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TECHNOLOGY
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Mr. Frank Dombrowski
Sr. Environmental Consultant
We Energies
333 W Everett Street, A231
Milwaukee WI, 53203

February 10, 2015
(1508)

RE: **Supplemental Site Investigation Work Plan**
Appleton City (Coal Tar), aka Appleton MGP
337 Water Street, Appleton, Wisconsin
WDNR BRRTS Activity #02-45-000042,
FID #445033380

Dear Mr. Dombrowski,

Natural Resource Technology, Inc. (NRT) has prepared this Work Plan to complete soil borings, install groundwater monitoring wells and piezometers, and install soil gas probes near the former manufactured gas plant (MGP) site located at 337 Water Street in Appleton, Wisconsin. These activities will take place at the Fox River Apartment Buildings owned by Heartland Properties Inc., near the Middle Appleton Dam (Figure 1). This work plan has been prepared in response to observations of non-aqueous phase liquid (NAPL) in piezometer PZ-26 during routine sampling events in 2014. Additional details regarding site history can be found in the 2013 Annual Report[1]. Details regarding the installation of PZ-26 and 2014 monitoring events will be presented in the 2014 Annual Report planned for submittal in the first quarter of 2015.

Introduction

In April of 2014 NRT installed piezometer PZ-26 (Figure 1) to monitor the same shallow bedrock zone monitored by PZ-23. No odors or elevated PID readings were observed during the construction of PZ-26. However, oily NAPL was observed at the top and bottom of the water column in PZ-26 during subsequent sampling events in April, May, July, and October of 2014. NAPL measurements collected in 2014 were up to 4.8' thick. Groundwater elevations were also collected from PZ-26. The groundwater elevations collected from PZ-26 are approximately 6 feet lower than those collected from PZ-23 (screened in the same formation) and 7.5 feet lower than the pool elevation of the headwaters above the Middle Appleton Dam as measured from SG-3 (Figure 2). The appearance of NAPL after well installation and relatively low groundwater elevation indicates groundwater near PZ-26 is likely isolated from the headwaters of the dam and the PZ-23 area. A site visit and file review was completed to investigate the construction of the apartment buildings (former mill buildings that can be seen in the background of photographs taken from the former MGP site dating back to the 1920s). The following sections describe proposed site investigation activities to evaluate conditions observed at PZ-26 including: soil borings, monitoring wells, and soil vapor probes. Locations, rationale, and monitoring objectives are also summarized on Table 1.

Soil Borings – Historical Middle Appleton Dam

During the file review and site visit of the Middle Appleton Dam on November 4th, 2014, it was discovered that there was an older dam that was a precursor to the current Middle Appleton Dam. Underground structures remaining from this historical dam (a Needle Dam) may connect to the foundations of the apartment buildings. This was corroborated by the presence of settling cracks in the parking lot that align with the upstream edge of the former Needle Dam. It was also observed that portions of the Needle Dam are still in existence near the eastern end of the southern apartment building (415 S. Olde Oneida St. Apts., Figure 1) where it appears the top of bedrock was covered in concrete prior to construction of the Needle Dam. The former location of the Needle

[1] 2013 Annual Report, NRT, dated March 21, 2014.

Dam is not mapped and could be disrupting, or even obstructing, groundwater flow to the area surrounding PZ-26. We propose to evaluate the presence of a buried structure in the area of the settling cracks using soil borings. One or more exploratory boreholes will be attempted to locate and evaluate the presence of a potential structure (SB-2014 area on Figure 1).

It is anticipated that the soil borings (and monitoring wells described below) will be completed using rotary sonic drilling methods. A description of this method can be found in the NRT Drilling Methods General Standard Operating Procedure (SOP) (Attachment A). The borings will be logged continuously until the structure is located, or until three borings have been completed to bedrock. The soil borings will be logged and abandoned in accordance with the methods described in NRT Field Logging of Soil and Sediment SOP (Attachment B), and NRT Borehole and Monitoring Well Abandonment SOP (Attachment C) and consistent with Wisconsin Administrative Code (WAC) NR 141. No soil samples will be collected from these borings. If required by the disposal facility, a waste characterization sample will be collected from the cuttings and soil borings. Investigation derived waste will be containerized in 55 gallon drums, labeled, and staged at a secure We Energies facility pending disposal.

Groundwater Monitoring

In addition to evaluating the presence/absence of the former dam structure, 5 monitoring wells and an additional staff gauge are proposed to evaluate groundwater flow characteristics around the apartment buildings. These will include the following:

- A shallow watertable well (Figure 1, MW-26) will be paired with PZ-26 to evaluate vertical gradients and connection of the watertable with the headwaters of the Middle Appleton Dam.

- A shallow watertable well and piezometer (Figure 1, MW/PZ-27) will be constructed east of nest location 23 to evaluate groundwater flow direction and groundwater quality adjacent to the apartment buildings. As this area has several logistical challenges, final locations for these borings will be determined in the field.

