From:	Dombrowski, Frank J <frank.dombrowski@wecenergygroup.com>
Sent:	Thursday, January 16, 2020 2:41 PM
To:	Gielniewski, Margaret <gielniewski.margaret@epa.gov> (gielniewski.margaret@epa.gov)
Cc:	Krueger, Sarah E - DNR; Fitzpatrick, William - DNR; Bougie, Cheryl - DNR; DNR RR NER; adrienne.korpela@jacobs.com; Marcus Byker (Marcus.Byker@ramboll.com); Prasad, Narendra M
Subject:	Former WPSC Marinette, WI MGP - PDIWP Rev 1 - Submittal to EPA for Review
Attachments:	2020-01-16 Marinette MGP Prelim Design Investigation Work Plan Revision 1.pdf

Margaret,

In accordance with the Administrative Settlement Agreement and Order on Consent for Remedial Design (RD-AOC) - Comprehensive Environmental Response, Compensation, and Liability Act Docket No. V W 18-C-009, effective March 26, 2018, and the attendant Statement of Work, in response to your comments received on 10/9/18, and consistent with the WPSC letter dated 11/18/2019, WPSC hereby submits the revised *Preliminary Design Investigation Work Plan* (Rev. 1) for the former WPSC Marinette, WI MGP site.

As you are aware, the City of Marinette has expressed some concerns with implementing the investigation outlined in the attached between May, 2020 and approximately October, 2020. Accordingly, any efforts that could be made to expedite the review and feedback on the current revision would be most appreciated as we are hoping to schedule and implement the field activities associated with the investigation work prior to May 1, 2020 (with the City's concurrence and input).

As always, please feel free to contact me at your convenience if there are any questions or if additional information may be needed.

Thanks,

Frank Dombrowski
Principal Environmental Consultant

WEC Energy Group – Business Services
Environmental Dept. - Land Quality Group
333 W. Everett St., A231
Milwaukee, WI 53203
Office: (414) 221-2156
Cell: (414) 587-4467
Fax: (414) 221-2022

Serving WEC Energy Group, We Energies, Wisconsin Public Service, Michigan Gas Utilities, Minnesota Energy Resources, Peoples Gas and North Shore Gas

Wisconsin Public Service Corporation
700 North Adams Street
P.O. Box 19001
Green Bay, WI 54307-9001
www.wisconsinpublicservice.com

January 16, 2020

Ms. Margaret Gielniewski
Remedial Project Manager
United States Environmental Protection Agency
77 W. Jackson Boulevard
Chicago Illinois, 60604-3590

RE: Submittal of Preliminary Design Investigation (PDI) Work Plan – Revision 1 and Response to USEPA's October 9, 2018 Comments on the PDI Work Plan – Rev 0
Marinette Former Manufactured Gas Plant Site, Marinette, Wisconsin
Wisconsin Public Service Corporation
CERCLA Docket No. V-W-06-C-847; Site Spill ID – B5BT; CERCLIS ID – WIN000509952

Dear Ms. Gielniewski,

This letter provides responses to United States Environmental Protection Agency (USEPA) comments issued on October 9, 2018 regarding the Preliminary Design Investigation Work Plan (PDI Work Plan) – Revision 0) for the WPSC Marinette Former Manufactured Gas Plant (MGP). This letter contains responses to comments provided by USEPA in the October 9, 2018 letter. Responses provided below have been incorporated into the attached Predesign Investigation Work Plan – Revision 1. For ease of review, USEPA comments are presented below in italics, followed by the responses.

> ***Comment 1: Executive Summary.*** *Please change the word "assessible" in the third paragraph to accessible.*

Response: The text has been revised to "accessible".

> ***Comment 2: Section 1.4.3.*** *The noted section is confusing and does little to help the reader understand what remedy was selected. State that EPA chose and modified Alternative 3 as defined by the final version of the Feasibility Study (Revision 3) and as presented in the Record of Decision.*

Response: The text has been revised to "USEPA selected and modified Alternative 3 as defined by the final version of the Feasibility Study Report – Revision 3 (NRT, 2017) and as presented in the ROD (USEPA, 2017)."

> ***Comment 3: Section 2.1.*** *Please include slurry supported excavation in example technologies listed. This method of excavation is applied in soil remediation and may provide a safer means of removing contaminated materials from the site. In the same section, use of hydraulic-based strategies is specifically excluded; the technical basis and rationale for not including this type of excavation equipment should be presented.*

Response: The text has been revised to include slurry and grouting as earth support techniques and describe why hydraulic-based removal is not being considered.

> ***Comment 4: Page 9. Section 2.1. Solubility.*** *Instead of using Florida Department of Environmental Protection's definition of "low" dissolved phase concentrations, EPA refers to the November 1991 guidance, "A Guide to Principal Threat Waste and Low Level Threat Wastes," (which was referenced, and therefore not enclosed) that points to an ELCR ≥ 10-3 and HI ≥ 10.*

Response: The discussion of the key term "MGP Source Material" has been modified to remove the sub-headers of "liquid waste", "toxicity", and "solubility/mobility". The definition of MGP source material has been modified to be consistent with the definition documented in the November 18, 2019 letter from WPSC to USEPA.

> ***Comment 5: Section 2.1. Mobility.*** *Multiple factors influence the ability (or inability) of non aqueous phase liquid (NAPL) to migrate in the subsurface; advection is one such factor. This section is overly simplified. It should either be expanded to provide a full description of the forces/factors that regulate NAPL flow or truncated to concisely state that the presence of mobile NAPL will be evaluated during the PDI.*

Response: See Response to Comment 4. The sub-bullet on "Mobility" has been removed from Section 2.1.

> ***Comment 6: Section 3.1.*** *Resolution of data gap 6 may be an unrealistic goal. Direct correlation of a numeric concentration to determine the absence or presence of principal threat waste is unconventional and unlikely to provide utility in the definition of soil that is subject to remediation or removal.*

Response: Data Gap 6 has been removed from the text. Subsequent data gaps have been renumbered.

> ***Comment 7a: Section 4.1.2.*** *Response to comments. WPSC is unclear regarding the scope of RA in the WWTP Zone to address surficial soil risk. ROD Paragraph N appears to indicate that institutional controls are sufficient to address surficial soil risks, whereas Pages 1-2, Paragraph 1, appears to indicate that a horizontal engineered barrier, coupled with institutional controls, is necessary.*
>
> *EPA Response: In order to reach Wisconsin DNR Case Closure ARARs, horizontal engineered barriers and ICs are necessary.*

Response: Section 4.1.2 has been removed from the text because the administrative elements of the ROD requiring further discussion have been resolved through further correspondence between WPSC and the USEPA. A discussion of the evaluation criteria by which it will be determined if the WWTP Zone requires a horizontal engineered barrier has been added to Section 4.4.2.

> ***Comment 7b: Section 4.1.2.*** *The Proposed Plan indicated that NAPL in the subsurface soil is considered the principal threat waste, whereas PAH-contaminated soils are low-level threat wastes, as they are not highly mobile. Paragraph N the subsequent ROD identified both NAPL- and PAH- contaminated soil as a principal threat waste, because the toxicity of NAPL- and PAH-contaminated soil poses a potential risk of 10-3. The exposure scenario and magnitude of PAH concentrations which must be present in soil to result in designation as a principal threat waste is unclear. Potential resolution of this item is provided above in Section 2.3*
>
> *EPA Response: Section 2.3 accurately defines principal threat waste and low level threat waste from the EPA November 1991 guidance. The Proposed Plan definition of the wastes was more accurate.*

Response: Section 4.1.2 has been removed from the text because the administrative elements of the ROD requiring further discussion have been resolved through further correspondence between WPSC and the USEPA. An updated definition of principal threat waste and MGP source material has been added to Section 2.3 as described in the Response to Comments 4 and 5.

> ***Comment 7c: Section 4.1.2.*** *The ROD identified both NAPL- and PAH-contaminated soil as a principal threat waste, because it contributes to groundwater contamination. The magnitude at which adsorbed concentrations must be present in soil to result in USEPA designation as principal threat waste is unclear. Potential resolution of this item is provided above in Section 2.3.*
>
> *EPA Response: See above response.*

Response: See Response to Comments 4, 5, and 7B.

> ***Comment 8: Section 4.2.1.*** *In addition to contacting the Wisconsin Diggers Hotline, consider a provision to integrate a third-party utility location service to support identification of subsurface utility infrastructure. Although this approach is included in the following section, a bullet might be helpful to define what tasks are included under the utility clearance task. Special precaution should be taken for confirmation of subsurface utilities adjacent or within the rail corridor as National Railroads may or may not participate in one-call location services for utilities located within their property right-of-way.*

Response: A bullet has been added stating: "Subcontract a third-party utility location service to support identification of subsurface utility infrastructure." The following bullet has been revised to state: "Coordinate with participating utility-owning companies and Canadian National Railway Company to locate and mark all respective subsurface utility lines…"

> ***Comment 9: Section 4.2.2.2.*** *Consider adding a current aerial photograph of the site to document pre-investigation conditions in survey-related activities. If such a photograph is included in the site survey control update, please revise the PDI text to include this.*

Response: In addition to a traditional topographic survey, WPSC intends to complete a unmanned aerial vehicle (UAV) survey, provided that adjacent property owners will approve unmanned aerial vehicle (UAV) photography. If property owner approvals can be obtained, an UAV survey will be completed to aid in the understanding of current site conditions. Additional text has been added to Section 4.2.2 that describes the proposed UAV survey.

> ***Comment 10: Section 4.3.1.1.*** *The migration of NAPL in thin seams is a common observation in the characterization of former MGP sites. While it is understood that some boundary of definition must be applied to establish the lateral extents of investigation, establishing a numerical cut-off (or aggregate thickness limit) seems arbitrary. An alternate approach should be considered to establish investigation boundaries.*

Response: To the extent spatially practical, soil borings will be advanced until no oil-coated or oil-wetted observations are present in perimeter borings, the cumulative lifetime incremental cancer risk is less than 10^{-3} and the hazard index is less than 10. With respect to visual observations, the delineation requirements have been revised to state: "No oil-coated or oil-wetted observations are present."

> ***Comment 11: Section 4.3.1.*** *The potential use of TarGOST to confirm the lateral and vertical extent of soil contamination is notably absent in the discussion of proposed investigation methods described in this section. Is there a specific reason why the use of direct push technology (DPT) with real time data reduction was not considered advantageous to assess contaminant extent?*

Response: There is no default TarGOST response that is indicative of source material. A site-specific correlation must be established through association between visual observations and TarGOST borings within each unique site lithology. Given the heterogenous nature of the fill material, the number of

TarGOST borings required to make a statistically significant correlation between TarGOST response within each site lithology is impractical. Additionally, direct push-based technologies (method by which TarGOST is most commonly advanced) are likely to have poor ability to achieve sufficient penetration in areas of wood waste and debris, such as in the former slough. Rather than TarGOST, visual observation from soil borings will be used to identify the lateral and vertical extents of impacts.

> ***Comment 12: Section 4.3.2.*** *This section speaks to geotechnical borings but does not clarify the means of drilling. Since geotechnical engineering is an empirical science, it will be important that these borings are performed by mud rotary or hollow stem auger drill rigs with the ability to obtain standard penetrometer test (SPT) blow counts at every sample interval. Also, neither the type of rock core nor acceptable rock-quality designation (RQD) were clarified. We recommend using a NX-size double tube core barrel equipped with a diamond bit. Diorite core with less than 50 percent RQD should result in a second 5-foot core*

Response: An additional sentence has been added to Section 4.3.2 that states "Geotechnical borings will be advanced using mud rotary or hollow stem auger drill rigs with the ability to obtain standard penetrometer test blow counts in accordance with ASTM D1586." In addition, the text in Section 4.3.2 has been revised to state: "Upon reaching bedrock, a minimum of 5 feet of NX rock core will be collected from one soil boring in each of the three source area excavations, at locations identified on Figure 4. The rock coring will be performed in accordance with ASTM D2113. If the rock core sample is extremely weathered, then a second 5 feet of NX core shall be collected."

> ***Comment 13: Section 4.3.3.*** *Installation of monitoring wells to assess NAPL mobility would require a great deal of effort to generate data that may or may not support overall understanding of subsurface NAPL mobility at the site. Was the measurement of pore fluid saturation in different types of site soil considered? Would data generated by this type of testing be a more useful metric to assess what saturation level of site NAPL is considered mobile, potentially mobile, or immobile? An additional benefit of this approach may be development of a site-specific correlation between concentration and mobility.*

Response: As described in Response to Comment 4 and 5, NAPL mobility is no longer being used as a key metric to identify principal threat waste. Accordingly, measurements of pore fluid saturation would not aid in refining the required excavation area as delineation will be determined by a combination of visual observations and laboratory testing of adsorbed-phase concentrations. Further, a site-specific correlation must be established through association of pore fluid saturation and mobility within each site lithology. Given the heterogenous nature of the fill material, the number of samples required to make a statistically significant correlation between pore fluid saturation and mobility within each site lithology is impractical. Note that monitoring wells and groundwater sampling are still proposed for the following reasons: to assess migration to groundwater, which will be a key long-term metric to determine remedial success, to perform slug testing to assess dewatering requirements, to understand dissolved phase flux to determine in-situ reagent dosage, and to quantify the petroleum-degrading bacteria present in Site groundwater. As such, the discussion of temporary well installation has been moved from Section 4.3.3 (WWTP and Boom Landing Source Area) to Section 4.5.1 (USEPA-Selected Groundwater Remedy).

> ***Comment 14: Section 4.3.3.3.*** *Passive accumulation of NAPL is certainly an indication of subsurface product mobility. However, in the absence of water table reduction from pumping, there may be insufficient gradient to laterally mobilize product to the well. Experience has shown that the first onset of NAPL accumulation in a monitoring well occurs only after the well is pumped for sampling activities. As such, the presence of a static monitoring well that does not accumulate NAPL does not necessarily equal a subsurface condition where mobile NAPL is not present. Since dewatering likely is needed to support excavation activities, understanding how NAPL may*

or may not move when the aquifer is stressed by extraction will be important in understanding both the technical elements and costs necessary to manage fluids generated by dewatering operations.

Response: Each well will be pumped during development and sampling potentially mobilizing product to the well. However, as described in Response to Comment 4 and 5, NAPL mobility is no longer being used as a key metric to identify principal threat waste. With respect to dewatering, the dewatering contractor will be equipped to manage NAPL, if generated.

Comment 15: Section 4.3.3.4. *The use of groundwater measurements to define the source area can be a helpful tool (line of evidence) to identify contaminant extent. However, since solubility of a contaminant is controlled by many chemical and physical factors, it is not entirely representative of the mass of contaminants that might be present within soil. For this reason, reliance on groundwater data to define a soil source area should be avoided. Because soil borings will be advanced throughout the areas to be investigated, the use of soil samples to identify the extent of source contamination (within the soil matrix) is recommended. This data set will provide a much better basis to inform remediation decisions. Under this approach, more frequent soil samples would be collected and analyzed for site-related compounds. Soil sampling to define boundaries avoids the need for well construction/ sampling and presents a clear, consistent, and logical approach to defining a source area. A comprehensive set of spatial soil data set also would identify the reservoir of contamination available to partition to groundwater with much greater accuracy. It would also identify which areas have contaminants exceeding remedial goals.*

Response: As described in Response to Comments 4 and 5, NAPL solubility is no longer being used as a key metric to identify principal threat waste. High resolution soil sampling will be conducted as part of the PDI to inform remedial decisions as described in section 4.3.1.

Comment 16: Section 4.3.4. *Construction dewatering to support excavation may pose significant technical and cost challenges during remediation. For this reason, it is paramount to fully understand the hydraulic properties of the aquifer within the work area. A continuous or step pump test should be considered in lieu of slug testing to provide a more robust data set for analysis and better inform remedial design and planning efforts pertaining to excavation water management. An alternative test could be performed during planned test pitting. Digging each test pit to a known size and measuring groundwater rise within the test pit over time can provide an accurate account of groundwater infiltration for future dewatering design. Care must be taken during this test to make sure test pit walls remain stable as water seeps into the test pit.*

Response: Pump testing is currently not being considered due to the time and infrastructure required to execute the test (oil-water separator and frac tanks) and practical limitation to complete the test at one of three excavation areas. WPSC believes that well-distributed slug test data, along with conservative interpretation of slug tests, are sufficient to complete the dewatering design. If the slug tests results are unexpected or highly variable, pump testing or another alternative will be considered. Excavation during the PDI phase of the project is currently not allowed for by the third-party property owners. Note: WPSC staff were recently involved in dewatering of an excavation in a similar setting at the North Shore Gas South Plant site in Waukegan, IL. This recent dewatering case study will provide insights on relationship between dewatering rate PDI hydrogeologic data.

Comment 17: Section 4.4.2.2. *The decision units should correlate with the exposure potential for various areas of the site. Because more frequent exposure around the buildings is likely, a decision unit that is more focused around the buildings should be identified. Other decision units* *should be identified for the remaining areas and categorized based on the frequency and intensity of exposure in the remaining areas.*

Response: The WWTP decision unit was split based on the location of pathways and buildings. Figure 5 has been updated to reflect this change. The text has been revised to state: "The WWTP Zone is split up into Decision Units A and B, with WWTP Zone Decision Unit B mostly comprised of cells with buildings or major pathways where exposure risk may be higher. WWTP Zone Decision Unit A comprised of the remainder of the facility in areas that employees are anticipated to be less frequently." Note that the number of increments in each decision unit has been reduced to approximately 30 consistent with the ITRC guidance. The number of samples was modified for consistency across decision units

Comment 18: Section 4.6. *If a contingency remedy is needed for the WWTP zone, EPA will need additional information for those technologies, equivalent to the information presented in the Alternatives Array and FS. How will these technologies help achieve the remediation goals at the WWTP Zone of the Site? How will they screen against the Nine Criteria? EPA is open to contingency remedies; if one is selected, it will call for a ROD Amendment.*

Response: Pending the results of the PDI investigation, WPSC will potentially present a proposal for an alternate remedy.

If you have any questions, please do not hesitate to contact me at (414) 221-2156 or via email at frank.dombrowski@wecenergygroup.com.

Sincerely,

Frank Dombrowski
Principal Environmental Consultant
WEC Business Services – Environmental Dept.

cc: Ms. Sarah Krueger, WDNR (via US Mail and email)
Mr. William Fitzpatrick, WDNR (via US Mail and email)
Ms. Cheryl Bougie, WDNR (via email)
WDNR Northeast Region (via email to DNRRRNER@wisconsin.gov)
Ms. Adrienne Korpela, Jacobs (via email)
Mr. Marcus Byker, Ramboll (via email)

Enclosures: PDI Work Plan Revision 1

Intended for
WEC Business Services, LLC

Date
January 16, 2020

Project No.
73068

PRELIMINARY DESIGN INVESTIGATION WORK PLAN REVISION 1

FORMER MARINETTE MANUFACTURED GAS PLANT SITE
MARINETTE, WISCONSIN

WISCONSIN PUBLIC SERVICE CORPORATION

RAMBOLL Bright ideas. Sustainable change.

PRELIMINARY DESIGN INVESTIGATION WORK PLAN
REVISION 1
FORMER MARINETTE MANUFACTURED GAS PLANT SITE

Project name	**Former Marinette MGP Site**
Project no.	**73068**
Recipient	**WEC Business Services, LLC**
Document type	**Preliminary Design Investigation Workplan**
Revision	**1**
Date	**January 16, 2019**
Prepared by	**Abigail Small, PE**
Checked by	**Marcus D. Byker, PE**
Approved by	**Jennifer M. Hagen, PE**

Ramboll
234 W. Florida Street
Fifth Floor
Milwaukee, WI 53204
USA

T 414-837-3607
F 414-837-3608
https://ramboll.com

Marcus D. Byker, PE
Managing Engineer

Jennifer M. Hagen, PE
Senior Managing Engineer

CONTENTS

TABLES (WITHIN TEXT)

TABLES (ATTACHED)

FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
BLRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
City	City of Marinette
CN	Canadian National Railway Company
COC	Constituent of Concern
Diggers	Wisconsin Diggers Hotline
DNAPL	Dense Non-Aqueous Phase Liquid
FS	Feasibility Study
FSP	Field Sampling Plan
GIS	Geographic Information System
IBS	Integrys Business Support
IDW	Investigative Derived Waste
ISS	In-situ stabilization/solidification
ITRC	Interstate Technology and Regulatory Council
kg	Kilogram
L	Liter
µg	Microgram
mg	Milligram
MGP	Manufactured Gas Plant
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NAPL	Non-aqueous Phase Liquid
NRT	Natural Resource Technology
NTCRA	Non-Time Critical Removal Action
PAH	Polyaromatic Hydrocarbons
PDI	Preliminary Design Investigation
PDIWP	Preliminary Design Investigation Work Plan
PPE	Personal Protective Equipment
RA	Remedial Action
Ramboll	O'Brien & Gere Engineers, Inc., a Ramboll company
RAO	Remedial Action Objective
RCM	Reactive Core Mat
RD	Remedial Design
RD AOC	Administrative Settlement Agreement and Order on Consent for Remedial Design
RG	Remedial Goals
RI	Remedial Investigation
ROD	Record of Decision
ROW	Right-of-Way
RPI	Remediation Projects, Inc
SAS	Superfund Alternative Site
SOP	Standard Operating Procedure

UAV	Unmanned Aerial Vehicle
USEPA	United States Environmental Protection Agency
WDNR	Wisconsin Department of Natural Resources
WPSC	Wisconsin Public Service Corporation
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This Preliminary Design Investigation Work Plan (PDIWP) describes field activities and associated laboratory analyses that are necessary to support design of the United States Environmental Protection Agency (USEPA)-selected remedy for Wisconsin Public Service Corporation's (WPSC) Former Marinette Manufactured Gas Plant (MGP) Site (Site). Following the conclusion of MGP operations, the Site was sold to the City of Marinette and is currently occupied by a public boat launch and a waste water treatment plant (WWTP). The selected remedy includes excavation of source material located in three distinct areas on the property, construction of a horizontal engineered barrier over portions of the Site where surface soils exceed soil remedial goals (RGs), one-time placement of a treatment reagent within the source area excavation backfill to expedite groundwater restoration, and corresponding monitoring and institutional controls.

Before developing the PDI scope of work, it is essential to identify data gaps necessary to fill in order to complete a successful remedial design (RD). Identified data gaps are presented in Section 3, and include: as-builts of existing structures, topography and utility surveys, geotechnical and hydraulic information to facilitate earth retention design, and a refined understanding of the horizontal and vertical extent of impacts. Developing a scope to define horizontal and vertical extent of affected soil over which a horizontal engineered barrier construction is required can be performed with relative ease by comparing soil analytical results to the soil remedial goals. Developing a scope to define the horizontal and vertical extent of affected soil that requires removal on the basis that it represents source material or principal threat waste is more challenging, due to the absence of numeric criteria against which analytical results or field observations can be compared.

To provide clarity as to what material represents source material or principal threat waste that would require removal or treatment, Section 2 proposes a framework to defining key terms, such as accessible, safely removable, and MGP source material. Defining these terms in the PDIWP will provide certainty that the PDI field work will adequately delineate the horizontal and vertical extent of source material requiring removal or treatment and will confirm the accessibility and practicality of such actions.

Based on the defining key terms that provide clearer definition as to which material must be removed or treated, this PDIWP outlines a field investigation and laboratory analysis program to resolve data gaps and provide the information necessary to complete a thorough RD. The scope of the PDIWP includes the following:

- Meeting with the City of Marinette and the WWTP to understand considerations that may affect remedy design and remedial action (RA) sequencing (Section 4.1.1).
- Completing topographic, boundary, utility, structural integrity, and existing horizontal barrier condition surveys (Sections 4.2 and 4.4.1).
- Defining the horizontal and vertical extent of source area excavations by reoccupying eight historic borings with oil-coated/oil-wetted observations, advancing 30 borings in transects surrounding the historic borings, and advancing contingency or step out borings, as necessary (Section 4.3.1).
- Collecting geotechnical and hydrogeologic information to support design of earth retention and dewatering systems (Sections 4.3.2 and 4.3.3).

- Conducting incremental sampling of surface soils to determine the necessity of horizontal engineered barrier installation (Section 4.4.2).
- Installing temporary wells within and downgradient of source areas to inform assessment of excavation extent and selection of groundwater treatment reagent. (Section 4.5.3).
- Performing studies to assist in selection of the proper in-situ treatment reagent to place during post-remediation backfill (Section 4.5).

Due to accessibility, safety, and structural integrity constraints, an evaluation of the PDI data may indicate that extent and dimensions of source area excavations are impracticable, particularly the excavation located adjacent to the WWTP aeration basin. In preparation for this possibility, the PDIWP also identifies contingency investigations to support alternate technical approaches for remedial action (RA) in the identified source areas. The scope of the contingency investigations and testing will be clarified, if necessary, through a PDIWP Addendum. This PDIWP scope includes collection and storage of representative soils to support contingency bench-scale testing for these alternative approaches. Collecting and storing the soil samples needed during this PDI will minimize potential future schedule delays should it be determined that an alternate technical approach for RA is necessary.

The PDI field activities will be scheduled following USEPA-approval of this PDIWP and will be dependent upon weather conditions, execution of access agreements, WWTP operational constraints, concerns raised by the City of Marinette regarding access and use of public facilities, and contractor availability. WPSC will inform USEPA of the proposed schedule for PDI field activities prior to mobilization.

1. INTRODUCTION

On behalf of Wisconsin Public Service Corporation (WPSC), O'Brien & Gere Engineers, Inc., a Ramboll company (Ramboll) has prepared this Preliminary Design Investigation Work Plan (PDIWP) for the WPSC Marinette Former Manufactured Gas Plant (MGP) Superfund Alternative Site (SAS) located in Marinette County, Wisconsin (Figure 1; Site). The primary objective of the PDIWP is to specify the additional data collection efforts necessary to design the remedy selected by the United States Environmental Protection Agency (USEPA) in the *Record of Decision (ROD) - Wisconsin Public Service Corporation Marinette Former Manufactured Gas Plant Site Marinette, Wisconsin* (USEPA, 2017b), and meet the requirements of the *Administrative Settlement Agreement and Order on Consent for Remedial Design* (RD AOC) (USEPA, 2018).

1.1 Overview

WPSC and USEPA entered into an RD AOC under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No. V W 18-C-009, which became effective March 26, 2018. The RD AOC requires WPSC to develop a remedial design (RD) for the Site, which includes source material excavation, horizontal engineered barrier construction, groundwater restoration, and corresponding monitoring and institutional controls.

Existing remedial investigation data was sufficient to complete the Remedial Investigation and Feasibly Study (RI/FS) Reports. As the Site progresses toward RD, additional information is required to effectively design the USEPA-selected remedy for the upland portions of the Site. This additional information will be obtained through implementation of this PDIWP.

The RD AOC contained several content requirements for the PDIWP. The following is a list of those requirements along with the section within this PDI that addresses the requirement:

- An evaluation and summary of existing data and description of data gaps (Section 3).
- A detailed plan of Preliminary Design Investigation (PDI) activities targeted at resolving identified data gaps. Among other elements, this plan will include data quality objectives, media to be sampled, contaminants or parameters for which sampling will be conducted, location, and number of samples anticipated (Sections 4.1-4.3, Table 1).
- A description of a treatability study to determine the most appropriate treatment reagent and activator(s) to be applied in the source area excavations (Section 4.5.2).
- Cross references to quality assurance/quality control requirements (Section 4).

In addition, the data collected as part of this PDIWP will be used to refine the CSM presented in the RI Report and the RI CSM may be updated based upon the data collected.

1.2 Site Description and Surrounding Land Use

The Marinette Former MGP property is located in the City of Marinette, Wisconsin (Figure 1). The upland portion of the Site is approximately 15 acres in area and is primarily located within areas zoned as heavy manufacturing, railroad, and park districts. Small portions of the Site also are located within areas zoned as community business and waterfront overlay districts. Most of the Site is covered with pavement, buildings, compacted gravel, or well-maintained lawn. The Site includes properties owned by WPSC, Canadian National Railway Company (CN), Marinette Central

Broadcasting, and the City of Marinette (Boom Landing, waste water treatment plant [WWTP], fire station, and city right-of-way [ROW]), as discussed below and shown on Figure 2.

- **WPSC Property –** The triangle-shaped property located on the west side of the Site, and north of Mann Street, is owned by WPSC. The property is zoned community business and waterfront overlay district.
- **Canadian National Railway Company –** The railroad in the middle of the Site, parallel to Mann Street, is owned by CN.
- **Marinette Central Broadcasting –** Marinette Central Broadcasting owns the property to the west of Boom Landing, in the northern part of the Site. The property is zoned for community business and waterfront overlay district.
- **City of Marinette (City) –** The City owns properties covering the majority of the Site, including: Boom Landing in the north and along the Menominee River; the City WWTP in the south; the fire station in the southwest corner; and Mann Street, Ely Street, and Ludington Street, bordering the WWTP to the north, southeast, and southwest, respectively. The eastern portion of Boom Landing is zoned as a park district and the western portion of the Boom Landing is community business district and waterfront overlay district. The WWTP is zoned as a heavy manufacturing district, and the fire station is zoned as a commercial business district.

For purposes of this PDIWP, the Site has been divided into two remediation zones: Boom Landing Zone and WWTP Zone, separated by the CN railroad, as shown on Figure 3. These zones were previously described in approved regulatory submittals and were developed to combine areas with shared land ownership and/or similar physical access limitations.

1.3 Site History

The Site history has been described in detail in numerous previous regulatory submittals [*e.g.*, *Remedial Investigation Report – Revision 2* (Natural Resources Technology [NRT], 2015) and *Feasibility Study Report – Revision 3* (NRT, 2017)]. A summary of the Site history, as presented in previous submittals, is reiterated in the following sections.

1.3.1 Former MGP Property

The former MGP facility was constructed between 1901 and 1910 and operated through 1960. Prior to 1903, the property and facility were owned by the Marinette Lighting Company. In 1903, electric and gas utilities in Marinette, Wisconsin, and Menominee, Michigan, were merged to form the Menominee and Marinette Light and Traction Company. In 1922, WPSC acquired Menominee and Marinette Light and Traction Company and operated it as a wholly-owned subsidiary. The subsidiary was merged with the parent company in 1953, and in 1962, the former MGP property was sold to the City of Marinette under a land contract. The City subsequently used the property to expand its WWTP facilities. All the above-ground and most of the below-ground structures associated with the MGP were removed and/or demolished by the City in the 1960s to support WWTP expansion.

1.3.2 City of Marinette Waste Water Treatment Plant Property

The City of Marinette WWTP was originally constructed in 1938 and located east of a former slough. The plant was then expanded in 1945 and 1952. Historic WWTP infrastructure included fuel oil underground storage tanks and the City's asphalt manufacturing plant, which operated from the early 1960s to 1990. Following the City's purchase of the former MGP property in 1962, the WWTP was expanded in 1972, and again in 1989, to the current layout.

1.3.3 Former Slough/Boom Landing

A former slough, a meander of the Menominee River, was present at the Site until approximately 1945. The history of the former slough is summarized below. An outline of the configuration of the former slough is shown on Figure 3.

