bioassay bottle(s) if needed to the employee with instructions to return bioassay.

2. External Dosimetry

Collect the employee's dosimetry if issued and any other dosimetry devices issued to the employee.

3. Dosimetry shall generate an updated Estimated NRC Form 3 (or equivalent), sign, and give copy to employee if required. If impractical to give to the employee at time of termination, the form shall be mailed to the employee's last known address within 30 days of termination date.

F. Records

1. Attachment 1 shall be retained in the employee's Training file.

2. Attachments 2 - 3 shall be retained in the employee's Dosimetry file.

3. Form 3 and other forms generated under this procedure shall be maintained in the employee's Dosimetry file.

Records that are required by this procedure shall be maintained in accordance with the applicable regulatory requirements.

G. Attachments

1. Attachment 1 – Radiological Training Validation

2. Attachment 2 – Exposure History Form

3. Attachment 3 – Request for Monitoring Results

4. Attachment 4 – Initial Exposure Limits for New Employees

Attachment 1

Radiological Training Verification

Employee Name_____

Employee # (or SSN)_____ Date Hired_____

Will the employee perform radiological work or frequently enter the Restricted Area? Y___ N___

If the answer is "No," then skip to Line 7. If the answer is "Yes," then complete Lines 1 through 6.

		Date Completed	Verified by (init.)
1	Health Physics Technician Qualified		
	a) Radiation Worker Training		
	b) Current RCT Training or ABHP Certification		
	c) Other training (must be approved by RSO)		
	d) Respiratory Protection Training		
	Respirator Fit Test		
2	Respirator Physical		
3	HAZWOPER Physical		
4	Reg. Guide 8.13 Training		
5	Initial Bioassay issued		
6	Radiological Awareness Training		

Employee Signature: _____

Supervisor Signature: _____

RSO Signature: _____

Attachment 2

Exposure History Form

LAST NAME	FIRST NAME	MI	SSN
DATE OF BIRTH	WORK GROUP		LOCATION

EMPLOYER NAME			EMPLOYMENT DATES -
STREET ADDRESS			
CITY	STATE	ZIP CODE	ESTIMATED DOSE RECEIVED mrem
EMPLOYER NAME			EMPLOYMENT DATES -
STREET ADDRESS			
CITY	STATE	ZIP CODE	ESTIMATED DOSE RECEIVED mrem
EMPLOYER NAME			EMPLOYMENT DATES -
STREET ADDRESS			
CITY	STATE	ZIP CODE	ESTIMATED DOSE RECEIVED mrem
EMPLOYER NAME			EMPLOYMENT DATES -
STREET ADDRESS			
CITY	STATE	ZIP CODE	ESTIMATED DOSE RECEIVED mrem

Signature: ____ Date: ____________________

Attachment 3

Request for Monitoring Results

To (previous employer):

Subject: Request for report of radiation exposure history

FULL NAME:_____ SSN:_____

BIRTH DATE: _____

Dear Sir/Madam:

The above-name individual has indicated he/she was monitored for occupational radiation exposure while engaged in work at your facility. We request a report of the occupational radiation exposure received by this individual at your facility. Please include results of any calculations and analyses of radioactive materials deposited in the body which may have been performed during the same period. A statement authorizing the release of this information is below.

Please address your reply to:

Sincerely,

I authorize the release of my dosimetry records, including estimates of internal or external exposure, to.

_____ _____

Signature Date

Cc: Individual Dosimetry File

Attachment 4

Initial Exposure Limits for New Employees

Employee Name:_____

Employee # (or SSN):_____ Date of Birth:_____

Dose equivalents below are in mrem unless otherwise noted

		TEDE	LDE	SDE(ME)	SDE(SK)	CEDE	CDE
A	Legal Limits (Not applicable to new employees)	5000	15000	50000	50000	5000	50000
B	Administrative Limits	2000	6000	20000	20000	2000	20000
C	Limits for Minor	500	500	500	500	500	500
D	Limits if monitored this year and record dose not received	500	500	500	500	500	500

Indicate the applicable set of limits here (use A, B, C, or D):_____

CAUTION: If the employee is a Declared Pregnant Worker, the STOP here and contact RSO prior to allowing entry to restricted area or issuance of Dosimetry.

Approved by RSO (Sign/Date):_____

If "D" was selected above, complete the following after exposure records have been received from previous employer(s) for the current calendar year.

		TEDE	LDE	SDE(ME)	SDE(SK)	CEDE	CDE
1	Legal Limits (Not applicable to new employees)	5000	15000	50000	50000	5000	50000
2	Current year dose from previous employer(s)						
3	Subtract Line 2 from Line 1						
4	Administrative Limits	2000	6000	20000	20000	6000	20000
5	Enter the LESSER of the value in Line 3 or Line 4 for EACH column						

Approved by RSO (Sign/Date):_____

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

LUDLUM 2929 OPERATION

PROCEDURE NO: HP-NMI-18

Rev. 1

October 2018

Table of Contents

A. Scope

This procedure provides instructions for setup and use of the Ludlum Model 2929 dual channel scaler with the 43-10-1 detector. This procedure is applicable to all work when the Model 2929 is used.

B. References

1. Regulatory Guide 4.15, Quality Assurance for Radiological Monitoring Programs (Normal Operations) – Effluent Streams and the Environment

2. HP-NMI-05, Radiological Surveys

3. Ludlum Model 2929 Technical Manual

C. Precautions and Limitations

1. Handle sources, especially electroplated sources, carefully. Hold sources by the edges and avoid touching the face.

2. Keep sources in their respective cases when not in use to avoid scratching or losing the source.

3. The detector face is covered with thin Mylar material and is susceptible to damage. Sticky smear material can curl up and damage the Mylar.

4. Make sure the sample well drawer is fully inserted before turning the lock down knob. Do not over-tighten the lock down knob as it will strip.

5. Samples that are suspected to be highly contaminated should be field checked before being counted in the 2929. If field check indicates the sample is likely to exceed 5000 dpm alpha or 50,000 dpm beta-gamma, the sample should not be counted in the 2929. Contact the Project Manager or RSO for guidance.

6. The operating temperature for the instrument is between 5ºF to 122ºF.

D. Pre-operation

1. Place the instrument on a flat surface away from temperature and humidity extremes.

2. Plug the instrument into a standard 110V AC outlet.

3. Turn instrument ON.

4. Verify the high voltage (HV) is within 50 volts of the value recorded at calibration.

5. Ensure the sample tray is in the drawer and there is no visible dust or dirt. If dust and/or dirt are visible, clean the tray and drawer using a commercial cleaner.

E. Initial Setup

1. The initial setup shall be performed:

    a. Prior to first use after the instrument is received from calibration; and

    b. Prior to first use whenever check sources to be used are different from those used for the initial set after calibration.

2. Perform pre-operational steps, if not already done.

3. Ensure there is an empty, clean planchette in the sample tray.

4. Perform background and source counts.

    a. One copy of Attachment A shall be used for ALPHA counts; a separate copy shall be used for BETA counts.

    b. Perform a 10-minute background count. Record the average background count rate on Attachment A.

NOTE: Ensure the source(s) selected emit alpha and beta particles. Pure alpha emitters will spill over into the beta channel as crosstalk, and should not be used to test the beta channel. The only radionuclide that emits both alpha and beta particles in sufficient quantity for instrument checks is U-238. If a U-238 source is not used, then use an alpha source such as Th-230 or Pu-239, and a beta source such as Tc-99, C-14, or Sr-90. Check sources should emit particles that are representative of those expected to be encountered in the field. Sources used for Chi Squared and routine response checks do not need to be NIST traceable.

    c. Reset timer and perform a series of twenty, 1-minute source counts using the designated source. Record gross counts in Column B.

    d. Calculate the mean (average) source count rate, and record in Column B.

e. Subtract background. Record each NET count in Column D.

f. Calculate the mean BETA source count rate, and record in Column D.

5. Calculate and evaluate Chi-squared (X^2).

$$X^2 = \sum \frac{\left(X_g - \overline{X_g}\right)^2}{\overline{X_g}}$$, where:

X_g = Gross count rate
$\overline{X_g}$ = Expected gross count rate (average of the 20 individual counts)

a. In each block in Column B, subtract the mean gross source count (bottom of Column B) rate from the gross counts for that individual count. Square the difference. Divide by the mean, and enter the result in the appropriate block.

b. Add all twenty data points in Column B.

c. The X^2 value determined above must be less than 30.14. This represents the 95% confidence interval that each of the source counts obtained during setup falls within the expected range.

6. Calculate the standard deviation (□).

$$\sigma = \sqrt{\frac{\sum\left(X_n - \overline{X_n}\right)^2}{n-1}}$$, where:

X_n = Net count rate
$\overline{X_n}$ = Expected net count rate (average of the 20 individual counts)
n = The number of source count trials (20)

a. In each block in Column E, subtract the mean net source count rate (bottom of column D) from the net counts for that individual count. Square the difference and enter in the appropriate block.

b. Add all ten data points in Column E.

c. Divide the sum obtained in Step b. by 19.

d. Calculate the square root of the value obtained in step c. This is the standard deviation (σ).

e. Record standard deviation on Attachment A.

f. Calculate and record 2σ and 3σ.

F. Response check

1. The instrument shall be response checked daily, or prior to each day's use, whichever is less frequent.

    a. Retrieve Attachments A, B, and C for the instrument being used.

    b. Place a clean planchette in the sample tray. Close and latch the drawer.

    c. Count background for one minute.

    d. Place the BETA source (as designated on the instrument set-up sheet) in the sample tray. Close and latch the drawer, and count for one minute. Record net counts.

    e. Place the ALPHA source (as designated on the instrument set-up sheet) in the source tray. Close and latch the drawer, and count for one minute. Record net counts.

2. Record the source counts on Attachment B.

3. Evaluate net source counts.

    a. If both source counts are within ±2σ of the mean, the instrument is OK to use.

    b. If either source count is within ±3σ but not within ±2σ of the mean, evaluate whether or not a problem exists.

        i. Check for obvious causes, such as operating voltage, timer setting, foreign material in the sample tray, bad cord, etc., and correct them.

        ii. Re-count the affected source(s).

iii. If the recount is within ±3σ, then the instrument is ready for use.

c. If at any time the source count is outside ±3σ of the mean, do the following:

i. Count the source three more times. If all counts are outside ±2σ of the mean in the same direction, or if two or more counts are outside ±3σ, then place the instrument out of service. Otherwise, the instrument is OK to use.

d. Plot the daily source count for each source on the Control Chart.

e. Periodically evaluate trends in the data'

i. Approximately 65% of the daily source counts should be within ±2σ of the mean.

ii. Approximately 99% of the daily source counts should be within ±3σ of the mean.

iii. Daily source check values should appear to vary randomly above and below the mean. A steady increasing of decreasing trend, or more than five counts in a row appearing above or below the mean, may be indicative of a problem.

G. Minimum Detectable Activity

1. Minimum detectable activity (MDA) is the minimum amount of radioactivity that can be measured within the desired confidence interval (95%).

2. MDA is determined using the following equation:

$$MDA = \frac{3 + 3.29\sqrt{B_r \cdot t_g\left(1 + \frac{t_g}{t_b}\right)}}{t_g \cdot E}$$, where:

B_r = Background count rate in cpm
T_g = Counting interval of the sample in minutes
T_b = Counting interval of the background count in minutes
E = Total instrument efficiency (4π efficiency)

3. If $t_g = t_b$, then the equation may be shortened to:

$$MDA = \frac{3 + 4.65\sqrt{B_r}}{E}$$

H. Counting Samples with the 2929

1. Ensure the instrument is set up properly, has a current calibration, has been response checked, and shows no obvious signs of damage.