- Another shallow watertable well and piezometer (Figure 1, MW/PZ-28) will be constructed west of the former dam structure (if located) to evaluate groundwater flow direction and groundwater quality between nest location 26 and nest location 23.

- A staff gauge (Figure 1, SG-4) is also proposed between the north (405 S. Olde Oneida St.) and south (415 S .Olde Oneida St.) apartment buildings to monitor the tailwater elevation of the Fox River after it passes through the hydroelectric units present in the north apartment building. This will provide measurements of the potential head on the downstream side of the Dam. If it is not practicable or safe to place a staff gauge between the apartment buildings, a potential alternate location has also been identified on Olde Oneida Street (Figure 1, SG-4 Alternate).

The installation of the monitoring wells, piezometers, and the staff gauge will allow for groundwater contouring in this area. This information will be used to evaluate groundwater flow in both watertable and upper bedrock flow systems and provide useful data for the evaluation of the apparent anomalous groundwater flow and quality at PZ-26. Watertable wells and piezometers will be installed and developed according to NRT Monitoring Well Construction and Development SOP (Attachment D) and WAC NR 141. While logging the soils for the monitoring well boreholes, we will be looking carefully for any concrete on top of bedrock similar to what was observed at the eastern end of the apartment building noted during the site visit.

The three watertable wells will be installed to a depth of approximately 14 to 16 feet below ground surface (bgs). The watertable wells will have 10-foot screens. The two piezometers will be installed to a depth of approximately 25 feet bgs, approximately 10-feet into the upper bedrock. The piezometers will be completed with 5-foot screens to monitor the same formation as PZ-23 and PZ-26.

The new monitoring wells and piezometers will be added to the groundwater monitoring program that was reviewed and approved by WDNR in 2014. The proposed monitoring plan is included as Table 2. Initially, the wells and piezometers will be sampled quarterly (4 rounds) for two years following the implementation of this work plan. All locations will be analyzed for BTEX (full VOC list for the first two quarters) and naphthalene. Arsenic will be monitored annually. RNA parameters, field parameters, DNAPL measurement, and water levels will be collected from all locations. After two years, the quarterly sampling schedule would be assessed and likely reduced to semi-annual or annual sampling events consistent with the monitoring schedule for the rest of the wells in network. Groundwater samples will continue to be collected using low-flow methods.

PZ-26 NAPL Monitoring and Recovery

Starting in April 2015, NAPL will be removed from PZ-26 during quarterly sampling events to monitor NAPL recovery. During each groundwater sampling event, routine NAPL thickness and water levels measurements will be collected at PZ-26. Following those measurements, a bailer, peristaltic pump, or other recovery method will be used to collect NAPL from PZ-26. Observations will be made about the volume of NAPL recovered, the water level, and NAPL thickness after the NAPL is removed. The recovered NAPL and water mixture will be containerized and staged at a secure We Energies facility pending profiling and disposal. Details and discussion of the NAPL monitoring will be included in the 2015 Annual Report. Water quality sampling will not be conducted at this location as long as NAPL remains present.

Vapor Intrusion Pathway Investigation

During the November 2014 site visit, a preliminary assessment of the potential for vapor intrusion to the occupied buildings was also completed. The upper bedrock piezometer with NAPL observations (PZ-26) is located within 30 feet of the south face of the southern apartment building (Figure 2). The top of the filter pack at PZ-26 is 16 feet bgs (approximate elevation of 707 feet); which is about 8 feet below the bottom floor of the apartment building. Observations from well nest MW-23 and PZ-23 indicate contaminants are confined within the upper bedrock and have not impacted the watertable. The new monitoring well MW-26 will provide data to determine if the same conditions are present at the PZ-26 area. An underground parking garage with its own ventilation system is present beneath most of the apartment building. The apartments that are not located above the parking garage are located on the bottom floor of the building (same elevation as the floor of the garage) or underlain by small crawl spaces with dirt floors. The presence of the parking garage and the lack of contaminants observed in the water table suggest the apartment building may not be at risk of vapor intrusion from the impacts confined to the upper bedrock. Six soil vapor probes are proposed to evaluate the presence of contaminants in soil gas near the apartment building. No sub-slab soil vapor probes within the underground garage are planned at this time due to the possibility of groundwater being in contact with the garage floor. Sub-slab vapor sampling or other soil vapor sampling may be considered in the future pending results of this work plan.