Table A – Summary of History of Slough

Date	Description
1800s	The slough existed as a meander of the Menominee River and was used for floating logs to the main river. Water flow direction flowed from north to south.
1945	Southern portion of the slough was filled during the expansion of the WWTP. Water flow direction changed from south to north due to fill placement.
1960	The slough south of the MGP plant was completely filled by May 1960.
1970	The slough was gradually filled with silt from apparent natural deposition.
1982	The slough was completely filled to the Menominee River and the boat landing was constructed over the mouth, along the riverbank.
1987	The area around Boom Landing was developed.
2004	The current boat landing was reconstructed, including the expansion of the parking area, a wider boat ramp, and two floating piers.

1.4 Overview of USEPA-Selected Remedy

The following subsections provide an overview of the USEPA-selected remedy detailed in the ROD (USEPA, 2017b), as it pertains to the PDIWP development.

1.4.1 Remedial Action Objectives

A Remedial Action Objective (RAO) describes the goal(s) that the proposed remedial action is expected to accomplish. The RAOs for the Site were developed based on remaining constituents of concern (COCs), potential exposure pathways, possible human and ecological receptors, and an acceptable constituent level for each impacted media, assuming continuation of current uses of the Site. Provided below is a summary of the six RAOs established for the Site.

- **Soil/Soil Vapor:**
  - **RAO-1:** Prevent human exposure, including dermal contact and incidental ingestion, of particulates and vapor to dense non-aqueous phase liquid (DNAPL)-saturated soil and subsurface soil containing MGP related contaminants greater than remedial goals (RG).
- **Groundwater:**
  - **RAO-2:** Prevent human exposure, including dermal contact, incidental ingestion and inhalation (as a result of vapor intrusion), of groundwater containing MGP residuals exceeding RGs.
  - **RAO-3:** Restore groundwater to RGs for MGP-related contaminants within a reasonable timeframe.

- **RAO-4:** Minimize, to the extent practicable, the potential for migration of groundwater with MGP-related constituents above the RGs to surface water.

- **Sediment:**
  - **RAO-5:** Demonstrate the reactive core mat (RCM) remains effective at preventing non-aqueous phase liquid (NAPL) from migrating into the Menominee River, and that at least six inches of clean sand remains over areas with remaining MGP-residuals.
  - **Non-Time Critical Removal Action (NTCRA) RAO:** Remove NAPL and polyaromatic hydrocarbons (PAH)-contaminated sediments that have the potential to affect human health and ecological receptors. The NTCRA RAO was satisfied, to the extent practicable, as part of the NTCRA activities.

1.4.2 Remediation Goals

RGs are long-term target goals used during analysis, evaluation, and implementation of remedial alternatives. Achieving the RGs through remedial action (RA) will result in protection of human health and the environment. The RGs for soil and groundwater that were finalized by USEPA in the ROD (USEPA, 2017b) are provided in Tables B and C, respectively.

Table B – Soil Remediation Goals

Constituent of Concern	Remediation Goal (mg/kg)
Ethylbenzene	37
Benzo(a)pyrene	2.11
Naphthalene	26

Table C – Groundwater Remediation Goals

Constituent of Concern	Remediation Goal (µg/L)
Benzene	5
Ethylbenzene	700
Benzo(a)pyrene	0.2
Benzo(b)fluoranthene	0.2
Chrysene	0.2
Naphthalene	100

During implementation of a remedy, flexibility will be provided to potentially modify the RGs by conducting a post-remedy risk assessment following the *Multi-site Risk Assessment Framework, Former Manufactured Gas Plant Sites Revision 0* (Exponent, 2007), as negotiated in the *Settlement Agreement and Administrative Order on Consent for the Conduct of Remedial Investigations and Feasibility Studies at Six WPSC MGP Sites in Green Bay, Manitowoc, Marinette, Oshkosh, Stevens Point, and Two Rivers, Wisconsin* (USEPA, 2006). If the post-remedy risk assessment (pending review and concurrence from USEPA) concludes that the cumulative site risk is below the target cancer risk and noncancerous hazard index for the targeted exposure scenario, then no additional intrusive RA will be required. Non-intrusive remedies, such as institutional controls and/or long-term monitoring, may be implemented, as necessary, dependent on the supplemental risk assessment findings.

1.4.3 USEPA-Selected Remedial Actions

USEPA selected and modified Alternative 3 as defined by the final version of the *Feasibility Study Report – Revision 3* (NRT, 2017) and as presented in the ROD (USEPA, 2017). The following subsections summarize the selected remedy as described in the ROD.

1.4.3.1 Soil Remedial Action

The first component of the soil RA selected by USEPA involves excavation and off-site disposal of accessible subsurface source material, located within the Boom Landing and WWTP Zones.

The Boom Landing Zone soil RA is anticipated to include the following elements:

- Completing PDI and waste characterization sampling, both to further define the horizontal and vertical extent of subsurface contamination in the areas of previously identified MGP-source material, and to establish waste characterization data.
- Obtaining access agreements and demolishing/removing parking lot, fish house, utilities, and existing concrete and asphalt pavement areas in the Boom Landing Zone.
- Installing temporary shoring to facilitate deeper excavations.
- Installing a temporary dewatering system to lower the water table within the excavation footprint.
- Excavating non-affected overburden soil and stockpiling on-site, for use as post excavation backfill.
- Excavating MGP source material and transporting material to a Subtitle D Landfill.
- Backfilling excavation to surrounding grades with granular backfill and stockpiled overburden material.
- Restoring the Site to pre-RA conditions.

The WWTP Zone soil RA will include the following elements:

- Completing PDI and waste characterization sampling, both to further define the horizontal and vertical extent of subsurface contamination in the areas of previously identified MGP-source material, and to establish waste characterization data.
- Obtaining access agreement from the City to allow for a deep excavation adjacent to WWTP infrastructure, including an aeration basin.
- Installing temporary shoring to facilitate deeper excavations.
- Installing a temporary dewatering system to lower the water table within the excavation footprint.
- Excavating non-affected overburden soil and stockpiling on-site, for use as post excavation backfill.
- Excavating accessible MGP source material to maximize principal threat waste removal, while minimizing impact to surrounding infrastructure, and transporting material to a Subtitle D Landfill.

- Backfilling excavation to surrounding grades with granular backfill and stockpiled overburden material.
- Restoring the Site to pre-RA conditions.

The soil RA selected by USEPA involves horizontal engineered surface barriers in both the Boom Landing and WWTP Zones, which will include the following elements:

- Monitoring and maintaining existing engineered surface barriers, including paved parking lots and roadways.
- Further investigating, as part of the PDI, the horizontal extent of surficial soil where a barrier is required.
- Mitigating potential exposure by excavating accessible surficial soil containing COCs above RGs to two feet below ground surface (bgs) and backfilling the excavated areas with 18 inches of clean fill and six inches of clean topsoil. Alternative barrier approaches, including gravel and/or asphalt, will be evaluated during the RD phase. In addition, consistent with the ROD, Section N (USEPA, 2017b), institutional controls without a horizontal engineered barrier will also be considered during the RD phase for the WWTP Zone.

1.4.3.2 Groundwater Remedial Action

Removal of accessible source material will reduce the mass of sorbed contaminant mass available for dissolution into groundwater. Groundwater monitoring will be performed following source material excavation to assess on-going monitored natural attenuation (MNA). To enhance groundwater restoration, the USEPA selected one-time placement of an in-situ treatment reagent within the base of excavations prior to backfilling. Groundwater RA includes the following elements:

- Selecting the in-situ treatment reagent type and dosing rate required to most-effectively address COCs.
- Completing one-time placement of reagent into the exposed saturated zone resulting from excavation of Boom Landing and WWTP Zones.
- Conducting groundwater monitoring until groundwater trends indicate RGs will be achieved.

1.4.3.3 Sediment Remedial Action

The NTCRA removed NAPL and sediment with total PAH concentrations above 22.8 milligrams per kilogram (mg/kg), to the extent practicable. A residual sand cover was placed over a portion of the river bottom and an RCM was placed along a portion of the river bank in areas where conditions prevented complete removal of impacted material. As part of the ROD, the USEPA selected long-term effectiveness monitoring of the residual sand cover and the RCM, which includes the following elements:

- Completing regular effectiveness monitoring of the RCM to assess potential for ebullition or migration of MGP source materials that were not addressed during the 2012 NTCRA. RCM effectiveness monitoring will consist of visual surface water sheen monitoring, coupled with installation of an additional groundwater well within the former slough (pending utility clearance), and sampling of the newly-installed well and two existing shoreline wells.

- Monitoring the 160 cubic yards of dredge inventory that remained after the NTCRA, to ensure at least six inches of clean sand remain over those areas with MGP residuals remaining, and that the top six inches of the sand cover remains below RA levels.

1.4.3.4 Institutional Controls for Soil, Soil Gas, Groundwater, and Sediment

Boundaries for institutional controls will be established, based on more thorough delineation of MGP COCs on affected parcels to RGs, as determined through PDI and RA activities. Wisconsin Department of Natural Resources' (WDNR's) Geographic Information System (GIS) Registry will be used to implement the institutional controls. Requirements, limitations, or conditions relating to restrictions of sites listed on the WDNR GIS database are required to be met by all property owners [Wisconsin State Statutes § 292.12(5)]. As a result, the statute requires that the GIS database conditions be maintained for a property, regardless of changes in ownership. A violation of Section 292.12 is enforceable under Wisconsin Statutes § 292.93 and 292.99.

1.5 Contingency Planning

Due to site safety and structural integrity constraints, an evaluation of the PDI data may indicate that extent and dimensions of excavations, as specified in the ROD, are impracticable, particularly the excavation located adjacent to the WWTP aeration basin. In preparation for this possibility, the PDIWP also includes contingency investigations to support alternate technical approaches for RA in the identified source material areas. Performing these contingency investigations as part of the other necessary PDI activities will take advantage of cost and schedule efficiencies.

1.6 Multi-Site Documents Applicable to the PDI

WPSC enrolled six former MGP sites into the USEPA Superfund Alternatives Program in 2006. To promote a consistent methodology for investigating and evaluating these six sites, WPSC developed multi-site documents that outline general approaches and concepts, with the intent to streamline preparation of work plans and to minimize review times for future deliverables. In addition, the multi-site documents provide a consistent approach to investigate and assess all sites within the program. PDI field work will be carried out in accordance with relevant elements of these multi-site documents. Specifically, field documentation, sample collection, and sample handling will be conducted in accordance with Standard Operating Procedures (SOPs) defined in the Multi-Site Field Sampling Plan (FSP), Rev 4, September 2008 (Integrys Business Support [IBS], 2008) and SOPs relevant to this document are included in Appendix A. Similarly, laboratory analysis and data management will be managed in accordance with Multi-Site Quality Assurance Project Plan, Rev 2, September 2007 (IBS, 2007) and subsequent addenda.

2. DEFINITION/CLARIFICATION OF KEY TERMS USED IN THE ROD

A key element of the PDI will involve developing a more precise and complete delineation of "principal threat waste source material" in the subsurface and the resulting horizontal and vertical extent of the excavations. The ROD (USEPA, 2017b) specifies removal of "accessible" source material from two locations in the WWTP Zone and one location on the Boom Landing Zone. Additional communication with USEPA following ROD issuance indicated that USEPA will only require excavation of source material that could be "safely" removed. Definitions of accessible, safely removable, and source material will be critical to determining when the delineation of horizontal and vertical extent of the source area excavations are complete under the PDI. Definition of these terms will also allow for efficient transition from the PDI phase of the project to the RD phase, as a working understanding of the material to be targeted for excavation will already be in place. The below sections propose definitions of these key terms and supporting information as to why the definition is appropriate for use at the Site to guide PDI, RD, and RA activities.

2.1 Key Term 1: Accessible

The USEPA-selected remedy for soil specifies excavation and off-site disposal of accessible source material located within the Boom Landing and WWTP Zones. A main component of the PDI is to obtain sufficient information to establish the horizontal and vertical extent of excavation activities. As a part of this investigation, "accessible" material for excavation will be defined as material that meets all of the below requirements:

- Material that, if removed using conventional excavation and earth support techniques (e.g., sheet pile, soldier piles, trench boxes, slurry, grouting, etc.) or dewatering methods, would be unlikely to undermine, destabilize, or cause differential settlement that could affect regular operations of the WWTP, impact structural integrity of on-site structures, critical utilities and below-ground infrastructure, or the adjacent rail line or cause differential settlement to areas within or adjacent to such excavation areas.
- Material outside of mandated offset distances of WWTP structures, critical utilities and below-ground infrastructure, or the rail line, as specified by the WWTP, utility company, and railroad operator.
- Material suitable for removal by traditional earth moving equipment (i.e., excavator). Hydraulic-based removal of material is not considered practical due to the limited volume of material anticipated to be excavated, challenges in visually confirming magnitude of impacts on excavated material and subsequent verification that removal goals have been achieved, and limited production rates associated with this method.

Once the PDI is completed, WPSC and USEPA may discuss additional refinements to the accessibility definition that become evident based on the results of the PDI document review/research and fieldwork. For example, should mandated offsets from structures or critical utility reduce the volume of accessible material to a narrow wedge, this narrow wedge may be considered inaccessible on a case-by-case basis.

2.2 Key Term 2: Safely Removable

In the Responsiveness Summary Section of the ROD, USEPA states "*EPA will rely on design engineering to refine the areas to be excavated to maximize principal threat waste removal and minimize impact to surrounding structures*." It is likely that the most substantial impact to surrounding structures would result from the installation of shoring systems, or the failure of the shoring system used to stabilize surrounding structures during excavation activities. Given the sensitive nature of the nearby critical structures, a failure of the shoring system for this application includes excessive deflections, or the creation of void space in the abandonment of shoring elements, which could cause settlement of the structures.

In geotechnical engineering, a common method of analyzing and mitigating risk of failure is to employ a factor of safety. The minimum factor of safety for failure against sliding and overturning of an excavation support element in a temporary condition is 1.5 (Das [2007], EM 1110-2-2504, Steel Sheet Pile Manual, USS [1984]). When considering deep excavations similar to those specified in the USEPA-selected remedy, the factor of safety and allowed limit of deflections is closely related to the overall cost of excavation activities. USEPA Publication 9200.3-23/FS – "The Role of Cost in the Superfund Remedy Selection Process" – 1996 states that "*Cost is a central factor in all Superfund remedy selection decisions*." USEPA Publication 9200.1-23P – "A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents" (USEPA 1999), Highlight 6-28 further states that "*Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the administrative record file, an explanation of significant differences, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.*"

The FS-level cost estimates were conceptual in nature and based on the best available data gathered during the RI. WPSC will collect additional geotechnical information with increased data density as part of the PDI. Based on the results of the PDI, WPSC will develop a refined preliminary cost estimate for completing the excavation with a minimum factor of safety of 1.5. This refined cost estimate will be included as part of PDI Data Evaluation Report. If the cost of the excavation increases by more than 50 percent above the FS-level cost for Source Area Removal, WPSC may pursue documenting the major change consistent with the procedures outlined in "*A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents"* (USEPA, 1999).

2.3 Key Term 3: MGP Source Material

The waste characteristics that constitute "source material" are not specifically defined in the ROD; however, the ROD uses the term "principal threat wastes" in the discussion of the removal remedy, suggesting that "source material" and "principal threat wastes" may be synonymous. USEPA guidance (Superfund Publication 9380.3-06FS, November 1991) indicates that "*Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present significant risk to human health or environment should exposure occur. They include liquid and other highly mobile materials or materials having high concentrations or toxic compounds.*" The same USEPA guidance indicates that "*Low level threat wastes are those source materials that generally can be reliably contained and that would present only a low risk in the event of release. They include source materials that exhibit low toxicity, low mobility in the environment, or are near health-based levels.*"

Consequently, an important component of the PDI will be to develop data and criteria to define and characterize the extent of a principal threat waste/source material (i.e., those materials having impacts of sufficient magnitude as to require physical removal). Consistent with USEPA guidance (Superfund Publication 9380.3-06FS, November 1991; USEPA, 1991) and the correspondence between WPSC and USEPA (WPSC, 2019), for the purpose of the Site RA, principal threat waste for excavation will be defined as soil that meets one or more of the following metrics:

- NAPL identified as separated liquid.
- Oil-coated or oil-wetted soil.
- Highly adsorbed phase concentrations of COCs exceeding a lifetime incremental cancer risk of 10^{-3} or a hazard index of 10 under applicable, industrial land use assumptions.

As part of the PDI activities described in Section 4, samples will be collected from a range of soil potentially affected by former MGP operations based on visual observations. Soil samples will be sent for laboratory analysis of soil COCs. Analytical results from these soil samples will be imported into the WDNR's cumulative risk calculator for the default industrial land use scenario. The horizontal and vertical extent of intrusive remedial action will focus on soil with hypothetical industrial risk-based exceedances greater than a lifetime incremental cancerous risk of 10^{-3} or a noncancer hazard index greater than 10.

3. DATA GAP IDENTIFICATION

Sufficient investigation activities were conducted during the RI and FS phases to estimate the extent of affected media, determine risk for potential exposure, and develop and evaluate remedial alternatives. Additional data beyond the scope of the RI and FS is required to facilitate development of the RD and implementation of RA. The following sections identify current data gaps needed to complete the RD. Proposed investigation to resolve these data gaps is presented in Section 4.

3.1 General

General data gaps related to overall fundamental design needs of the proposed remedy are presented below.

- **Data Gap 1:** Topographic, property boundary, and utility location information is out of date and the accuracy of current information is unknown.
- **Data Gap 2:** As-built drawings and details related to the aeration basin, service building, and above ground/subsurface utilities in the WWTP and Boom Landing Zones are unknown.
- **Data Gap 3:** City-desired requirements for closing Boom Landing to facilitate excavation activities are unknown.
- **Data Gap 4:** City-mandated requirements for partial or full shutdown of the aeration basin and corresponding infrastructure at the WWTP are unknown.
- **Data Gap 5:** City, railroad, and utility requirements for setbacks from WWTP structures, rail lines, and underground infrastructure are unknown.
- **Data Gap 6:** The potential for, and requirements of discharging water generated during RA implementation to the WWTP is unknown.

3.2 Source Material

- **Data Gap 7:** The delineation of the horizontal and vertical extent of potential source material in the WWTP and Boom Landing Zones is insufficient for design purposes.
- **Data Gap 8:** Insufficient geotechnical information is available for use in design of the shoring systems required to complete the proposed excavations.
- **Data Gap 9:** Existing hydrogeologic information is insufficient for use in design of a dewatering system.

3.3 Horizontal Barriers

- **Data Gap 10:** The required extent of horizontal barriers is unknown, due to insufficient density of surface soil samples.
- **Data Gap 11:** The required extent of horizontal barriers is unknown, due to uncertainty regarding the adequacy of existing barriers.

3.4 Groundwater

- **Data Gap 12:** There is uncertainty regarding the type and concentration of reagents and/or activating agents required to address post-excavation COCs and enhance the long-term efficacy of MNA.
- **Data Gap 13:** The potential solubility and mobility of NAPL is unknown.

4. PRELIMINARY DESIGN INVESTIGATION SCOPE

4.1 Administrative Considerations

Design and implementation of the USEPA-selected remedy will be influenced by administrative and engineering considerations. Investigation work to address engineering considerations are identified in later subsections. This subsection presents the administrative elements that need to be better understood prior to proceeding with the RD.

Intrusive remedial activity associated with the USEPA-selected remedy is exclusively focused on land owned by the City and currently serving as either the WWTP or public boat launch. While some degree of temporary disruption of the City's use of these properties is unavoidable, WPSC desires to minimize the magnitude of this disturbance through use of administrative and construction scheduling/sequencing methods. Accordingly, WPSC will meet with the City to discuss the following considerations:

- Requirements for scheduling, sequencing, and temporary infrastructure necessary for temporary closure and excavation of Boom Landing
- Possibility of, and requirements for, temporary shutdown of a portion, or the entirety of, the aeration basin
- Variations in daily or seasonal loading to the WWTP, for consideration in remedy construction scheduling
- City standard or preferred offset distances for excavation adjacent to utilities and other infrastructure
- The duration and magnitude of WWTP employee activities that may potentially result in exposure to MGP-affected media for use in a pre- and/or post-remedial action risk assessments
- The potential for, and permitting requirements of discharging water generated during RA implementation to the WWTP
- Other City standards or concerns associated with implementing the USEPA-selected remedy on City property

In addition to contacting the City, WPSC will coordinate with non-City owned utilities and CN to obtain standard or preferred offset distances for excavation adjacent infrastructure.

4.2 Utility Clearance and Topographic and Visual Surveys

4.2.1 Utility Clearance

Preliminary understanding of above-ground and subsurface utilities was obtained during implementation of the RI. Consideration was given to the known utilities when selecting the proposed investigative locations identified in Figure 4. Prior to initiation of any drilling or other intrusive work, underground and overhead utilities, including electric lines, gas lines, storm and sanitary sewers, and communication lines, will be identified. The process for conducting utility clearance is outlined below:

- Locate all investigative borings with flagging, survey stakes, and/or marking paint prior to the utility locate.

- Submit a request to Wisconsin's Diggers Hotline (Diggers), the utility one-call system, to initiate the utility-locating activities. Wisconsin state law requires that Diggers be notified at least three working days, and not more than 10 working days, before subsurface work is conducted.
- Subcontract a third-party utility location service to support identification of subsurface utility infrastructure (Section 4.2.2.1).
- Coordinate with participating utility-owning companies and CN to locate and mark all respective subsurface utility lines present within the Approximate Extent of Upland Site boundary, as outlined on Figure 3.
- Precautions regarding safe distance from the overhead electrical lines will be reviewed and equipment offset distances flagged and marked, in accordance with the WPSC-required clearances.
- Drilling and other intrusive activities will proceed with due caution for the top ten feet of each investigation location.
- Proposed sampling locations identified on Figures 4 and 5 may be shifted to avoid subsurface and overhead utilities, as appropriate.

If offset borings are required beyond the boundary of the area on which utility clearance has been completed, a new request will be submitted to Diggers and work will not commence until the locates associated with the new request have been completed.

4.2.2 Survey

4.2.2.1 Utility Survey

Following completion of the Diggers locate, a private utility locator will be mobilized to verify the accuracy of the Diggers locate, expand the extent of utility locates where needed, and conduct locates on privately-owned property outside the scope of the Diggers locate. Prior to commencing work, Ramboll will coordinate an on-site meeting between the City WWTP staff and the private utility locator to convey any legacy information regarding known alignments of active or inactive utilities. To the extent practical, the private utility locator will note the material of the subsurface utility to assist in conducting a desktop material compatibility evaluation between the utility and potential groundwater treatment amendments during remedy design. The private utility locator will mark utilities in accordance with the Uniform Color Code and Marking Guidelines for future survey by a licensed Wisconsin professional surveyor, as discussed in Section 4.2.2.2.

4.2.2.2 Topographic, Boundary, and Utility Survey

In order to develop a suitable base map to support the RD, a Site survey will be completed by a licensed Wisconsin professional surveyor. Property boundaries will be established and recorded for all parcels identified on Figure 2. Included in this boundary survey will be key site features and existing easements. As part of this work, existing property surveys on record with the City and County of Marinette will be obtained and reviewed. Any existing building plans and records will also be reviewed and incorporated into the Site base mapping, as appropriate. The surveyor will be responsible for providing a plat of survey for parcels, surrounding roads, and ROWs within the Approximate Extent of Upland Site boundary outlined on Figure 3, which includes the following:

- Property boundaries
- Surrounding streets/ROWs, structures and driveway entrances

- Easements
- All above-ground and underground utilities, including utility poles and manholes, as identified during the Diggers and private utility locate process
- Existing Site features, including fences, fence gates, asphalt/concrete surfaces, monitoring wells, tree/brush, and grass areas within the survey area
- The final location of all soil borings, wells, ground control points utilized for the potential Unmanned Aerial Vehicle (UAV) survey (as discussed in Section 4.2.2.2), and other information necessary to document the location of PDI activities
- A Site topographic survey with 1-foot contours

All survey information will be completed in accordance with Multi-Site SOP SAS-02-02, using Wisconsin State Plane Central Zone as the horizontal datum and North American Vertical Datum of 1988 as the vertical datum. All survey information will be uploaded into Ramboll's database to produce accurate and updated figures for design and implementation of the remedy.

4.2.2.3 Unmanned Aerial Vehicle (UAV) Survey

In addition to the traditional Site survey, a UAV survey is being considered to aid in the understanding of current site conditions. Final selection of the UAV Survey is contingent on the outcome of ongoing discussions with the City and adjacent property owners regarding ability to complete a UAV survey of infrastructure on their property. If completed, the survey will produce orthoimagery, surface elevations (including contours and a digital surface model), and a 3D model. The 3D model will consist of photorealistic surface topography and building/WWTP structures adjacent to source areas.

If completed, UAV survey information will be completed in accordance with Federal Aviation Administration Part 107 rules. Ground control points will be used during the flight and will be surveyed by a licensed Wisconsin professional surveyor prior to post processing. Products produced will be referenced to Wisconsin State Plane Central Zone as the horizontal datum and North American Vertical Datum of 1988 as the vertical datum. If completed, UAV images will be collected at a resolution between one and two pixels per inch.

4.2.2.4 Structural Integrity Survey

WPSC will attempt to obtain construction documents from the City of Marinette for the WWTP process units and buildings prior to initiating PDI field work. These documents will be used as the basis of the structure and geotechnical analysis used to design the excavation support systems necessary to facilitate the WWTP and Boom Landing Source Area excavation activities.

As part of the PDI field work, a licensed structural engineer or designated alternate will complete a visual inspection of structures near proposed excavation activities. The purpose of this visual inspection is to both document differences between the current structure and historic construction documents, as well as to document existence of visually observable deterioration or damage to the structure. The inspection of these structures will be completed and documented in accordance with the American Concrete Institute's Guide for Conducting a Visual Inspection of Concrete in Service (ACI 201.1R-08, 2008) and will generally focus on the following items:

- **Deviations from Construction Documents –** Length, width, height, section dimensions
- **Exposure** - Weather, freezing/thawing, chemical, abrasion

- **Distress Indicators** – Cracking, permanent deflected shape, staining, surface deposits, or visible leakage
- **Surface Condition of Concrete** – General condition, cracking, scaling, spalls/pop-outs, evidence of previous patching/repairs, and surface coatings
- **Foundation Conditions** – Soil types, evidence of pumping, evidence of settlement
- **Surrounding Soil** – Evidence of erosion, ground settlement, cracking, or sloughing of slope

4.3 WWTP and Boom Landing Source Area

4.3.1 Horizontal and Vertical Extent

4.3.1.1 Locations, Visual Observations, and Field Delineation

Existing characterization of the source material areas is predominantly based on limited borings and test pits completed prior to enrollment of the Site in the USEPA SAS Program. There is uncertainty regarding how well visual observations from legacy borings reflect the current subsurface conditions. To address the uncertainty of visual observations from legacy borings and the heterogeneity of NAPL distribution within adjacent borings, the first phase horizontal and vertical extent evaluation will involve advancing a soil boring at each location where visual observations of oil-coated or oil-wetted material were made during previous investigations, as summarized in **Table D** and presented on **Figure 4.**

Table D - Summary of Historic Soil Boring to be Reoccupied

Source Area Name	Historic Borings /Test Pits to be Reoccupied
Boom Landing Zone Source Area	MW310, MW311, SB336, SB341, SB342
WWTP Zone Source Area – North	SB351
WWTP Zone Source Area – South	TP301, TP302

The Baseline Risk Assessment (BLRA) included in the 2015 *Remedial Investigation Report – Revision 2* (NRT, 2015) used screening levels and slope factors applicable at the time. Based on the BLRA, two sample locations (TP301 in the WWTP Zone Area - South and TP303 in the WWTP Zone Area – North) were identified with concentrations of PAHs exceeding a risk-based lifetime incremental cancerous risk of 10^{-3} under an industrial land use scenario. In 2017, the USEPA updated the IRIS Toxicological Review of Benzo(a)pyrene (USEPA, 2017a) which resulted in lower calculated cancer risks associated with benzo(a)pyrene and other PAHs for a given concentration. To understand how this update impacts the calculated risks at the Site, the analytical results associated with the two samples that originally exceeded the 10^{-3} cancer risk were input into the updated WDNR's cumulative risk calculator for the default industrial land use scenario. The updated cumulative risk associated with both samples is less than 10^{-3} indicating that the historical sampling data does need exceed a cumulative cancer risk of 10^{-3} and does not meet the definition of principal threat waste on the basis of adsorbed concentrations in soil (see Section 2.3). Based on this evaluation, additional delineation borings beyond those needed for to delineate legacy of oil-coated or oil-wetted observations is not required.

Soil boring methodology will be assessed based on availability during driller procurement, but preference will be given to methods that provide a large diameter sample and an ability to penetrate debris likely to be encountered in the former log-run/slough alignment. Unless otherwise noted, sampling will be continuous, to define the presence/absence and vertical extent of affected soil at each boring location, and extend until competent bedrock is encountered (approximately 20 feet bgs). Following advancement of soil borings at the locations of previously-identified oil-coated or oil-wetted material, the initial delineation borings identified in Figure 4 will be advanced on an approximately 25-foot grid in the area that generally represents the extent of potential source area excavations, as presented in the ROD. Similarly, these borings will extend until competent bedrock is encountered.

For the purpose of guiding PDI fieldwork, the horizontal or vertical extent of principle threat waste/source material will be considered delineated if a perimeter boring, within a given transect, meets both of the following requirements:

- No oil-coated or oil-wetted observations are present.
- The cumulative lifetime incremental cancer risk is less than 10^{-3} and the noncancer hazard index is less than 10.

Alternately, due to the presence of substantial buildings and WWTP Process units, delineation will be considered completed if a substantial building or WWTP Process Unit (aeration basin or service building) is encountered, preventing implementation of additional step-out borings.

As delineation is dependent on receipt of soil laboratory test results, soil laboratory analysis of perimeter delineation borings will be analyzed with an accelerated turn-around time to avoid leaving a drill rig on standby while the analysis is completed. Additionally, the sequence of drilling activities will be optimized to minimize downtime.

If, using the above methodology, a definition of the horizontal extents is not achieved after installation of the initial delineation borings, contingent delineation step-out borings will be advanced to satisfy delineation data gaps. The potential locations of contingent delineation step-out borings are show on Figure 4; however, these locations may be modified to reflect actual delineation data gaps.

All borings advanced as part of the PDI will be continuously logged, following Multi-Site SOP SAS-05-02, and will include a record of blow counts (as applicable), the presence of fill material, moisture content, photoionization detector readings, the nature of each geologic unit encountered, and visual and olfactory observations indicating the presence of hydrocarbon-like residuals (staining, oil-coated, or oil-wetted, *etc.*). Soil boring locations will be recorded in accordance with Multi-Site SOP SAS-03-03 and will be abandoned in accordance with the methods described in Multi-Site SOP SAS-05-05. Field equipment will be calibrated prior to use, as required by Multi-Site SOP SAS-02-01 from the Multi-Site FSP.