2. Count samples and record results in accordance with HP-MA-06, Contamination Surveys.

I. Attachments

1. Attachment A: Initial Setup and Chi-squared (X^2) Calculation

2. Attachment B: Model 2929 Set-up Record

3. Attachment 3: Model 2929 Response Check Record

J. Records

1. Each active instrument will have the following records associated with it:

    a. Attachment A (Separate alpha and beta sheets)

    b. Attachment B

    c. Attachment C (Separate alpha and beta sheets)

2. At least the last 30 days of control charts after calibration should remain with the instrument. The remainder may be filed with the original calibration certificate.

Attachment A: Initial Setup and X^2 Calculation

Model	**Detector**	**Calibration Date**
Serial #	**Serial #**	**Calibration Due**
Setup Date	**Reason for Setup**	
Alpha **Beta-Gamma**		**Source ID**
20 1-minute BKG Counts:		**BKG cpm:**

A	B	C	D	E
Count # *(n=20)*	**Gross Counts** *(X_g)*	$\frac{\left(X_g-\overline{X_g}\right)^2}{\overline{X_g}}$	**Net Counts** *(X_n)*	$\left(X_n-\overline{X_n}\right)^2$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTAL				
Mean ($\overline{X}$)				
Chi-squared $X^2=\sum\frac{\left(X_g-\overline{X_g}\right)^2}{\overline{X_g}}=$				
Standard Deviation $\sigma=\sqrt{\frac{\sum\left(X_n-\overline{X_n}\right)^2}{n-1}}=$			**2σ=**	**3σ=**

Is X^2 ≤30.14? _____If YES, then instrument is good to use. Otherwise, return for calibration.

Performed by/Date:_____ Reviewed/Date:_____

Instrument Initial Set-Up Form

Instrument Model	Instrument Serial Number	Calibration Due Date
Detector Model	**Detector Serial Number**	**Detector Area (cm^2)**
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**
Calibrated Efficiency (4pi)	**Project Efficiency (4pi)**	**High Voltage**

Background Count Time (t_B)	
	minute(s)

Source Count Time (t_S)	
	minute(s)

Background Counts	
Count #	**Background Count Rate**
Background CPM	

Source Counts		
Count #	**Gross Source Count Rate**	**Net Source Count Rate**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Source Mean		

Static Measurement MDC	
	dpm/100cm^2

Source Reproducibility (+ /- 20%)	

$$MDA = \frac{3 + 3.29\sqrt{B_R \cdot t_S (1 + \frac{t_S}{t_B})}}{t_S * E_{tot} * \frac{A}{100}}.$$

Performed By: _____ **Date:** _____

Reviewed By: _____ **Date:** _____

Instrument Model	Instrument Serial Number	Calibration Due Date	Project Efficiency
Detector Model	**Detector Serial Number**	**Detector Area**	**High Voltage**
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to

Date (M/D/Y)	Time	Type	Background (CPM)	Gross Count Rate (CPM)	Net Count Rate (CPM)	SAT/UNSAT	Comments	Initials
		α						
		β						
		α						
		β						
		α						
		β						
		α						
		β						
		α						
		β						
		α						
		β						
		α						
		β						
		β						

Reviewed By: Date:

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

RADIOLOGICAL WASTE CLASSIFICATION AND PACKAGING

PROCEDURE NO: HP-NMI-019

Rev. 1

October 2018

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A. Overview

The purpose of this procedure is to provide the general instructions for the classification and packaging of waste that is radiologically impacted.

B. Applicability

1. This program applies to radiological work activities at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. Customer-required procedures and controls may be implemented to meet contractual requirements provided they are at least as stringent as the controls mentioned herein.

C. References

NTCRA Health and Safety Plan – Appendix A, Radiation Protection Program

10 CFR 20, Standards For Protection Against Radiation

49 CFR 171, General Information, Regulations, and Definitions

49 CFR 172, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans

HP-NMI-02, Definitions

D. General Requirements

In general, this procedure covers the requirements for classification and packaging of waste with radiological contamination.

The procedures contained in this document are to be used by personnel when screening, packing, marking, labeling radioactive waste. All waste packaging shall be conducted in accordance with procedure *HP-NMI-01*, “Conduct of Radiological Work”.

The steps in this procedure do not have to be followed sequentially and in many cases they can be performed simultaneously.

E. Preliminary Classification of Radioactive Waste

Materials that are to be packaged as radioactive waste shall be screened to determine the proper waste category. The majority of wastes produced from the RD/RA will be

impacted soils, concrete foundation debris, landfilled debris, etc. This will ensure packaged waste meets and follows the correct pathway for the appropriate Waste Acceptance Criteria (WAC) for the designated disposal or treatment facility. The waste categories for the NTCRA are as follows:

- **Waste Type I-** Potentially Contaminated Items that have the potential to contain minimal DU contamination. These items will be screened and on average found to be below the regulatory release limits as state in Regulatory Guide 1.86. 1,000 dpm/100cm^2 for total alpha contamination.

- **Waste Type II-** These waste items are expected to contain higher concentrations of DU with an average of 0.05% by weight. Contaminated items that are found to be above 1,000 dpm/100cm^2 total alpha contamination during field screening will be considered Waste Type II. This waste type will have an upper threshold limit of 40,000 dpm/100cm^2 total alpha contamination.

- **Waste Type III-** Waste will DU concentrations less than 18,000 pCi/gram for solids. During field screening, contaminated items that are found on average to be above 40,000 dpm/100cm^2 total alpha contamination. This waste type will have an upper threshold limit of 475,000 dpm/100cm^2 total alpha contamination on average.

- **Waste Type IV-** DU materials with greater than 18,000 pCi/gram for solids. During field screening, contaminated items that are found on average to be above 475,000 dpm/100cm^2 total alpha contamination.

Screening will be performed by personnel training in the operation of radiological field instrumentation to establish waste type categories. These measurements will be compared to laboratory data from representative surfaces/materials obtained during Pre-Demolition Survey.

Dose rates will be obtained from prepared packages where the radioactive waste is generated in order to properly characterize the waste packing class.

Prior to shipment, all waste will undergo a non-destructive assay with portable field instrumentation to assure that proper waste type has been identified.

Document all screening surveys as required by *HP-NMI-05* “Radiological Surveys”.

F. Packaging of Radioactive Materials

General Packaging Requirements

- Waste shall be packaged in compliance with the disposal site's WAC and per the packaging manufacturer specifications.
- All packaged waste will be appropriately marked with radionuclide, activity, generation date, weight and labeled as "Caution Radioactive Material" as appropriate.
- Waste shall be appropriately segregated by material type and waste Type I or II to prevent comingling of different waste types.
- Waste packaged into cubic yard sacks will be placed into 6-mil liners and properly sealed upon completion of packaging.
- Waste shall be inventoried, weighed and staged in the designated waste staging locations.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Operation of the Ludlum 2224-1

PROCEDURE NO: HP-NMI-21

Rev. 1

October 2018

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A. PURPOSE

This procedure provides instructions for the operation of the Ludlum Model 2224-1 Alpha/Beta scaler/ratemeter with the Ludlum 43-89 Alpha/Beta detector.

B. APPLICABILITY

This procedure is applicable to instrument use for determining the amount of alpha and beta contamination concurrently. These instruments are used to measure radiation levels in units of counts per minute, ranging from typical background values to those expected in most NMI operations. This instrument is suitable for the following types of surveys:

- Equipment surface contamination
- Radiological area identification
- Radioactive material shipments
- Characterization

When connected to the appropriate detector, this instrument will indicate relative contamination levels and identify changes in contamination levels.

C. PRE-REQUISITES

The Ludlum Model 2224-1 ratemeter/scaler is designed to be used with a dual phosphor probe. This Ludlum probe model 43-89 or equivalent probe will be used with the 2224-1.

D. RESPONSIBILITIES

1. The project RSO, Senior Health Physics Technicians, or designee is responsible for ensuring this procedure implementation occurs.
2. Survey team members are responsible for following this procedure.

E. INSTRUCTIONS

- ***Pre-Operational Checks***

1. Perform a visual inspection of the meter and probe. Look for any damage to the meter and probe, such as, scratches or holes in the detector window, frayed cord, excessive meter damage, cracked meter face, etc.

2. Instruments with damage sufficient to impair the operability will be tagged "Out of Service" and returned for repair.

3. Check to see if the calibration is valid by checking the calibration sticker on the instrument. An instrument that is out of calibration will be tagged "Out of Service" and returned for calibration.

   Note: The calibration interval for this instrument is not to exceed twelve (12) months.

4. Turn the selector knob so that it points to the "BAT" label and verify that the reading is in the "BAT OK" region of the meter movement. If the reading is out of this region then replace the batteries and perform this check again. If the meter still does not reach the "BAT OK" region, then tag the meter "Out of Service" and return it to an authorized calibration facility for evaluation.

- ***Instrument Source Check***

CAUTION: The following steps must be performed prior to initial use of the instrument for the day.

1. Turn the toggle knob to the "X 1" position.

2. Place the "□□□□□□□□□□□□" toggle switch to the "□" position.

3. Place the "MIN" switch to the "1" location for a one minute count time.

4. Press the count button located in the top end of the handle and wait for count to be completed

   Note: If background has not been established yet, then use background established during calibration recognizing that there may be some variation from

local site background. Typically, readings within 20% of the background are acceptable.

5. Place the "□□□□□□□□□□□□□"□toggle switch to the "α" position record the number indicated in the LCD in the "Alpha Background" column and then switch to "□" position and record the number in the "Beta Background" of source check form (see HP-NMI-15).

6. Place the "□□□□□□□□□□□□□"□toggle switch to the "α" position.

7. Place the probe face directly over the alpha check source, depress the count button and wait for count to complete. Record the number displayed in the LCD in the "Alpha Check Source" of the Check source form.

8. Place the "□□□□□□□□□□□□□"□toggle switch to the "□" position.

9. Place the probe face directly over the beta check source, depress the count button and wait for count to complete. Record the number displayed in the LCD in the "Beta Check Source" of the Check source form.

Note: If the record values deviate from the expected values by more than ± 20 % of the values indicated on the source check form, then tag the meter "Out of Service" and return the meter to the calibration facility for evaluation.

- ***Scanning Surface Measurement Meter Use***

1. Place the "□□□□□□□□□□□□" toggle switch to the appropriate type of emission. If scanning a sample with the possibility of mixed isotopes use the ".□□□□□□" setting.

2. Hold the probe approximately 1/8" from the surface. Avoid allowing the probe face to contact the material being scanned. This can lead to mylar breakthrough and the instrument needing to be repaired.

3. Scan the surface slowly at a rate of approximately 1-2 inches per second.

4. Adjust the rate meter range selector so that the analog meter registers the counts.

5. If any elevated audible indication is heard during scanning, hold the probe over the area for 5 seconds to determine the possible presence of contamination.

6. If the elevated audible indication continues, hold the probe over that position for an additional 15 seconds to confirm the presence of contamination.

7. If surface contamination is confirmed, hold the probe in place over the area of concern. Then depress the count button to obtain a one-minute scaler count and record the gross cpm readings on the survey sheet (see attached Radiological Survey Form).

   Note: The 2224-1 in scaler mode has an upper limit of 500,000 counts. If the scaler exceeds 500,000 counts decrease the count time and multiply the measured counts to determine counts per minute.

- ***Determine the activity per 100cm^2 as follows:***

1. Divide total counts by count time in miuntes, to get gross counts per minute (gcpm).

   $C / T_C = gcpm$

2. Take the gcpm value and subtract the background for net counts per minute (ncpm).

   gcpm- bcpm = ncpm

3. Multiply the net counts per minute times 100 divided by the open counting area of probe being used to get ncpm/100cm^2.

   ncpm * (100 cm^2/ A cm^2)= ncpm/100cm^2

Note: The open area of the LMI 43-89 probe is 100 cm^2

4. Determine the average activity per 100cm^2 by dividing the net cpm/100cm^2 by the detection efficiency of the instrument.

ncpm per 100 cm^2/ eff (%) = net dpm per 100 cm^2

F. REFERENCES

1. Users manual for Ludlum Model 43-89, Model 43-90 and Model 44-116 Alpha/Beta Scintillators

2. Users manual for Ludlum Model 2224-1 Scaler/ Ratementer

3. HP-NMI-15 – Instrument Response Checks

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Operation of the Ludlum 2350-1

PROCEDURE NO: HP-NMI-20

Rev. 1

October 2018

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A. PURPOSE

a. This procedure provides instruction for the use and operation of the Ludlum Measurements, Inc. (LMI) Model 2350-1 Data Logger with associated detectors and equipment on field projects. The 2350-1 is a versatile instrument that can be used with a variety of detector setups. The following detectors are the most common used for surveys:

b. Ludlum Model 43-68 Gas Flow Proportional Detector (126 cm^2 active detector area)

c. Ludlum Model 43-37 Gas Flow Proportional Detector (584 cm^2 active detector area)

d. Ludlum Model 44-10 Sodium Iodide Gamma Scintillator or equivalent detector

e. This list is not limiting. Other detectors may be used in accordance with manufacturer instructions or approved procedures.

B. RESPONSIBILITIES

a. Radiation Safety Officer (RSO)
   i. Administering and implementing this procedure, including project personnel procedural training.

b. Health Physics Staff
   i. Operating the instrument in accordance with this procedure, including informing the RSO/PRSO of any problems encountered.

C. INSTRUMENT DESCRIPTION/FEATURES

a. Ludlum Model 2350-1 Data Logger is a microprocessor-controlled, self-contained counting instrument designed for operation with scintillation, proportional, or G-M detectors. The 2350-1 provides for the following types of data readout:

   i. Digital ratemeter
   ii. Five decade log bar graph ratemeter
   iii. Timed scaler
   iv. Integrated dose scaler and timer

b. Count displays can be corrected for detector dead time to extend the useful range of the detector. The data logging memory can store the readings from 0

to 999 samples and setups for 16 different detectors. The following information is stored for each count:

i. Count data
ii. Location code
iii. Detector used
iv. Date and time
v. 2350-1 status

c. Detector setup memory contains the following information on each detector:

i. Detector model and serial number
ii. Display units, multiplier and time base
iii. High voltage setting
iv. Window setting
v. Count time
vi. Threshold setting
vii. Overload current
viii. Calibration constant
ix. Dead time correction value

d. Calibration and detector settings are entered with a terminal connected to the RS-232 serial I/O port supplied on the top of the instrument.

e. Instrument memory is maintained for approximately 30 minutes when batteries are removed to allow for battery replacement. These instruments should be shipped with the batteries installed to avoid losing the stored instrument parameters.

D. PREREQUISITES

a. For instrument use or performance testing, verify the Model 2350-1 Data Logger and each detector to be used has a valid and current calibration certification.

b. For site characterization and final release surveys, response checks shall be conducted once daily.

c. Calibrations will be completed using NIST traceable sources.

E. PRECAUTIONS AND LIMITATIONS

a. Do not allow battery voltage to drop below 4.5 volts. Proper operating voltages may not be achieved at lower battery voltages.

b. Instrument memory will be lost if the batteries are removed for more than 30 minutes.

F. EQUIPMENT/SUPPLIES

a. Ludlum Model 2350-1 Data Logger and terminal.

b. If gas flow proportional detectors are used: P-10 gas, a regulator capable of accurately setting 5 psi and flow meters capable of setting flow rates applicable to detectors being used.

c. Appropriate response check sources for nuclide being evaluated.

G. PRE-OPERATIONAL SETUP AND RESPONSE CHECKS

a. Instrument Setup:

Note: In order to execute the command, keypad commands have to be followed by ENTER. The space between the command and parameter entry is to clarify the examples only and should not be used when entering commands.

i. Verify that a current and complete calibration label is attached to the 2350-1 Data Logger.
ii. Inspect the instrument and detectors for physical damage that could affect performance. If damaged, remove from service.
iii. Plug in the portable keypad into the Model 2350-1 Data Logger serial I/O port, switch the instrument ON.
iv. Display turns blue for about two seconds
v. EPROM version/Memory Test/CPU Test screen displays with both tests

listed as OK.

vi. Display changes to the last active screen prior to turning the instrument OFF.
vii. If the display appears abnormal, remove instrument from service.
viii. Enter the first parameters display mode with the command SVD1 and verify the following:
ix. Battery voltage (BAT) greater than 4.5 volts

b. Time and date are correct

1. Set date with the following command, as necessary:
    a. SD MO/DY/YR Example: SD 12/25/99
2. Set time with the following command (24 hour clock) as necessary:
    a. ST HR:MN Example: ST15:25

c. Enter the normal display mode with the command SVD0.

d. Obtain the detector calibration parameter sheet for each instrument and detector to be used.

e. Select the desired detector with the command Dx where x is the detector parameter file number as listed on the detector parameter sheet.

f. Enter the detector display mode with the command SVD2 and verify the following detector parameters:

i. Detector model number (M)
ii. Detector serial number (N)
iii. Units (U) (Code 4=Roentgen, 6=Disintegrations, 7=Counts, 8=Ci/cm^2)
iv. Multiplier (M) (Code 0=Auto range, 1=Micro, 2=Milli, 3=none, 4=Kilo)
v. Display time base (TB) (Code 0=Seconds, 1=Minutes, 2=Hours)
vi. High voltage (HV)
vii. Window setting (W)
viii. Threshold (T)
ix. Calibration constant (CC)
x. Dead time (DT)

Note: It is not necessary to verify the scaler count time (CT) parameter, as it varies with the needs of the user and is not critical to the calibration of the detector.

g. If any detector parameter is incorrect, perform one of the following:

1. Manually input the necessary detector calibration parameters using the portable keypad. Use of the Ludlum Model 2350-1 Portable Keypad, for guidance on the use of the keypad see instructional manual.
2. Download the detector calibration parameters using the Ludlum software package for the Model 2350-1 Data Logger. Follow the prompts provided within the program for guidance on operation of the software.
3. Remove the detector from service.

Note: If new parameters are input, save to the detector parameter file with the following command: SPx (where x is detector parameter file number). Enter the normal display mode with the command SVD0.

H. COMMON EQUIPMENT/INSTRUMENT SETUP

a. Ludlum 43-37 584 cm^2 Gas Flow Proportional Detector

i. Assemble detector, regulator, flow gauges, gas bottle, gas bottle cart and associated hoses. Ensure all hose are securely attached to the gas supply and detector before turning the gas supply on.

ii. Open the P-10 gas valve, and set the regulator to 5 psi.

iii. Slowly increase the flow to the flow rates and purge as indicated below:

1. Set the flow gauge to 100cc/min, and allow approximately 60 minutes purge time.

2. After purge set flow gauge to 40 – 60 cc/min.

b. Ludlum 43-68 126 cm^2 Gas Flow Proportional Detector

i. Assemble detector, regulator, flow gauges, gas bottle, gas bottle cart and associated hoses. Ensure all hose are securely attached to the gas supply and detector before turning the gas supply on.

ii. Open the P-10 gas valve set the regulator to 5 psi.

iii. Slowly increase the flow to the flow rates and purge as indicated below:

1. Set the flow gauge to 100cc/min, and allow approximately 45

minutes purge time.

2. After purge set flow gauge to 40 – 60 cc/min.

c. Instrument response setups and daily response checks shall be performed in accordance with HP-NMI-15, "*Portable Instrument Calibration and Response Checks*".

I. USE AND OPERATION

a. Scanning Surveys:

i. Scanning surveys are performed by moving the detector across a surface at a specific rate of speed (scan rate). The minimum detectable activity for scanning surveys is dependent on several factors including the efficiency of the surveyor to listen and respond to the audible increases. Other factors that influence the MDA of the detector are surface efficiency, detector efficiency, background influences, response setting (fast or slow), also known as resolving time, and scan rate. The specific scan rate will be determined by the Health Physics Staff, based on these variables.

1. Hold the detector approximately 1/8" above the surface.

2. Move the detector across the surface at the specified rate.

3. Listen to the audible response of the instrument. The initial indication of elevated activity is the increase in frequency of audible clicks produced by the detector response.

4. If elevated activity is suspected during the scan survey, then slow the scan rate in the area where the increase was detected holding the detector above the suspect area for 5-10 seconds.

5. If the audible increase is sustained, or increase in the displayed count rate, activity, or dose rate, then a static (timed) measurement should be performed to quantify the activity or dose rate.

b. Static (Timed) Measurements

Note: Static measurements should not be taken with the 43-37 detector. If elevated activity is suspected during scan surveys, then static measurements should

be taken with a 126cm^2 detector.

i. If appropriate, set the location codes for the intended count(s) by first entering the command SVD8. Set each component of the 40 digit location codes by entering the proper information in the L1-L8 parameters. For the L1 component enter the command L1xxxxx, where xxxxx is the first five digits if the location code. Enter the command L2xxxxx, L3xxxxx, etc. L8 is a numeric field only and can be set to auto-increment as data is logged.

Note: Entering and utilizing location code with the instrument is only performed when the information will be downloaded to a personal computer or as required by the Health Physics Staff.

ii. Change the instrument to the normal display mode by entering the command SVD0.

iii. Ensure the correct detector setup number is selected. This can be changed by entering the command Dx, where x is the desired detector setup number.

iv. Set the desired scaler count time by entering the command Fx, where x is the desired count time in seconds. The Health Physics Staff or designee will determine static count times.

v. Initiate and log a scalar count with the command Q1.

vi. Determine the net activity per 100cm^2 from the static count by subtracting the background count rate from the static count rate result and dividing the result by the total efficiency;

$$N_{dpm} = \frac{S_{cpm} - B_{cpm}}{E_{tot} * \frac{A}{100}}$$

Where: N_{dpm} = Net Activity in disintegrations per minute (dpm)

S_{cpm} = Static count activity in counts per minute
B_{cpm} = Background activity in counts per minute
E_{tot} = Total Efficiency
A = Area (open) of Detector in cm^2

vii. The number of logged readings in the lower right corner of the normal mode display will automatically increment to the next number. Do not exceed 990, as any further logged samples over 999 will delete previous samples taken.

viii. Periodically check the battery condition by entering the parameter display mode

with the command SVD1.

ix. The current samples logged data can be viewed by entering the logged data display mode with the command SVD4. The logged sample being viewed can be changed with the command SVLx where x is the logged sample number.

Note: If the sample number specified has not been used for data logging yet, "INVALID LOCATION" will be displayed when the SVLx command is used.

c. Recycle Mode

i. Recycle mode is available for repetitive counting. Selecting a different detector during the recycle mode setup may damage the detector connected to the instrument due to a possible change in high voltage. The RECYCLE MODE is used with the following commands:

1. Enter the recycle setup display by entering the command SVD6
2. Enable the recycle mode(s) by entering the command(s) SRx, where x is the desired recycle mode (up to 6 recycle files are available).

Note: Normally, only one recycle mode is used. If more than one recycle mode is enabled, then ensure that proper detector settings are chosen. Improper detector setup for the attached detector may result in voltage changes that damage the detector.

ii. After selecting the appropriate recycle mode, then setup the recycle mode parameters by entering the command SQ a x y z. Where;

1. a is the recycle file number
2. x is the current detector number
3. $0 \leq a \leq 15$)
4. y is the time delay between counts in seconds ($0 \leq y \leq 65535$)
5. z is the log mode (0 for ratemeter and 1 for scaler count)

iii. Select the desired number of recycles by entering the command SYx, where x is the number of recycles to perform.

iv. Enter the recycle display mode with the command SVD5.

v. Start the recycle counting mode with the command SSF.

vi. The recycle mode will stop upon completion of the number of cycles set.

vii. The recycle mode may be stopped at any time prior to completion with the command SSE.

J. REFERENCES

NUREG-1507 “Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions”.

Ludlum Model 2350-1 Data Logger Instruction Manual.

Ludlum Model 43-37 584 cm^2 Gas Flow Proportional Detector Instruction Manual.