Samples for analytical chemistry or geotechnical testing, as discussed below, will be identified for laboratory analysis, according to Multi-Site SOP SAS-06-01. Quality Control samples will be collected with the frequency described in Table 1, as required by Multi-Site SOP SAS-04-03. Samples will be labeled and packaged in accordance with Multi-Site SOP SAS-03-01 and shipped using chain-of-custody procedures described in Multi-Site SOP SAS-03-02. Non-dedicated equipment will be decontaminated after use, in accordance with Multi-Site SAS-04-04.

4.3.1.2 Soil Sampling and Analytical Parameters

Subsurface soil samples will be collected from all source area delineation borings. One sample will be collected based on the most notable field observations of potential MGP residuals, including oil-coated/oil-wetted material. If no field observations of potential MGP residuals are identified, a soil sample will be collected from a random two-foot interval of water-saturated material, representing saturated subsurface conditions at the boring location. The second sample will be collected from the bottom of the boring to fully document vertical extent at that location. If field observations of MGP residuals are identified within a boring, a third sample will be collected from the interval, immediately beneath the field observations of potential MGP residuals, to document vertical extent. Soil samples will be submitted for laboratory analysis of soil COCs, additional carcinogenic PAHs (benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene) for use in cumulative risk calculations, and total organic carbon, as identified in Table 1.

4.3.2 Geotechnical Evaluation

Geotechnical characterization is needed to design the excavation support system for source area excavations. Based on a review of the environmental delineation borings, co-located geotechnical boring locations will be chosen to provide the geotechnical characterization necessary to design the excavation soil retention system.

Based on review of previous soil borings completed on Site, there are three distinct geologic layers, as described below:

A. Fill is encountered at or near the surface over much of the Site. At locations in, or adjacent to, the former slough, the fill layer is as thick as 18 feet. The fill material typically consists of fine sands with discontinuous clay, silt, and gravel. Glass, wood, brick, and concrete were also found, especially in the area of the former slough and the former MGP building locations.

B. The fill layer is underlain by lacustrine, fluvial, and glacial till deposits, consisting predominantly of fine sand, with thin clay and silt lenses.

C. Bedrock occurs beneath the lacustrine, fluvial, and glacial till deposits at approximately 20 feet bgs and consists of dolomite of the Galena-Platteville Formation.

Following completetion of the environmental delineation borings, co-located geotechnical borings will be advanced at select locations such that three representative samples of each of the distinct geologic layers identified during the horizontal and vertical extent evaluation will be analyzed for the applicable geotechnical information described below. If any additional geologic layers are encountered during investigation, additional analysis will be performed on that layer. Analysis will depend on the cohesiveness of the soil. Geotechnical borings will be advanced using mud rotary or hollow stem auger drill rigs with the ability to obtain standard penetrometer test blow counts in accordance with ASTM D1586. Thin-walled tube samples (Shelby tubes) will be advanced, in accordance with ASTM D1587, for the fine-grained soils encountered (*e.g*., silt and confining clay layer). The following geotechnical analyses will be performed to facilitate remedy design:

- Particle-Size Distribution – ASTM D422-63
- Moisture Content – ASTM D2216
- Specific Gravity of Soils – ASTM D854
- Bulk Density of Soils – ASTM D2937

- For cohesive soil (fine-grained soil only):
  - Atterberg Limits (fine-grained soil only) – ASTM D4318
  - Unconfined Compressive Strength Test – ASTM D2166

Upon reaching bedrock, a minimum of 5 feet of NX rock core will be collected from one soil boring in each of the three source area excavations, at locations identified on Figure 4. The rock coring will be performed in accordance with ASTM D2113. If the rock core sample is extremely weathered, then a second 5 feet of NX core shall be collected. The following test will be completed on the rock cores:

- Unconfined Compressive Strength Test – ASTM D2166

4.3.3 Aquifer Testing

Dewatering will be required to lower the water table during the excavation in the source area. Slug testing will be performed to estimate the hydraulic conductivity in order to design the dewatering system. Single well slug tests will be completed at the temporary wells (described in Section 4.5.1) and three previously-installed monitoring wells (MW-304, MW-307R, and MW-311), in accordance with Multi-Site SOP SAS-08-04. A minimum of two tests, each test consisting of one falling head (slug-in) and one rising head (slug-out), will be completed at each well. Pressure transducers will be used to record water level changes, and manual water measurements will be recorded throughout the test for confirmation of transducer data. Slug test data will be analyzed using aquifer test analysis software (*i.e.*, AQTESOLV) to provide an estimate of hydraulic conductivity.

4.4 USEPA-Selected Horizontal Barrier Area

4.4.1 Horizontal Barrier Condition Survey

The USEPA-selected remedy involves monitoring of existing barriers (where present) and installation of new barriers in areas where there are RG exceedances in the top two feet of soil. The preliminary extent of the horizontal engineered surface barriers over the Boom Landing and WWTP Zones is shown in Figure 5 and will be refined through the incremental sampling process outlined in Section 4.4.2. Wisconsin's *Guidance for Cover Systems as Soil Performance Standard Remedies* (WDNR, RR-709), which allows for use of existing pavement and buildings to serve as direct contact cover systems, provided that the cover addresses concerns related to:

- Erosion from precipitation, surface water flows, or wind
- Human activities, such as digging, gardening, and construction;
- Cracking and deterioration from natural forces
- Settlement and shifting
- Contaminant migration

To verify that that existing pavement and buildings are in sufficient condition to serve as a direct contact barrier, a Ramboll field team member will conduct a visual survey documenting the condition of the area to be potentially subjected maintenance of a horizontal engineered barrier, as identified in Figure 3. Surface improvements that may serve as a direct contract barrier may be categorized as WWTP process units, buildings, and pavement. Survey considerations for each category are summarized below.

- **WWTP Process Units –** Includes primary and final clarifiers and aeration basins, all of which are designed to retain water. Structures designed to retain water will also inherently meet WDNR direct contact cover system requirements; additional survey is unnecessary.
- **Buildings –** Includes Vehicle Storage Building, Services Building, Multi-Purpose Building, and buildings housing support equipment for WWTP Process Units. The floor of the lowest level in the building will be visually inspected for competency as a direct contact barrier. Minor cracks (less than one-half inch wide) are likely associated with settlement or expansion/contraction typical in building slabs and do not represent a direct contract risk. Cracks larger than one-half inch in width will be noted in a log book and recorded using digital photography and a measuring tool. The frequency and distribution of cracks in basement floor slabs, as it relates to adequacy as a direct contact barrier, will be evaluated on a case-by-case basis during the RD.
- **Pavement –** Includes parking lots, sidewalks, roadways, and other areas paved with concrete asphalt, or gravel. The pavement surface will be visually inspected for competency as a direct contact barrier. Minor cracks (less than one-half inch wide) are likely associated with settlement or expansion/contraction typical in exterior pavement and do not represent a direct contract risk. Cracks larger than one-half inch in width will be noted in a log book and recorded using digital photography with a reference measuring tool. The frequency and distribution of cracks in paved areas, as it relates to adequacy as a direct contact barrier, will be evaluated on a case-by-case basis during the RD.

4.4.2 Horizontal Barrier Extent Evaluation

An incremental sampling program is proposed to evaluate the concentration of soil COCs in the top two feet of soil. The primary objective of this proposed sampling effort is to better characterize the potential soil COC impacts to surficial soils within the WWTP and Boom Landing Zones where previous soil RG exceedances had been identified.

4.4.2.1 Incremental Sampling Background

Incremental sampling will be used to further characterize soil conditions in designated decision units established across the Site. Incremental sampling involves the unbiased collection of multiple, relatively uniform aliquots of soil throughout the decision units, and combining these aliquots into a single mass. The single mass will be submitted to the laboratory for processing into a representative composite sample, followed by laboratory analysis. When compared to a discrete sampling approach, incremental sampling has the potential to give more reliable and reproducible central tendency concentration estimates for a particular decision unit, with fewer overall analytical samples. Incremental sampling may be applied to both volatile and non-volatile constitutions, although there are sample handling and laboratory processing requirements unique to applying incremental sampling for volatile constituents. The Interstate Technology and Regulatory Council (ITRC) developed a web-based "*Incremental Sampling Methodology Guidance"* in 2012 (ITRC, 2012) from which additional background on incremental sampling can be obtained. This ITRC Guidance provided the basis for the development of the incremental sampling plan described below.

4.4.2.2 Development of Decision Units

A key element to the accuracy and validity of incremental sampling is determining the size, shape, and number of decision units. The primary use of incremental sampling data is to estimate average exposure concentrations; therefore, decision units should be developed to account for the type and frequency of exposure. Three decision units have been established for the Site. Figure 5 shows the approximate boundaries of the proposed decision units and each of these decision units is discussed in further detail below:

- **Boom Landing Zone Decision Unit –** Includes the 11,000-square-foot grassy area on the northwest portion of the Boom Landing Zone where exceedances of RGs in surface soils had been identified during the RI. Exposure in this area is expected to be uniform, as there are no fences or barriers limiting access, and no notable features towards which exposure is likely to be concentrated. ITRC generally recommends a minimum of 30 to 50 incremental sampling locations per decision unit, resulting in a sampling grid of approximately 20 feet by 20 feet, as shown on Figure 5.
- **WWTP Zone Decision Units A and B –** Includes the 111,000 square feet of grassy areas surrounding WWTP Process Units and supporting buildings on the western portion of the WWTP Zone where exceedances of RGs in surface soil had been identified during the RI. There are no fences or barriers in this area limiting access, The WWTP Zone is divided into Decision Units A and B, with WWTP Zone Decision Unit B mostly comprised of cells with buildings or major pathways where exposure risk may be higher. WWTP Zone Decision Unit A comprises the remainder of the facility, including areas that employees are anticipated to be less frequently. Following ITRC's general recommendation of a minimum of 30 to 50 incremental sampling locations per decision unit, a sampling grid has been developed of approximately 50 feet by 50 feet, as shown on Figure 5.

4.4.2.3 Sampling Methods

Incremental sampling will be performed in each decision unit, following ITRC guidance (ITRC, 2012). As indicated above, the grid-based sampling approach will yield approximately 30 individual samples collected in each decision unit. By collecting samples from multiple, randomly selected locations within the grid network, this sampling method helps eliminate error and addresses distributional heterogeneity, also referred to as grouping and segregation error.

Figure 5 presents the grids and systematic random sampling locations for each grid area. Three systematic random sampling locations denoted with an X, O, or ☐ are shown within each cell (assuming that the sampling location falls within a cell for partial cell locations). The locations of the Xs, Os, and ☐s were determined by random number generation. Three systematic random sampling locations were determined to allow the collection of replicate samples, in this case triplicates, to determine the precision and reproducibility of the sampling results due to COC variability. Consistent with ITRC guidance, triplicate sampling should be collected to provide a measure of Site variability. A summary of sampling requirements is included as part of Table 1.

Consideration for horizontal engineered barrier installation is due to concentrations of benzo(a)pyrene in the 0-2-foot bgs interval. Remaining soil COCs (ethylbenzene and naphthalene) were either not detected or present below soil RGs in all surface soil samples collected as part of the RI. Accordingly, incremental sampling and analysis will focus on benzo(a)pyrene and will be conducted consistent with ITRC Guidance for non-volatile methods.

Ramboll will utilize a portable global positioning system receiver capable of submeter accuracy to locate the sampling locations in the field, based on the established grid system shown on Figure 5. Approximately 30 hand augers will be advanced within each decision unit, to a depth of approximately 2 feet bgs. At each boring or increment location, at least 40 grams of soil will be collected into a new clean container (*i.e.*, a one- or two-gallon plastic sealable bag) from the steel core (direct-push sampler) advanced by hand. Once an aliquot is collected, sampling will continue at the next sample increment location (*i.e.*, no decontamination of the hand core will be necessary, because all aliquots will be collected to form a single sample), until all aliquots in a decision unit have been collected. Sample aliquots will be stored in a cooler with ice until delivery to the analytical laboratory. Samples will be labeled and packaged in accordance with Multi-Site SOP SAS-03-01 and shipped using chain-of-custody procedures described in Multi-Site SOP SAS-03-02. Sampling equipment that will be used for aliquot collection will be decontaminated, in accordance with Multi-Site SOP SAS-04-04 from the Multi-Site FSP, prior to use and after all samples have been collected from a specific decision unit.

4.4.2.4 Subsampling

Once field sampling is complete, the 30 single increment samples (for each of the three individual replicates) from each decision unit will be delivered to the analytical laboratory for sample preparation and analyses for benzo(a)pyrene. Laboratory sample preparation will include drying and sieving each increment sample entirely and compositing all 30 aliquots into one representative sample per decision unit (this will be complete for each replicate sample as well). From this representative sample, the laboratory will then obtain a single representative subsample from each of the processed, field-generated, incremental sample masses to form a final subsample mass (i.e., the aliquot mass) that contains equal parts of all 30 incremental samples collected. This final subsample will be used to complete the analytical preparation step.

4.4.2.5 Quality Assurance and Quality Control

Triplicate samples will be collected from each decision unit to verify that an increment sample truly represents the decision unit. Collection of a triplicate sample allows for the calculation of relative standard deviation. Results of all three samples will be included in the PDI Evaluation Report.

4.4.2.6 Data Evaluation

Analytical results for the incremental sampling-based central tendency concentration for each decision unit will be imported into the WDNR's cumulative risk calculator for the default industrial land use scenario. Consistent with WDNR NR 720.12, a horizontal engineered barrier will be required if the excess cancer risk for individual compounds exceeds 10^{-6} or the cumulative excess cancer risk exceeds 10^{-5}. If the incremental sampling-based central tendency concentration exceeds either of these risk scenarios, delineation of the Horizontal Engineered Barrier footprint will be determined through a soil sampling approach, based on sampling and analysis of discrete surface soil locations on an approximately 30-foot grid in the Boom Landing Zone and an approximately 100-foot grid in the WWTP Zone. This supplemental sampling to support this delineation will be completed following receipt and analysis of incremental sampling and the sampling approach will be further defined in a PDIWP Addendum.

4.5 USEPA-Selected Groundwater Remedy

4.5.1 Temporary Groundwater Monitoring Well Installation

Removal of accessible source material will reduce the mass of sorbed contaminant mass available for dissolution into groundwater. The success of the remedy will be determined via long-term groundwater monitoring. While the current well network is sufficient to define the extent of the groundwater plume, the groundwater concentrations within and immediately downgradient of the source areas are unknown. Temporary monitoring wells will be installed in the source area and downgradient of the source area to allow for long-term evaluation of remedy success. The monitoring wells will also be used to perform slug testing to assess dewatering requirements (Section 4.3.3), to understand dissolved phase flux to determine in-situ reagent dosage (Section 4.5.2), and to quantify the petroleum-degrading bacteria present in Site groundwater (Section 4.5.3).

Conceptual locations of these wells are identified in Figure 4. One temporary well will be installed at the soil boring location that contained the most significant field observations of MGP residuals in each area. A second well will be installed in the center of the transect, located immediately downgradient (north) of the field-delineated source area. Note that a downgradient well is likely not necessary in the Boom Landing Zone, due to the location of MW-307R. If there is significant variability in the magnitude of field observations of MGP residuals in a source area, a second well may be installed at the soil boring location that best represents the average field observations of MGP residuals. As part of drilling for each temporary well installation, an undisturbed sample will be collected using thin-walled sampler (Shelby-tube) or lined sampler, centered on the interval with the most notable visual observations identified during the horizontal and vertical extent soil boring program. This sample will be capped, placed in a cooler with dry ice, and sent to a laboratory for frozen storage. This core will be available for future laboratory mobility testing, should the USEPA and WPSC determine that laboratory mobility testing may add clarity to remedial design considerations.

4.5.1.1 Temporary Well Construction

Temporary wells will be constructed according to Multi-Site SOP SAS-05-03, and thread joints will be tightened per manufacturer requirements. A 2-inch inner diameter poly vinyl chloride well with a 0.01-inch factory slotted screen will be installed, and the annular space around the wells will be backfilled with filter pack, bentonite seal, and finished with a steel flush mount cover. The overall depth of the well and the corresponding length of well screen will be determined in the field by the Ramboll field personnel, based on subsurface information collected during soil boring advancement. Monitoring well screen placement and length will be selected based on depth to water, saturated thickness, and depth to bedrock. The following guidelines will be considered when selecting screen placement and length:

- A minimum 3-foot annular seal is preferred; however, a shorter seal length is acceptable if dictated by field conditions.
- Monitoring well screens will be either 10 feet or 15 feet in length.
- The bottom of the screen interval shall be placed on the top of bedrock, to function as a sump to facilitate measurement of potential DNAPL thickness.
- When saturated thickness and available screen intervals allow, the top of the screening interval shall be at least two feet above the water table, to facilitate seasonal fluctuations in groundwater levels.

4.5.1.2 Well Development

Following installation, temporary wells will be developed in accordance with Multi-Site SOP SAS-05-04. Existing monitoring wells MW-304, MW-311, and MW-307R will also be evaluated at this time to determine if six inches or more of sediment has accumulated within the well. If six inches or more of sediment has accumulated, the well(s) will be redeveloped. Wells will be developed using an electric submersible pump for surging and pumping. Field parameters—specific conductance, pH, temperature, dissolved oxygen, oxidation-reduction potential, and turbidity—will be measured during development using a flow-through cell. Wells will be considered developed when field parameters meet the stabilization criteria detailed in Multi-Site SOP SAS-05-04. Purge water will be discharged, under permit to the WWTP for treatment, or containerized and managed as investigative derived waste (IDW), as detailed in Section 4.8.

4.5.1.3 Observation of NAPL Accumulation

Following installation and development of temporary wells, the thickness of DNAPL in the wells (if present) will be measured on a consistent monthly basis for three months, using a weighted cotton string. If DNAPL is observed at a measurable thickness, a bail-down DNAPL transmissivity testing will be conducted, consistent with ASTM E2856.

4.5.1.4 Groundwater Sampling

Solubility of source material in the three source areas will be assessed by collecting groundwater samples from the temporary wells installed within, and immediately downgradient of, each of the source areas (based on the field-delineation, as identified in Section 4.3.1). Temporary wells will be sampled for groundwater COCs, using low-flow sample techniques, in accordance with Multi-Site SOP SAS-08-02. Groundwater sampling will be conducted shortly following temporary well installation, and three months following initial sampling events. The need for additional sampling at these wells will be discussed with USEPA once the results of the initial two rounds of sampling have been received. These temporary wells will be either abandoned or incorporated into the long-term monitoring network as RD and RA progresses.

4.5.2 Bench-Scale Testing Evaluation

The USEPA selected a one-time placement of an in-situ treatment reagent within the base of the source area excavations, prior to backfilling, to enhance restoration of groundwater quality. The FS conceptually recommended that bench-scale testing of Site soil and groundwater with varying types and percentages of reagents be conducted to determine the most effective approach to address COCs in groundwater. As part of the development of this PDI, additional analysis of potential groundwater treatment reagents was conducted for the purpose of designing the treatability study. Oxygen-release compounds (*i.e.*, calcium peroxide) aimed at establishing conditions suitable for aerobic biodegradation, were removed from consideration, as the aquifer is naturally reducing, which will limit the longevity of a one-time placement of an oxygen-release compound.

An activated carbon-based product (Remediation Products, Inc’s [RPI’s] BOS-200®, or similar) was retained for additional consideration. BOS-200® is a powdered activated carbon product that is blended with nutrients, sulfate-based electron acceptors, and petroleum-degrading bacteria. The powdered activated carbon adsorbs the dissolved phase contaminant mass, allowing for sulfate reduction to occur in the pore structure of the carbon.

An activated sodium persulfate product (PeroxyChem’s Klozur CR®, or similar) was also retained for additional consideration. When activated, using the high pH resulting from calcium peroxide addition, Klozur CR® generally persists as an oxidant for days to weeks. In addition to activating the persulfate, calcium peroxide also serves as an oxygen-release compound to enhance post-oxidation aerobic bioremediation of the downgradient plume. Once the calcium peroxide is expended, the residual sulfate will promote long-term anaerobic bioremediation by sulfate-reducing bacteria of any remaining plume mass.

RPI and PeroxyChem were contacted to obtain suggestions regarding recommended dosing rates for inclusion in the bench-scale study. Both vendors indicated that for bulk mixing, post-source area excavation scenarios, bench-scale studies are not typically performed or necessary. It is often challenging to accurately reflect post-excavation conditions in a bench-scale study, which would add uncertainty to the testing results. In addition, the relative cost of the reagents used for post-source area excavations is small. It is typically more prudent to spend the treatability study costs on conservatively applying additional reagent to increase probability of success.

Based on recommendations of the vendors providing the two reagents retained for additional analysis, a bench-scale study to optimize dosing rates is not proposed as part of the PDI. Reagent selection will be completed as part of the RD and will be informed by additional Site information obtained during the PDI.

4.5.3 Microbial Testing

A consideration in selecting between a biostimulant (BOS-200®) and a chemical oxidant (Klozur CR®) will, in part, be based on the presence and quantification of existing petroleum-degrading bacteria present in Site groundwater. To better understand the native bacterial colony present in groundwater, Microbial Insights' QuantArray® testing will be conducted at the three wells located immediately downgradient of each of the three source areas. Testing is not proposed within the source areas, as source area removal and dewatering efforts are likely to have a significant effect on the native bacterial colony within the source areas.

To conduct QuantArray® testing, microbial insights' Bio-Trap Sampler will be placed in each of the three wells, in accordance with the Bio-Trap DNA Sampling Protocol. Once installed, the Bio-Trap will remain in the well for a 30-day incubation period. The retrieved Bio-Trap Sampler will be labeled, placed into a cooler, and sent to the laboratory via priority overnight methods consistent with Multi-Site SOP SAS-03-01 and Multi-Site SOP SAS-03-02.

The results of the QuantArray® will be presented in the PDI Evaluation Report, along with the initial recommendation of either a bio-stimulant or chemical oxidant for use in the post-source area excavations.

4.6 Contingency Investigations for Potential Alternate Remedy

Due to site-specific constraints within the source areas, as discussed in Section 1.6, two alternative remedies may be taken under consideration. As a part of this PDI, contingency soil will be collected and held for the necessary parameter and bench-scale testing, if evaluation of these alternatives proceeds. The two potential alternatives currently under consideration include in-situ stabilization/solidification (ISS) and bio-sparging. The following sections provide a brief overview of each remedy and the pre-design data needed to evaluate the efficacy of each. Only material collection will be conducted during this investigation. No bench-scale testing or data evaluation will take place, unless the decision is made to move forward with consideration of either option. Prior to commencing any bench scale testing of either the ISS or bio-sparging alternative, a Treatability Study Work Plan would be developed for USEPA review and approval.

4.6.1 In-situ Stabilization/Solidification

In order to determine the appropriate reagent mix design for the potential ISS alternate remedy, a treatability study would need to be conducted on representative soils from the three source areas. This study would entail mixing the Site's impacted soil with various types, combinations, and quantities of stabilization/solidification reagents necessary to meet RAOs. As part of this PDI, no treatability testing will be conducted. Rather, the objectives of this PDI will be to:

- Collect samples of representative soil material for bench-scale testing of various in-situ stabilization/solidification mix designs.
- Document the magnitude of subsurface obstructions and/or lack of accessibility that may reduce the viability of ISS as an alternate remedy.

In preparation for evaluation of this alternative, and a possible future treatability study, the necessary soil will be collected. Nine five-gallon buckets of bulk soils will be amassed during drilling activities. This soil will consist of drill cuttings from investigative borings. Three five-gallon buckets will be collected from each area. The stratigraphy and soil characteristics are generally similar across the Site; primary differences are the greater amounts of fill found in the northern portion of the Site, as compared to the greater amounts of native sand and clay found further south. The bulk samples collected will attempt to represent the proportional composition of each area. Additionally, an attempt will be made to collect approximately half of the bulk samples as representative of moderate-to-low MGP impacts, and the other half of the bulk samples as representative of greater MGP impacts. This will be determined in the field through visual observation and odors. The following is the ideal proportion of material collected from each area:

- WWTP Zone Source Area—South: 1 bucket fill material, 1 bucket sand, 1 bucket clay
- WWTP Zone Source Area—North: 2 buckets fill material, 1 bucket sand (or 1 bucket of each material, if significant clay is present)
- Boom Landing Zone Source Area: 2 buckets fill material, 1 bucket clay

These proportions will be adjusted in the field as visual observations refine the subsurface conditions. All the bulk samples collected for ISS evaluation will be sent to an analytical laboratory and kept frozen until needed.

During drilling for horizontal and vertical extent evaluation, observations will be made in relation to any subsurface obstructions that may pose an impediment for implementation of ISS. Additionally, a review of general Site conditions will be conducted to evaluate any accessibility issues that may reduce the viability of ISS. Subsurface observations will be noted as part of the investigative logs and surface observations through digital photography and as part of the daily field notes.

4.6.2 Bio-sparging

In order to determine the design parameters necessary to implement bio-sparging as an alternate remedy to address potentially inaccessible MGP source material, a bench-scale study may need to be conducted on representative soils from the three source areas. This study would involve injecting air through a representative column of soil and groundwater to assess biodegradation rates and determine the optimal dissolved oxygen content. To facilitate this potential bio-sparging bench-scale testing, a lined soil core, representative of the most significant field observations of MGP-impacted material, will be collected, capped, and sent to the laboratory for storage in the freezer. If bench-scale study for bio-sparging is conducted, Site groundwater would be collected at a future date, in accordance with a treatability study work plan.

4.6.3 Laboratory NAPL Mobility Testing

A discussed in Section 4.5.1, undisturbed soil samples will be collected at each temporary well location where visual MGP-residuals are observed. Undisturbed samples will be capped, placed in a cooler with dry ice, and sent to a laboratory for frozen storage. If WPSC and USEPA agree that laboratory mobility testing may provide insights into the extent of potential removal action or inform selection of an alternate remedy, frozen core samples will be available to laboratory mobility testing. Prior to completing laboratory mobility testing, WPSC will submit a PDIWP addendum to USEPA, describing procedures used to select an interval for mobility testing, the method of laboratory mobility testing, and a framework of how results should be interpreted.

4.7 Waste Characterization

Waste characterization samples will be collected for each unique material, in order to document waste characteristics for profiling purposes and to evaluate disposal options. Disposal facility requirements will be identified for each facility and sample analysis performed, accordingly. One soil sample, one DNAPL sample, and one groundwater sample will be analyzed for the parameters included in Table 1.

4.8 Investigative-Derived Waste Management

All IDW generated during the PDI will be collected in properly labeled, 55-gallon drums or bulk containers (*e.g.* roll-off container lined with polyethylene sheeting for solids, fractionation tanks for liquids). IDW includes soil cuttings, decontamination pad and plastic sheeting, personal protective equipment, decontamination water, well-development water, and pumped groundwater. WPSC is in contact with the City to obtain a permit to discharge purge water directly to the WWTP. If the permit is obtained, all IDW fluids compliant with permit requirements will be discharged to the WWTP.

Drums and containers of material will be labeled as "PENDING ANALYSIS – INVESTIGATION-DERIVED WASTE" with a description of the source (*e.g*., soil cuttings, decontamination water, pumping test water, *etc*.) and temporarily stored, pending characterization and proper disposal. The containerized soils will be disposed of off-site, at a facility permitted to accept such material.

Disposal facilities will meet the requirements of the "Off-site Rule" (USEPA, September 1993) for the disposal of investigation-derived waste. Prior to undertaking any disposal, Ramboll will contact the Off-Site Rule Coordinator at the facility to confirm the facility complies with the Off-Site Rule.

4.9 Reporting

In accordance with the RD AOC, the information collected from the PDI will be presented to USEPA in the PDI Evaluation Report. The PDI Evaluation Report will refining the CSM presented in the RI Report based upon data obtained during the PDI.

4.10 Schedule

The PDI field activities will be scheduled following USEPA-approval of the PDIWP, and will be dependent upon weather conditions, execution of access agreements, WWTP operational constraints, concerns raised by the City of Marinette regarding access and use of public facilities, and contractor availability. Winter conditions in this area of northern Wisconsin can be harsh, with average snowfall of 44 inches, monthly average low temperatures of 10 degrees Fahrenheit, and frost depths up to 5.5 ft. (US Climate Data, 2018). Given the scope of this investigation involves land surveying, pavement inspections, surface soil sampling, and water management, it is not considered practical or valuable to conduct PDI field activities in the winter months (approximately defined as late November to late March). WPSC will inform USEPA of proposed schedule for PDI field activities following USEPA's approval of the PDIWP.