Ludlum Model 43-68 126 cm^2 Gas Flow Proportional Detector Instruction Manual.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Tennelec Series 5 OPERATION

PROCEDURE NO: HP-NMI-22

Rev. 0

October 2018

Table of Contents

A. Scope

This section provides an outline of the procedure for acquiring and analyzing gross alpha and gross beta information with the use of the Eclipse LB software and the Tennelec Series 5. The Tennelec Series 5 is a low background alpha/beta counter, consists of a gas-flow proportional detector with a thin window, a sample changer, sample planchets, P-10 (argon & methane) counting gas, computer, and Eclipse software from Canberra. This procedure is applicable to all DDES work when the Tennelec is used.

B. Precautions and Limitations

1. Handle sources, especially alpha smear sources and electroplated sources, carefully. Hold sources by the edges and avoid touching the face. Smear sources are fragile and the active surface should never be touched or wiped for leak testing.

2. Keep sources in their respective cases when not in use to avoid scratching or losing the source.

3. Samples that are suspected to be highly contaminated should be field checked before being counted in the Tennelec. If field check indicates the sample is likely to exceed 10,000 cpm of alpha radiation the sample should not be counted in the Tennelec. Contact the Project Manager or RSO for guidance.

4. The operating temperature for the instrument is between 32ºF to 122ºF.

C. Pre-operation

1. Observe the Tennelec's system status indicator on the control panel for any flashing lights.

2. Check the P-10 gas tank to ensure there is gas in the tank and the gas pressure is set at 5psi.

3. Check the computer to ensure there are no error messages prior to operation.

It should be noted that due to the complexity of the Tennelec's instrument, any in-depth troubleshooting should be referred to the Project Manager or designee for assistance.

D. Annual Calibration

There should be coordination between the project manager and the health physicist to determine an ideal time for the machine to be calibrated without impacting work progress. This work must be completed by a Canberra representative. However the calibration frequency shall not exceed 12 months.

E. Initial Setup

1. New operators should be trained by experienced laboratory personnel and should be familiar with the instruction manual. The instruction manual for the Canberra/Tennelec Low Background Alpha/Beta Counter should be consulted for additional detail. Particularly difficult operating problems should be discussed with a system analyst or the vendor.

> NOTE: Calibrated (NIST Traceable) standards are required for the accurate calibration of the counting system. Check sources should emit particles that are representative of those expected to be encountered in the field. ^{241}Am (Americium) will be used as the alpha emitting calibration standard, while the ^{90}Sr (Strontium) will be used as the Beta emitting calibration standard. The source data is entered into the Eclipse LB database.

2. Wipes will be counted in a 5/16” deep planchet in the simultaneous, Alpha + Beta, counting mode. Results will be efficiency corrected to report findings in disintegrations per minute (dpm). Results will be corrected for alpha into Beta and Beta into Alpha spillover. Results will be corrected for system background contributions.

3. The initial instrument setup shall be performed.

    a. Prior to first use after the instrument is calibrated;

    b. Prior to first use whenever check sources to be used are different from those used for the initial set after calibration; or

    c. When the detector window has been replaced.

4. Perform pre-operation steps, if not already done.

5. Perform background and source counts.

a. One copy of Attachment A shall be used for both background and source counts.

b. Load the group plate with the alpha and beta daily QC samples and then load the group plate for the background daily QC sample. Place an end plate after the background daily QC sample. Sequence as follows:

END
100 – Background
99 – Beta Source
98 – Alpha Source
QC PLATE

Caution: if an "END" plate is not loaded at the end of any run the unit will continue to try and feed additional plates in indefinitely. This can damage the drives on the instrument.

c. Perform a series of twenty daily QC runs. Record gross counts in the appropriate column.

d. Calculate the mean (average) background and source count rates, and record in the appropriate column in the Background Count Rates (cpm) table.

It should be noted that the background is automatically subtracted; therefore the net count is the recorded result.

e. Calculate the mean (average) ALPHA and BETA source count rate in the appropriate column in the Efficiency (%) table.

6. Calculate the standard deviation (σ).

$\sigma = \sqrt{\frac{\sum\left(X_n - \overline{X_n}\right)^2}{n-1}}$, where:

X_n = Net count rate
$\overline{X_n}$ = Expected net count rate (average of the 20 individual counts)
n = The number of source count trials (20)

a. In each block for the background count rates and source count rates, subtract the mean net source count rate (bottom of each table) from the

net counts for that individual count. Square the difference and enter in the appropriate block.

b. Obtain average Backgrounds and Efficiencies for both Alpha and Beta from the sample set of 20 measurements.

c. Obtain the standard deviation (σ) of each column.

d. Record standard deviation on Attachment A.

e. Obtain and record ±2σ values for Backgrounds and Efficiencies for both Alpha and Beta values.

F. Response Check

1. The Tennelec shall be response checked daily, or prior to each day's use, whichever is less frequent.

2. Load the group plate with the alpha and beta daily QC samples and then load the group plate for the background daily QC sample. Place an end plate after the background daily QC sample.

   END
   100 – Background
   99 – Beta Source
   98 – Alpha Source
   QC PLATE

3. Click on the green **GO** button 

on the menu bar. Once the GO button is selected, a window with defined analyses will appear. Select the QC analysis option.

4. Evaluate net source counts.

   a. If both source counts (alpha and beta) and background counts are within ±2σ of the mean, the instrument is OK to use.

   b. If either source count or background count is within ±3σ but not within ±2σ of the mean, evaluate whether or not an instrument problem exists.

i. Check for obvious causes, such as operating voltage, gas flow, foreign material in the sample tray, etc., and correct them.

ii. Re-count the QC group.

iii. If the recount is within ±3σ, then the instrument is ready for use.

c. If at any time the source count is outside ±3σ of the mean, do the following:

i. Re-count the QC group three more times. If all counts are outside the ±2σ of the mean in the same direction, or if two or more counts are outside ±3σ, then place the instrument out of service. Otherwise, the instrument is OK to use.

d. It should be noted that the Eclipse Software records and saves all data which produces QC charts of all data points. To print a QC chart for the daily background and source count rates, do the following:

i. From the **QC** menu, select **Create Charts.** The **Create a QC Chart** window will appear.

ii. In the **Display** column on the left, select **Date Range for Chart** and enter the desired dates.

iii. In the **Select a QC Profile** on the right, select all profiles.

iv. Select **Show Chart** at bottom of window to display charts

v. Print each QC profile and file in record book.

e. Periodically evaluate trends in the data'

i. Approximately 65% of the daily source counts should be within ±2σ of the mean.

ii. Approximately 99% of the daily source counts should be within ±3σ of the mean.

iii. Daily source check values should appear to vary randomly above and below the mean. A steady increasing or decreasing trend, or more than five counts in a row appearing above or below the mean, may be indicative of a problem.

G. Minimum Detectable Activity

1. Minimum detectable activity (MDA) is the minimum amount of radioactivity that can be measured within the desired confidence interval (95%).

   It should be noted that the Eclipse Software automatically calculates the MDA for each source. The following steps describe the MDA.

2. MDA is determined using the following equation:

$$MDA = \frac{3 + 3.29\sqrt{B_r \cdot t_g\left(1 + \frac{t_g}{t_b}\right)}}{t_g \cdot E}$$, where:

   B_r = Background count rate in cpm
   T_g = Counting interval of the sample in minutes
   T_b = Counting interval of the background count in minutes
   E = Total instrument efficiency (4π efficiency)

3. If $t_g = t_b$, then the equation may be shortened to:

$$MDA = \frac{3 + 4.65\sqrt{B_r}}{E}$$

H. Counting Samples with the Tennelec

1. Place samples on planchets in the numbered carriers. Load carriers into the sample changer following a lead carrier known as a group plate. The groups are A-J. Place an END plate (end plates do not have holes) following the samples on the sample changer.

2. Once the samples are loaded, set the counting parameters. This is accomplished using the Eclipse GO 

button on the menu bar. Once the "GO" button is selected, a window with analysis options will appear.

   a. Select **2 Minute Wipes** from the left column.

   b. From the **Group** drop down menu, select the group plate name (A-J) that matches the lead group plate selected.

   c. Select **OK** to initiate count.

d. While samples are counting, double click on the first sample and enter the analysis batch name. Click on the box that applies the batch name to all samples

e. When the samples have finished counting, close the counting window for the batch and answer YES to the save data questions. DO NOT CLOSE THE ECLIPSE COUNTING SOFTWARE. THIS WOULD STOP OTHER PROCEDURES THAT MAY BE COUNTING.

f. It should be noted that the when samples have finished counting, the data will automatically print

I. Records

1. The Eclipse database is automatically backed up to Microsoft Access based program.

2. All reports will be printed per procedure and filed in the Tennelec Records book.

J. References

1. Regulatory Guide 4.15, Quality Assurance for Radiological Monitoring Programs (Normal Operations) – Effluent Streams and the Environment

2. ANSI N42.25, Calibration and Usage of Alpha/Beta Proportional Counters

3. HP-NMI-05, Contamination Surveys

4. Eclipse Control and Analysis Software

K. Attachments

1. Attachment A: Initial Setup and $\pm 2\sigma$ Calculation

Attachment A: Initial Setup and ±2σ Calculation

DDES Instrument Initial Set-Up Form

Instrument Model	Instrument Serial Number	Calibration Due Date

Background Count Time (t_B)	
	minute(s)

Source Count Time (t_S)	
	minute(s)

Background Count Rates (cpm)		
Count #	**Alpha**	**Beta**
Background DPM		
Std Dev		
2 Sigma Low		
High		

Efficiency (%)		
Count #	**Alpha**	**Beta**
Mean % Eff		
Std Dev		
Low		
High		

Performed By: _____ **Date:** _____

Reviewed By: _____ **Date:** _____

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Operation of the Ludlum 3 with a 44-10

PROCEDURE NO: HP-NMI-23

Rev. 1

October 2018

TABLE OF CONTENTS

A. PURPOSE

This procedure provides instructions for the operation of the Ludlum Model 3, with scaler option, attached to a Model 44-10 that contains a 2 in by 2 in NaI (Tl) Crystal.

B. APPLICABILITY

The detector measures a wide range (energy dependent) of gamma and X-rays. This procedure is applicable to determining gross contamination in a variety of matrices. The properties of gamma and X-rays allow them to travel unabated through a variety of mediums making this an ideal choice for screening of soil samples, machinery, super sacks, and drums for gross contamination with DU. Both alpha and beta emissions will interact with matter around them and generate characteristic X-rays. These instruments are used to measure radiation levels in units of counts per minute, ranging from typical background values to those expected in most NMI operations. When connected to the appropriate detector, this instrument will indicate relative contamination levels and identify changes in contamination levels.

C. PREREQUISITES

The Ludlum Model 3 ratemeter/scaler is designed to be used with a variety of probes. This procedure applies only to a ratemeter, setup and calibrated for use with a model 44-10 NaI (Tl) probe.

D. RESPONSIBILITIES

1. The project RSO, Senior Health Physics Technicians, or designee is responsible for ensuring this procedure implementation occurs.
2. Survey team members are responsible for following this procedure.

E. INSTRUCTIONS

Pre-Operational Checks

1. Perform a visual inspection of the meter and probe. Look for any damage to the meter and probe, such as dents or damaged casing, rattling inside the probe, frayed cord, excessive meter damage, cracked meter face, etc.

   Note: The 44-10 probe is often used with a lead shield to collimate the detector. Ensure that the meter has the appropriate lead shield in place if it was setup

with a shield. The presence of the shield will greatly affect both background and activity readings.

Safety Note: Lead is a highly toxic heavy metal; the shield should always be covered with paint or tape. If bare metal is exposed, cover the area with tape and/or repaint when time allows. Always wash your hands after handling lead materials.

2. Instruments with damage sufficient to impair the operability will be tagged "Out of Service" and returned for repair.

3. Check to see if the calibration is valid by checking the calibration sticker on the instrument. An instrument that is out of calibration will be tagged "Out of Service" and returned for calibration.