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TABLES

TABLE 1 - SAMPLING AND ANALYSIS PLAN SUMMARY
WISCONSIN PUBLIC SERVICE CORPORATION- FORMER MARINETTE MANUFACTURED GAS PLANT SITE
1603 ELY STREET, MARINETTE, WISCONSIN
BRRTS# : #02-38-000047
USEPA# : WIN00050995

Sample Type	Sample Frequency	Estimated Number of Samples[1]	Parameter	Method	Field Duplicates (1 extra volume)	MS/MSD (2 extra volumes)	Equipment Blanks	Trip Blanks	Total Number of Samples[1]	Estimated No. of Containers[1]	Container Type	Minimum Volume	Preservation (Cool All Samples to 4° ± 2°C Unless 'None' Indicated)	Holding Time from Sample Date
WWTP Plant Zone and Boom Landing Zone Source Areas														
Soil Sampling - Horizontal and Vertical Extent Evaluation	1 subsurface sample per boring based on most notable field observations of potential MGP residuals, including oil-coated/oil-wetted material 1 subsurface sample from bottom of boring 1 subsurface sample of interval immediately beneath the field observations of potential MGP residuals to document vertical extent	Continuous	Logging	Multi-Site SOP SAS-05-02	--									
		Up to 3 per boring	Ethylbenzene	5035/8260B	1 per 20	1 per 20	Equipment blanks will be collected at a frequency of 1 per soil or sediment sampling day with non-dedicated sampling equipment.	VOC trip blanks will accompany each cooler containing VOC samples.	To Be Determined	To Be Determined	5 g (3/sample)	15 grams	NaSO4 and MeOH	14 days
		Up to 3 per boring	Naphthalene, Benzo(a)pyrene, and 6 non-Constituent of Concern PAHs[2]	8270D	1 per 20	1 per 20			To Be Determined	To Be Determined	Glass	8 oz.	--	14/40 days
		Up to 3 per boring	Total Organic Carbon	Lloyd Kahn Method	1 per 20	1 per 20			To Be Determined	To Be Determined	Plastic	100 g	keep in dark	28 days
Geotechnical Parameters	Three representative samples of each of the distinct geologic layers identified during Horizontal and Vertical Extent Evaluation soil logging	12	Grain Size Distribution	ASTM D422-63	--	--	--	--	12	12	Glass or Plastic	16 oz.	None	--
		12	Moisture Content	ASTM D2216	--	--	--	--	12	12	Glass or Plastic	16 oz.	Keep in dark	28 days
		3	Atterberg Limits	ASTM D4318	--	--	--	--	12	12	Glass or Plastic	8 oz.	None	--
		12	Bulk Density	ASTM D2937	--	--	--	--	12	12	Undisturbed Sample	Shelby Tube	None	--
		12	Specific Gravity of Soil Solids	ASTM D854	--	--	--	--	12	12			None	--
		6	Unconfined Compressive Strength	ASTM D2166	--	--	--	--	3	3			None	--
Aquifer Testing	1 Event from each of MW304, MW307R, and MW311 along with 6 temporary wells	9	Slug Testing	Multi-Site SOP SAS-08-04	--									
Horizontal Barrier Areas														
Incremental Sampling	~30-point incremental sample from each of 3 decision units. As part of sampling, duplicate and triplicate samples will be collected from each of 3 decision units	9 (3 decision units, original, duplicate, and triplicate)	Benzo(a)pyrene	Prep - 8330B Analysis - 8270D	--				9 - ~30 point sample sets	9 - ~30 point sample sets	Sealable Plastic bag	40 grams for each point	--	14/40 days
Groundwater Remediation														
Microbial Testing	3 wells located down gradient of delineated source areas	3	Microbial Insights QuantArray®	Lab-specific	--				3	3	Microbial Insights - BioTrap®	--	--	24 hours
DNAPL Accumulation	Monthly monitoring of MW304, MW307R, and MW311 along with 6 temporary wells for presence of DNAPL over a 3 month period	24	NAPL Thickness	Multi-Site SOP SAS-08-02	--									
Groundwater Sampling	Groundwater Sampling of 6 temporary wells both initially and 3 months following installation	12	Benzene and Ethlybenzene	5035/8260B	1 per 10	1 per 20	Equipment blanks will be collected at a frequency of 1 per sampling day with non-dedicated sampling equipment.	VOC trip blanks will accompany each cooler containing VOC samples.	To Be Determined	To Be Determined	Glass Vial	Three 40 mL	HCl to pH<2, Zero Headspace	14 days
		12	Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene, and Naphthalene	8270D	1 per 10	1 per 20			To Be Determined	To Be Determined	Amber Glass	2-1 L	--	7/40 days
		12	Field Parameters[3]	Field	--									
Waste Characterization														
Soil Waste Characterization	1 composite sample of material within a highly-effected soil boring	1	VOCs[4]	5035/8260B	0	0	Equipment blanks will be collected at a frequency of 1 per soil or sediment sampling day with non-dedicated sampling equipment.	VOC trip blanks will accompany each cooler containing VOC samples.	1	1	5 g (3/sample)	15 grams	NaSO4 and MeOH	14 days
		1	SVOCs and PAHs[5]	8270D	0	0			1	1	Amber Glass	8 oz.	--	14/40 days
		1	Total Phenolics	9066	0	0			1	1	Glass	4 oz.	--	10 days
		1	pH	D4982-89A	0	0			1	1	Plastic	4 oz.	--	Immediately
		1	Flashpoint	9045B	0	0			1	1	Glass or Plastic	9 oz.	--	10 days
		1	Paint Filter	9095B	0	0			1	1	Plastic	4 oz.	--	180 days
		1	Reactive Sulfide	D4978	0	0			1	1	Plastic	4 oz.	--	--
		1	Reactive Cyanide	D5049, 9012A	0	0			1	1	Plastic	4 oz.	--	14 days
		1	PCBs	8082A	0	0			1	1	Glass	4 oz.	--	7/40 days
		1	TCLP Metals[6]	1311/6010B	0	0			1	1	Plastic	500 grams	--	180 days
		1	TCLP Herbicides/Pesticides [8,9]	1311/8151A & 8081A	0	0			1	1	Glass	500 grams	--	14/40 days
		1	TCLP VOC[10]	1311/8260B	0	0			1	1	Glass	500 grams	--	14/21 days
		1	TCLP SVOC[11]	1311/8270C	0	0			1	1	Glass	500 grams	--	14/40 days
Groundwater Waste Characterization	Composite	1	VOCs[3]	5035/8260B	--	--	--	VOC trip blanks will accompany each cooler containing VOC samples.	1	3	Glass Vial	Three 40 mL	HCl to pH<2, Zero Headspace	14 days
		1	Metals[7]	6020 or 7470A	--	--	--		1	1	Plastic	250 mL	HNO3 to pH <2	6 mo./ 28 days for Hg
Contingency Sample Collection														
Horizontal Barrier Areas - If Incremental Sampling concentrations exceeds an excess cancer risk for individual compounds of 10^{-6} or a cumulative excess cancer risk of 10^{-5} under the default industrial land use scenario	Sample of 0-2 ft. on specified grid until delineation is achieved	TBD	Benzo(a)pyrene	8270D	1 per 20	1 per 20	Equipment blanks will be collected at a frequency of 1 per soil or sediment sampling day with non-dedicated sampling equipment.	VOC trip blanks will accompany each cooler containing VOC samples.	To Be Determined	To Be Determined	Glass	8 oz.	--	14/40 days
Contingent NAPL Transmissivity Testing - Hold material for future testing	One event at each well with measurable NAPL accumulations	TBD	NAPL Transmissivity	ASTM E2856	--				TBD	TBD	--			
Contingent Laboratory NAPL Mobility Testing - Hold material for future testing	One interval of oil-coated/oil-wetted material from each of 6 temporary well installation	TBD	Initial and Residual NAPL Saturation	TBD	--				TBD	TBD	Undisturbed Sample	Shelby Tube	Frozen	--
In-situ Stabilization Study - Hold Material from Horizontal and Vertical Extent Evaluation for Potential Future Bench-scale testing	Collection of (3) 5 gallon buckets of representative soil from each of 3 source areas. Hold for potential future bench scale treatability study	9	Potential Treatability Study	Lab-specific	--				9	9	Plastic	9 Gallons	Frozen	--
Bio-sparge study - Hold Undisturbed Core of Soil with Oil-wetted Observations for Future Bench-scale Testing	1 core	1	Potential Treatability Study	Lab-specific	--				1	1	Undisturbed Sample	Shelby Tube	--	--

Notes:

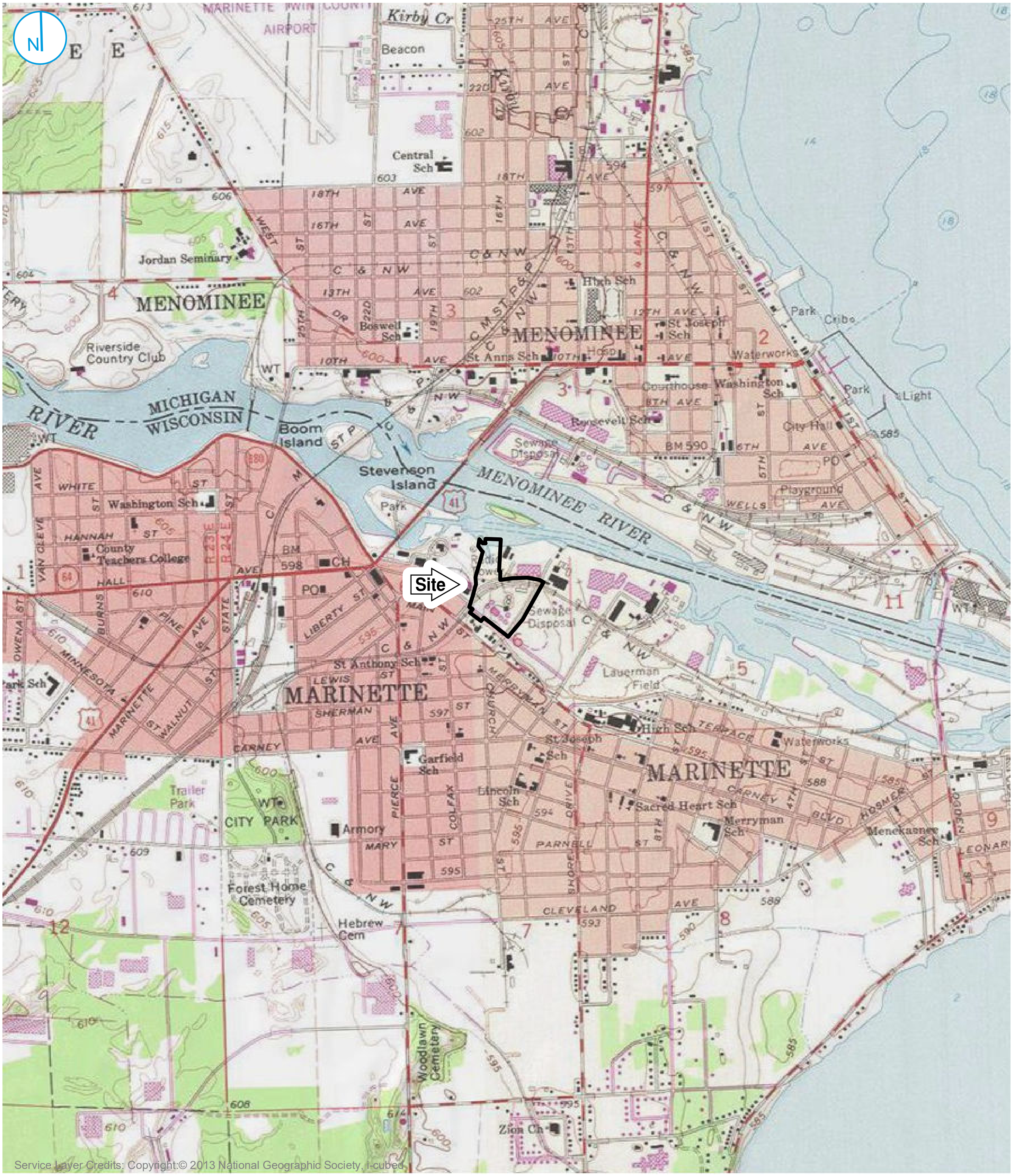
1. Proposed number of samples per sampling event. Sample numbers do not include contingency investigation locations.
2. Non-constituent of concern PAHs include: benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene
3. Field parameters for groundwater include pH, temperature, turbidity, dissolved oxygen, oxidation/reduction potential, and conductivity.
4. VOCs include benzene, ethylbenzene, toluene, xylenes (total), Bromoform, Carbon Tetrachloride, Chlorobenzene, Chloroform, 1,2-Dichloroethane, 1,1-Dichloroethene, cis-1,2-Dichloroethene, trans-1,2-Dichloroethene, Dichlorobromomethane (0.2 mg/kg), Dichloromethane (methylene chloride), 1,2-Dichloropropane, 1,3-Dichloropropene, Styrene, Tetrachloroethene, 1,1,1-Trichloroethane, 1,1,2- Trichloroethane, Trichloroethene, and Vinyl Chloride
5. SVOCs and PAHs include: N-Nitrosodiphenylamine, N-Nitrosodi-n-propylamine, Bis (2-chloroethyl) ether,Bis (2-ethylhexyl) phthalate, 1,2-Dichlorobenzene, 1,4-dichlorobenzene, Hexachlorocyclopetadiene, 1,2,4- Trichlorobenzene, naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene, and 2-methylnaphthalene.
6. Metals include Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver
7. Metals include Aluminum, Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickle, Potassium, Selenium, Silver, Sodium, Strontium, Sulfur, Thallium, Tin, Titanium, Tungsten, Vanadium, Zinc.
8. TCLP Pesticides includes Chlordane, Dieldrin, Endrin, Heptachlor, Heptachlor epoxide, Lindane, Methoxychlor, and Toxaphene
9. TCLP Herbicide 2,4,5-TP, 2,4-D
10. TCLP VOCs include Benzene, Carbon tetrachloride, Chlorobenzene, Chloroform, 1,4-Dichlorobenzene, 1,2-Dichloroethane, 1,1-Dichloroethene, Methyl ethyl ketone, Tetrachloroethene, Trichloroethene, Vinyl chloride
11. TCLP SVOCs include 2-Methylphenol, 3-Methylphenol, 4-Methylphenol, 2,4-Dinitrotoluene, Hexachlorobenzene, Hexachloro-1,3-butadiene, Hexachloroethane, Nitrobenzene, Pentachlorophenol, Pyridine, 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol

PAH - Polycyclic aromatic hydrocarbon
VOC - Volatile organic compound
SVOC - Semi-volatile organic compound
NAPL - Nonaqueous Phase Liquid

FIGURES

Y:\Mapping\Projects\6\67979\MXD\RemedialDesignWP\1912\Figure 1_Site Location Map.mxd

DATED: 12/27/2019 | DESIGNER: STOLZSD



KEY MAP

Map Scale: 1:1:24,000;
Map Center: 87°37'23"W 45°5'56"N

0 1,000 2,000 Feet

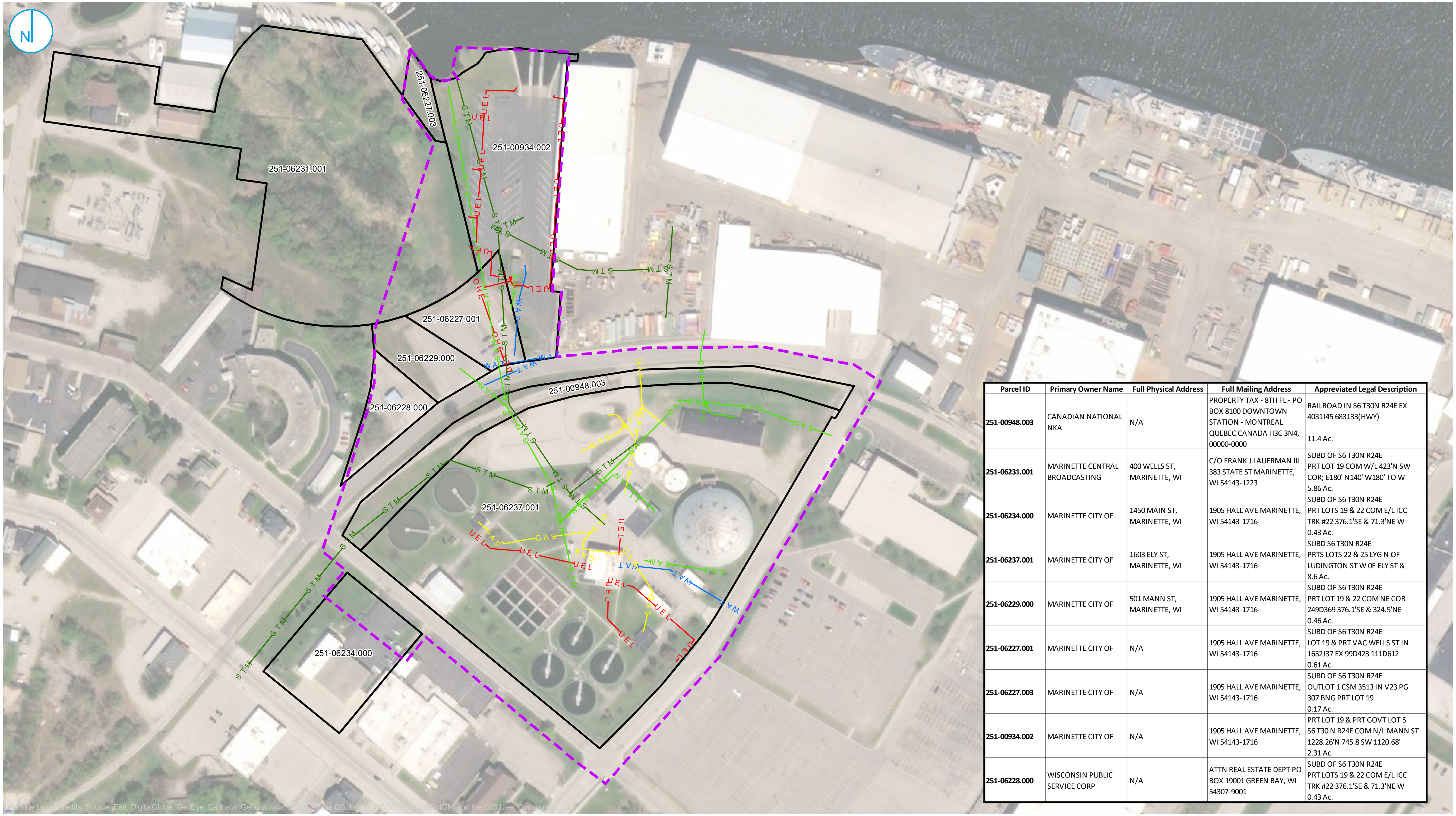
SITE LOCATION MAP

PRELIMINARY DESIGN INVESTIGATION WORK PLAN
WPSC MARINETTE FORMER MGP SITE
MARINETTE, WISCONSIN

FIGURE 01

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

RAMBOLL



Parcel ID	Primary Owner Name	Full Physical Address	Full Mailing Address	Appreviated Legal Description
251-00948.003	CANADIAN NATIONAL NKA	N/A	PROPERTY TAX - 8TH FL - PO BOX 8100 DOWNTOWN STATION - MONTREAL QUEBEC CANADA H3C 3N4, 00000-0000	RAILROAD IN S6 T30N R24E EX 4031J45 683133(HWY) 11.4 Ac.
251-06231.001	MARINETTE CENTRAL BROADCASTING	400 WELLS ST, MARINETTE, WI	C/O FRANK J LAUERMAN III 383 STATE ST MARINETTE, WI 54143-1223	SUBD OF S6 T30N R24E PRT LOT 19 COM W/L 423'N SW COR; E180' N140' W180' TO W 5.86 Ac.
251-06234.000	MARINETTE CITY OF	1450 MAIN ST, MARINETTE, WI	1905 HALL AVE MARINETTE, WI 54143-1716	SUBD OF S6 T30N R24E PRT LOTS 19 & 22 COM E/L ICC TRK #22 376.1'SE & 71.3'NE W 0.43 Ac.
251-06237.001	MARINETTE CITY OF	1603 ELY ST, MARINETTE, WI	1905 HALL AVE MARINETTE, WI 54143-1716	SUBD S6 T30N R24E PRTS LOTS 22 & 25 LYG N OF LUDINGTON ST W 0F ELY ST & 8.6 Ac.
251-06229.000	MARINETTE CITY OF	501 MANN ST, MARINETTE, WI	1905 HALL AVE MARINETTE, WI 54143-1716	SUBD OF S6 T30N R24E PRT LOT 19 & 22 COM NE COR 249D369 376.1'SE & 324.5'NE 0.46 Ac.
251-06227.001	MARINETTE CITY OF	N/A	1905 HALL AVE MARINETTE, WI 54143-1716	SUBD OF S6 T30N R24E LOT 19 & PRT VAC WELLS ST IN 1632J37 EX 99D423 111D612 0.61 Ac.
251-06227.003	MARINETTE CITY OF	N/A	1905 HALL AVE MARINETTE, WI 54143-1716	SUBD OF S6 T30N R24E OUTLOT 1 CSM 3513 IN V23 PG 307 BNG PRT LOT 19 0.17 Ac.
251-00934.002	MARINETTE CITY OF	N/A	1905 HALL AVE MARINETTE, WI 54143-1716	PRT LOT 19 & PRT GOVT LOT 5 S6 T30 N R24E COM N/L MANN ST 1228.26'N 745.8'SW 1120.68' 2.31 Ac.
251-06228.000	WISCONSIN PUBLIC SERVICE CORP	N/A	ATTN REAL ESTATE DEPT PO BOX 19001 GREEN BAY, WI 54307-9001	SUBD OF S6 T30N R24E PRT LOTS 19 & 22 COM E/L ICC TRK #22 376.1'SE & 71.3'NE W 0.43 Ac.

Y:\Mapping\Projects\1669079\MXD\RemedialDesignWP\1912\Figure 2_Land Ownership and Known Utilities.mxd

PROJECT: 169000XXXX | DATED: 12/27/2019 | DESIGNER: STOLZSD

APPROXIMATE EXTENT OF UPLAND SITE

PARCEL BOUNDARY (MARINETTE COUNTY, ACCESSED 7/16/2018)

UTILITY TYPE

- GAS — GAS
- OHE — OVERHEAD ELECTRIC
- SAN — SANITARY SEWER
- STM — STORM SEWER
- UEL — UNDERGROUND ELECTRIC
- WAT — WATER

0 90 180 Feet

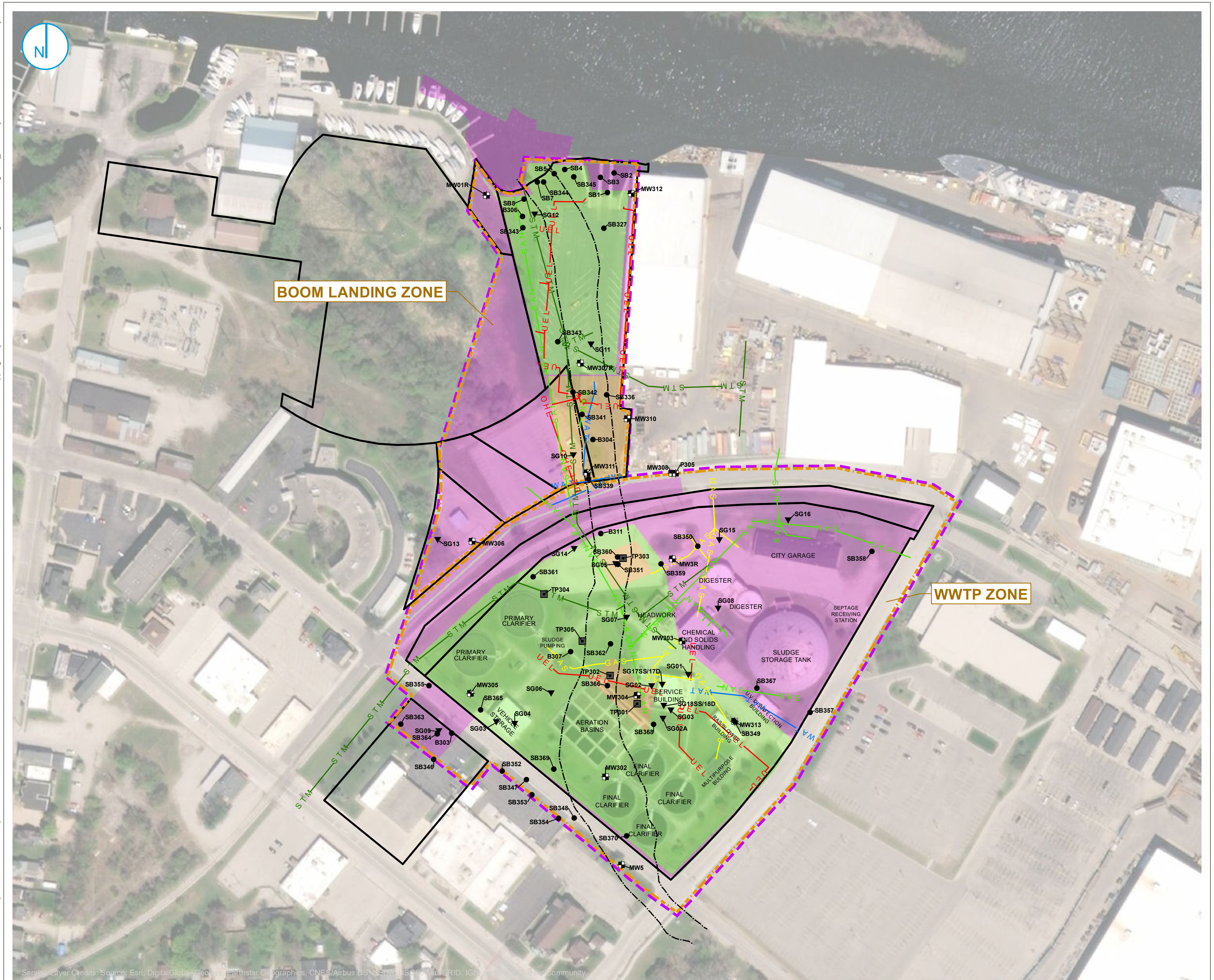
LAND OWNERSHIP AND KNOWN UTILITIES

PRELIMINARY DESIGN INVESTIGATION WORK PLAN
WPSC MARINETTE FORMER MGP SITE
MARINETTE, WISCONSIN

FIGURE 02

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

RAMBOLL



- EXISTING MONITORING WELL LOCATION
- EXISTING SOIL BORING LOCATION
- EXISTING SOIL GAS PROBE LOCATION
- EXISTING TEST PIT LOCATION

UTILITY TYPE

- GAS — GAS
- OHE — OVERHEAD ELECTRIC
- SAN — SANITARY SEWER
- STM — STORM SEWER
- UEL — UNDERGROUND ELECTRIC
- WAT — WATER
- FORMER SLOUGH/ LOG RUN
- SOURCE REMOVAL AREA
- HORIZONTAL BARRIER AREA
- INSTITUTIONAL CONTROL AREA
- REMEDIATION ZONE
- APPROXIMATE EXTENT OF UPLAND SITE
- PARCEL BOUNDARY (MARINETTE COUNTY, ACCESSED 7/16/2018)

0 90 180 Feet

SUMMARY OF USEPA-SELECTED REMEDY

PRELIMINARY DESIGN INVESTIGATION WORK PLAN
WPSC MARINETTE FORMER MGP SITE
MARINETTE, WISCONSIN

FIGURE 03

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

RAMBOLL

Y:\Mapping\Projects\6\67979\MXD\RemedialDesignWP\1912\Figure 4_Subsurface Soil and GW Investigation.mxd

PROJECT: 169000XXXX | DATED: 12/27/2019 | DESIGNER: STOLZSD

- PROPOSED SOIL BORING - CO-LOCATED WITH PREVIOUS OIL-COATED/OIL-WETTED OBSERVATION
- PROPOSED SOIL BORING - INITIAL DELINEATION
- PROPOSED SOIL BORING - CONTINGENT DELINEATION STEP-OUT
- PROPOSED TEMPORARY MONITORING WELL (ACTUALL LOCATION DEPENDANT ON FIELD OBSERVATIONS)
- SOIL BORING - EXTENDED 10 FT INTO BEDROCK
- EXISTING MONITORING WELL LOCATION
- EXISTING SOIL BORING LOCATION
- EXISTING SOIL GAS PROBE LOCATION
- EXISTING TEST PIT LOCATION

UTILITY TYPE

- GAS — GAS
- OHE — OVERHEAD ELECTRIC
- SAN — SANITARY SEWER
- STM — STORM SEWER
- UEL — UNDERGROUND ELECTRIC
- WAT — WATER
- FORMER SLOUGH/ LOG RUN
- SOURCE REMOVAL AREA
- HORIZONTAL BARRIER AREA
- INSTITUTIONAL CONTROL AREA
- REMEDIATION ZONE
- APPROXIMATE EXTENT OF UPLAND SITE
- PARCEL BOUNDARY (MARINETTE COUNTY, ACCESSED 7/16/2018)

0 45 90 Feet

SUBSURFACE SOIL AND GROUNDWATER INVESTIGATION

PRELIMINARY DESIGN INVESTIGATION WORK PLAN
WPSC MARINETTE FORMER MGP SITE
MARINETTE, WISCONSIN

FIGURE 04

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

RAMBOLL

INCREMENTAL SAMPLE LOCATION
INVESTIGATION AREA
GRID NOT TO BE SAMPLED DUE TO PRESENCE OF EXISTING DIRECT CONTACT BARRIER

UTILITY TYPE

GAS — GAS
OHE — OVERHEAD ELECTRIC
SAN — SANITARY SEWER
STM — STORM SEWER
UEL — UNDERGROUND ELECTRIC
WAT — WATER
FORMER SLOUGH/ LOG RUN
SOURCE REMOVAL AREA
HORIZONTAL BARRIER AREA
INSTITUTIONAL CONTROL AREA
REMEDIATION ZONE
APPROXIMATE EXTENT OF UPLAND SITE
PARCEL BOUNDARY (MARINETTE COUNTY, ACCESSED 7/16/2018)

SURFACE SOIL INVESTIGATION

PRELIMINARY DESIGN INVESTIGATION WORK PLAN
WPSC MARINETTE FORMER MGP SITE
MARINETTE, WISCONSIN

FIGURE 05

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

Y:\Mapping\Projects\6\67979\MXD\RemedialDesignWP\1912\Figure 5_Surface Soil Investigation_new.mxd

PROJECT: 169000XXXX | DATED: 12/31/2019 | DESIGNER: STOLZSD

APPENDIX A
RELEVANT MULTI-SITE STANDARD OPERATING PROCEDURES

Author:	T. Gilles	Q2R & Approval By:	J. Gonzalez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-02-01

EQUIPMENT CALIBRATION, OPERATION, AND MAINTENANCE
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for controls, calibration, and maintenance of measurement and testing equipment to be used for obtaining samples for chemical analyses, for measuring field parameters, and for testing various parameter/characteristics. The purpose of this SOP is to ensure the validity of field measurement data generated during field activities as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Measurement and testing equipment ;
- Equipment/instrumentation-specific operation manuals;
- Equipment/instrumentation-specific cases, battery chargers, and attachments; and
- Calibration standards (e.g. standard gas(es), calibration fluids, pH standards, etc.).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Field measurements are used to verify sampling procedures, assist in sample selection, and evaluate field conditions. A variety of equipment/instrumentation may be utilized to obtain the field measurements required to satisfy and document project goals outlined in Work Plans or otherwise specified. Therefore, instrument operators must be thoroughly familiar with the operation of measuring instruments. Users will complete the appropriate training and be certified, if required, before using the instrument in the field.

All equipment/instrumentation will be uniquely and permanently identified (model/serial number, equipment inventory number, etc.). Manufacturer's guides/operation manuals will be kept with the instrument or a designated area on the Site, as appropriate. The Site Manager or designee will obtain, identify, and control all equipment/instrumentation to be used during the project.

4.2 Calibration

Measuring equipment/instrumentation must be calibrated before initial use as recommended in the manufacturer's guide/operation manual. Equipment/instrumentation shall be re-calibrated following 1) the manufacturer's recommended calibration frequency, 2) long periods between uses, 3) readings observed above or below the range of the instrument, and/or 4) signs or evidence of equipment malfunction. Daily calibration and re-calibration activities will be recorded in the field logbook and/or on the appropriate field form and will include the following information:

- Date and time of calibration or re-calibration;
- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Method of calibration (may reference procedures outlined in the guide/instrument manual);
- Calibration standard(s) used; and
- Deviations, if any, from the manufacturer's recommended procedure(s) or calibration frequency.

4.3 Operation

Manufacturer's instructions will be followed for correct method(s) of operation. Equipment malfunctions and deviations, if any, from the manufacturer's recommended method(s) of operation will be documented in the field logbook and/or on the appropriate field form. Readings obtained from each instrument shall be recorded in the field logbook or on the appropriate field form.

4.4 Maintenance

Equipment/instrumentation will be maintained in accordance with the manufacturer's recommendations. Equipment/instrumentation that malfunctions or is scheduled for routine maintenance will be clearly labeled to prevent its continued use until repairs/maintenance is completed. The Site Manager or her/his designee will be responsible for ensuring that malfunctioning equipment is identified, marked for repair, repaired either in-house or by an outside company in accordance with manufacturer guidelines, checked following repair, and returned to service. The Site Manager or her/his designee will maintain an equipment log, which contains the following:

- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Recommended calibration frequency;
- Recommended maintenance frequency, as appropriate;
- Status (in service, not in use, or out of service for repair/maintenance);
- Dates of status changes (e.g. date returned to service); and
- Inspection and maintenance/repair dates.