   Note: The calibration interval for this instrument is not to exceed twelve (12) months.

4. Turn the selector knob so that it points to the "BAT" label and verify that the reading is in the "BAT OK" region of the meter movement. If the reading is out of this region then replace the batteries and perform this check again. If the meter still does not reach the "BAT OK" region, then tag the meter "Out of Service" and return it to an authorized calibration facility for evaluation.

Instrument Source Check

CAUTION: The following steps must be performed prior to initial use of the instrument for the day.

1. Turn the toggle knob to the "X 1" position.

2. Place the "MIN" knob, located on the meter bezel to the "1" location for a one minute count time.

3. Position the probe in an upright position over the γ source jig without the source in place. This will be the background count.

   Press the count button located in the top end of the handle and wait for count to be completed. A set of colons will appear during the count and disappear once

the count has been completed. **Note:** If background has not been established yet, then use background established during calibration recognizing that there may be some variation from local site background. Typically, readings within 20% of the background are acceptable.

4. Record the number indicated in the LCD in the "γ Background" column of source check form (see HP-NMI-15).

5. Place the gamma standard, usually Cs-137 in equilibrium with Ba-137m, under the source jig and return the probe to the same upright orientation on top of the source jig, as the background count. Press the count button and wait for count to complete. Record the number displayed in the LCD in the "γ Check Source" of the Check Source Form.

   Note: If the recorded values deviate from the expected values by more than ± 20 % of the values indicated on the source check form, then tag the meter "Out of Service" and return the meter to the calibration facility for evaluation.

Scanning for Contamination and Meter Use in the Field

1. Due to the long range of gamma and x-rays; for gross determination you can be up to a meter away from the object being scanned. However for finer measurements you should hold the probe approximately 1" from the surface. Avoid allowing the probe face to contact the material being scanned. It can contaminate the probe. Also, this can lead to damage to the case, or worse, cracking of the NaI (Tl) crystal, making the unit inoperable.

2. Scan the surface slowly at a rate of approximately 6 inches per second.

3. Adjust the rate meter range selector so that the needle operates in a range of 20%-80% full deflection.

4. If any elevated audible indication is heard during scanning, hold the probe over the area for 5 seconds to determine the possible presence of contamination.

5. If the elevated audible indication continues, hold the probe over that position for an additional 15 seconds to confirm the presence of contamination.

6. If contamination is confirmed, hold the probe in place over the area of concern. Then depress the count button to obtain a one-minute scaler count and record the gross cpm readings on the survey sheet (see attached Radiological Survey Form).

   Note: The Model 3 in scaler mode has an upper limit of 500,000 counts. If the scaler exceeds 500,000 counts decrease the count time and multiply the measured counts to determine counts per minute.

   Determine the activity per 100cm^2 as follows:

   Note: This instrument system is very sensitive to different energies. Gamma emissions are monoenergetic and the instrument is calibrated to a limited number of these nuclides. X-ray emissions generated from the Bremsstrahlung effect of Alpha and Beta particles will follow the energy curve of said Alpha and Beta nuclides. This combined with complex geometry situations created by the long range of gamma and x-rays can make it very difficult to assign absolute activities using this counting system. The need for correction factors and secondary confirmation should be evaluated by Health Physics personnel on a case-by-case basis. The following procedure **only** applies if the nuclide of concern is positively identified, the proper efficiency has been calculated, and there is geometry consistent with the source used for calibration.

1. Divide total counts by count time in minutes, to get gross counts per minute (gcpm).

   $C / T_C = gcpm$

2. Take the gcpm value and subtract the background for net counts per minute (ncpm).

   gcpm - bcpm = ncpm

F. REFERENCES

Users manual for LUDLUM MODEL 44-10

Users manual for LUDLUM MODEL 3 RATEMETER with Scaler Addendum

HP-NMI-15, Instrument Response Checks

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Operation of the Falcon 5000 HPGe Spectrometer

PROCEDURE NO: HP-NMI-024

Rev. 0

March 2018

Table of Contents

1.0 PURPOSE

This procedure describes operating the Canberra Falcon Assay System ISOCS detector using Genie 2000 assay software.

2.0 SCOPE

This procedure is applicable to all personnel responsible for operating and/or supervising the operations of the Canberra Falcon assay system using Genie 2000. The Falcon assay system has been factory calibrated and uses mathematically modeled calibrations to provide accurate results for a variety of activity distributions in a variety of waste packages, containers and conveyances. ISOCS calibrations are modeled and do not use sources. Energy calibrations and daily instrument performance checks do not require NIST traceable sources. Efficiency calibrations are not within the scope of this procedure.

3.0 REFERENCES

Falcon 5000R Portable HPGe Spectrometer User's Manual
Genie™ 2000 Spectroscopy Software Operations Manual

4.0 DEFINITIONS

Counter: The physical configuration of detector, collimator, transmission sources, and electronics such as a Falcon system of ISOCS detectors.

Geometry: A specific position of detector, absorbers, collimator, etc. in the field relative to the waste being assayed

Count type: A particular counting operation, like sample counting, calibration check, or background.

Analysis sequence file: The prescription for the data analysis to be performed on a particular processing stage.

Processing parameter: The specific data analysis conditions defined for each count type and processing stage.

ISOCS Calibrated: Efficiency calibrations using characterized germanium detectors.

Action Flag: A QC parameter failure indicated by an (**Ac**) where the parameter is outside of either +/- 3 sigma or the 99% confidence interval.

Investigate Flag: A QC parameter warning indicated by an (**In**) where the parameter is outside of either +/- 2 sigma or the 95% confidence interval.

Boundary Flag: A QC parameter warning indicating that an upper or lower level has been exceeded.

5.0 EQUIPMENT

5.1 Canberra Falcon Assay System

ISOCS Calibrated Germanium Detector

- Signal processing electronics

An operator's terminal including as needed:

- Personal computer or laptop
- Computer keyboard
- Mouse
- Monitor
- Printer

5.2 Assay System Hardware Setup

Assembly of the Falcon ISOCS system is not required. All electronics are contained in the main housing, the unit is battery operated and data is transmitted wirelessly to a field laptop.

Figure 1 - The Falcon 5000

The Falcon 5000 components are housed in a single unit and consist of the following:

- HPGe Detector
- GM Tube Detector
- Cryostat Cooler and Controller
- InSpector 2000 MCA
- WLAN/LAN module
- Internal Battery Charger
- Wireless Enabled Laptop

Connectors

This is a brief description of the Falcon 5000 rear panel connectors. For more detailed information, refer to the appendix *Specifications* on page 141. The Falcon 5000 can operate by using either a lithium-ion battery or an ac adapter. Refer to the appendix *Power System* on page 125 for more information.

RS-232 Connector

The RS-232 connector is now located under the Status Indicators front panel and is used to update the firmware and configure the WiPort. You will need to remove the panel to gain access to the connector. This is done by removing the four Stainless M3 Socket Head Cap screws securing the bezel (black plastic cover on top of the Falcon where the interface panel is located). A green ribbon cable will restrain the bezel; this cable cannot be removed, so the bezel will not completely be detached. In the void under the bezel, the serial interface cable will be wrapped in a bundle. This cable is a 10-conductor ribbon cable roughly 1/2 in. wide. Unwrap this cable and pull it out to access the serial connector. Reverse these instructions when completed.

External Power Connector

Connect to an external power source. Power input of 24 ± 0.5 V dc at 10 A maximum supplied by external power supply (included as part of the Falcon).

Power Push button

The Falcon's power push button controls power to the instrument. Power is enabled when the push button is pressed. Press the push button a second time to disable the power.

Note: This push button must also be held for three seconds to toggle the unit power On or Off.

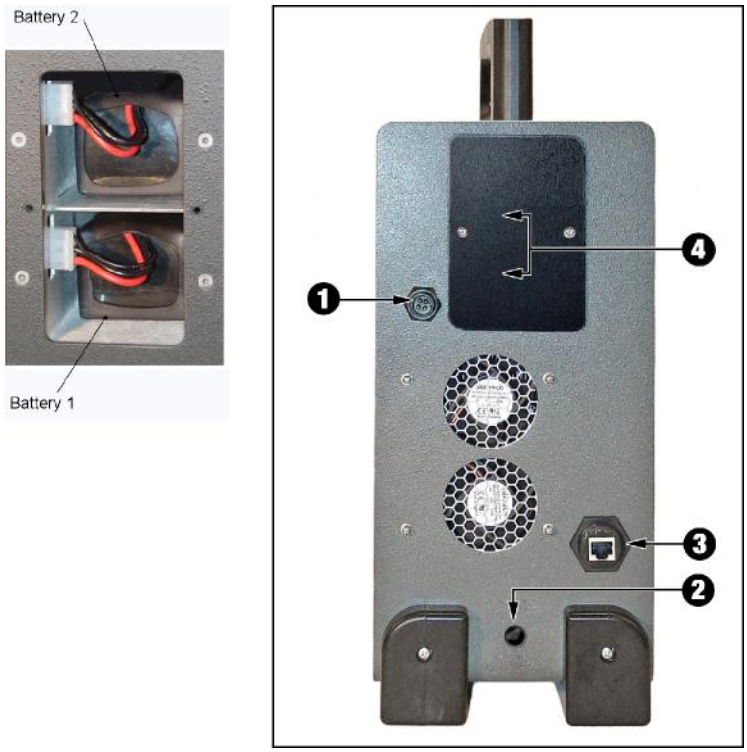
Ethernet Connector

10/100 wired Ethernet port for connecting to a Tablet PC or LAN.

Batteries

Up to two Li-ion batteries can be installed.

Figure 2 - The Falcon 5000 Rear Panel

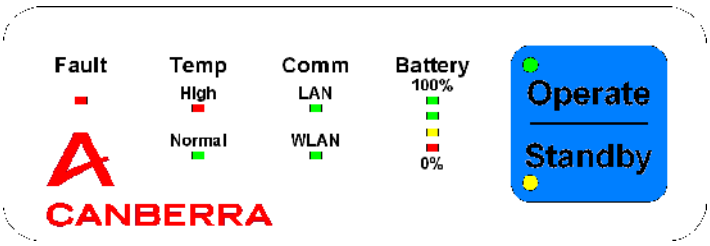


Note: Only remove/replace one battery pack at a time.

Status Indicator

Located on the top of the Falcon 5000 are five indicators showing the status of the system diagnostics, temperature, communication with host computer, battery charge status, and system operating status. See Figure 3.

Figure 3 - Falcon 5000 Status Indicators



Fault

Red LED indicates a fault has occurred.

Temp

The temperature of Cryostat: high (above the operating limit) or normal (ready for use).

Comm

The two LEDs indicate if the Falcon is configured for wireless/wired communications. Refer to the appendix *Communication Setup* for more information.

WLAN

Indicates a connection to a wireless network. The WLAN LED will blink while it is searching for a wireless network, will then blink at a faster rate while it "associates" with that network and then remain illuminated while connected to the network.

LAN

Indicates a connection to a wired network. The LAN LED will illuminate whenever the unit is connected to another device (computer) through a "wired" connection, otherwise it will not be illuminated.

Battery

LED bar graph indicates status of the battery from 100% to 0% in 25% decrements. Refer to the appendix *Power System* on page 125 for more information.

Hardware Operating Status

The Falcon offers two modes of operation:

- Operate where the unit is fully functional.
- Standby where in the unit is in a power saving mode; the HVPS is off and the Falcon 5000 is powered down; keeps the unit cool and batteries charged.

Note: The unit shall be placed into standby mode when the unit is not in use for a period of more than an hour. This will shut off the HVPS.

5.3 Genie-2000 Software Setup

NOTE: The operator should consider a warm-up period of approximately one hour upon initial power-up of a given system. The Falcon unit will be left on indefinitely and connected to ac power at the end of each shift so that the equipment is stabilized and ready for use.

- Verify that the Genie-2000 software is properly configured for use with the Falcon assay system. Follow the steps described in the Genie 2000 User Manuals.
- Verify that the MCA Input Definition file is established and configured. Follow the steps described in Genie2000 User Manual.
- Ensure that the High Voltage Power Supply is ON and is ramped up to the appropriate voltage level though either the Falcon Software or Genie 2000 by checking the MCA status.

6.0 PROCEDURE

6.1 Starting the Assay system

- Logon to the assay laptop using the username and password
- Start the Falcon Operations software
- Verify wireless communications have been established
- Check that the Virtual Data Manager (VDM) is running
- Open the Genie 2000 Software through the Falcon interface

Note: Opening the Genie Software through the window's menus does not enable the detector.

6.2 Daily Background Check

Prior to running any sample counts, a QC background check shall be performed, at a minimum, at the start of the day and repeated at the end of the day. Additional optional background checks may be performed at any time. There should be no samples or sources in the vicinity of the assay system, while the background count is being performed. The background checks are used to identify changes in the background level that might affect the validity of the sample results.

6.2.1 Daily backgrounds shall be performed in the HP Field Trailer in a static location. Document the configuration in the operational logbook.

6.2.2 From the Genie 2000 Operations window, Analyze menu and click on Execute Sequence where the available assays will be displayed and select Background QC.

6.2.3 The Assay-Routine window will now be displayed. Ensure that the count time is appropriate for the area background (usually 300 seconds). Complete any remaining entries as appropriate.

6.2.4 A Background Count Information screen will now be displayed. Enter the ID, Description (QC_Bkg_03-04-13 AM), and Comment as applicable. Click on DONE when finished entering information.

6.2.5 An Assay window will be displayed showing the count progress. Review the K-40 peak at 1,461 keV to assure the gain has not shifted. You now have the option of letting the count finish, or interrupting the count by clicking on STOP. If STOP is selected a new window will be displayed with three choices available, STOP, ABORT and CANCEL.

- To stop the count early and save the data click on STOP.
- To stop the count early and not save the data click on ABORT.
- To return to the main window and let the count finish, click on CANCEL.

6.2.6 The MCA View window will be displayed at this time. The operator should observe this window to verify the acquisition has started and that there are not any significant peaks or high dead time. If there are any significant peaks

or high dead time (>10 %) the operator should ABORT the count and notify the Technical Supervisor or Project Manager for investigation and resolution.

NOTE: All other operations are automatic at this point. The acquisition will be analyzed and the QC parameter stored without operator intervention.

6.2.7 After the Background Check count is complete, a warning message will appear if any measurement control criteria were exceeded. To view the QA charts, perform the following:

6.2.7.1 Open the QA 2000 Data Review window and click on the QA menu choice, selecting Plots/Reports. This will open a new window.

6.2.7.2 Select the Background QC measurement parameter, and click the CHART button. This will enable the operator to look for data points that have exceeded the boundaries.

6.2.7.3 Alternatively, a Last Results Report may be automatically printed and reviewed or view the automatically produced report file in c:\Genie2Repfiles.

6.2.7.4 If any boundaries are exceeded, then the Background Check should be performed again. If the conditions persist contact the HP Supervisor or Project Manager for investigation and resolution. The outcome of the investigation shall be documented in the operational logbook.

6.3 Source Check

Prior to running any sample counts, a Source Check shall be performed, at a minimum, at the start of the day and repeated at the end of the day. There is normally two counting sessions per operational day.

Additional optional Source Checks may be performed at any time throughout the day such as at the end of the counting session after sample assays are complete for the day.

A Source Check is performed to ensure proper alignment and response of assay system.

6.3.1 Strap the manufacturer's provided ISOCS check source to the top of the detector using the Velcro strap with the designated configuration.

6.3.2 Ensure that the source is slid as close to the detector as possible. There is a built in "stop" that should be in contact with the detector.

6.3.3 In the Genie 2000 Operations window, select the Analyze menu and click on Execute Sequence where the available assays will be displayed and select QC Check Source ASF

6.3.4 The Start Assay window will now be displayed. Check that the correct container and geometry are selected and enter the assay count time (usually 60 seconds) as previously determined and any other parameters as appropriate

6.3.5 Click the START ASSAY button.

6.3.5 A QC Source Check window will appear. Enter information for the Item ID (QC_Source_03-04-2013 AM), Description, Sample Date of the check source, (03/12/12 at 12:00) and any other information that may be pertinent to the measurement.

6.3.6 Click on DONE when finished entering information.

6.3.7 An Assay window will be displayed showing the count progress. You now have the option of letting the count finish, or interrupting the count by clicking on STOP. If STOP is selected a new window will be displayed with three choices available, STOP, ABORT and CANCEL

- To stop the count early and save the data click on STOP.
- To stop the count early and not save the data click on ABORT.
- To return to the main window and let the count finish, click on CANCEL.

The MCA View window will be displayed at this time. The operator should observe this window to verify the acquisition has started and that there are peaks in the spectrum form the calibration source. If there are no peaks or the peaks have shifted, the operator should ABORT the count and notify the HP Supervisor or Project Manager and document in the logbook.

NOTE: All other operations are automatic at this point. The acquisition will be analyzed and the QC parameter stored without operator intervention.

6.3.8 After the QC Source Check is complete, a warning message will appear if any measurement control criteria were exceeded. To view the QA charts, perform the following:

6.3.8.1 Open the QA 2000 Data Review window and click on the QA menu choice, selecting Plots/Reports. This will open a new window.

6.3.8.2 Select the appropriate QC Source Check parameter, and click the CHART button. This will enable the operator to look for data points that have exceeded the boundaries.

6.3.8.3 Alternatively, a Last Results Report may be automatically printed and reviewed or view the automatically produced report file in c:\Genie2Repfiles.

6.3.8.4 If any parameters indicate an Action (Ac) flag then stop work and notify the project manager or technical supervisor for investigation.

6.3.8.5 Do not resume sample measurements until issue is resolved and a non-conformance report completed if warranted and the issue documented in the operational logbook. At least two consecutive successful points must established for the failed parameter to bring the unit back into service.

6.3.8.6 If the values on the QA Last Results Report exceed ± 2-Sigma, but do NOT exceed ± 3-Sigma boundary indicated by an "In" flag or if any values on the printed report indicate an “Ab” or “Be” flag, then repeat steps 6.3.5 through 6.3.7 no more than two times.

6.3.8.7 If the rerun performance measurement(s) result in data that do not exceed ± 2-Sigma or upper or lower boundary tests, then work may continue.

6.3.8.8 If the rerun performance measurements exceed ± 2-Sigma or upper or lower boundary test for the same parameters after two additional runs, then perform step 6.3.8.5 in this procedure.

6.3.8.9 If the results on the QA Last Results Report indicate no flags then document the successful measurement as completed in the operational logbook.

6.4 Assaying Waste Packages and Containers

Only Assay items on the assay system if the Background Check and Calibration Check were successful in accordance with sections 6.2 and 6.3 of this procedure. A variety of waste packages and containers will be assayed with the Genie 2000 software. The project has established geometries and counting assays for a variety of waste at the NMI site. These include but are not limited to cubic yard super sacks, combinations of super sacks, a variety of drums, and various conveyances.

6.4.1 Perform Sample Analysis as follows:

6.4.1.1 Measure and record the background count rate in the survey area using an alpha and beta scintillator probe before bringing assay items into the area. Record value in logbook.

6.4.1.2 Move item to be assayed to the designated area.

6.4.1.3 Use the alpha and beta scintillator to identify the side with the highest count rate and orient it toward the HPGe detector. Record this value in logbook.

6.4.1.4 Establish the correct geometry of the detector relative to the waste as defined in the assay protocol (Geometry Composer). This geometry shall be established to the nearest ½ inch.

6.4.1.5 Document sample information in the operational logbook and Genie 2000 Software.

NOTE: Specific executable sequences have been established under the Analyze Menu and defined for various waste container types. Changes or additions to these sequences do not require a change to the operating procedure.

6.4.1.6 In the Genie 2000 main window, select the Analyze menu, select Execute Sequence and then select appropriate sequence.

6.4.1.7 The Start Count window will be displayed, check that the container size, geometry setting, count time, and any other parameter entry fields are on the correct settings or completed as necessary.

6.4.1.8 The Item Information window will be displayed. Enter the Item ID Description, Location, weight in grams and any comment pertinent to the measurement. The other fields may be used as needed. Click DONE when finished entering item information.

6.4.1.9 An Assay window will be displayed showing the count progress. You now have the option of letting the count finish, or interrupting the count by clicking on STOP as discussed earlier in this procedure.

6.4.1.10 Check for unusually high dead time (greater than 50%). If a high dead time or other data problem exists, the operator should notify the HP Supervisor or Project Manager for further instructions. Make any pertinent notations in the operational logbook.

6.4.1.11 After the assay is complete the operator should review the raw data. The operator will verify that the recorded Item ID number and Item ID number of the waste item being removed from the assay system counting area are the same.

6.4.1.12 The operator will sign and date the raw results sheet if a hard copy is required. Otherwise data files shall be forwarded for review and analysis by the HP Supervisor.

6.4 Environmental Background

Environmental background counts are generally longer assays used for spectral background subtraction. The net peak area counts per second (count rate) of peaks located in the environmental background are subtracted from the same peaks if located in the waste package assay. Environmental background measurements are made periodically as detector count time is available such as at the end of the day or when a change in the background is suspected due to significant material movement into, out of, or within the assay area.

6.4.1 For ISOCS, an empty container should be used for environmental background measurements if available.

6.4.2 From the Genie 2000 Operations window, click on the green button or select the Assay menu, click on Routine Assay and the available assays will be displayed, allowing selection of a background assay.

6.4.3 The Assay-Routine window will now be displayed. Check that the correct container and geometry are selected. Ensure that the count time is appropriate for the area background (normally from 600 seconds to 3,600 seconds). Complete any remaining entries as appropriate.

6.4.4 Click on Start Assay. The environmental background count will begin collecting data.

6.4.5 An Environmental Background Count Information screen will now be displayed. Enter the Item ID, Description, and Comment as applicable. Click on DONE when finished entering information

6.4.6 An Assay window will be displayed showing the count progress. You now have the option of letting the count finish, or interrupting the count by clicking on STOP. If STOP is selected a new window will be displayed with three choices available, STOP, ABORT and CANCEL.

6.4.7 The MCA View window will be displayed at this time. The operator should observe this window to verify the acquisition has started and that there are not any significant peaks or high dead time. If there are any significant peaks or high dead time the operator should ABORT the count and notify the HP Supervisor or Project Manager for investigation and resolution.

6.4.8 All other operations are automatic at this point. The acquisition will be analyzed and data stored without operator intervention. The operator should review the peak locate report and bring any unusual results to the attention of the project manager. Any items of note should be recorded in the operational logbook and/or included in corresponding batch data reports.

7.0 RECORDS

Records Generated

Records generated from this procedure include the log book entries and final data report files generated from each of the following; Background Check, Calibration Check, Assaying Waste, and Environmental Background.

Data Archive

Data may be archived manually or from the Genie 2000 Operations screen by selecting Utility and Archive.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Heavy Equipment Decontamination and Free Release

PROCEDURE NO: HP-NMI-025

Rev. 1

October 2018

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A. Purpose

This procedure provides guidelines for the decontamination and free release for unrestricted use for heavy earth moving equipment at the Nuclear Metals site for unrestricted use.

B. Applicability

This procedure is applicable to all heavy equipment, including transportation vehicles, construction lifts, etc. that were used off road and/or have the potential to have come in contact with potentially impacted soils or contaminated materials at the NMI site. This will include containers and trailers that have the potential for contamination during waste loading activities.