5.0 REFERENCE

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

Author: T. Gilles | Q2R & Approval By: J. Gonzalez | Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-02-02

SURVEYING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for surveying activities that will be performed by the consultant. Timeframes or budgets may not always allow for surveying by licensed surveying professionals. The consultant may need to obtain information in a timely and cost effective manner that will aid in project decisions (e.g. groundwater flow direction, hydraulic gradient, etc.). In these cases, the consultant will perform basic surveying to obtain this information. The purpose of this SOP is to outline general procedures to obtain reliable surveying data in support of project goals and decisions as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Topcon Auto Level or equivalent;
- Tripod;
- Plumb line;
- Graduated surveying stick; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Survey equipment shall be inspected prior to commence of surveying activities to ensure that all components are present and functional. Graduations on the surveying stick should be well marked. Equipment not in satisfactory condition should be removed from service and repaired or replaced, as appropriate.

Operators must be thoroughly familiar with the operation of surveying equipment. Operators should complete the appropriate training and be certified, if required, before using the equipment in the field.

4.2 Benchmark Selection

A fixed, permanent reference point is critical for tying in surveying results to known site features and reproducing surveying results in the field. The benchmark should be a unique location, preferable one that would appear on a plat of survey, that is not likely have its elevation affected by field or outside activities (e.g. flange bolt on a fire hydrant, base of a property boundary stake, corner of a loading dock, etc.). The benchmark shall be documented and clearly described in the field logbook and/or on the appropriate field form. The location of the benchmark should also be measured relative to a minimum of two other permanent site features. These measurements should also be recorded in the field logbook and/or on the appropriate field form. Typically, a licensed surveyor will establish the benchmark which will be used on the site. If the benchmark cannot be established by a licensed surveyor, make sure the Project Manager is informed.

4.3 General Procedures

Surveying will be conducted following the procedures outlined below:

1. Make a table in the field logbook or utilized the appropriate field form to record the following information:
    a. Benchmark;
    b. Assigned benchmark elevation;

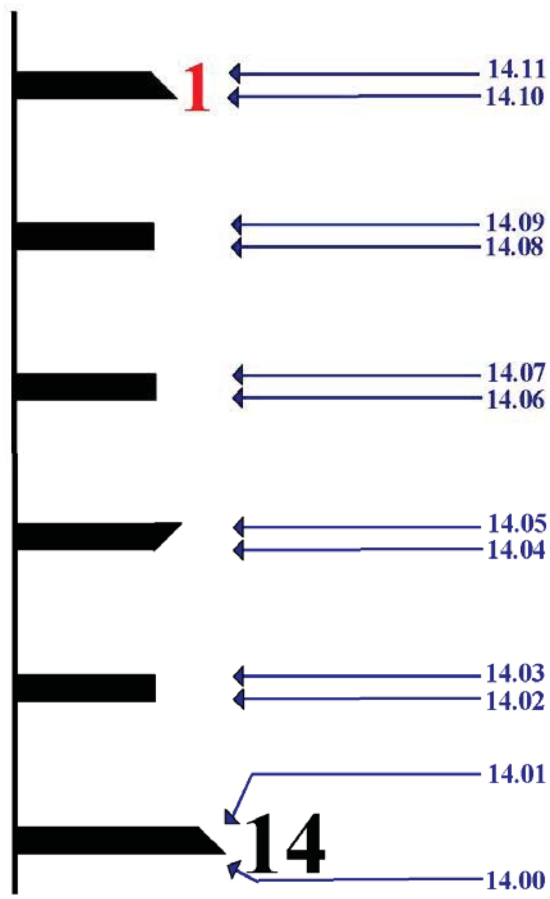
c. Instrument Height(s);
d. Temporary Benchmark(s);
e. Survey points (e.g. monitoring well top of casing, ground surface, etc.); and
f. Surveying stick graduation.

2. Locate a benchmark (BM).
3. Describe the BM in the field logbook and/or on the appropriate field form. The description must be detailed enough to allow a person unfamiliar with the Site to locate the BM.
4. Measure the location of the BM from at least two other permanent site features and record the measurements in the field logbook and/or on the appropriate field form.
5. Choose a location for the tripod that is in view of the benchmark and as many surveying points as possible.
6. Set up the tripod and attach the plumb line.
7. Adjust the tripod legs until the plumb line hangs at a 90-degree angle from the top plate of the tripod.
8. Place the Topcon Auto Level (or equivalent) on the tripod.
9. Adjust the auto level legs until the Topcon Auto Level is level as indicated by the leveling bubble (Note: The bubble should be centered in the circle).
10. Verify the auto level is level by rotating the auto level 90, 180, and 270-degrees. The bubble should be centered in the circle at all three positions. If the bubble is not centered in the circle, repeat Steps 7 through 10.
11. The surveying assistant will stand the surveying stick on the benchmark.
12. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
13. The operator shall record Instrument Height #1 (IH_1), which is obtained by adding the surveying stick graduation to the arbitrary benchmark elevation (usually 100.00 feet), in the field logbook and/or on the appropriate field form.
14. The surveying assistant will stand the surveying stick on a surveying point.

15. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the appropriate field form as the front sight measurement.
16. The operator shall record Survey Point #1 (SP_1) elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
17. Repeat Steps 14 through 16 until all survey points or all survey points visible from the first instrument location have been measured.
18. Locate a Temporary Benchmark (TBM_1).
19. The surveying assistant will stand the surveying stick on TBM_1.
20. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
21. The operator shall record TBM_1 elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
22. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of TBM_1.
23. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the back sight measurement.
24. The operator shall record Instrument Height #2 (IH_2), which is obtained by adding the surveying stick graduation to the TBM_1 elevation determined in Step 21, electronically or in the field logbook and/or on the appropriate field form.
25. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 26.
26. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
27. Locate another Temporary Benchmark ($TBM_{\#}$).
28. The surveying assistant will stand the surveying stick on $TBM_{\#}$.

29. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
30. The operator shall record $TBM_{\#}$ elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
31. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of $TBM_{\#}$.
32. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
33. The operator shall record Instrument Height # ($IH_{\#}$), which is obtained by adding the surveying stick graduation to the $TBM_{\#}$ elevation determined in Step 30, electronically or in the field logbook and/or on the appropriate field form.
34. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
35. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 27.
36. The surveying assistant will stand the surveying stick on the benchmark.
37. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
38. The operator record BM elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
39. If the BM elevation is within 02/100 of an inch ($\pm$0.02) of the initial or assigned BM elevation, the surveying has been completed successfully. If the BM elevation is not within 02/100 of an inch ($\pm$ 0.02) of the initial or assigned BM elevation, an error was made or the tripod and/or auto level were bumped during surveying. In this case, the surveying activities were not completed successfully and must be repeated.

4.4 Reading the Surveying Stick



5.0 REFERENCE

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

Author:	M. Skyer	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-03-01

SAMPLE IDENTIFICATION, LABELING, DOCUMENTATION AND PACKING FOR TRANSPORT
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for identifying, logging, packing, preserving and transporting environmental samples for chemical or physical analysis.

2.0 EQUIPMENT AND MATERIALS

- Sample containers;
- Sample labels;
- Field logbook;
- Pens with waterproof, non-erasable ink;
- Chain-of-custody (COC) forms;
- Custody seals
- Clear plastic sealing tape;
- Coolers for transporting samples to the laboratory;
- Ice (if required)
- Gallon-size sealable plastic bags; and
- Air bills or similar transportation provider forms.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE IDENTIFICATION

A unique 9-digit identification code will be assigned to each sample retained for analysis on all United States Environmental Protection Agency (USEPA) sites and on a site-specific basis as determined by the project manager. This code will be formatted as a number series with the sample month (2-digit), date (2-digit), year (2-digit) and consecutive sample number (3-digit).

Example: The first sample for a particular phase of an investigation collected on May 18, 2004 would be identified as 051804001, as detailed below.

05	**18**	**04**	**001**
Month	**Date**	**Year**	**Consecutive Sample Number**

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

Duplicate samples will be assigned a unique 9-digit identification code. Samples selected for matrix spike/matrix spike duplicates (MS/MSD) will include “MS/MSD” at the end of the unique 9-digit identification code. The unique 9-digit identification code is compatible with USEPA electronic data submittal requirements. Sample identification numbers will be used on sample labels, COC forms and other applicable sampling activity documentation.

Sample media codes will be noted on field notes and logs using the following media codes:

Sample numbering will consist of up to three components: a three-character alpha Site identification code; a four- to five-character alpha numeric sample type code; and the sample depth below ground surface (bgs, if soil) or the sample depth below top of mudline (sediment). Groundwater samples will typically not include sample depth bgs unless there are multiple intervals sampled in one open borehole. An example of a completely numbered sample, with each component identified follows.

Example: AES-SP01-(0-0.5)

Where: AES – Any Environmental Site

SP01 – Soil probe location number 1

(0-0.5) – soil sample collected 0-0.5 feet bgs

The site identification code (e.g. AES in the sample above) will remain the same for all samples collected at the Site.

The sample type code (SP01) will vary depending on sample type and location. The following are typical alpha codes to be used in the alphanumeric sample type code for samples:

- AS – air sparging sample;
- CF – confirmation soil sample;
- GP – gas probe sample;
- MW – groundwater monitoring well (if deep and shallow wells are sampled for the same location, this type code is modified to DMW (deep well) and SMW (shallow well);
- PZ – piezometer sample;
- RW – recovery well sample;
- SB – soil boring sample;
- SD – sediment sample;
- SP – soil probe sample;
- SS – surface soil sample;
- SR – source material (used if source material is known to exist);

- SV – soil vapor probe sample;
- SW – surface water sample;
- TP – test pit sample; and
- VE – vapor extraction sample.
- WC – waste characterization (may be preceded by S for solid waste or L for liquid waste).

If additional sampling type codes are required, they will be specified in the site-specific work plan.

When completing soil borings and probes, if a water sample is collected from an open boring or probe location a "w" will be attached to the end of the alpha-numeric sample type code (e.g., SB01W). The numerical portion of the sample type code will indicate the sample location (i.e., boring location 01, 02, 03, etc.).

5.0 SAMPLE LABELING

The following information will be included on each sample label: site name/client, sample number, name of sampler, sample collection date and time, depth of sample (if applicable), analyses or tests requested and preservations added. Information known before field activities (site name, analyses requested, etc.) can be preprinted on sample labels. Duplicate sample labels can be prepared when various sample aliquots must be submitted separately for individual analyses.

6.0 SAMPLE DOCUMENTATION

The following itemized list will be used as a general reference for completion of sample documentation:

- Record all pertinent sample activity in the field logbook in accordance with SOP SAS-01-01, Field Documentation and Reporting.
- Make or obtain a list of samples to be packaged and shipped that day.
- Determine number of coolers required to accommodate the day's shipment based on number of samples to be shipped, number of containers per sample and number of sample containers that will fit in each cooler.
- If samples are shipped by Federal Express or other express shipping service, complete an air bill.

- Assign chain-of-custody form to each cooler and determine which sample containers will be shipped in each cooler. (Note: More than one chain-of-custody form may be needed to accommodate number of samples to be shipped in one cooler).
- Determine which samples will be shipped under each chain-of-custody form. Each day that samples are shipped, record chain-of-custody form numbers, and air bill numbers (if used) in field logbook. Cross-reference air bill and chain-of-custody numbers.
- Complete COC forms in accordance with SOP SAS-03-02, Chain of Custody.
- Assign custody seals to each cooler and temporarily clip seals to each chain-of-custody form.
- Group paperwork associated with each cooler with a separate clip.
- Obtain necessary field team members' full signatures or initials on appropriate paperwork.

7.0 SAMPLE PACKING FOR TRANSPORT

The steps outlined below will be followed to pack the sample containers into coolers for shipment.

1. Each glass sample container will be wrapped with protective packing material.
2. Packing material will be placed in the bottom of each cooler for cushioning.
3. Sample containers will be placed inside each cooler, taking care not to overfill the cooler.
4. Ice will be double bagged sealable plastic bags and added to the cooler on top of the samples. Sample containers will be packed so that they are not in direct contact with ice. The remaining empty space in each cooler will be filled with packing material.
5. Packing material will be placed over the top of the bagged ice.
6. The chain-of-custody records will be signed, and the date and time at which the coolers are sealed for transport by a shipping company, or relinquished to a delivery service or the laboratory sample receiving department will be indicated.
7. Copies of chain-of-custody records will be separated. The original signature copies will be sealed in a large, sealable, plastic bag and taped to the inside lid of a cooler. A copy of each COC will be retained by the Site Manager.
8. If any cooler has a drain, the drain will be taped shut.
9. The lid to each cooler will be closed and latched. Custody seals will be affixed to each cooler between the lid and the body of the cooler. One custody seal will be placed on the front of the cooler, and one will

be placed on the back. Custody seals will be covered with clear plastic tape. An example of a custody seal is located in SOP SAS-03-02, Chain-of-Custody.

10. The cooler will be closed and taped shut on both ends with several revolutions of tape. Also, tape will be wrapped several times around the cooler body and the cooler lid to firmly secure the cooler lid and body together.
11. Samples will be packed and transported to the analytical laboratory within one day of collection.

8.0 REFERENCES AND ADDITIONAL RESOURCES

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

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

ASTM International, D4840-99(2004) Standard Guide for Sampling Chain-of-Custody Procedures.

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

International Air Transport Association (IATA), 2005, Dangerous Goods Regulations.
USEPA, 1981, *Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples*, Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

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

Author:	M. Skyer	Q2R & Approval By:	J. Gonzalez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-03-02

CHAIN OF CUSTODY
Revision 0

1.0 PURPOSE

This Standard Operating Procedure describes procedures for preparation and use of the chain of custody (COC) form that accompanies field-collected soil, sediment, water, air or geotechnical samples. Procedures are also provided for preparation and use of custody seals for securing openings of sample containers during transport of samples to the analytical laboratory. COC forms and custody seals are used to provide documentation of sample integrity from the time of collection to time of sample receipt and acceptance by the analyzing laboratory or testing laboratory.

2.0 EQUIPMENT AND MATERIALS

- COC forms;
- Custody seals;
- Gallon-size plastic sealable bags; and
- Clear plastic packing tape.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 METHODS/PROCEDURES

4.1 Chain of Custody Form Items to Complete

Attachment A presents an example COC form. The following general information must be completed on the COC form:

- Laboratory name, address, telephone number;
- Document control number;
- Site manager name on Attention line;
- Project number;
- Site name;
- Complete field sample identification number;
- Sample collection date for soil, sediment and water samples or sample start and collection dates for ambient air monitoring samples;
- Time of sample collection for soil, sediment and water samples or sample start and collection times for air monitoring samples;
- Sample matrix (i.e. liquid, solid, or gas);
- Number of containers;
- Analysis or testing method requested;
- End pressure, Summa can identification number, and flow controller serial number for air monitoring BTEX samples and filter identification number for air monitoring PM10 samples.
- Sample preservatives used (other than ice) in Remarks column;
- Turn-around time requested (specify if turn-around time is business or calendar days) in Special Instructions box;
- Signature of person(s) conducting sampling;
- Strike line with samplers initials and the date samples are relinquished in order to complete unused portion of COC form;
- Signature of person relinquishing the sample custody (person relinquishing custody must be a sampler to ensure chain of custody is maintained);
- Signature of person transporting samples to the lab if other than sampler/relinquisher or third-party carrier;

- **DO NOT** write "FedEx" or other third-party carrier's name in the Relinquished To box. The air bill and carrier's established custody documentation procedure is used to verify custody during transportation.
- Date and time samples are relinquished;
- Custody seal identification numbers; and
- Freight bill identification number in Special Instructions box or at bottom of Remarks column (if third party shipper is used to transport).

4.2 Chain of Custody Form and Procedures

- If a sampling event requires the use of more than one shipping container (cooler for soil/sediment/water samples or box for certain air monitoring samples or soil samples for geotechnical testing) a separate COC form must be completed for each shipping container. For each container, the associated COC form must list only the samples contained in that container.
- When it is known that numerous chains of custody will be required for a project or for a single sampling event, it is acceptable to pre-type the laboratory name, address, telephone number, project number, site name, 3-letter project name abbreviation in Document Control Number area, and site manager name. These are the only information fields that may be pre-typed.
- Each COC should contain a unique document control number in the format: 3-letter project name abbreviation – identification number – 4 digit year, e.g. AES-001-2006, AES-002-2006 and so on. For each project COC identification numbers should be assigned sequentially beginning with 001 for each calendar year. (Exception: for remediation ambient air monitoring projects that span two or more calendar years, continue sequential numbering throughout the project.)
- The COC form must be completed in ink.
- Corrections must be made by drawing a single line through the data that is in error and initialing and dating at the end of the line. The use of correction fluid or tape is not allowed. Do not write over text or numbers to correct. If multiple corrections are needed, copy correct information to a new COC and destroy copy with errors.
- If the number of samples included in the shipping container is less than the number of data entry lines on the COC, draw a single diagonal line running from left down to the lower right hand corner of the field sample data area. The sampler's initials and date must appear along the line.

- Seal the completed COC form in a plastic storage bag. For cooler shipping containers, tape the bag to the inside of the cooler lid prior to sealing the cooler. For box shipping containers, insert the bagged COC form into the box prior to sealing the box.
- If samples are to be shipped by a third party carrier (e.g. Federal Express) the third party carrier does not need to sign the chain of custody. The COC form may be sealed inside the container prior to shipping. If samples are to be hand-delivered to a laboratory by someone other than the sampler/relinquisher (e.g., site construction manager or laboratory courier), the sampler/relinquisher must transfer custody by having the carrier sign in the "Received By" section of the COC form and enter the date and time of transfer. Then seal the COC form inside the container.

4.3 Custody Seal Procedures

A sample custody seal is a strip of adhesive paper used to detect unauthorized tampering with samples prior to receipt by the laboratory. Attachment A presents an example of a completed custody seal. Custody seals are pre-numbered and should be used instead of laboratory custody seals whenever possible.

- A minimum of two custody seals are used per shipping container, one on each long side of the cooler or across each opening of a box. For coolers, one of the custody seals must be placed from the lid to the side of the cooler such that it would be necessary to break the seal in order to open the shipping container. Cover each custody seal with a single piece of clear packing tape wrap it around the perimeter of the cooler. For boxes, place a custody seal across each opening of the box (top and bottom) and cover with a piece of packing tape, making sure tape is secured in such a way that it cannot easily be removed.
- The relinquisher must sign and date each custody seal in ink and include the site identification abbreviation in the custody seal number area.
- Each custody seal has a pre-printed unique six-digit identification number. This number along with the site identification abbreviation must be transferred exactly to the Custody Seal Number box on the COC. The identification number of all custody seals used in conjunction with the COC must be listed on the COC. If a custody seal other than the pre-numbered one, a unique identification number must be printed on the seal and transferred exactly to the Custody Seal Number box on the COC.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

A copy of the COC forms and freight bills used in the above procedure will be transferred to the Project Manager and maintained in the project-specific file as part of the official chain of custody record.

6.0 QUALITY CONTROL AND QUALITY ASSURANCE

- Each COC will be checked for accuracy and completeness (i.e. sample list complete, sample data entered correctly etc.) by another member of the field sampling team before samples are relinquished for transport. In the event the sampler is the sole person on-site, the COC will be checked for accuracy and completeness within 24 hours of the sampling event by a member of the project team.
- Review of the COC forms and freight bills used in the above procedure will be conducted during evaluations of sampling procedures by personnel. The COC forms will also be reviewed as part of the data validation process when the laboratory returns the completed COCs following receipt and analysis of samples.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM, International, 1999, D 4840-99 (2004) Standard Guide for Sample Chain-of-Custody Procedures.

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

ATTACHMENT A
EXAMPLE CHAIN-OF-CUSTODY AND CUSTODY SEAL FORMS

Request for Chemical Analysis and Chain of Custody Record

Send Results to: Attention:	Laboratory: Address: City/State/ZIP: Telephone:	Document Control No.: Lab. Reference No. or Episode N

Project Number: | Sample Type

Site Name: | Matrix

Sample Number			Sample Event		Sample Depth (in feet)		Sample Collected		Matrix			Number of Containers	Parameter/Method Code						Remarks
Group or SWMU Name	Sample Point	Sample Designator	Round	Year	From	To	Date	Time	Liquid	Solid	Gas								

Sampler *(Print Name)*:	Sampler *(signature)*:	Custody Seal Number	Special Instructions

Relinquished By *(signature)*: 1.	Date/Time	Received By *(signature)*: 1.	Date/Time	Ice Present in Container: Yes ☐ No ☐	Temperature Upon Receipt:
Relinquished By (signature): 2.	Date/Time	Received By (signature): 2.	Date/Time	Laboratory Comments:	

Signature ______________________________

Date ______________________ # -112504

Author:	M. Skyer	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M Kelley

STANDARD OPERATING PROCEDURE NO. SAS-03-03

SAMPLE LOCATION IDENTIFICATION AND CONTROL Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the identification of sample locations and field measurements of topographic features, water levels, geophysical parameters, and physical dimensions frequently required during groundwater, hazardous waste, and related field investigation activities. The scope of such measurements depends on the purpose of the field investigation. Samples collected from each sampling location will have a unique sample identified in accordance with ENV-03-01.

All sampling locations shall be uniquely identified and depicted on an accurate drawing or a topographic or other site map, or be referenced in such a manner that their location(s) are established and reproducible. A sample location must be identified by a coordinate system or other appropriate procedures which would enable an independent investigator, to collect samples from reproducible locations. Repetitive sampling might be performed, for example, to monitor the progress of a remedial program, to check for suspected erroneous results from an initial sampling, or to check the reproducibility of results.

2.0 EQUIPMENT AND MATERIALS

- Site map;
- Surveying equipment;
- Measuring tape;
- Field notebooks/logs; and
- GPS unit.

3.0 SAMPLE LOCATION IDENTIFICATION

Locations for collection of samples are assigned alphanumeric codes which are used to coordinate laboratory data tracking and graphic depiction of sample locations on drawings and figures. Samples collected from each sampling location will have a unique sample identified in accordance with ENV-03-01. Each sample location is issued a unique numeric code that corresponds to a specific map location on a plan view of a site and vicinity. An alpha-code (letter) is used to describe the type of sampling activity performed at the specific numeric location. The following alpha codes will be used:

Air	AS	Air Sparging Point
	GP	Gas Probe
	GM	Gas Monitoring Well
	SV	Soil Vapor Probe
	VE	Soil Vapor Extraction Well
Material	AC	Asbestos Containing Material
	LS	Lead Wipe Sample
Sediment	SD	Sediment
Soil	SB	Soil Boring
	SS	Surface Soil
	TP	Test Pit
	EB	Excavation Base
	EW	Excavation Well
Water	MW	Groundwater Monitoring Well
	PZ	Piezometer
	PW	Potable Water Well
	RW	Recovery Well
	TW	Temporary Monitoring Well
	SW	Surface Water
	SG	Surface Water Staff Gauge

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

Each sample location will have only one alphanumeric code. A borehole drilled for the purpose of installing a monitoring well will be identified as MW01. There should not be a location SB01 for soil sample location identification and MW01 for groundwater sample location identification.

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

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

4.0 SURVEYED LOCATIONS

Survey control should be performed following monitoring well and borehole installations by a surveyor licensed in the state of the project site. Vertical elevations to the top of each new well casing will be established within ± 0.01 foot. Ground surface elevations at each well and borehole location should be established within ± 0.01 foot. Elevations should be referenced to the North American Vertical Datum of 1988 (NAVD 88). Alternative systems may be used on a project-specific basis, with appropriate reference documentation in the master project file and final reports.

Lateral locations based on an established grid system will be determined for each sampling location. Lateral locations should be calculated to within ± 1-foot. The site map should include at minimum sampling locations, structure boundaries, property boundaries, nearby surface water, site grid system origin according to either a state plane coordinate system or latitude and longitude, bar scale, and a north arrow. Specific state reporting and mapping requirements should be checked prior to final plan development.

In conducting vertical surveys, the following procedures should be used or should be referenced in subcontractor service agreements with licensed surveyor:

- When practical, level circuits will close on a bench mark other than starting bench mark;
- Readings should be recorded to the closest 0.01 foot using a calibrated rod;
- Foresight and backsight distances should be reasonably balanced;
- Rod levels should be used;
- No side shot should be used; and
- Benchmarks should be traceable to USGS benchmarks.

Field staff and contractors will record all field data collected during survey activities in accordance with SOP SAS-01-01 for incorporation into site data reports, maps, tables, etc.

5.0 TRIANGULATION

Triangulation shall be used if a registered surveyor is not contracted. This method encompasses distance measurement from sampling points relative to two and sometimes three known points. Distance measurements should be accurate to within ±1 foot allowing for sag in the measuring tape and other inaccuracies. Measuring to two known points is typically adequate for rough measurements made with a pocket transit and 100-foot tape; however, measuring to three known points reduces potential error. Distance measurements should be made relative to distinctive features having a probable life span in excess of 10 years. Examples include the following:

- Power pole located on north side of plant entrance #1 driveway;
- SE corner of plant building 2 located at 111 Survey Circle; or
- NW corner of retaining wall running north-south along Bass Creek.

Unacceptable triangulation points include fence posts, trees, temporary stakes or markers etc., unless these features are to be located within 15 days by survey.

When locating sampling points, decide which site features will be important to illustrate on a site map in the report. If appropriate, also locate areas of known or suspected spills and manholes which may represent migration pathways. Establish relative locations of these and other pertinent site features by triangulation.

The client should be consulted regarding the existence of plant drawings or other surveyed maps which accurately show the relative location of major site features. The field notebook should record information describing the drawing (e.g., who it was prepared by, date, drawing number, etc.) and describe the points on the drawing being used for triangulation purposes.

If only one site feature is convenient for triangulation, the remaining two reference points can be established by running a line toward a more distant site feature, which can be easily located later, and the recorded distance from a defined point along that line.

6.0 GLOBAL POSITIONING SYSTEM (GPS)

Global Positioning System (GPS) is an appropriate method to determine the location of site investigation features in limited circumstances, and is solely at the discretion of the project manager.

There are significant accuracy limitations with GPS which limits the effectiveness of this technology in the role of sample location. For sites where accuracy less than ± 10 feet is acceptable, or surveying is impractical, GPS is a suitable sample location method. GPS is not suitable for sites requiring a higher degree of accuracy. However, the recording of GPS coordinates is encouraged for all sites where monitoring wells or other permanent features may be obscured by snow, vegetation, or other obstructions. In such cases, GPS may assist in locating the monitoring well, etc. despite the accuracy limitations.

7.0 REFERENCES

ASTM International, 2002, D5906-02 Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths.

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

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

Zilkoski, David B., J.H. Richards, and G.M. Young , 1992, Results of the General Adjustment of the North American Vertical Datum of 1988, American Congress on Surveying and Mapping, Surveying and Land Information Systems, Vol. 52, No. 3, 1992, pp.133-149.

Authors:	M. Skyer / T. Gilles	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-04-03

QUALITY CONTROL SAMPLES
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of quality control (QC) samples. QC samples are utilized to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness and comparability of data obtained during investigative activities.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials for the collection and analysis for quality control samples shall be identical to those used for the collection and analysis of the sample of similar media and collection method.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 QUALITY CONTROL SAMPLES

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

4.1 Field Duplicate Samples

Duplicate samples are collected from various media to evaluate the representativeness and comparability of data obtained during investigative activities. These samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of duplicate sample collection for each sample media shall be specified in the Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.2 Matrix Spike and Matrix Spike Duplicate Samples

MS/MSD samples are collected from various media to evaluate the precision and accuracy of laboratory procedures. As with field duplicate samples, MS/MSD samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of MS/MSD sample collection for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the (QAPP).

4.3 Trip Blanks

Trip blanks are used as control or external quality assurance/quality control (QA/QC) samples to detect contamination that may be introduced in the field, in transit to or from the sampling site, or in bottle preparation, sample log-in, or sample storage sites within the laboratory. Trip blanks will also reflect contamination that may occur during the analytical process. Trip blanks are samples of reagent free water, properly preserved, which are prepared in a controlled environment prior to field mobilization. These samples are prepared by the analytical laboratory. The trip blanks are kept with the laboratory provided containers through the sampling process and returned to the laboratory with the other aqueous samples for VOC analysis. Trip blanks must be used for samples intended for VOC analysis and are preserved and analyzed for

VOCs only. One trip blank will accompany each cooler containing aqueous samples for VOC analysis or as specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.4 Field/Equipment Blanks

Field/equipment blanks are used to determine 1) if non-disposable equipment decontamination procedures are being carried out properly and there is no "carryover" from one sample to another and 2) ensure that disposable equipment is free of measurable concentrations of constituents of potential concern. Field/equipment blank shall be collected by pouring distilled or ultrapure/DI water onto or into the sampling equipment and direct filling the appropriate sample containers with the DI water from the sampling equipment. Field blank will be handled and treated in the same manner as all samples collected unless noted otherwise below. Field/equipment blanks are always collected after sampling equipment has been decontaminated and may be performed prior to collecting the first sample, after collecting highly impacted samples, and/or at the conclusion of sampling. The minimum/required frequency of field/equipment blanks for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above-mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

5.0 REFERENCES AND ADDITIONAL RESOURCES

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

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

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

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

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

Author:	M. Skyer	Q2R & Approval By:	T. Gilles	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-04-04

EQUIPMENT DECONTAMINATION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for decontamination of equipment prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site as specified in the Site-Specific Work Plan or as otherwise specified. Personnel decontamination is described in the site-specific Health and Safety Plan (HASP).

2.0 EQUIPMENT AND MATERIALS

Decontamination equipment and materials may vary based on the size or type of equipment, but generally include the following:

- Decontamination detergents (e.g. Alconox);
- Tap water;
- Deionized, distilled and organic-free water;
- Acid solution (optional);
- Approved cleaning solvent (e.g. isopropanol, hexane, Stoddard) (optional and/or site-specific);
- Metal scrapers;
- Brushes;
- Buckets;
- Steam cleaner or high-pressure, hot water washer;
- Racks, normally metal (not wood) to hold miscellaneous equipment;
- Buckets, 55-gallon drums, or other approved storage containers;
- Plastic sheeting;
- Utility pump (optional);
- Paper towels;
- Personal protective equipment; and

- Logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific HASP based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General Requirements

All expected types and levels of contamination shall be discussed during field activity planning and a decontamination plan sufficiently scoped within the Site-Specific Work Plan. Until proven otherwise, all personnel and equipment exiting the area of potential contamination/work zone will be assumed to be contaminated. Personnel involved in decontamination efforts shall be equipped with the same personal protective equipment as those conducting the field activity until a lower level of risk can be confirmed.

Decontamination procedures may be subject to federal, state, local, and/or the client's regulations. All regulatory requirements shall be satisfied, but the procedures adopted shall be no less rigorous than those presented in this SOP.

Climatic conditions anticipated during decontamination activities may impact the implementation of the procedures describe in this SOP. Special facilities or equipment may be needed to compensate for weather conditions (e.g. temporary, heated structures for winter work). In addition, it may be necessary to establish special work conditions during periods of high heat or cold stress.

4.2 Preparation

4.2.1 Site Selection

The equipment decontamination facility or area shall be located in an area where contaminants can be controlled and at the boundary of a "clean zone" or "cold zone". The location shall also be selected to prevent equipment from being exposed to additional or other contamination. When Site layout and size allow, a formal "contamination reduction zone" or "warm zone" shall be established in which decontamination efforts will be conducted. This area shall be conspicuously marked as "off-limits" to all personnel not involved with the decontamination process.

The equipment decontamination facility or area shall also be located where decontamination fluids and materials can be contained and easily discarded or discharged into controlled areas of waste. This facility or area shall have adequate space for the storage of unused and used storage containers, until such time as they can be relocated or disposed of.

4.2.2 Decontamination Pad

Some Site may have an existing decontamination pad. If a decontamination pad has been previously constructed, it shall be evaluated for logistics capabilities, such as water supply, electrical power, by-product handling capabilities, and cleanliness. An existing decontamination pad shall be used or modified to the extent practical. If a decontamination pad is not present or the existing pad cannot be used or modified for use, a pad consisting of a sturdy base, lined with plastic sheeting of high-density polyethylene with four raised sides and a sump for collection of fluids will be constructed unless otherwise specified by the Site-Specific Work Plan. Some field activities, which consist of hand sampling or other small equipment, may not require a decontamination pad. In these cases, buckets, small wash tubs, or small pools may be sufficient for equipment decontamination.

4.2.3 Water Supply

Large volumes of water, often exceeding 1,000 gallons per day, may be required for decontamination activities, especially for drill rigs and other large equipment. The water used for decontamination must be clean, potable water. In most cases, municipal water supplies are adequate. Private potable water supplies shall be evaluated on a case-by-case basis prior to use.

4.2.4 Cleaning Equipment and Supplies

A portable steam cleaner or high-pressure hot water washer is normally required to clean contaminated heavy machinery (e.g. drill rig, backhoe, etc.) as well as materials and associated tools. Most steam cleaners and washers are commercially available for both portable generators or supplied AC power. Site logistical considerations may dictate the type of equipment required. Typical steam cleaners/washers operated on relatively low water consumption rates (2 to 6 gallons per minute) and can be used in conjunction with other cleaning fluids mixed with the water. High-pressure steam is preferred to high-pressure water because of steam's ability to volatilize organics and to remove oil and grease from equipment. Since units tend to malfunction easily and are susceptible to frequent maintenance and repair (especially under frequent use and freezing conditions), a second or back-up unit should be available onsite or arranged for with a nearby vendor to the extent practical, for longer duration field activities.

Garden sprayers may be used for final rinsing or cleaning. However, these sprayers shall be limited to use with small hand tools and sampling equipment. Since these sprayers tend to malfunction or break down easily, a second or backup sprayer shall be maintained onsite.

Metal scrapers and brushes shall be used to physically remove heavy mud, dust, etc. from equipment prior to and during the equipment rinses. Scrapers and brushes are relatively inexpensive and shall be replaced as necessary to support cleaning activities.

Decontamination solutions may consist of the following:

- Laboratory detergent shall be a standard brand of laboratory detergent such as Alconox® or Liquinox®;
- Nitric acid solution (10 percent) will be made from reagent-grade nitric acid and deionized water;
- Cleaning solvent;
- Potable water;
- Deionized water;
- Distilled water; and
- Organic-free water.

The use of cleaning solvents shall be carefully considered prior to use with respect to safety, handling and disposal, and potential impact to analytical results and the environment.

Potable, deionized, distilled, and organic-free water should contain no heavy metals or other inorganic compounds (i.e., at or above analytical detection limits) as defined by a standard Inductively Coupled Argon Plasma Spectrophotometer (ICP) scan and no pesticides, herbicides, extractable organic compounds, and less than 5 µg/l of purgeable organic compounds as measured by a low-level GC/MS scan. The level of QA/QC required during the project to verify and document the purity of the water and the number of rinsate blanks required to verify and document the effectiveness of decontamination procedures shall be based on data quality and project objectives as specified by the Site-Specific Work and/or Quality Assurance Project Plan (QAPP). The use of non-potable or untreated potable water supply for decontamination is not acceptable.

4.3 Equipment and Vehicle Decontamination Procedures

4.3.1 General Procedures

The following procedures are presented as general guidelines and shall be followed unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Steam or water wash with potable water to remove particles;
3. Rinse critical pieces of equipment with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);

4. Steam or water wash with a mixture of detergent and potable water;
5. Steam or water rinse with potable water; and
6. Air dry.

4.3.2 Special Case – Drilling Equipment

During decontamination of drilling equipment and accessories, clean auger flights, drill rods, and drill bits as well as all couplings and threads. Generally, decontamination can be limited to the back portion of the drill rig, drill rig tires, drill rig mast, and parts that come in direct contact with samples or casings or drilling equipment placed into or over the borehole.

Some items of drilling equipment cannot typically be decontaminated. These items include wood materials (e.g. planks), porous hoses, engine filters, etc. These items shall not be removed from site until ready to dispose of in an appropriate manner.

Other drilling equipment that requires extensive decontamination is water or grout pumps. Circulating and flushing with a potable water and detergent solution followed by potable may be sufficient to clean them. However, if high or unknown contaminant concentrations or visible product is known to exist, then disassembly and thorough cleaning of internal parts shall be required before removal of the equipment from the Site.

4.4 Sampling Equipment Decontamination Procedures

4.4.1 General Procedures

Sampling equipment shall be decontaminated prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site using the following procedure as general guidelines unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Rinse with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);
3. Wash and scrub with a detergent and potable water solution;
4. Rinse with potable water;

5. Rinse with high-grade water (deionized, distilled, or organic-free);
6. Air dry; and
7. Wrap in aluminum foil, shiny side out, for transport.

4.4.2 Special Cases

Steel tapes, water and interface probes, transducers, and thermometers, shall be cleaned with a detergent solution and rinsed with high-grade water. Water quality meters shall be rinsed with high-grade water.

Pumps with internal components that contact a water sample (e.g., bladder pump) shall be deconned by pumping a detergent solution (minimum two gallons) followed by potable water rinse (minimum two gallons) and a high-grade water rinse (minimum two gallons). If field conditions (e.g., the presence of product) indicate circulating and flushing a pump with a detergent solution followed by potable water is not an adequate field decontamination procedure, the pump shall be disassembled and internal parts thoroughly cleaned with a detergent solution followed by potable water rinse and a high-grade water rinse.

4.5 Well Material Decontamination Procedures

Well construction materials, including end cap, screen, and riser pipe, whether polyvinyl chloride (PVC), stainless steel, or other material shall be cleaned with a steam cleaner or high-pressure hot water washer before it is installed in the borehole. Well construction materials shall be handled while wearing latex, nitrile, or equivalent gloves.

4.6 Equipment Segregating and Labeling

Decontaminated equipment shall be stored separating from contaminated equipment in a manner that prevents the recontamination of “clean” equipment. Equipment that is cleaned utilizing these procedures shall receive a final decontamination process at the completion of field activities and will be tagged, labeled, or marked with the date that the equipment was cleaned.

4.7 Disposal Practices

4.7.1 General Disposal Requirements

Disposal practices shall be in accordance with the procedures specified in the Site-Specific Work Plan. Decontamination derived waste shall be contained, consolidated, and disposed shall be conducted to prevent the spread of contaminants offsite or to “clean” locations onsite and in a manner consistent with the acceptable disposal practices for the type and concentration of wastes that may be contained in the decontamination derived waste. Contaminated equipment or solutions shall not be discarded in any manner that may lead to the contamination of the environment by the migration of hazardous constituents from the Site by air, surface, or subsurface transport mechanisms.

4.7.2 Onsite Storage, Treatment, and Disposal

On controlled, secured facilities, most decontamination derived waste shall remain onsite pending waste characterization and disposal. The decontamination derived waste shall be labeled and stored in a manner that does not pose a threat to contamination of personnel or areas to be sampled or a threat of release to the environment. Liquids and solids shall be containerized separately in approved storage containers. Each storage container shall be labeled with the following:

- Contents (e.g. decontamination fluids);
- Incompatibilities (if applicable);
- Accumulation date; and
- Contact person and phone number.

In some cases, an onsite treatment system is available for certain types of decontamination derived waste. Treatment of decontaminated derived wastes shall be performed in accordance with any applicable permit requirements and federal, state, and local laws and regulations.

In some cases, certain materials that are not contaminated or contain very low levels of contamination may be disposed of onsite. Such materials may include may include drill cuttings, wash water, drilling fluids, and water removed during the purging or sampling of wells. The low level of contamination (concentrations below applicable cleanup objectives) shall be confirmed prior to onsite disposal. Onsite disposal shall comply with federal, state, and local laws and regulations.

4.7.3 Offsite Disposal

In most cases, decontamination derived waste cannot be disposed of or treated onsite. Decontaminated derived waste shall be properly characterized prior to shipment to a licensed and approved treatment, storage, and disposal facility. Decontamination fluids discharged to sanitary and/or storm sewers shall be properly permitted prior to discharge. Offsite disposal shall comply with federal, state, and local laws and regulations.

5.0 DOCUMENTATION

Decontamination activities, including deviations for general procedures, shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work.

6.0 REFERENCES

ASTM International, D5088-02 Practices for Decontamination of Field Equipment Used at Waste Sites.

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia.

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

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-01

SUBSURFACE EXPLORATION CLEARANCE
Revision 0

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to ensure intrusive site activities are conducted with the knowledge and approval of property owners, utility providers, and governmental agencies, as appropriate, in a manner that minimizes potential exposure to subsurface hazards and damage to subsurface utilities. Clearance of intrusive activity areas must be obtained from appropriate authorities and site operators. This clearance comes in the form of 1) permission to enter a property, 2) ensuring subsurface conditions will not be encountered that endanger the safety of site personnel, subcontractors, and authorized visitors, and 3) demarcation of subsurface utilities/structures.

2.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

3.0 SITE ACCESS AND ENTRY

Access to properties subject to activities conducted under the contracted scope of services/work order is the responsibility of the client as set forth in the environmental engineering and consulting services agreement. The client will give reasonable access to client-owned properties for performance of services. If the client does not own or operate the property, it will secure an access agreement or other authorization for consultant access to the site that will address the terms of access as well as any access restrictions.

Site entrance procedures are as follows:

- The client will be advised of the date and time of site entrance and the purpose of the entrance.
- In addition, if the site is not owned by the client, the owner of the property will be advised of the date and time of site entrance and the purpose of the entrance.
- Entrance to the site shall be through the main gate or other entrance specified by the client or owner.
- If a site contact is present at the site, the consultant will introduce herself/himself and provide the site contact with a business card. The consultant shall also identify other personnel who are or will be on-site and explain their functions.
- The consultant will complete any general sign-in procedures required for site entrance, unless otherwise instructed by the client or property owner.
- If a liability waiver is presented that is not pre-agreed to by the consulting company and the client or owner, the consultant will call her/his Project Manager for instructions.
- If entry is refused, the consultant will leave the site entrance and call her/his Project Manager for instructions.
- The time of site entrance, or refusal of entrance will be included in the field logbook entry for the day.

4.0 SITE CLEARANCE

Site clearance is required prior to commencement of any investigation or remediation activities. Three categories of site clearance are required:

1. Property boundary identification,
2. Utility clearance, and
3. Clearance of any on-site subsurface obstructions, hazards or protected structures identified by the client or property owner.

4.1 Property Boundary Identification

The first step in site clearance is to demarcate the property boundaries. A client- or property owner-provided plat of survey will be used if available. If no current plat of survey is available, the client or property owner may be asked to have a licensed surveyor conduct a survey and mark the property boundaries or the consultant may hire a surveyor to conduct the survey on behalf of the client. All property boundaries should be fully known and marked prior to commencement of any site investigation activities. If an investigation location appears to be outside of the property boundaries that encompass the area to which access has been granted, the Project Manager shall be consulted prior to commencement of any activity at that location.

4.2 Utility Clearance

Written clearance of all underground utilities (private, commercial, and public) must be obtained prior to commencing intrusive site activities (e.g. soil borings, GeoProbe advancement, test pit or trench excavation). Utility clearance is vital for safe operations and provides notification to utility companies of intrusive work being conducted in the vicinity of underground lines and structures. The utility clearance process is initiated by calling a state- or city-specific one-call utility clearance hotline. One-call center information may be obtained by calling "811" or visiting http://www.call811.com/state-specific.aspx. Generally, utility clearance must be requested at least 48 hours in advance of the commencement of intrusive activities. In some states, including Illinois, utility clearance is the responsibility of the contractor performing the intrusive work (e.g. drilling subcontractor or excavation company) rather than the contracting environmental consultant.

Assemble the following information to make the call or provide this information to the subcontractor:

- Name, address and phone number of person making request;
- Type and extent (size of excavation) of work being performed;
- Start date and time of excavation;
- Address, including street, number, city, and county (township range, section and quarter section information may also be required);
- Nearest crossroad; and
- General legal description, if available.

The following table lists the one-call-center contact information for the Midwest.

	One Call System Name	Non-Emergency	Emergency	Website
Illinois (except City of Chicago)	J.U.L.I.E. Joint Utility Locating Information for Excavators	(800) 892-0123	- - -	http://www.illinois1call.com
City of Chicago	DIGGER	(312) 744-7000	- - -	http://www.cityofchicago.org
Indiana	I.U.P.P.S. Indiana Underground Plant Protection Service	(800) 382-5544	- - -	http://www.iupps.org
Iowa	Iowa One Call	(800) 292-8989	(800) 292-8989	http://www.iowaonecall.com
Kansas	Kansas One Call	(800) 344-7233	- - -	http://kansasonecall.com
Michigan	MISS DIG System Inc.	(800) 482-7171	- - -	http://www.missdig.org/MissDig/
Missouri	Missouri One Call System	(800) 344-7483	- - -	http://www.mo1call.com
Wisconsin	DIGGER	(800) 242-8511	(800) 500-9592	http://www.diggershotline.com

Utility location agencies may only mark-out utilities on public right-of-ways adjacent to the property under investigation and sewer and water departments may not be included in the locating services provided by the one-call centers. Request additional information from any utility companies or public utilities departments not included in the one-call locating services. It may be advisable at some properties to hire a private utility locating contractor to do additional on-site clearance prior to commencement of intrusive activities. Consult with the Project Manager about conducting additional locating activities if the information provided by the one-call center is not complete with respect to what is known about possible underground utilities at the site.

Do not proceed with any intrusive activities until all utility clearances and mark-outs have been performed by the locating services or participating utility companies. Do not proceed without verification from the subcontractor that the utility clearance has been performed if it was the subcontractor’s responsibility to request the utility locating service. Prior to start of intrusive activities, walk the site and surrounding public right-of-way with the subcontractor locating any utility markers and discuss procedures for avoiding marked utilities during the site investigation. If at any time, a potential hazard exists at a proposed investigation location that cannot be resolved with available information and utility location markings, contact the Project Manager for instructions.

4.3 On-Site Subsurface Obstructions, Hazards and Protected Structures Clearance

The property owner (client or third party) or a designated representative shall also be contacted prior to commencement of any intrusive activities to obtain additional information regarding on-site subsurface obstructions, hazards or protected structures and clearance to conduct the activities in pre-determined locations on the site. If possible, as part of the investigation planning activities, obtain architectural or engineering drawings of the site that include building layouts and locations of subsurface utilities and structures. Schedule an on-site meeting prior to commencement of activities to review locations of proposed locations for intrusive activities. Request that the owner or his authorized representative mark or flag the locations of any known subsurface obstruction, hazard or structure that must not be damaged. In some cases, it may be appropriate to make a site visit prior to the on-site review meeting to mark out proposed subsurface investigation locations for approval by the owner or his representative. During the review meeting, if verbal approval is given to proceed, make an entry in the field logbook including the date, time and person granting approval along with details of the approval given. Record any refusals of permission to perform intrusive activities in the same manner. Include detailed information regarding the reason for the refusal in the field logbook.

If permission for any proposed intrusive activities is refused by the property owner or his representative, inform the Project Manager. If the investigation location approval meeting is performed on a day scheduled for investigation activity, and any locations are not authorized by the owner or his representative, contact the site manager immediately for instructions. Do not proceed with any intrusive activity in the non-authorized locations unless subsequent approval is forthcoming, and do so only upon receiving approval to proceed from the owner/representative and the site Project Manager. Make a detailed record of the refusal and subsequent resolution in the field logbook.

On vacant or undeveloped sites, or sites located in remote areas, on-site client/owner approval of investigation areas may not be practical. In such situations, prior approval of investigation areas may be obtained from the client or owner by means of a site investigation map that includes investigation locations (boreholes, test pit or trench locations, monitoring wells, etc.). Site features, boundary lines, and any known subsurface utilities or structures shall also be included on the site investigation map to provide the reviewer with adequate information to determine if any subsurface hazards exist in the vicinity of any of the proposed intrusive activities.

5.0 REFERENCES

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

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-02

FIELD LOGGING AND CLASSIFICATION OF SOIL AND ROCKS
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for logging and classifying soil samples and rock cores during subsurface explorations as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface geologic conditions at a Site.

2.0 EQUIPMENT AND MATERIALS

General:

- Ruler or tape measure in 0.01-foot increments;
- Field logbook and field boring log forms;
- Pen(s) with waterproof, non-erasable ink;
- Camera;
- 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
- Aluminum foil or roll-plastic; and
- Personnel protective equipment, as appropriate, including nitrile gloves for handling impacted soil samples.

Soil Logging:

- Large sharp stainless-steel knife;
- Slim stainless-steel spatula or carpenter's 5-in-1 tool;
- Color chart;
- Comparative charts; and
- Pocket penetrometer.

Rock Coring and Logging:

- Core box(es);
- Hand lens; and
- Comparative charts.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

Geologic logging and material classification shall be conducted only by a trained logging technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist). Field data and observations associated with field logging and material classification shall be documented during logging and for all drilling and sampling activities in accordance with SOP ENV-01-01, Field Documentation and Reporting, if not otherwise specified in this SOP. All field drilling activities should be recorded in a field logbook and/or on a field boring log form. In addition, tools and equipment used while logging boreholes shall be decontaminated between boring/probe locations and prior to each sampling event in accordance with the Quality Assurance Project Plan (QAPP).

5.0 LOGGING AND DOCUMENTATION PROCEDURES

The logging technician shall record all pertinent drilling information in the field logbook and/or on the field boring log form (Attachment A). At a minimum, the following technical information with respect to pre-sampling, drilling operations and observations, and sample recovery loss shall be recorded, if applicable:

- Project name and number;
- Location (well or boring/probe number) or other sample station identification, including a rough sketch;
- Name of the logging technician overseeing the drilling operations;
- Drill rig manufacturer and model;
- Drilling company name and city and state of origin;
- Driller and assistant(s) names;
- Drilling method(s) and fluids used to drill the borehole;
- Drilling fluid manufacturer;
- Drilling fluid gain or loss;
- Depth of drilling fluid loss;
- Water source (e.g. fire hydrant, faucet, municipality, etc.);
- Borehole diameter;
- Borehole start time and date;
- Borehole completion time and date;
- Sample type (e.g. split spoon, macrocore, etc.);
- Hammer weight/drop and blow counts;
- Sample recovery/loss and explanation of loss, if known;
- Drilling rates when applicable to lithology classification;
- Description of soil and/or rock classification and lithology;
- Lithologic changes and boundaries;
- Depth to water (first encountered [during drilling] and stabilized [upon completion of drilling]);
- Total borehole depth;
- Evidence of impact (e.g. staining, odors, free-phase product, etc.);
- Well materials, construction, and placement information (e.g. casing type and diameter, screen type and diameter, etc.);
- Sample identifications and depths for chemical and geotechnical samples;
- A description of any tests conducted in the borehole; and
- Problems with the drill rig or drilling process.

When rock coring is performed, the following information shall also be recorded:

- Top and bottom of cored interval;
- Core length;
- Coring rate in minutes per foot;
- Core breakage due to discontinuities (e.g. natural fractures versus coring-induced breaks);
- Total core breakage; and
- Number of breaks per foot.

6.0 SOIL SAMPLE CLASSIFICATION AND DESCRIPTIONS

6.1 Description of Hierarchy

The required order of terms is as follows:

1. Depth measured in tenths of a foot;
2. Soil color;
3. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (e.g. silty CLAY);
4. Unified Soils Classification System (USCS) Group Symbol in parentheses (e.g. ML);
5. Evidence of environmental impacts, if encountered (e.g. free-phase product, staining, sheen, etc.);
6. Other soil components of the sample listed with the appropriate percent descriptor (i.e. “with”, “some” or “trace.”);
7. Consistency, relative density or degree of cementation;
8. Moisture and plasticity, if relevant; and
9. Miscellaneous (e.g. condition of sample, deposition, fractures, seams, bedding dip, bedding features, fossils, oxidation, drilling rate data when applicable for sample classification, etc.).

6.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory color(s) thereafter (e.g. clay, yellowish gray (5Y 7/2) with pale green (5G 7/2) mottles). If descriptors are used for other soil components, the color designation follows each descriptor.

6.3 Soil Types

Soil descriptions and classification shall be conducted in accordance with the USCS (ASTM D2488-06). The order and presentation of the primary textural classification terms is as follows:

1. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (gravelly, sandy, silty, or clayey). Nouns are unabbreviated (e.g. CLAY); “TOPSOIL” is an adequate single term for the naturally occurring organic soil found at the ground surface. In urban areas, “FILL” is used to denote previously disturbed soil, followed by a description of the major and minor soil components (e.g. “FILL, silty clay with some fine sand”). USCS Group Symbol follows the major soil component in parentheses.
2. Other soil components of the sample are listed in descending order of percentage using adjectives “with”, “some” and “trace.”
3. Using the Wentworth Scale in Attachment E, add size, sorting or angularity modifiers to granular material descriptions as appropriate.

6.4 Consistency and Relative Density

The relative density of cohesionless soils and the consistency of cohesive soils should be included in visual classifications. Attachments B and C can be used in describing the consistency of cohesive soils and the relative density of cohesionless soils, respectively.

A pocket penetrometer will be used to measure consistency of cohesive soils with the result recorded on the field boring log form. Attachment B includes information for determining soil consistency from penetrometer measurements.

6.4 Moisture Content

Moisture Content – Criteria for describing moisture content of soils are described in Attachment D.

6.5 Miscellaneous Descriptions

1. Structure – Some soils possess structural features (e.g. fissures, slickensides, or lenses) that if present, should be described.
2. Accessories or Inclusions – Elements such as rock fragments, fine roots, or nodules are included in the soil description following all other modifiers for the major components of the soil matrix. Any mineralogical or other significant components should be described, as well as man-made or apparently foreign constituents that indicate the presence and possible source of fill material.
3. Environmental Impacts – If monitoring instruments or visual observations indicate the potential presence of environmental impacts, it will be noted in detail. Additional information for describing specific types of impacts may be found in the Work Plan.

To provide consistency in logging soils, tables with additional guidelines for soil description are included in Attachment E.

7.0 ROCK CLASSIFICATION

7.1 Lithology and Texture

The logging technician should describe the lithology of the rock and its mineral composition. The geological name, such as granite, basalt, or sandstone, usually describes the rock's origin. The stratigraphic unit should be identified and assigned the local geological name, if appropriate. Stratigraphic age or period should be identified, if possible. Modifiers will be included to describe the rock texture, including grain size, sorting, packing, cementation, etc. (e.g. interlocking, cemented, or laminated-foliated).

7.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory colors thereafter. If secondary or tertiary descriptors are used, the color designation follows each descriptor.

7.3 Hardness

Terms used to describe hardness are described below. One common method to determine hardness is the Mohs Scale of Hardness, which is defined as follows:

Descriptive Term	Defining Characteristics
Very Hard	• Cannot be scratched with a knife. • Does not leave a groove on the rock surface when scratched.
Hard	• Difficult to scratch with a knife. • Leaves a faint groove with sharp edges.
Medium	• Can be scratched with a knife. • Leaves a well-defined groove with sharp edges.
Soft	• Easily scratched with a knife. • Leaves a deep groove with broken edges.
Very Soft	• Can be scratched with a fingernail.

7.4 Weathering

Terms used to describe weathering are described below (ASTM D 5434-03):

Descriptive Term	Defining Characteristics
Fresh	• Rock is unstained. • May be fractured, but discontinuities are not stained.
Slightly	• Rock is unstained. • Discontinuities show some staining on the surface, but discoloration does not penetrate rock mass.
Moderate	• Discontinuous surfaces are stained. • Discoloration may extend into rock mass along discontinuous surfaces.
High	• Individual rock fragments are thoroughly stained and can be crushed with pressure of a hammer. • Discontinuous surfaces are thoroughly stained and may crumble.
Severe	• Rock appears to consist of gravel-sized fragments in “soil” matrix. • Individual fragments are thoroughly discolored and can be broken with fingers.

7.5 Rock Matrix Descriptions

Grain size is a term that describes the fabric of the rock matrix. It is usually described as fine-grained, medium-grained or coarse-grained. The modified Wentworth scale should be used or as required by the Work Plan or otherwise specified.

A description of bedding (after Ingram, 1954) or fracture joint spacing should be provided according to the following:

Spacing	Bedding	Joints/Fractures
< 1 inch	Very thin	Very close
1 – 4 inches	Thin	Close
4 inches to 1 foot	Medium	Moderately close
1 foot to 4.5 feet	Thick	Wide
> 4.5 feet	Very Thick	Very Wide

Discontinuity descriptors are terms that describe number, depth, and type of natural discontinuities. They also describe density, orientation, staining, planarity, alteration, joint or fractural fillings and structural features.

8.0 ROCK CORE HANDLING

The following guidelines shall be followed for rock core handling:

1. Core samples must be placed into core boxes in the sequence of recovery, with the top of the core in the upper left corner of the box.
2. At the bottom of each core run, spacer blocks must be placed to separate the runs. The spacer should be indelibly labeled with the drilling depth to the bottom of the core run regardless of how much core was actually recovered from the run.
3. Spacer blocks should be placed in the core box and labeled appropriately to indicate zones of core loss, if known. Where core samples are removed for laboratory testing, blocks equal to the core length removed should be placed in the box. Note: If wooden core boxes are used, spacer blocks should be nailed securely in place.

4. The core boxes for each boring should be consecutively numbered from the top of the boring to the bottom.
5. The core boxes containing recovered rock cores should be photographed. One core box should be photographed at a time with the box lid framed in the picture to include information printed on the inside of the lid. Be sure to include a legible scale in the picture. Photographs are taken in the field most easily and efficiently with natural light and while the core is fresh.
6. When transporting a boxed core, the box should be moved only if the lid is closed and secured with tape or nails.

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2007, D653-07b Terminology Relating to Soil, Rock, and Contained Fluids.

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2006, D2488-06 Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM International, 2001, D4083-89R01E01 Practice for Description of Frozen Soils (Visual-Manual Procedure).

ASTM International, 2007, D4543-07 Practice for Preparing Rock Core Specimens and Determining Dimensional and Shape Tolerances.

ASTM International, 2002, D5079-02 (2006) Practice for Preserving and Transporting Rock Core Samples.

ASTM International, 2003, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, 2000, D5715-00 (2006) Test Methods for Estimating the Degree of Humification of Peat and Other Organic Soils (Visual/Manual Method).

ASTM International, 2004, D6236-98 (2004) Guide for Coring and Logging Cement- or Lime-Stabilized Soil.

ASTM International, 2004, D7099-04 Terminology Relating to Frozen Soil and Rock.

Johnson, R.B., and J.V. DeGraff, 1988, Principles of Engineering Geology, John Wiley and Sons, New York.

U.S. Army Corps of Engineers, 2001, Engineering Manual EM1110-1-1804 - Engineering and Design - Geotechnical Investigations, January 1.

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

Wentworth, C.R., 1922, A scale of grade and class terms for clastic sediments, Journal of Geology, 30: 377-392.

ATTACHMENT A
DRILLING LOG

Drilling Log

	Project Name	Project No.	Boring/Monitoring Well Number
	Site-Specific Coordinates	Ground Elevation	Page 1 of 1
	Total Depth (feet) / Hole Size (inches)	Driller (s)	
Drilling Rig		Drilling Company	
Date / To	Logged By:	Reviewed by:	Approved by:

Elevation (feet)	Depth (feet)	Description	Graphic Log	SAMPLING: Sample Type	Sample Interval	Blow Counts per 0.5'	N Value	Sample Recovery/Length (feet)	Penetro-meter (TSF)	PID Reading (PPM)	Remarks
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										

▽ Depth to water while drilling

▼ Depth to water after drilling

ENVIRONMENTAL LOG COPY OF OSI 2003.GPJ BURNS_MO.GDT 8/30/07

ATTACHMENT B
CONSISTENCY OF COHESIVE SOILS

Author: T. Gilles Q2R & Approval By: C. Barry Q3R & Approval By: M. Kelley

CONSISTENCY OF COHESIVE SOILS

Consistency	Rule-of-Thumb	Blows Per Foot[1] (N value)[2]	Penetrometer (tons/ft^2)
Very Soft	Core (height = twice diameter) sags under own weight	0 – 1	0.0-0.25
Soft	Can be easily pinched in two between thumb and forefinger	2 – 4	0.26-0.49
Firm (Medium Stiff)	Can be imprinted easily with fingers	5 – 8	0.5-0.99
Stiff	Can be imprinted with considerable pressure from fingers	9 – 15	1.0-1.99
Very Stiff	Barely can be imprinted by pressure from fingers	16 – 30	2.0-3.99
Hard	Cannot be imprinted by fingers	> 30	4.0+

Notes:

1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT C
RELATIVE DENSITY OF COHESIONLESS SOILS

RELATIVE DENSITY OF COHESIONLESS SOILS

Consistency	Rule-of-Thumb	Blows Per Foot (N value)[2]
Very Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	0 - 4
Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	4 - 10
Medium Dense	Easily penetrated with a ½-inch diameter steel rod driven with a 5-pound hammer	11 - 30
Dense	Penetrated a foot with a ½-inch diameter steel rod driven with a 5-pound hammer	31 - 50
Very Dense	Penetrated only a few inches with a ½-inch diameter steel rod driven with a 5-pound hammer	> 50

Notes:
1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT D
CRITERIA FOR ESTIMATING MOISTURE CONTENT OF SOILS

CRITERIA FOR ESTIMATING MOSITURE CONTENT OF SOILS

Adapted from USACE EM 1110-1-1804 and ASTM D 2488-06

Term	Description of Relative Moisture
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, no visible water
Wet	Fine grained: well above optimum water content Coarse grained: visible free water
Saturated	Water is dripping from sample, usually encountered below water table

ATTACHMENT E
STANDARD SOIL DESCRIPTORS

Author: T. Gilles **Q2R & Approval By:** C. Barry **Q3R & Approval By:** M. Kelley

STANDARD SOIL DESCRIPTORS

Grain Size Terminology		
Soil Type		**Diameter**
Boulders		12-inches or greater
Cobbles		3- to 12 inches
Gravel	Coarse	0.75-inch to 3 inches
	Fine	0.19-inch to 0.75-inch
Sand	Very Coarse	1 mm to 2 mm
	Coarse	0.5 mm to 1 mm
	Medium	0.25 mm to 0.5 mm
	Fine	0.06 mm to 0.25 mm
Silt		0.004 mm to 0.06 mm
Clay		Less than 0.004 mm

Notes:
1) mm = millimeter
2) Based on Wentworth Grain Size Scale for Sediment (Wentworth 1922).
3) This terminology can also be used to describe clast size in rock cores.