C. Prerequisites

The decontamination of equipment should be performed by trained and qualified personnel. Employees should be aware of the possible presence of depleted uranium (DU) and the applicable survey methods. The health physics (HP) technician shall be familiar with the laboratory equipment operation and limitations. HP technicians conducting the decontamination and free release operations shall be familiar with the following procedures;

i. *HP-NMI-01 Conduct of Radiological Work*
ii. *HP-NMI-05 Radiological Surveys*
iii. *HP-NMI-06 Personnel Monitoring and Decontamination*

D. Responsibilities

1. The project RSO, Senior Health Physicist, or designee is responsible for ensuring this procedure is implemented.
2. HP technicians are responsible for following this procedure.

E. Decontamination

1. Upon completion of site work, all heavy equipment leaving the site shall be decontaminated and surveyed for free release.
2. Heavy equipment that has been used off-road shall be dry decontaminated prior to a free release survey.
    a. Off-Road shall imply the use of equipment off paved road ways and designated staging locations.

3. A dry decontamination area will be set up at the edge of the work area where the equipment was used.
    a. Dry Decontamination shall include the use of shovels and brushes, wiping free any debris/soils that may be built up on equipment surfaces(i.e. tires, tracks, undercarriage, buckets, bits)
    b. After the gross debris has been removed, HEPA vacuums will be used to remove the remaining residues from equipment surfaces to they can be properly evaluated for total and removal radioactive contamination.

4. Upon completion of dry decontamination a HP technician will perform a free release survey.

F. Free Release Survey

Following the dry decontamination, a free release survey of the equipment will be performed. Free release surveys are to include total and removable contamination measurements of representative areas and the areas with the highest potential for contamination. Free release surveys will be completed in compliance with the NMI RPP Procedures. Free release surveys will not be completed under wet conditions (rain, snow, when the equipment is wet, etc.) as water can mask potential presence of radiological contamination.

Once the free release survey has been reviewed and approved by the HP supervisor, the equipment will be "green tagged" indicating that it has been properly surveyed and cleared to leave the site. All radiological results must meet the NMI Site free release criteria based on NRC Regulatory Guide 1.86. All survey records shall be maintained onsite both as an electronic file and a hard copy. These survey records will be maintained by the project for a minimum of ten (10) years.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

LUDLUM MODEL 19 OPERATION

PROCEDURE NO: HP-NMI-26

Revision 0

October 2018

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A. Overview

The purpose of this procedure is to provide consistent methodology and guidelines for operation of the Ludlum Model 19 Micro R (µR) Meter.

B. Applicability

This procedure is applicable to all health physics personnel that perform radiological surveys. The Ludlum Model 19 Micro R Meter is used to measure radiation levels in units of exposure rate, i.e., microroentgens per hour (µR/hr). The Ludlum Model 19 Micro R Meter can be used to determine area radiation levels ranging from typical background values (10 µR/hr) to those expected on the NMI Site (1,000 µR/hr). The Ludlum Model 19 Micro R Meter is typically calibrated for accurate response at the Cs-137 gamma energy. It will indicate relative radiation levels and identify changes in radiation levels, but, because of the energy dependent response of the Nal detector, this instrument should not be expected to provide accurate exposure rate measurements at other gamma energies.

Exposure rate indicated by this instrument will overestimate the true level by as much as a factor of ten at energies below the calibration energy and underestimate the true value by as much as a factor of five at energies above the calibration energy.

C. Precautions

The Ludlum Model 19 will be used to determine contact and area dose rates for personnel protection and transportation surveys. The Ludlum Model 19 Micro R Meter utilizes an internally mounted 1" x 1" Nal scintillator crystal and is sensitive to gamma radiation. A single rotary range switch turns the Model 19 meter on and selects the desired range. Front panel controls include switches for range, audio speaker, fast/slow response, lighted display, meter reset, and battery condition check. Front panel access to the calibration and high voltage potentiometers is provided under a protective CAL cover. The Model 19 Meter has two color-coded scales on the meter face. The lower (red) scale (0 to 25) is used for the 25 µR/hr (0.025 mR/hr) and the 250 µR/hr (0.25 mR/hr) ranges. The upper (black) scale (0 to 50) is used for the 50 µR/hr (0.05 mR/hr), 500 µR/hr (0.5 mR/hr), and 5,000 µR/hr (5.0 mR/hr) ranges. The range switch positions are marked in corresponding colors. Separate calibration potentiometers (cal pots) are provided for each range. High voltage (HV) is adjustable from 400 to 1500 volts direct current.

D. Preparation

4.1 Perform a visual check of the meter and probe for damage such as broken switches, knobs, or buttons, holes in the case,, excessive meter damage, meter face cracked, etc.

4.2 Check to see if that the calibration is valid by observing the dates on the calibration sticker on the instrument. If past "calibration due" date, immediately tag meter as "Out of Service" and notify RSO or designee.

4.3 Turn the selector knob so that it points to the "BAT" label and verify that the reading is in the "BAT OK" region of the meter movement. If the reading is out of this region then replace the batteries and perform this check again. If the meter still does not reach the "BAT OK" region, immediately tag meter as "Out of Service" and then notify RSO or designee.

E. Procedure

5.1 Instrument Source Check

CAUTION: The following steps must be performed prior to initial use of the instrument for the day:

5.1.1 Initially place the selector switch to the lowest scale and observe the background reading.

5.1.2 Record the background count on Instrument Source Check Form on the γ line.

Note: If background has not been established yet, then use background established during calibration recognizing that there may be some variation from local site background. Typically, readings within 20% of the background are acceptable.

5.1.3 Turn the RATEMETER switch to the "5,000" position.

5.1.4 Position the Cs-137 check source on the front of the meter as indicated by the circular mark.

5.1.5 Turn the RATEMETER knob to the appropriate scale and observe average reading in µR/hr after the reading stabilizes.

5.1.6 Record the check source reading on the Instrument Source Check Form on the γ line.

Note: If the instrument meets all of the preceding criteria, proceed to the next step.

Note: If the instrument does not meet all the preceding criteria, note on Instrument Source Check Form, immediately tag meter as “Out of Service” and notify the RSO or designee of the faults and choose another survey instrument.

5.2 Scanning and Measurement

5.2.1 Confirm that the instrument has a current and legible calibration label; if not, remove from service and do not use until the condition is corrected.

5.2.2 Assure that daily instrument performance tests have been satisfactorily completed (all readings are within the defined acceptable range) and documented on a Daily Test Sheet or perform those tests in accordance with established procedures.

5.2.3 Depress the instrument "bat" pushbutton. Assure that the needle response is within the "bat TEST" range on the meter; if not, replace the batteries and retest.

5.2.4 Turn the "AUDIO ON/OFF" toggle switch to ON.

5.2.5 Select the "S" position on the "F/S" toggle switch for slow response.

5.2.6 Holding the Ludlum Model 19 Micro R Meter away from your body and in the radiation field of interest, turn the scale switch to highest scale, allowing adequate time (approximately 15-20 seconds depending on the scale) for response. Continue to select lower scales until the meter indication is as high as achievable without being beyond the upper meter scale limit

5.2.7 After waiting for the meter reading to stabilize, note the indicated value on the meter and multiply by the selected scale to determine the exposure rate in µR/hr.

When measurements are complete, turn the Ludlum Model 19 Micro R Meter scale selector switch to "OFF".

F. References

User’s Manual for Ludlum Model 19

HP-NMI-15 – “Instrument Response Checks”

Contamination Instrument Response Check Log

Instrument Model	Instrument Serial Number	Calibration Due Date	Project Efficiency
Detector Model	**Detector Serial Number**	**Detector Area**	**High Voltage**
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to
Source Isotopes	**Source Serial Number**	**Source Activity (uCi)**	**Source Reproducibility**
			to

Date	Time	Type	Background	Gross Count Rate	Net Count Rate	SAT/UNSAT	Comments	Initials
		α						
		β						
		γ						
		α						
		β						
		γ						
		α						
		β						
		γ						
		α						
		β						
		γ						

Reviewed By: Date:

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

WASTE CONVEANCE HANDLING AND SHIPPING

PROCEDURE NO: HP-NMI-27

Revision 1

October 2018

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A. Overview

The purpose of this procedure is to provide consistent methodology and guidelines for the control, loading, and survey of waste conveyances at the NMI Superfund Project located at 2229 Main Street in Concord, MA. This procedure provides detail on the radiological control during waste loading and the performance of shipping surveys. Waste conveyances will be surveyed for radiological contamination on prior to loading NMI specific waste streams. The conveyances will typically be intermodal containers on rail frame trailers which will be loaded in exterior areas of the site.

The exterior of the conveyances and the rail frame trailers will be protected from cross contamination during loading activities. Radiological surveys of the exterior of the waste container and rail frame trailer will be performed prior to the release of the conveyance from the interior building loading operations. These surveys will include both large area wipes and 100 cm^2 removable contamination measurements. The results of the removable contamination survey must indicate levels are below 1,000 dpm/100 cm^2 prior to leaving the radiologically controlled area.

B. Applicability

This procedure is applicable to loading, packaging and transport of bulk waste packages at the NMI Site. This procedure is designed to establish checkpoints to assure radioactive materials are appropriately controlled during loading, packaging and onsite transport operations at the Site.

C. Prerequisites

Personnel should be aware of the possible presence of depleted uranium (DU) and the applicable survey methods. The health physics (HP) technician shall be familiar with the laboratory equipment operation and limitations. HP technicians overseeing contamination controls and release operations shall be familiar and proficient with the following procedures;

1. HP-NMI-01 Conduct of Radiological Work
2. HP-NMI-05 Radiological Surveys
3. HP-NMI-21 Ludlum 2224-1 Operation
4. HP-NMI-10 Radiological Air Sampling

D. Responsibilities

The Project RSO, Senior Health Physicist, or designee is responsible for ensuring this procedure is implemented. HP technicians are responsible for following this procedure.

E. General Requirements

Waste conveyances are typically in the form of 32 or 25 cubic yard intermodal containers loaded onto rail frame trailers. An incoming radiological survey is performed on each incoming empty container prior to loading to determine if radiological contamination is present.

Once the container is loaded, the exterior surfaces of the container and trailer will be decontaminated to remove any visible debris.

A health physics technician will obtain large area wipes from the sides of the container, and trailer. Field measurements of the large area wipes will be made with a Ludlum 2224-1 with 43-89 probe to screen for surface contamination. Any large area wipes with elevated readings will require the further decontamination of the affected area. Removable contamination measurements will be obtained from two locations on the exterior surface of the container to complete the DOT survey requirements.

A health physics technician will survey the exterior surfaces of the container with a Ludlum Model 19 dose rate meter, or equivalent. The health physics technician will scan the bottom and sides of the container, noting the location with the highest dose rate. The scanning values will be averaged and also noted on the survey. All survey records shall be maintained onsite as an electronic file and a hard copy.

Nuclear Metals, Inc. Superfund Site
Health Physics Procedures

Exterior Perimeter High Volume Air Sampling

PROCEDURE NO: HP-NMI-28

Rev. 5

October 2018

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1. Overview

The purpose of this procedure is to provide guidance and instruction for exterior Site perimeter high volume air sampling. Air sampling will be designed for unattended continuous 24-Hour air monitoring that will be housed in a secure, freestanding weather resistant aluminum enclosure.

The DF-60810D Series Air Sampling Systems are designed for remote unattended continuous air sampling applications. The DF-60810D Series Air Samplers feature a brushless motor with electronic motor speed control that maintains a user selectable flow rate. The flow rate range attainable through the filter media is dependent upon the air porosity of the filter media. The DF-60810D Series design accommodates rapid field service and component replacement.

For durability and weather resistance, the system is housed in a freestanding powder coated aluminum enclosure. The sample air is drawn in under the eaves of the hinged lid from all four sides and is exhausted near the bottom of the enclosure. The locking swing door on the enclosure provides convenient access for servicing the equipment inside. A lockable latch on the top cover restricts unauthorized tampering with the filter holder.

Sample flow rate is adjustable between 18 and 50 CFM (141 and 1415 LPM). The filter holder is 8 by 10 inch in dimension.