Estimated Plasticity for Silt and Clay Content		
Thread Diameter (inches)	**Plasticity Index (PI)**	**Identification**
1/4	0	Silt
1/8	5 – 10	Clayey Silt
1/16	10 – 20	Clay and Silt
1/32	20 – 40	Silty Clay
1/64	40	Clay

Relative Proportions of Components	
Descriptive Term	**Percent**
Trace	1 – 10
Little	11 – 20
Some	21 – 30
And	30 – 50

Adapted from ASTM D2488-06

Author: T. Gilles **Q2R & Approval By:** C. Barry **Q3R & Approval By:** M. Kelley

STANDARD DESCRIPTORS – VISUAL OBSERVATIONS OF NAPL

Descriptive Term	Definition
No Visible Evidence	No visible evidence of oil on soil or sediment sample
Sheen	Any visible sheen in the water on soil or sediment particles or the core
Staining	Visible brown or black staining in soil or sediment; can be visible as mottling or in bands; typically associated with fine-grained soil or sediment
Coating	Visible brown or black oil coating soil or sediment particles; typically associated with coarse-grained soil or sediment such as coarse sand, gravels, and cobbles.
Oil Wetted	Visible brown or black oil wetting the soil or sediment sample; oil appears as a liquid and is not held by soil or sediment grains

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley
Update:	S. Wiskes	Q2R & Approval By:	T. Norris	Q3R & Approval By:	B. Hennings

STANDARD OPERATING PROCEDURE
NO. SAS-05-05

BOREHOLE AND WELL ABANDONMENT
Revision 3

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for borehole and well abandonment. When boreholes and wells are no longer needed to complete project goals and objectives, they must be properly abandoned to prevent them from acting as a conduit for migration of contaminants from the ground surface to the water table or between transmissive zones.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on borehole and well accessibility and depth and well construction. Field personnel should use the equipment and materials required by the Site-Specific Work Plan or otherwise specified for the project. All non-disposable equipment shall be decontaminated before and after introduction into borehole or well. Equipment Decontamination should be performed in accordance with SOP SAS-04-05 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Borehole and well abandonment procedures should meet applicable regulatory agency requirements. Well abandonment procedures are dependent upon several factors which include:

- Geologic data availability
- Aquifer formation (creviced consolidated)
- Aquifer formation (non-creviced consolidated)
- Aquifer formation (unconsolidated)
- More than one water bearing formation

In addition, licensing and/or certification of the driller are typically required however licensing requirements vary by state. Please refer to the applicable Illinois and Wisconsin Administrative Codes referred to in Section 6.0 of this SOP. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) with knowledge of the applicable state regulations should be present during well abandonment to document the activities. The supervising technician should complete and submit a well abandonment form, as required, to the appropriate regulatory agency. Attachment A contains the Illinois Department of Public Health Water Well Sealing Form as an example. If wells are abandoned in other states, the relevant forms and procedures shall be implemented. A brief description of the Wisconsin and Illinois abandonment procedures is provided below.

WISCONSIN – NR141.25(2) Abandonment Procedures

(a) *Boreholes.* Any borehole intersecting the water table or greater than 10 feet deep, whose use has been discontinued, shall be abandoned according to the requirements of part (d).

(b) *Monitoring wells* - *impermeable annular space seals.* A permanent groundwater monitoring well known to be constructed with an impermeable annular space seal shall be abandoned according to the requirements of part (d) after the protective cover pipe and ground surface seal have been removed and the well casing cut off at least 30 inches below the ground surface. The well casing may be completely removed during abandonment by pulling the well casing, overdrilling around the casing and then pulling the well casing out of the ground or by drilling out the well casing completely. If the well casing is to be removed, the well shall be sealed as the casing is removed.

(c) *Monitoring wells* - *permeable annular space seals and wells in waste areas.* A groundwater monitoring well not known to be constructed with an impermeable annular space seal or located in an existing or planned future waste disposal or treatment area shall be abandoned by removing the protective cover pipe and the ground surface seal and then completely removing the well casing. The well casing shall be pulled out of the ground as the well is filled according to the requirements of part (d)

(d) *Sealing requirements.* Boreholes and groundwater monitoring wells shall be abandoned by complete filling with neat cement grout, bentonite-cement grout, sand-cement grout, concrete or bentonite-sand slurry. When a tremie pipe is used to place the sealing material, the procedures of s. NR 141.10 (2) shall be followed. A tremie pipe shall be used to abandon groundwater wells and boreholes greater than 30 feet in depth or with standing water. Groundwater monitoring wells and boreholes greater than 100 feet in depth shall be sealed with a tremie pipe-pumped method. Bentonite may be used as a sealing material without the use of a tremie pipe under the following conditions:

1. Bentonite granules may be used for abandonment of boreholes and groundwater monitoring wells less than 25 feet deep and when there is no standing water above the filter pack seal.

2. Bentonite chips no greater than 3/8 inch in diameter or bentonite pellets may be used for abandonment of boreholes and groundwater monitoring wells less than 50 feet deep and the depth of standing water is less than 30 feet.

3. Bentonite chips no greater than 3/8 inch in diameter or bentonite pellets may be used for abandonment of boreholes and groundwater monitoring wells which are greater than 4 inches in diameter and less than 250 feet deep and the depth of standing water is less than 150 feet.

ILLINOIS – Section 920.120 Abandoned Wells (b) Sealing Requirements

Where geologic data does not exist for a particular abandoned drilled water well, the water well shall be sealed, from the bottom up to where the well casing is removed, with neat cement grout or any bentonite product manufactured for water well sealing. Water wells, borings or monitoring wells that are abandoned shall be disinfected by introducing a sufficient amount of chlorine to produce 100 parts per million of chlorine in the water in the well and shall be sealed by placing the sealing materials from the bottom of the well to the surface by methods that will avoid segregation or dilution of material, in accordance with the following requirements:

1) Non-creviced, Consolidated Formations. Wells extending into non-creviced sandstone, or other water-bearing consolidated formations shall be sealed by filling the well with disinfected clean pea gravel or limestone chips to within 10 feet below the top of the water-bearing formation or to within 10 feet of the bottom of the casing, whichever is less. Neat cement grout or any bentonite product manufactured for water well sealing shall be placed for a minimum of 20 feet above this point. The upper part of the well to where the well casing is removed shall be sealed by neat cement grout or any bentonite product manufactured for water well sealing. Concrete or cement may be used for sealing if the upper part of the well is dry.

2) Creviced Formations. Wells extended into creviced formations shall be sealed by filling with disinfected clean pea gravel or limestone chips to within 10 feet below the top of the water-bearing formation or to within 10 feet below the bottom of the casing, whichever is less. Neat cement grout or any bentonite product manufactured for water well sealing shall be placed for a minimum of 20 feet above this point. The upper part of the well to where the well casing is removed shall be sealed by neat cement grout or any bentonite product manufactured for water well sealing. Concrete or cement may be used for sealing if the upper part of the well is dry. If the earth cover is less than 30 feet, the hole shall be grouted from 10 feet below the creviced formation to where the well casing is removed.

3) Unconsolidated Formations. If the water-bearing formation consists of coarse gravel and producing wells are located nearby, the well shall be sealed by filling with disinfected clean pea gravel or limestone chips to 10 feet below the top of water-bearing formation. Neat cement grout or any bentonite product manufactured for water well sealing shall be placed for a minimum of 20 feet above this point. The upper part of the well to where the well casing is removed shall be sealed by neat cement grout or any bentonite product manufactured for water well sealing. Concrete or cement may be used for sealing if the upper part of the well is dry. Abandoned dug and bored wells shall be sealed by using one of the following methods:

   A) Filling with disinfected clean pea gravel or limestone chips to within 20 feet below the top of the casing. The upper part of the well to where the well casing is removed shall be sealed for a minimum of 20 feet by filling with neat cement grout, any bentonite product manufactured for water well sealing, or impervious material such as clay. Concrete or cement may be used for sealing if the upper part of the well is dry;

   B) Placing a one foot layer of any bentonite product manufactured for water well sealing at the bottom of the well, followed by alternating layers of agricultural limestone (limestone fines) and any bentonite product manufactured for water well sealing. The alternating layers of agricultural lime shall be 5 to 7 feet thick and the alternating layers of any bentonite product manufactured for water well sealing shall be 6 inches thick. The uppermost or top layer shall be agricultural lime; or

   C) Completely filling with concrete, cement grout or impervious material such as clay.

4) More than One Water-Bearing Formation. If wells extend into more than one water-bearing formation, each water-bearing formation shall be sealed independently in the manner described in this Section. Neat cement grout or any bentonite product manufactured for water well sealing shall be placed a minimum of 10 feet above and below at all intermittent water-bearing formations except artesian wells and artesian formations. Disinfected clean pea gravel or limestone chips shall be placed in each water-bearing formation between plugs. When the lower formation has an upflow of water into the upper formation, a pressure seal is required to shut off the upflow while a neat cement plug at least 50 feet in length is pumped in place and allowed to set. The upper part of the well to where the well casing is removed shall be sealed with neat cement grout or any bentonite product manufactured for water well sealing. Concrete or cement may be used for sealing if the upper part of the well is dry.

5) Artesian Wells. A cement retainer shall be used with pressure grouting equipment used to place cement grout. Neat cement grout, containing bentonite from 2% to 6% by dry weight, shall be placed for a minimum of 10 feet below and 10 feet above the water bearing formation. The upper part of the well to where the well casing is removed shall be filled with neat cement grout or any bentonite product manufactured for water well sealing. Concrete or cement may be used for sealing if the upper part of the well is dry.

6) Buried Slab Bored Wells. Wells shall be sealed by filling with disinfected clean pea gravel or limestone chips to within 1 foot below the buried slab. The upper part of the well to where the casing is removed shall be sealed with neat cement or any bentonite product manufactured for water well sealing.

7) In lieu of filling the well with disinfected clean pea gravel or limestone chips as required in subsections (b)(1) through (6), wells may be sealed by grouting from the bottom up by using neat cement grout or any bentonite product manufactured for water well sealing. This material shall be applied the full depth of the well and shall terminate within 2 feet of the ground surface. Concrete grout may be used in the upper part of the well if the upper part of the well is dry.

5.0 EXECUTION

Taking into account the applicable state requirements noted above, unless otherwise specified in the Site-Specific Work Plan, either of the following guidelines shall be followed.

5.1 OVERDRILLING WELL ABANDONMENT METHOD

One well abandonment method is to completely remove the well casing and screen from the borehole. This may be accomplished by auguring with a hollow-stem auger over the well casing (overdrilling) down to the bottom of the borehole, thereby removing the grout, bentonite seal, and filter pack from the hole. The well casing shall then be removed from the borehole with the drill rig. The remaining borehole and boreholes not utilized for the construction of a monitoring well, will be subsequently backfilled with the appropriate backfill material. The backfill material (e.g. hydrated bentonite, Neat Portland cement, etc.) shall be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method) to within 30 inches of the ground surface. Bentonite should be hydrated with potable water in lifts not to exceed 5 feet. Neat cement shall be made of the following composition; Neat cement is a mixture of Type I Portland cement and water in the proportion of 5 to 6 gallons of clean water per bag (94 pounds or 1 cubic foot) of cement mixed with 2% to 6% of bentonite by weight. The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs unless land use requires a design modification to use native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) to bring the former well location to grade. If the area has heavy traffic and/or construction use, the location will be barricaded until the plug has cured or concrete plug recessed below ground surface will be used to maintain the surface seal. This abandonment method can typically be accomplished on small-diameter wells (4-inches or less in diameter).

On large-diameter wells (diameter greater than 4-inches) with little to no grout, a drill stem with a tapered wedge assembly or solid-stem auger should be used to ream out the borehole and extract the well materials. Wells that are badly corroded and/or have thickly grouted annular space have a tendency to twist and/or break off in the borehole. Should this occur, the well would be grouted with the remaining casing left in the borehole. In this case, the well and borehole shall be pressure grouted by placing a tremie pipe in bottom of the well casing, which will be the well screen or bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter pack and up the inside of the well casing sealing holes and breaks that are present. The tremie pipe shall be retracted slowly as the grout fills the casing. The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs. The well casing shall then be cut off at least 30 inches below. Native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) may be used to bring the former well location to grade. If the casing has been broken off below the surface, the grout shall be tremied to within 30 inches of the ground surface and then finished similar to the surrounding features.

Brittle polyvinyl chloride (PVC) well casings may be more difficult to remove from the borehole than stainless-steel casings. If the PVC well casing breaks during removal, the borehole shall be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by the drilling fluid. Another method is to use a solid-stem auger with a carbide auger head to grind the PVC casing into small cuttings that will be brought to the surface by the rotating flights. After the casing materials have been removed from the borehole, the borehole shall be cleaned out and pressure grouted with the approved grouting materials. As previously stated, the borehole shall be finished with a concrete surface plug or site-specific surface restoration material with adequate surface protection, unless otherwise directed or required by the Site-Specific Work Plan.

5.2 IN-PLACE WELL ABANDONMENT METHOD

5.2.1 Cement Grout

The in-place monitoring well or borehole abandonment method completely fills the monitoring well or borehole with concrete, cement grout, or a low permeability material such as bentonite. When using concrete or cement grout the monitoring well or borehole shall be pressure grouted by placing a tremie pipe in bottom of the well casing, which will be the well screen or bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter pack and up the inside of the well casing sealing holes and breaks that are present. The tremie pipe shall be retracted slowly as the grout fills the casing. The well casing shall then be cut off at least 24 inches below ground surface. Native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) may be used to bring the former well location to grade.

When grout is used for abandonment care should be taken in coarser-grained aquifers or where wells are nested close together as grout can travel or migrate in sand and gravel aquifers. Each well location should be evaluated to see if grout migration may be a concern. If grout migration is a concern, a thicker grout should be mixed or use of bentonite pellets or chips should be used in place of grout if possible.

5.2.2 Dry Bentonite

When granular bentonite, bentonite pellets or bentonite chips are used to abandon the monitoring well or boreholes the following guidelines shall be followed.

- Granular bentonite should be used only when the borehole or well is less than 25 ft deep and when there is no standing water above the filter pack.
- Bentonite chips no greater than 3/8 inch in diameter or bentonite pellets should be used for abandonment of boreholes or monitoring wells less than 50 ft deep and the depth of standing water is less than 50 ft.

Granular bentonite, bentonite chips or bentonite pellets should be placed slowly into the monitoring well or borehole to be sure they reach the bottom of the well to prevent bridging in the well. When the material has risen to the top of the well casing or borehole clean water shall be poured into the well to hydrate the bentonite material. The well casing shall then be cut off at least 24 inches below ground surface. Native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) may be used to bring the former well location to grade.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2005, D5299-99 (2005) Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

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

Illinois Administrative Code, Title 77: Public Health Chapter I: Water and Sewage Part 920 Illinois Water Well Construction Code Section 920.120 Abandoned Wells

Wisconsin Administrative Code, Chapter NR 141.25, Abandonment Procedures, March 2011

USEPA, 1991 Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA160014-891034

ATTACHMENT A
BOREHOLE / WELL ABANDONMENT FORM

BOREHOLE / WELL ABANDONMENT FIELD FORM

PROJECT INFORMATION

Site: ________________ Client: ________________

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

Field Personnel: ________________ Finish Date: ________ Time: ________

GENERAL INFORMATION

Ownership (Controlling Party): ________________

Street Address: ________________

City: ________________

County: ________________

State: ________ Zip: ________

Township: ________ Range: ________ Section: ________

________ 1/4 of the ________ 1/4 of the ________ 1/4

If Known, Latitude: ________ Longitude: ________

If Known*, Northing: ________ Easting: ________

*Coordinate System: ________________

Reason for Abandonment:

Permit Number (If applicable): ________________

BOREHOLE / WELL INFORMATION

Borehole / Well ID: ________ Unique Well ID:

Installation Date: ________

☐ Borehole

☐ Monitoring Well

☐ Water Well

(Attach Well Completion Report, if available)

☐ Other (specify): ________

Construction Type:

☐ Drilled ☐ Driven (Sandpoint)

☐ Other (specify): ________

Formation Type:

☐ Unconsolidated Materials ☐ Bedrock

Borehole/Well Details:

Borehole Diameter: ________ Inches

Total Borehole Depth: ________ FT BGS

Casing Diameter: ________ Inches ☐ Not Applicable

Total Casing Depth: ________ FT BGS ☐ Not Applicable

Depth to Water: FT BGS ☐ Not Encountered

SEALING INFORMATION

Pump & Piping Removed? ☐ Yes ☐ No ☐ Not Applicable

Liner(s) Removed? ☐ Yes ☐ No ☐ Not Applicable

Screen Removed? ☐ Yes ☐ No ☐ Not Applicable

Entire Casing Removed? ☐ Yes ☐ No* ☐ Not Applicable

If No, Upper 2 feet Removed? ☐ Yes ☐ No

Method of Sealing Material Placement:

☐ Conductor Pipe - Gravity ☐ Tremie Pipe - Pumped

☐ Screened & Poured ☐ Other (specify): ________

Sealing Material Rose to Surface? ☐ Yes ☐ No

Material Settled After 24 Hours? ☐ Yes* ☐ No

*If Yes, Was Hole Re-Topped? ☐ Yes ☐ No

Sealing Material Used	From	To	Volume/Quantity
	Surface		

SEALING WORK PERFORMED BY

Individual's Name: ________ License Number:

Company Name: ________

Street Address: ________

City: ________ State: ________ Zip: ________

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-06

TEST PIT EXCAVATION, LOGGING AND SAMPLE COLLECTION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for conducting test pit excavation, logging and sample collection as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface conditions at the site.

2.0 EQUIPMENT AND MATERIALS

- General:
  - Excavator or backhoe;
  - Metal shovel;
  - Spray paint or survey lathe and tape;
  - Visquene sheeting;
  - Tape measure in 0.01-foot increments;
  - Field logbook and field boring log forms;
  - Pen(s) with waterproof, non-erasable ink;
  - 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
  - Aluminum foil or roll-plastic wrap;
  - Stakes and fluorescent flagging tape;
  - Camera; and
  - Personnel protective equipment, as appropriate.
- Soil Logging:
  - Knife, spatula, carpenter's 5-in-1 tool or similar cutting tool;
  - Soil color chart;
  - Comparative charts; and

Author: T. Gilles | Q2R & Approval By: C. Barry | Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-06-01

SOIL SAMPLING FOR CHEMICAL ANALYSES AND GEOTECHNICAL TESTING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining surface and subsurface soil samples as stated in the Site-Specific Work Plan or as otherwise specified. Soil sampling is conducted for the purpose of chemical analyses and geotechnical testing to evaluate surface and subsurface conditions.

2.0 EQUIPMENT AND MATERIALS

In addition to materials provided by a subcontractor, the field personnel should have the following:

- Sample bottles/containers and labels;
- Sample cutting/extracting equipment (scoops, trowels, shovels, hand augers);
- Field logbook and/or the appropriate field form(s);
- Depth and length measurement devices with 0.01-foot measurement units;
- Camera;
- Stakes and fluorescent flagging tape;
- Decontamination materials;
- Coolers and ice;
- Chain of custody forms;
- Custody seals;
- Gallon size sealable plastic bags;
- Clear plastic packaging tape; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE TYPE, METHOD, AND EQUIPMENT SELECTION

4.1 Preparation

Site-Specific Work and/or Field Sampling Plans (FSP) which involve soil sampling shall be carefully conceived with respect to data quality objectives (DQOs) and cost effectiveness. Soil samples shall be strategically located to collect a representative fraction of soils with the minimum number of samples. To facilitate complete and successful sampling efforts by minimizing uncertainties with respect to site characterization the following factors shall, at a minimum, by considered during preparation activities:

- Project goals and DQOs;
- Location and duration of historical property uses (if available);
- Location and duration of current property uses;
- Chemical properties of contaminants of potential concern (COPCs);
- Anticipated location(s) of COPCs (e.g. surface, subsurface, etc.);
- Anticipated geologic conditions including presence and elevation of groundwater;
- Site accessibility; and
- Results of previous site reconnaissance and investigations (if available).

4.2 Field Considerations

Field personnel shall review and be familiar with Site-Specific Work and/or FSPs prior to commencement of sampling activities. Field personnel will also facilitate complete and successful sampling efforts by calibrating and operating field instruments/meters used for sample media screening in accordance with SOP ENV-02-01. In addition, field personnel shall be cognizant of the following during investigative activities:

- Indications of COPCs not previously anticipated;
- Evidence (e.g. visual, olfactory, etc.) of COPCs in locations not previously anticipated;
- Geologic conditions not anticipated;
- Changes in site accessibility; and
- Meteorological conditions (e.g. high humidity, rain, etc.) that have the potential to negatively impact operation and performance of field screening instruments, and sample quality.

Field personnel shall notify the Project Manager when field conditions and observations deviate from those anticipated during sampling event preparations. The Project Manager shall approve any deviation from the Work and/or Sampling Plans prior its occurrence. Deviations and approval to deviate from Site-Specific Work and/or FSPs shall be documented in the field logbook and/or on the appropriate field form by the field personnel.

5.0 SAMPLE TYPES

5.1 Grab Samples

Grab samples are collected to identify and quantify compounds at a specific location or interval. Grab samples are limited in areal and vertical extent. A grab sample shall be comprised of no more than the minimum amount of soil necessary to obtain the volume of sample dictated by the required sample container.

5.2 Composite Samples

Composite samples are a mixture of a given number of sub-samples/aliquots and are collected to characterize the average composition of a given surface area, vertical interval, etc. The number of sub-samples/aliquots forming a composite sample shall remain consistent with the context of the investigation. The number and pattern for collection of sub-samples/aliquots within a grid, interval, etc. shall be selected based on project goals and DQOs and shall not change. Composite sampling is associated with two potential interferences:

1. Low concentrations, if present in individual sub-samples/aliquots, may be diluted to the extent that the total composite concentration is below the analytical reporting limits.
2. Sub-samples/aliquots that are predominantly moist clay can be difficult to composite to produce a homogenous mixture. The resulting sample, as represented by the portion selected by the analytical chemist, may not be representative of an average of all the sub-samples/aliquots.

6.0 SAMPLING METHOD

6.1 Random

Random sampling removes the subjective collection of samples based on personal judgment. Soil samples are typically selected from all investigation area(s) when a suspected area of contamination is unknown. Generally, this method is utilized with site screening investigations when there is no strong indication of contamination or distinct depositional areas are present that provide excellent screening samples.

6.2 Biased

Biased sampling involves the collection of samples based on evidence of contamination (e.g. staining, stressed vegetation, elevated field screening results, etc.). Background and control samples are also considered biased, since they are collected from locations anticipated to be impacted or expected to be clean.

6.3 Grid-Based

Grid-based sampling involves the systematic collection of samples based on the size and configuration of an area. This approach is used to characterize the presence and distribution of contaminants and is commonly utilized for large areas. Grid size will be selected during the preparation phase and shall be specified in the Work or Sampling Plan. Common grid sizes shall be developed based on the size and configuration of the area, project goals, and DQOs. It may be appropriate and acceptable to integrate several different grid sizes in a single investigation.

When a Site is extremely large (typically over several acres), it may not be practical and cost-effective to consider sampling every grid. In this case, it will be necessary to statistically select a sub-set of the total number of grids in order to reduce the number of samples collected. On the other hand, it may be more appropriate to use relatively inexpensive screening level analytical techniques to define the areas that will need to be sampled and analyzed for a higher level of data quality. In all cases, grid points shall be located using a site survey and shall be semi-permanently marked to facilitate relocating the sample locations for subsequent sampling.

7.0 SAMPLING EQUIPMENT AND PROCEDURES

7.1 Manual Sampling

In general, hand sampling using manually operated equipment is a quick and inexpensive sampling technique for shallow depths when precise data or high quality control is generally not required. The most common hand-operated samplers are hand augers, plugs, tubes, split-barrel or fixed piston samplers that are pushed or driven by hand.

Hand augers are easily used at depths less than 10 feet. The most commonly used, manually-operated hand augers include the ship, closed-spiral, and open-spiral augers. In operation, a hand auger shall be attached to the bottom of a length of pipe that has a cross-arm at the top. The hole shall be drilled by turning this cross-arm at the same time the operator presses the auger into the ground. As the auger is advanced and becomes filled with soil, it shall be taken from the hole, and the soil shall be removed. Additional lengths of pipe will be added as required to reach the sampling depth as required by the Site-Specific Work Plan or otherwise specified. Care shall be taken to prevent (to the extent possible) mixing of the soil from upper portions of the hole with lower samples. This is most likely to be a problem when augers are used to advance a hole and obtain samples from soil cuttings.

Pushed samplers can be used to obtain samples within about 3 feet of the surface or, with appropriate extensions, ahead of an augured hole. The sampler will be pushed to the desire depth by the operator. The pusher sampler shall be used with extension(s) and/or in combination with a hand auger to reach sample depths greater than 3 feet below ground surface. When the sampler becomes filled with soil, it shall be taken from the hole and the soil removed. Care shall be taken to prevent mixing of soil from upper portions of the hole with lower samples.

Because of the unpredictable operations that may have been used at many uncontrolled waste sites, sampling devices will never be forced into an abruptly hard material. The stiffness may be a natural lithology change, a rock ledge or cobble, or a buried drum. If resistance is encountered while auguring or pushing a sampler, the procedure will be stopped. The depth at which resistance was met should be recorded into the field logbook and/or on the appropriate field form.

7.2 Split-Spoon Sampler

The split-spoon sampler is a thick-walled steel tube that is split lengthwise. A cutting shoe is attached to the lower end of the barrel; the upper end contains a check valve and is connected to the drilling rods. When a boring is advanced to the point that a sample is to be taken, drill tools are removed, and the sampler is lowered into the hole attached to the bottom of the drill rods.

The split-spoon sampler is driven by a 140-lb hammer falling 30 inches. The split-spoon sampler shall be driven 18 inches into the ground or until 50 blows have been applied in a 6-inch increment, a total of 100 blows have been applied, or there is no observable advance of the sampler after 10 successive blows. The effort taken to drive the sampler shall be recorded at 6-inch intervals and the sampler shall be removed from the boring. The density of the sampled material shall be determined by summing the blow counts for the second and third 6 inches of penetration ("standard penetration resistance" or "N-value") per ASTM D 1586-99. Only disturbed samples are obtained using this procedure.

The standard size split-spoon sampler is 2-inch outside diameter (OD), $1^3/8$-inch inside diameter (ID), and 24 inches long. When soil samples are taken for chemical analysis, a 2- or 2½-inch ID sampler shall be used to provide a larger volume of material, but cannot be used to calculate strength or density properties as stated in the ASTM D 1586-99 test method.

Upon retrieval, excess soil or drilling fluid shall be rinsed or wiped from the sampler's exterior, the cutting shoe removed, and sampler broke open into the two halves. The sample shall be logged and classified in accordance with SOP ENV-05-03. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated. The split-spoon sampler shall be decontaminated between sample intervals in accordance with SOP ENV-04-05.

Liner tubes or sleeves may be incorporated in certain samplers to contain samples temporarily. The liner tubes may be constructed from brass, plastic, or other inert materials used to store and transport the samples. If a sample is to be stored in the liner tube, the tube ends shall first be covered with Teflon film, followed by a plastic slip cap. On each sample end, the Teflon film shall be trimmed, and the cap sealed with vinyl tape to the liner tube. If the sampler is not to be stored in the liner, it will be transferred from the sampler to the appropriate sample container using either the liner tube or a stainless steel or plastic spoon or spatula.

When taking samples for geotechnical testing, the disturbed soil samples shall be removed from the sampler are placed in a sealable glass jar or other containers approved by the geotechnical laboratory and labeled to indicate the project name and number, boring number, sample number, and depths at top and bottom of the sample interval. This information shall be marked on the jar lid using a permanent marker. Other information required by the Site-Specific Work and/or FSP shall be recorded in the field logbook and/or on the appropriate field form.

7.3 Continuous Core Barrel Sampler (CME-Type)

A continuous core barrel sampler (CME-Type) is 5 feet long and fits inside the lead auger of the hollow-stem auger column. The sampler retrieves a 5-foot section of partially disturbed soil samples. The sampler assembly consists of either a split barrel or solid barrel that can be used with or without liners. The split-barrel sampler is most commonly used because it is easier to access and remove the core samples. The core barrel sampler takes the place of the pilot bit, thereby reducing sampling time. The sampler is most efficient in clays, silts, and fine sand.

The sampler shall be attached to the drill rod and locked in-place inside the auger column. The open end of the sampler shall extend a short distance ahead of the cutting head of the lead auger. The hollow-stem auger column shall be advanced 5 feet while the soil enters the non-rotating core sampling barrel. The barrel shall then be retrieved with the drill rod, and the core extruded from the sampler. The sample shall be logged and classified in accordance with SOP ENV-05-03. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP ENV-04-05.

7.4 Thin-Walled (Shelby) Tube Samplers

Thin-walled samplers, such as a Shelby tube, should be used to collect relatively undisturbed samples of soil from borings. The samplers are constructed of steel tubing about 1 to 3 mm thick, depending upon its diameter. The lower end has a tapered cutting edge. The upper end is fastened to a sample head adapter with a check valve to help hold the sample in the tube when the tube is being withdrawn from the ground. Thin-walled tube samples are obtained by any one of several methods including pushed-tube, Pitcher sampler, Denison sampler, and piston sampler methods.

In obtaining pushed-tube samples, the tube shall be advanced by hydraulically pushing it in one continuous movement with the drill rig. At the end of the designated push interval and before lifting the sample, the tube shall be twisted to break the bottom of the sample. The tube shall be retrieved from the boring using the drill rig. One of two methods shall be employed for handling the sample once it is retrieved from the boring:

1. Extruding the sample from the sample tube in the field using an extruding device on the drilling rig, and subsequently handling and containerizing the specimen at the drilling site.
2. Leaving the sample in the sampling tube, preparing it for transportation, with subsequent extrusion and handling elsewhere.

A hydraulic extruder shall be used in all cases to minimize disturbance. To extrude the sample from the tube, the tube shall be connected to the extruding device in the appropriate fashion for that type extruder. Some extruding devices push the sample in the same direction that the sample entered the tube, pushing out the top, while others push it out the bottom. It does not matter for environmental sampling, but the orientation of the sample shall be known and kept clear by the sampling personnel. The sample shall be caught on a split section of PVC pipe lined with polyethylene sheeting or aluminum foil. Waxed paper will not be used. Drilling fluids shall be carefully poured off and cuttings or slough material at the top end of the sample raked away, leaving only the true sample interval. The sample shall be transferred to a cutting board by lifting with the poly/sheeting or aluminum foil and length of the sample shall be measured. The sample shall be logged and classified in accordance with SOP ENV-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP ENV-04-04.

Shelby tubes will not be reused for subsequent sampling intervals. A sufficient number of decontaminated sampling tubes shall be brought to the sampling location to complete the required scope of work and protected from being contaminated before use.

7.5 Cuttings or Wash Samples

Drill cuttings or wash samples may be taken as the boring is advanced. A stainless steel or plastic scoop shall be used to obtain a sample from the cuttings pile. The shovel used by drilling personnel to move cuttings shall be stainless steel. The sample shall be logged and classified in accordance with SOP ENV-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04.

7.6 Test Pit Excavation and Sampling

Test pits, including trenches, consist of open shallow excavations used to determine the subsurface conditions for engineering and geological purposes. Test pits are typically conducted for subsurface characterization and to investigate underground structures that may contain impacts. Test pits shall be excavated manually or by machine (e.g. backhoe, bulldozer, or trackhoe), as required by the Site-Specific Work Plan or otherwise specified, and will be in accordance with OSHA regulations, 29 CFR 1926, 29 CFR 1910.120, and 29 CFR 1910.134. Test pit shall be logged and classified in accordance with SOP ENV-05-06.

Soil samples shall be collected from the backhoe/trackhoe bucket or directly from the wall or base of the test pit, depending on the depth of the pit. Disturbed samples shall be collected using a stainless steel scoop, shovel, or trowel. Undisturbed samples shall typically be collected using a hand auger and/or other coring tool. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04.

7.7 Surface Soil Sampling

Surface soil samples are collected to determine the surface soil conditions. Surface soil samples are generally collected at depths of less than 1 to 3 feet below the ground surface or as defined in SSWPs, considering DQOs. The use of discrete or composite samples will be determined in the SSWPs.

Before sample collection, all surface materials (i.e., excess gravel, vegetation, etc.) shall be removed from the sample location. Soil samples shall be collected using a stainless steel scoop, trowel, hand auger, or other equipment as required by the Site-Specific Work Plan or otherwise specified. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04. The sample appearance, depth, and location should be recorded in the field logbook and/or on appropriate field form using the standardized descriptions in SOP ENV-05-03, Attachment E.

8.0 ANALYTICAL SAMPLE PREPARATION

Sections of the sample representative of the entire sampling interval shall be selected for chemical analyses and/or geotechnical testing. Based on analytical requirement and contracted laboratory specifications, chemical analysis samples shall be placed in appropriate sample containers. Specific analytical sample preparation procedures are as follows.

- Using a decontaminated sampling instrument, remove the desired thickness and volume of from the sample retrieval device.
- Conduct a direct screening of the sample with a photoionization detector (PID).
- Visual observations of affected soil will use the descriptors from SOP ENV-05-02 Attachment E.
- Describe and classify the sample in accordance with SOP ENV-05-02, Field Logging of Soil and Rocks.
- **Volatile Organic Compounds (VOCs) –** Discrete soil samples for VOC analyses will be collected as soon after sample retrieval as possible. Unless otherwise specified, soil samples for VOC analyses shall be collected by either Powerstop Handle™ or EnCore™ sampler methods in conformance to USEPA

Method 5035 requirements. Attachment A presents procedures for Powerstop Handle™ and EnCore™ sample collection. Secure container lid, apply label containing sample identification information and place in cooler with ice.

- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Soil samples for these analytes will be collected after collecting VOCs. Place soil in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Physical Characteristics –** For geotechnical testing of cohesive samples, cut minimally disturbed sections of the specimen and place it in the appropriate sample container. Samples for geotechnical testing, including Shelby tubes shall be handled and packaged in accordance with standard practices for geotechnical investigations or as required by the Site-Specific Work Plan or otherwise specified. If contamination potentially exists, samples shall be identified as potentially containing hazardous or toxic chemicals.
- Samples shall be identified, labeled, documented and prepared for transport in accordance with SOP ENV-03-01, Sample Identification, Labeling, Documentation and Packaging for Transport.
- SOP ENV-03-2 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP ENV-04-05.

Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

Samples should be preserved and holding times should be observed according to analytical requirements and laboratory specifications, as required by the Site-Specific Work and/or FSPs, or as otherwise specified. If replicate or split samples are required, adjust the sections so that the additional samples are essentially identical.

9.0 DOCUMENTATION

Sample identification, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Specific procedures for describing the samples and logging subsurface soil samples are presented in SOP ENV-05-03. Soil sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work Plan.

10.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2000, D4220-95 (2000) Practices for Preserving and Transporting Soil Samples.

ASTM International, 2004, D5730-04 Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Ground Water.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

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

ATTACHMENT A
ENCORE™ AND POWERSTOP HANDLE™ SAMPLING PROCEDURES

ENCORE™ SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)
- Using the T-handle for leverage, push the sampler into a freshly exposed surface of soil until the sampler is full.
- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.
- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.
- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult method 5035 or discuss procedure with an analytical laboratory for further details.)
- Use a stainless steel spoon or similar tool to collect an additional sample from the same soil stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)
- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection. These sample shipment or pickup timelines must be achieved to ensure the laboratory performs sample preservation or analysis within 48 hours of sample collection.

POWERSTOP HANDLE™ SAMPLING PROCEDURES

1. **Load Sampling Device**

   Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

   EPA Method 5035 Recommended 5-gram slot positions:

   - Use the heavy position for dense clay;
   - Use the light position for dry sandy soil; and
   - Use the medium position for all others.

2. **Collect Sample**

   Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. **Eject Sample Into Vial**

   Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into pre-tared vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

Author:	T. Gilles	Q2R & Approval By:	E. Hanis	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-02

LOW-FLOW GROUNDWATER SAMPLING
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures and guidelines for conducting low-flow groundwater sampling. This SOP provides a method that minimizes the impact of the purging process on groundwater chemistry and volume of water for disposal.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Well construction information;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate peristaltic pump or an adjustable rate low-flow submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing;
- Flow measurement supplies (e.g. graduated cylinder and stop watch);
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- Flow-through cell;
- Groundwater quality/indicator parameter monitoring instruments (flow-through cell capable);
- Instrument operation manual(s);
- Instrument calibration standard(s);
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;

- Chain of custody forms and seals;
- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Decontamination materials;
- Personal protection equipment; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION OF SAMPLING METHOD

Low-flow is one of several acceptable sampling procedures and may be performed using bladder or peristaltic pumps. Peristaltic pumps may be used when the well depth is less than or equal to fifteen feet, in zones of high contamination, or as approved in a SSWP. The sampling method may be modified to demonstrate attainment of cleanup goals in the future. Low-flow sampling shall not be used when one or more of the following conditions are present:

- Well will not accept or allow placement of the sampling device;
- Non-aqueous phase liquids (NAPLs). Reference SOP SAS-08-07 when sampling wells with NAPL;
- Formation screened will not allow drawdown to stabilize; and
- Water column is less than 2 feet in height.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and NAPL, if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSPs. Following sampling, the sampler may obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as detailed in SOP SAS-08-05 and as required by the Site-Specific Work and/or FSP or otherwise specified. Measuring the total well depth prior to sampling should be avoided. Total well depths may be obtained following sampling activities or at least two weeks prior to the sampling. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Pump/Tubing Intake Positioning

The sampler should determine and place or position the pump/tubing intake as appropriate relative to the position of the water level, screened interval, and constituents of concern. The position the pump/tubing intake should be a minimum of one foot above the well sump to the extent practical and preferably at an elevation near the center of the well screen. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing (type, inner diameter, and length), and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form. If the water quality instruments can be programmed to calculate the one tubing volume, the data collected during pump/tubing intake placement/positioning shall be entered into the instrument. If the instrument cannot be programmed to calculate the tubing volume, this volume shall be calculated by the sampler using the following formula.

$$\text{Tubing Volume}_{\text{(Gallons)}} = \text{Tubing Length}_{\text{(Feet)}} \times \text{Volume per One Foot of Tubing}^{\text{TDS}}_{\text{(Gallons/Foot)}}$$

Where: $^{\text{TDS}}$ = Tubing inner diameter-specific; tubing manufacturer provided information.

The calculated tubing volume shall also be recorded in the field logbook and/or on the appropriate field form.

5.4 Equipment Assembly and Calibration

The sampler shall connect the tubing from the well to the inflow fitting at the bottom of the flow-through cell. A length of tubing shall be connected to the outflow fitting at the top of the flow-through cell with the other end extending into a 5-gallon bucket. The 5-gallon bucket shall be used to collect the purge water. Groundwater quality/indicator parameter monitoring instruments will be calibrated in accordance with the instrument operation manual(s) and SOP SAS-02-01 using the manufacturer prescribed calibration standards. During instrument calibration, the instrument shall be set up to measure and record data in the units (e.g. microsiemens per centimeter (uS/cm), milligrams per liter (mg/L), etc.) specified in the Site-Specific Work and/or Sampling Plan(s). Calibration shall be documented in the field logbook and/or on the appropriated field form. Following calibration, the instruments shall be connected to the flow-through cell.

5.5 Flow Rate and Drawdown Determination

The sampler shall re-gauge the depth to groundwater from the top of well casing. The sampler shall turn on the pump at its lowest setting and determine the flow rate by measuring the volume of water removed over a one-minute period using a graduated cylinder and stop watch or other approved flow rate measuring device. The sampler shall monitor the water column drawdown and shall adjust the pump to avoid a drawdown of more than 0.1 meter or 0.3 feet (4 inches). The flow rate of the pump shall generally be adjusted to between 0.2 and 0.5 liters per minute (L/min). During pump start-up, drawdown may exceed 0.3 feet provided the drawdown stabilizes and the groundwater level does not fall below the intake level. The water level shall not fall below the top of the well screen if the water level was greater than 0.5 feet above the well screen prior to commencing pumping activities. Pump adjustments shall be made within the first 15 minutes of purging. The final flow rate and stabilized drawdown shall be recorded in the field logbook and/or on the appropriated field form.

5.6 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSPs shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin after a minimum of tubing volume has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters every three to five minutes (during continuous purging) until parameters have stabilized. A generic groundwater sampling field form is provided in Appendix B. Five-minute intervals are typical; three-minute intervals are used during flow rates in highly permeable media that will allow pumping rates that exceed typical low-flow rates. Parameter stabilization is considered to be achieved when three consecutive readings, spaced approximately 2 to 10 minutes, or 0.5 well volumes or more apart, are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or Sampling Plan(s).

Parameter	Stabilization Criteria[1]
Conductance, Specific Electrical	+/- 3% µS/cm @ 25^{o}C
Conductivity, Actual[2]	+/- 3% µS/cm
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
pH	+/- 0.1 standard units
Temperature	+/- 0.1 ^{o}C
Turbidity	$\leq$10 NTUs or $\pm$ 10% when turbidity is greater than 10 NTUs and/or visually clear water

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

Once the parameters have stabilized, purging is considered complete and sample collection shall commence.

5.7 Sample Collection

While water is being purged from the well, groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Water collected for analysis requiring field filtration will be filtered with an in-line Nalgene© disposable 0.45 micron (µm) filter, or equivalent. Water will be discharged directly from the in-line filter into the sample container following a filter pre-rinse, which will be performed by passing water through the filter, minimum of 500 milliliter (mL), and discharging prior to collection of the sample(s). Samples collected with bailers will be collected in intermediated unpreserved laboratory-provided containers and immediately field filtered as previous described with in-line filters.

Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSPs:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered, non-preserved samples;
- Filtered, preserved samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in an iced cooler.

5.8 Post-Sample Collection

Non-Dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or Sampling Plan(s). Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSPs. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSPs. A generic groundwater sampling field form is provided in Appendix B.

7.0 REFERENCES AND ADDITIONAL RESOURCES

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

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

Author: J. Sapp | Q2R & Approval By: A. Bazan | Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-04

AQUIFER TESTING
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for field evaluation of aquifer hydraulic conductivity. Variations in the hydraulic conductivity within or between formations or strata can create irregularities in groundwater flow paths. Formations of high hydraulic conductivity represent areas of greater groundwater flow and, therefore, zones of potential preferred contaminant migration. Further, anisotropy within strata or formations affects the magnitude and direction of groundwater flow. Thus, information on hydraulic conductivities is necessary to evaluate preferential flow paths and groundwater velocity.

Hydrogeologic assessments should contain data on the hydraulic conductivities of the significant formations underlying the site as measured in monitoring wells. It may be beneficial to use numerical or laboratory methods to augment results of field tests. However, field methods provide the best definition of the horizontal hydraulic conductivity in most cases. Field methods differ from laboratory methods which measure vertical hydraulic conductivity, typically in Shelby tube samples.

2.0 EQUIPMENT AND MATERIALS

- Pump (and generator if required) capable of withdrawal at a constant or predetermined variable rate that can meet the designed pumpage rate and lift requirements
- Water pressure transducers and data logger (bring transducers for the pumping well and each observation well as well as extras in case of malfunction)
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well
- Sufficient hose or pipe to convey discharge outside the recharge area of the pumping well and observation wells
- Electric water level indicator(s) capable of measurement to the hundredth of a foot
- Watch or stopwatch with second hand

- Barometer (some groundwater multiprobes include a barometer)
- Tape Measure of appropriate length based on distance to observation wells.
- Flashlights, lanterns, alarm clock, electrical tape
- Semi-log graph paper, pens, and field book

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 FIELD METHODS

Varieties of procedures are available for evaluating hydraulic conductivity in the field. ASTM D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques should be consulted in selecting an appropriate test method. Field methods for collecting hydraulic conductivity data are described in a number of ASTM standard practices:

- D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)
- D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
- D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems
- D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)
- D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

- D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method
- D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat
- D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test
- D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique
- D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method
- D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers
- D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well
- D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer
- D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes
- D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)
- D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems
- D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells
- D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well
- D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)
- D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

- D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method
- D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method
- D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method
- D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability
- D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test
- D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

5.0 SINGLE WELL TESTS

Hydraulic conductivity can be determined in the field using a variety of test methods, each addressing specific conditions, and/or data collection objectives. These methods are commonly referred to as bail down or slug tests and are performed by adding or removing a slug (known volume of water or solid inert material) from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. One method is described by McLane, et. al. (1990) and is contained in references to the Standard Practices.

When reviewing information obtained from slug tests, several criteria should be considered. First, they are run on one well and, as such, the information is limited to the geologic area directly adjacent to the screen. Second, the vertical extent of screen will control the part of the geologic formation that the test analyzes. Portions of the geologic formation(s) above or below the screen and sand filter pack and seal intervals may also require separate hydraulic conductivity testing. Third, the methods used to collect single well test data should accurately measure parameters such as changing static water (prior to initiation, during, and following completion of the test), the amount of water removed from the well (or slug volume introduced), and the elapsed time of recovery. The use of pressure transducers and high speed recording equipment is critical in highly permeable formations.

Observation wells with screens that intersect the water table (i.e. water table wells) will be tested only by methods involving removal of water or a slug from the well in order to minimize the potential for well screen filter pack interference. The addition of water to any monitoring well shall be avoided whenever possible, since the addition may affect water quality in sampling events. When addition of water to a well is unavoidable, the water must be of documentable quality and three times the volume added to the well must be removed immediately upon completion of the test. Addition of water to an observation well is appropriate only to piezometer installation when the dynamic water level is above the well screen and sand filter pack and seal elevations.

Full development of the well screen and filter pack adjacent to the interval under examination, in accordance with SOP SAS-05-04, should be completed following well construction to ensure the removal of fines or correct deleterious drilling effects. Determination of well integrity, SOP SAS-08-05, should be determined prior to performance of the well test.

It is important that slug tests be of sufficient duration to provide representative measures of hydraulic conductivity. Slug tests will range in length from less than a minute to several hours. The time required for a test is a function of the volume of the slug added or removed the formation hydraulic conductivity, and well construction.

Slug tests should be performed at least twice to ensure the accuracy of data collection. General procedures for a slug test are summarized below. The procedures required for a slug test may vary, depending on site-specific-conditions. Modifications to the test procedures will be contained in site-specific work plans.

5.1 Slug Test Procedures with Pressure Transducer and Data Logger

An individual Slug Test Field Form (Appendix B) should be completed for each well tested and should contain at least:

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Personnel - The personnel conducting the pumping test.
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale). The transducer psi range should be appropriate to the test (e.g. 0 to 5 or 0 to 10 psi).
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the slug test.
- Slug Withdrawal / Addition Start Time - The date when the test began, and start time using a 24-hour clock.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the slug test.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Notes - Appropriate observations or information that has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.

Prior to commencing the slug test, enter site-specific information in the data logger per manufacturer instructions. Store all logger data internally; and on laptop computer and/or portable data key. The data should be transferred to the chosen backup storage device as soon as practical after the test is completed.

Water levels should be measured as specified in the SOP SAS-08-02. Manual measurements are required as a backup to and verification of the data logger(s). It is critical that depth to water readings be measured accurately and the exact time of readings is recorded. Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and taking the average of the readings (see SOP SAS-07-02). Record information on the Slug Test Field Form (Attachment B). Additional information should be recorded on the Daily Activity Log in SOP SAS-01-04.

5.2 Slug Test Preparation

- Lower the transducer and cable in the well below the estimated target drawdown depth, ensuring the depth of submergence is within the transducer design range.
- Tape the transducer cable to the exterior of the well casing or protective cover to hold the transducer at a constant depth
- Connect the transducer cable to the data logger.
- Check the transducer accuracy by raising and lowering the transducer and comparing the change in water level from the transducer reading to the distance the transducer is raised or lowered.
- Enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions.
- Allow the static water level to equilibrate to within 0.1 feet of the initial water level.

5.3 Slug Test with Transducer Procedure

- Turn the data logger on and begin collecting data points.
- Smoothly lower the slug/bailer into the well and allow the water level to stabilize within 0.1 feet of the initial water level.
- Remove the slug/bailer as quickly and smoothly as practical. A smooth, rapid removal is required as slug test analysis assumes an instantaneous change in volume is created in the well when the slug is removed.
- The moment the volume is removed is time zero. Collect hand measured water level measurements (Table 1) as a data backup and to verify transducer data.
- Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to show a trend on a plot of water level recovery versus the logarithm of time in accordance with the chosen analysis method. Time will range from less than 1 minute to a few hours.
- Repeat the slug test once the static water level has recovered to within 95 % of the original water level.

Table 1: Time Intervals for Measuring Recovery in Slug Test Well

Elapsed Time Since Start or Stop of Test (Minutes)	OR (which ever is greater)	Percent Water Level Recovery (%)	Interval Between Measurements (Minutes)
0-2		0-30	0.1
2-5		30-50	0.5
5-10		50-60	1
10-60		60-70	5
60-120		70-80	10
120-240		80-100	30

5.4 Slug Test with Water Level Meter

This slug test method should only be used if a transducer/data recorder cannot be obtained or are malfunctioning. This method cannot be used for saturated zones with high hydraulic conductivities because stabilization of groundwater will occur rapidly. Slug test data should be recorded on the Slug Test Data form (Attachment B) in accordance with the completion instructions. Follow the same procedures for Slug Test with Transducer with increased data collection frequency.

Table 2: Time Intervals for Measuring Recovery in Slug Test Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-2	0.1
2-10	0.5
10-30	1
30-60	5
60-120	10
120-240	30

The interpretation of the single well test data should be consistent with the existing geologic information (boring log data). Staff should be aware of initial rapid water level recovery during a slug test may represent drainage of the filter pack material around the well screen. This is of particular concern in wells screened in low hydraulic conductivity formations (e.g. silty clay, shale). These data points should be ignored when selecting the appropriate data points to establish a water level recovery slope.

6.0 MULTIPLE WELL TESTS

Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication between units. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered in conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system, and (2) potential effects of groundwater pumping on existing waste plumes. The geologic constraints should be considered to interpret the pumping test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

7.0 LABORATORY METHODS

Laboratory analysis of undisturbed samples (e.g. Shelby tube) provides values of vertical hydraulic conductivity. When laboratory methods are to be used, the specific ASTM Standard Practice shall be referenced in samples provided to subcontractors. ASTM methods shall be consulted to assure that test methods specified are applicable to the sample to be tested.

8.0 CONTROLLED PUMPING TESTS

The most representative method for determining aquifer characteristics is by controlled aquifer pumping tests, because these tests stress a much larger volume of the formation than slug tests and laboratory tests. Pumping tests require a higher level of effort and expense than other types of aquifer tests, and are not always justified.

As an example, slug tests may be acceptable for site characterization, whereas pumping tests may be performed to support remedial design or modeling.

Aquifer characteristics that may be obtained from pumping tests include transmissivity (T), hydraulic conductivity (K), specific yield (Sy) for unconfined aquifers, and storage coefficient (S) for confined aquifers. These parameters can be determined by graphical solutions and computerized programs, such as Aqtesolv®.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required dependent on site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

8.1 Summary

If possible, continuously monitor pre-test water levels at the test site for about one week prior to performance of the pump test. This information allows for the determination of the barometric efficiency of the aquifer, as well as noting changes in head due to recharge or pumping in the area adjacent to the well. Prior to initiating the long-term pump test, a step test (Section 5.5) is performed to estimate the greatest flow rate that may be sustained by the pump well.

After the pumping well has recovered from the step test, the long-term pumping test begins. At the beginning of the test, the discharge rate is set as quickly and accurately as possible. The water levels in the pumping well and observation wells are recorded following a set schedule. The duration of the test is determined by project needs and aquifer properties; typically three days or until water levels becomes constant.

8.2 Interferences and Potential Problems

Prior to conducting a pumping test, efforts should be made to anticipate and resolve interferences and potential problems that could affect the aquifer or the test. These problems could be caused by changing atmospheric conditions, impact of local potable wells, contaminants in the aquifer, etc. Note that if it is necessary for a neighboring well to pump during the test, pumping should commence as early as feasible prior to start of the test at a constant rate and not started or stopped for the duration of the test.

8.3 Pumping Discharge

If a pumping test will be conducted in an area with contaminated groundwater, special arrangements must be made for proper handling, treatment, and disposal of the water. The preferred method is to discharge to a sanitary sewer, with prior approval.

Uncontaminated groundwater discharge generated during a pumping test should be sent to storm or sanitary sewers, abiding by all applicable regulations. If there are no sewers in the vicinity of the pumping well, the discharge may be sent to a river or pond. If the previously mentioned discharge options are not available, the groundwater may be discharged to the ground surface under either of the following conditions:

- The aquifer being tested is confined; or
- The end of the discharge hose/pipe is outside of the cone of depression created by the pumping well when testing an unconfined aquifer.

8.4 Pre-Test Procedures

The hydrostratigraphy of the aquifer should be fully characterized prior to performance of the test to identify formation thickness, whether it is confined or unconfined, whether confining layers are leaky and to identify any lateral boundaries that may influence results.

If the pumping test occurs at a site where existing production and/or monitoring wells will be used, confirm that the locations and screened intervals of the wells are within the same aquifer, and meet the requirements of the method of analysis.

If possible, continuously measure water levels in the pumping well and all observation wells for a period at least equal to the length of the test. Trends should be similar in all wells. A well with an unusual trend may indicate some local stress in the aquifer.

The magnitude of water-level fluctuations due to changes in barometric pressure will change throughout the test and should be adjusted based on the changes in the barometric pressure recorded during the test. Changes in barometric pressure will be recorded during the test in order to correct water levels for any possible fluctuations that may occur due to changing atmospheric conditions. These barometric changes are used to "correct" water levels during the test so they are representative of the hydraulic response of the aquifer due to pumping of the test well. Ideally, water levels should be measured in a well outside of the cone of depression before, during, and after pumping to determine background changes in water levels during the test and to establish correction factors for the wells within the cone of depression.

8.5 Step Test

The step drawdown test is performed to determine the maximum pumping rate that the pumping well can sustain and the minimum pumping rate necessary to assure drawdown in the observation wells. The pumping and observation wells are equipped with transducers prior to the test. Check the transducer accuracy by raising and lowering the transducer and comparing the change in water level from the transducer reading to the distance the transducer is raised or lowered.. The test is then performed by pumping at a low rate, relative to the expected final rate of pumpage, until drawdown in the pumping well stabilizes. The rate is then increased again until drawdown in the pumping well stabilizes (step 2). A minimum of three steps will be tested; the duration of each step will be similar, and should be between 30 minutes and 2 hours.

The data are then plotted on semi-log paper or on a computer. The maximum sustainable pumping rate that yields drawdown in the closest observation wells will be used as the target-pumping rate for the long-term test. These data may also be used to determine aquifer properties and well loss in the pumping well.

8.6 Pump Test Time Intervals

Commence the long-term pumping test after the pumping well has fully recovered from the step test. Place transducers into the observation wells prior to starting the test and allow time for them to equilibrate to the water temperature within the well and to collect pre-test water level data. At the beginning of the test, the discharge rate should be set as quickly and accurately as possible. Record the pumping and observation well water levels with transducers and a data logger(s) set to record logarithmically. As backup in case of transducer malfunction, manually record water levels on field forms and/or field notebooks according to the schedules in Tables 3 and 4:

Table 3: Time Intervals for Measuring Drawdown in the Pumped Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-10	0.5-1
10-15	1
15-60	5
60-300	30
300-1440	60
1440-termination	480

Table4: Time Intervals for Measuring Drawdown in an Observation Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-60	2
60-120	5
120-240	10
240-360	30
360-1440	60
1440-termination	480

For wells with a transducer malfunction, water levels records should be manually recorded on field forms and/or field notebooks according to the schedule in Table 5:

Table 5: Time Intervals for Measuring Drawdown in the Observation Wells with Transducer Malfunction

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-2	0.1
2-10	0.5
10-20	1
20-100	5
100-200	10
200-300	30
300-1440	60
1440-termination	480

8.7 Water Level Measurements

Water levels will be measured as specified in the SAS-08-02. During the early part of the test, sufficient personnel are required to initiate the pumping test data loggers and assist with manual water level measurements of the pumping well and flow rate measurements. Manual measurements are required as a backup to and verification of the data logger(s). After the first two hours, one to two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured accurately and the exact time of readings is recorded.

During a pumping test, the following data must be recorded accurately on the log book and/or the aquifer test data form.

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Distance and Direction from Pumped Well - Distance and azimuth to each observation well from the pumping well in feet.
- Personnel - The personnel conducting the pumping test.

- Pumping Start and End Date/Time - The date when the pumping began, and start time using a 24-hour clock.
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the pumping test.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the pumping test.
- Target Pumping Rate
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale). The transducer psi range should be appropriate to the test (e.g. 0 to 5 or 0 to 10 psi).
- Notes - Appropriate observations or information that has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Depth to Water (ft) – Manual depth to water measurement, to the nearest 0.01 feet, in the observation well at the time of the water level measurement.
- Flow Rate (gal/min) - Flow rate of pump measured from an orifice, weir, flow meter, container, or other type of water measuring device.

8.8 Pump Test Duration

The duration of the test is determined by the needs of the project and properties of the aquifer. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criterion. Different hydrogeologic conditions can produce straight-line trends on log-time versus drawdown plots. In general, longer tests produce results that are more definitive. Duration of one to three days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. Knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives is necessary in judging appropriate test duration. There is no need to continue the test once the water levels in the observation wells stabilize.

The recovery of water levels following pumping phase may be measured and recorded for a period equal to the pumping phase. The frequency of the water level measurements should be similar to the frequency of water level measurements during the pumping phase (Table 1).

9.0 POST OPERATION

The following activities are performed after completion of water level recovery measurements following a slug or pumping/recovery test:

- Decontaminate and/or dispose of equipment per SAS-04-05.
- When using an electronic data-logger, use the following procedures:
  - Stop logging sequence
  - Check file size, print data, and/or save memory to a reliable storage device (i.e. hard drive or USB drive): Backup the data as soon as possible upon completion of a test!
  - Do not clear the memory of the transducer until the data has been saved onto a hard drive
- Review field forms for completeness.
- Replace testing equipment in storage containers
- Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
- Interpret slug or pumping/recovery test field results.

10.0 CALCULATIONS

Upload the data from the test into a spreadsheet to be entered into a computerized program, such as Aqtesolv®. Use the information entered into the Data Acquisition Form to complete the computer analysis of the data. There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and conductivity. The appropriate method to use is dependent on the characteristics of the aquifer being tested (confined, unconfined, leaky confining layer etc.). When reviewing slug and pump test data, the following text and/or documents may be used to determine the method most appropriate to your case:

- Analysis and Evaluation of Pumping Test Data (Kruseman and Ridder, 1989)
- Applied Hydrogeology (Fetter, 2000)

- Groundwater and Wells (Driscoll, 1986)
- ASTM D4105-96(2002)
- ASTM D4106-96(2002)

11.0 QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Gauges, transducers, flow meters, and other equipment used in the pumping tests will be calibrated before use at the site. Copies of the documentation of instrumentation calibration will be filed with the test data records. The calibration records will consist of laboratory measurements and, if necessary, any on-site zero adjustment and/or calibration that were performed. Where possible, all flow and measurement meters will be checked on-site using a container of measured volume and stopwatch; the accuracy of the meters must be verified before testing proceeds. For QA/QC purposes, a minimum of two single well tests (slug test) should be performed in each well that hydraulic conductivity testing is performed.

12.0 DATA REDUCTION AND INTERPRETATION

Slug and multiple well test data can be analyzed by a variety of methods, depending on the responses observed, geologic conditions, and specific well parameters. Texts such as Driscoll (1986) or other well hydraulics references should be consulted for selection of the proper method of data analysis. In reviewing hydraulic conductivity measurements, the following criteria should be considered to evaluate the accuracy or completeness of information.

- Values of hydraulic conductivity between wells in similar lithologies should generally not exceed one order of magnitude difference.
- Hydraulic conductivity determinations based upon multiple well tests are preferred. Multiple well tests provide more complete information because they characterize a greater portion of the subsurface.
- Use of single well tests will require that more individual tests be conducted at different locations to sufficiently define hydraulic conductivity variation across the site.
- Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens will have to be shorter. If the average hydraulic conductivity for a formation is required, entire formations may have to be screened, or data taken from overlapping clusters.

It is important that measurements define hydraulic conductivity both vertically and horizontally across the site. Laboratory tests may be necessary to ascertain vertical hydraulic conductivity in saturated formations or strata. Results from boring logs should also be used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should be considered in the determination of hydraulic conductivity. Additionally, information from boring logs can be used to refine the data generated by single well or pumping tests.

13.0 REFERENCES AND ADDITIONAL RESOURCES

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McLane, G. A., D. A. Harrity, K. O. Thomsen, "Slug Testing In Highly Permeable Aquifers Using a Pneumatic Method", Hazardous Materials Control Research Institute, Conference Proceedings, November, 1990, pp 300-303.

ASTM International, D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)

ASTM International, D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques

ASTM International, D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

ASTM International, D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

ASTM International, D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

ASTM International, D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method

ASTM International, D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat

ASTM International, D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test

ASTM International, D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique

ASTM International, D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method

ASTM International, D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers

ASTM International, D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well

ASTM International, D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer

ASTM International, D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes

ASTM International, D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)

ASTM International, D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells

ASTM International, D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well

ASTM International, D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method

ASTM International, D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method

ASTM International, D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method

ASTM International, D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability

ASTM International, D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test

ASTM International, D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

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