This program applies to radiological work activities for at the Nuclear Metals Inc. (NMI) Site in Concord, MA.

2. References

- 10 CFR 20, Standards for Protection Against Radiation.
- Health and Safety Plan – Appendix A, Radiation Protection Program.
- Digital Air Monitoring System, F&J Model DF-60810D 110V
- HP-NMI-02, Definitions
- Regulatory Guide 4.15, Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment, July 2007.
- Regulatory Guide 4.20, Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees Other Than Power Reactors, December 1996.
- Regulatory Guide 8.37, ALARA Levels for Effluents from Materials Facilities, July 1993.
- U. S. Environmental Protection Agency. 1991. Guidance on Implementing the Radionuclide NESHAPS. Office of the Radiation Protection Programs. Washington, DC.

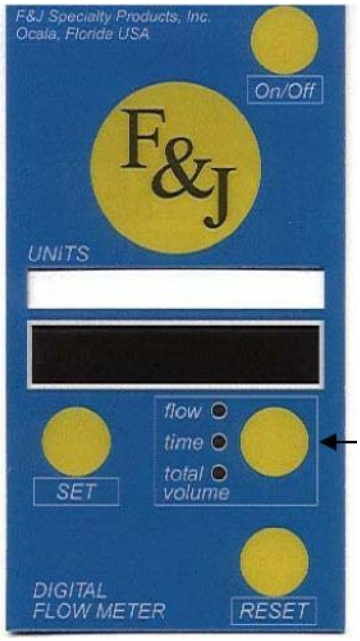
3. General Requirements

- The high volume air sampling program includes.
    - 24-Hour exterior high volume air monitoring at designated north, south, east and west Site boundary locations from Site activities that have the potential to release airborne radioactive materials and to determine worse case potential internal dose to members of the general public.
    - Guidance and instruction for the review and documentation of exterior air monitoring and exterior air sampling activities.
- This procedure serves as a complement to the Site Management and Security Plan that outlines a comprehensive exterior perimeter monitoring program that includes both radiological as well as chemical contaminants.
- Samples should be collected in accordance with FSP/QAPP.
- Investigation levels for air effluents are 50% of the EPA NESHAPS standards.
- Exterior Environmental monitoring may be performed to.
    - Monitor potential internal dose to members of the general public.
    - Monitor potential radiological and chemical releases to the environment.
- Exterior perimeter high volume air monitoring shall be performed until the Radiation Safety Officer, with concurrence from the Project Coordinator and Site Operations Manager, has determined the radiological contaminant levels at the site or the site activities can no longer generate effluents that would result in a total effective dose equivalent to a member of the public in excess of 10 mrem/yr.
- Exterior perimeter high volume air monitoring shall be conducted to meet the limits established in:
    - 10 CFR Part 20.1302, “Compliance With Dose Limits For Individual Members of The Public”.
- As site conditions change (e.g., a building or structure is vacated or the building’s operational status changes), evaluations/assessments shall be performed by the RSO to determine if a change in perimeter air sampling requirements is necessary.

4. Operation of the High Volume Air Sampler

The keypad for the Digital Flow Meter (DFM) series of air samplers has the following features.

- Four keypad buttons
- 6 character LED display of 0.5 inch (1.2 cm) height
- Label indicating the engineering units for the digits displayed by the LED. (These engineering units are factory selectable and cannot be changed in the field).



ON OFF: The ON-OFF button is located in the upper right corner of the DFM module. Pressing the ON-OFF button while the air sampler is connected to line power but not running will place the unit in standby mode. Power is enabled to the DFM.

RESET: The RESET button is located in the lower right hand corner of the DFM module, and is utilized to start and stop the air sampler, to commence a sampling event or to terminate a sampling event. The DFM must be in flow mode to function as a pump On-Off button.

The accumulated elapsed time and accumulated total volume are not automatically reset to zero when the air sampler is started. This feature allows the operator to temporarily suspend sampling for maintenance, to implement a different set up or to enable different features.

In Time display mode, pressing the RESET button zeros the Elapsed time. In Total Volume mode, the RESET button zeros Total Volume.

UNITS: The UNITS button is located on the right side of the DFM module.

Pressing the UNITS button enables an operator to display Flow, Elapsed Time or Total Volume by advancing the green LED to the different positions.

The default position of the green LED is the Flow position upon start up or return to power after a power outage.

Pressing the UNITS button once moves to the Elapsed Time position displayed in HHH:MM (Hours-Minutes mode). Pressing the UNITS button when the green LED is in the TIME position advances to the TOTAL VOLUME position.

NOTE: Do not assume that total volume and elapsed time are zero when flow is zero. Check both the elapsed time and total volume values prior to commencing a sample event.

In Time display mode, the colon (O blinks when the motor is turned on and is continuously illuminated when the air sampler is in stand-by condition. The blinking colon also indicates that the Elapsed time accumulation is in progress.

Engineering Units:

The engineering units for Reference flow and volume are listed on the label above the LED display. The factory set options, selectable by the user at the time of purchase, are as follows:

Flow	**Volume**	
SCFM	SCF	Standard Cubic Feet per Minute / Standard Cubic Feet
SLPM	SLPM	Standard Liters per Minute / Standard Liters
SCMH	SCM	Standard Cubic Meters per Hour / Standard Cubic Meters

A user cannot switch engineering units in the field. The Digital Flow Meter electronic unit must be returned to the factory with the flow sensor to change the engineering units and to recalibrate the system sensors.

Operating Temperature Range: -20ºF* to 122ºF (-29ºC* to 50ºC)

*warm start/continuous operation

Operating Relative Humidity: 0 – 95% RH

Typical Flow Rate Range:* 18 – 117 CFM (30 - 200 m^3 /hr)

START and STOP a New Air Sample

Start a New Air Sample Activity

- Press the ON-OFF button to place the DFM in standby mode.
- Press the UNITS button to view the elapsed time value and total volume value to ensure that they are zero.

Note: If these values are not zero, press the RESET button when the green LED is in the Time position to zero the elapsed time. Press the RESET button when the green LED is in the Total Volume position to zero the total volume value.

- Press the UNITS button to return the green LED to the flow position.

- Press the RESET button to start the sample event.

Note: The DFM must be in Flow mode to start the unit.

Temporary Suspension of a Sample Activity

- With units in the flow mode, press the RESET button to shut off the pump motor. The accumulated elapsed time and accumulated volume up to the time of suspension is saved and viewable by the operator.

Note: Elapsed time is not counted when the pump motor is off. The Total Volume value is frozen because Flow is zero when the pump motor is off.

- With units in the flow mode, press the RESET button to resume the sample activity.

Terminating a Sample Activity

- With the units in the flow mode.
- Obtain and record the elapsed time and total volume values.
- Press the ON-OFF button to remove power from the DFM.
- Remove the filter(s) from the filter holder for laboratory analysis.

Perimeter Air Sampling Results

- Samples shall be counted to meet a lower limit of detection (LLD) value of Uranium (Gross α): $\leq 5 \times 10^{-14}$ µCi/ml.
- The RSO shall be notified of air sample results with an activity greater than the LLD values specified above.
- Sample results should be reviewed and evaluated against previous sampling results.
- Quality assurance aspects of perimeter air sampling, along with the review and evaluation of sampling results, should be consistent with the NTCRA Field Sampling Plan/Quality Assurance Project Plan (FSP/QAPP).

Filter Change

The following demonstrates the loading and unloading of filter samples. A Quartz Microfiber filter (8” x 10”) will be used for all perimeter high volume air monitoring. The filter is changed weekly or when a filter is damaged.

- Open instrument panel door and record data from the DFM. Once data is recorded turn off the DFM.
- Using proper radiological techniques don new gloves and remove filter frame to expose the filter.
- Carefully remove the exposed filter from the supporting screen by holding it gently at the ends (not at the corners).
- Fold the filter lengthwise so that the particulate matter is contained inside.

Note: The particulate matter will include pollen and insects especially in the warmer months.

- Place the folded filter in the protective manila folder lined with wax paper
- Apply a sample label to the manila folder. CAUTION: do not write on the filter or affix a sample label directly to the filter.
- Always store filters horizontally a shelf system is available for this purpose in the Health Physics Lab.
- Keep filters out of sunlight and maintain at room temperature.

CAUTION: Do not chill samples.

- Clean the air monitor with a lint free cloth.
- Don new gloves and carefully center a new filter, rough side up on the supporting screen and secure with filter frame.
- Follow the starting procedure to start or reset a new air monitoring session.
- Fill out the chain-of-custody and place in a small box with the samples. Include any field quality control samples as necessary. Place the samples in a U-lined bag for shipping. It is critical to ship the samples in a rigid container such as a cardboard "FedEx" box for protection. The box should not be so large that the samples move around. Add padding as necessary.

Note: For shipping filters follow standard radioactive shipping procedures.

5. Calibration of High Volume Air Sampler (DF-60810D)

- The high volume air sampler shall be calibrated.
    - Upon installation or first use.
    - Semi-annually.
    - After any major maintenance or repair.
- The Digital Flow Meter calibration accuracy should be verified on a semi-annual frequency absent of any suspected or observed damage to the unit.
- The DF-60810 Air Sampler is calibrated within (+-) 4% accuracy of the average deviation across a flow rate range of 18 to 50 SCFM using the WC-870B-VFB World Calibrator.

NOTE: DF-60810 manufacturer certification and calibration due date are logged in the Critical Equipment Inventory Log stored in the HP trailer and logged electronically on the PC.

- The World Calibrator should be connected to the inlet of the DF-60810D Air Sampler filter holder assembly via an adapter specifically designed to provide and airtight seal between the calibrator and the air sampler inlet. The adapter secures with a quick connect fitting to the air sampler and to the calibrator with tubing.
- Ensure the air sampler and calibrator are on a level surface.
- Ensure the calibrator has warmed up at least 10 minutes.

- Confirm the unused filter paper in the air sampler is the same filter paper used for routine sampling activity;
    - The Digital Flow Meter High Volume Series Air Sampler indicates flow rate at a reference T (temperature) and P (pressure) and also displays T and P, therefore, a direct comparison can be made between them if the reference T and P are the same for the calibrator and air sampler.
    - Set the calibrator to display the same engineering units that the air sampler is reading (SCFM or LPM). Confirm that the filter paper is installed and no air leakage is in the system.
    - Start the air sampler and adjust to sample at or near maximum flow. Allow the flow to stabilize for take 3 to 4 minutes prior to documenting the comparison of flows. Allow calibrator and air sampler to run for approximately 10 minutes.
    - Compare the flow rate on the calibrator with the reading on the air sampler for ten SCFM's (18, 22, 26, 30, 34, 38, 40, 44, 48, 50). Record these readings on the High Volume Air Sampling Calibration Sheet. This is an electronic form stored in a Microsoft Access database. It may be necessary to average the readings over a 15-20 second period if there are minor fluctuations in the flow rate values.

        Note: Make sure that the flow rates entered on are the Reference Volume not the Actual Volume as both are displayed on the World Calibrator.
    - Compare the flow rate on the calibrator with the reading on the air sampler at 40 SCFM for 15 minutes recording the results at the start, 5 minutes, 10 minutes and 15 minutes.
    - Compare the total volume over a 15 minute interval from the High Volume Air Sampler and the calibration device.
    - Compute all deviations and the percent deviations for each of the readings and record on the calibration sheet. Sign and date calibration sheet.
    - Investigate any unacceptable deviations greater than (+-) 4% between the calibrator and the air sampler.

<u>World Calibrator Measurement Ranges</u>

- Air flow: Various flow ranges available.
- Temperature: -40º - 122º F (-40º - 50º C).
- Barometric pressure: 30 - 22 In-Hg (760 - 559 mm-Hg); (101.325-74.5 kPa)
  approx. Sea level to 5900 ft. (1800 m) elevation above sea level
  optional low range to 10 In-Hg (254 mg) (33.86 kPa).
- Best results in calm conditions with no precipitation.