Three soil gas probes will be installed along the south face of the southern apartment building (415 S. Oneida St.) and one soil gas probe along the west face near the elevator shaft (Figure 1, SV-1 through SV4). Water levels around the southern apartment building have ranged from less than 4 feet bgs (MW-23) to the west and greater than 10 feet bgs (PZ-26) to the south. In areas of water level deeper than 5 feet bgs, the probes will be placed

1-2 feet above the water table as recommended by the WDNR guidance[2]. Where the water table is less than 5 feet bgs, probes will be installed between 3 and 4 feet bgs. Proposed soil vapor probes SV-5 and SV-6 will be in a recessed courtyard area located between the section of the building above the underground garage and other apartments that are not above the garage. The depths of the soil vapor probes will be determined in the field based on depth of the water table and type of material at the surface (i.e., if the area is paved, shallow soil gas probes between 2 and 3 feet bgs may be attempted to simulate sub-slab samples). If the vadose zone is greater than 7 feet thick, a second vapor probe will be constructed approximately 2-3 feet above the initially proposed soil vapor probe. This will allow for 2-3 feet of vertical separation between probes and the shallow probe will be at least 3 feet bgs to minimize the potential for the probe to short circuit to the atmosphere. Soil vapor probes will be constructed of 6-inch stainless steel mesh screens attached to 1/4 –inch inert tubing that connects to a valve at the ground surface. The mesh screens will be surrounded by sand filter pack and topped with hydrated bentonite annular space seals. Each probe location will be completed with a small diameter flush-mounted protective cover. Nested probes, if completed, will be marked to identify the relative depths of the probes.

Soil vapor samples will be collected in 1L summa canisters and follow the procedures of the NRT Soil Vapor Sampling SOP (Attachment E). These procedures are consistent with those recommended by WDNR RR800 guidance (footnote 2 above), including the use of a helium leak test prior to sample collection. Samples will be analyzed using EPA method TO-15 (Table 3), as suggested in WDNR RR800 and results will be reported for the following constituents of concern (COCs): benzene, toluene, ethylbenzene, xylene (BTEX) and naphthalene. A minimum of two soil vapor sampling events are proposed to capture cold and warm weather seasonal variation. The first would be scheduled this March or April and represent the cold weather, with the warm weather sampling taking place in the summer of 2015. Additional samples may be collected to confirm initial results.

All analytical samples will be collected and maintained under secure conditions and documented through chain of custody (COC) procedures described in NRT Chain of Custody SOP (Attachment F). Soil vapor results will be compared to Residential Risk Screening Levels for sub-slab and shallow soil gas calculated using the WDNR quick look up table (Attachment G) and applicable attenuation factors. Current screening levels are calculated by dividing the indoor air vapor action levels (VAL) by an attenuation factor of 0.1 for sub-slab and shallow soil gas at residential and small commercial buildings (Table 4). The summa canisters will be sent to a qualified analytical laboratory that can reliably achieve reporting limits at or below the screening levels on Table 4.

Following completion of the work plan all soil borings, monitoring wells, soil vapor probes, and the staff gauge will be surveyed by a to obtain accurate location and elevation information.

Documentation

In accordance with NR 716.14(2), results collected from the monitoring wells and vapor probes will be transmitted to WDNR and the property owner (Heartland Properties, Inc) within 10 days of receipt of the final lab reports. Work plan activities including the findings from the monitoring wells and vapor sampling will be discussed in the 2015 Annual Report to the WDNR. WDNR field forms will be used to document soil boring activities. This report will also offer recommendations on future groundwater and vapor investigation, as applicable.

Schedule

We plan to proceed with drilling and soil gas sampling in March 2015. The implementation schedule is also contingent upon finalization of the access agreement between We Energies and Heartland Properties, Inc.

[2] Wisconsin Department of Natural Resources (WDNR) Addressing Vapor Intrusion at Remediation and Redevelopment Sites in Wisconsin (RR-800) December 2010

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To facilitate this schedule, we ask that WDNR communicate any questions or concerns regarding this work within two weeks of the date of this work plan.

Sincerely,

NATURAL RESOURCE TECHNOLOGY, INC.

Brian Hennings, PG
Hydrogeologist

Figures: Figure 1 – Proposed Locations and Underground Basement Outline
Figure 2 – Relevant Elevations

Tables: Table 1 – Monitoring Well Location and Soil Gas Probe Rationale
Table 2 – Groundwater Sample Analysis Plan
Table 3 – Soil Vapor and Waste Characterization Sample Analysis Plan
Table 4 – January 2015 Calculated Residential Risk Screening Levels

Attachments: Attachment A – Drilling Methods General, NRT 07-05-03
Attachment B – Field Logging of Soil and Sediment, NRT 07-06-03
Attachment C – Borehole and Monitoring Well Abandonment, NRT 07-05-07
Attachment D – Monitoring Well Construction and Development, NRT 07-05-05
Attachment E – Soil Vapor Sampling, NRT 07-09-07
Attachment F – Chain of Custody, NRT 07-03-03
Attachment G – Indoor Air Vapor Action Levels for Various VOCs Quick Look-Up Table

FIGURES

DRAWN BY/DATE: TDC 2/3/15
REVIEWED BY/DATE: PMH 2/3/15
APPROVED BY/DATE: BGH 2/10/15

PROPOSED SAMPLING LOCATIONS

FORMER APPLETON MANUFACTURED GAS PLANT (MGP) FACILITY
WE ENERGIES
APPLETON, WISCONSIN

PROJECT NO: 1508

FIGURE NO: 1

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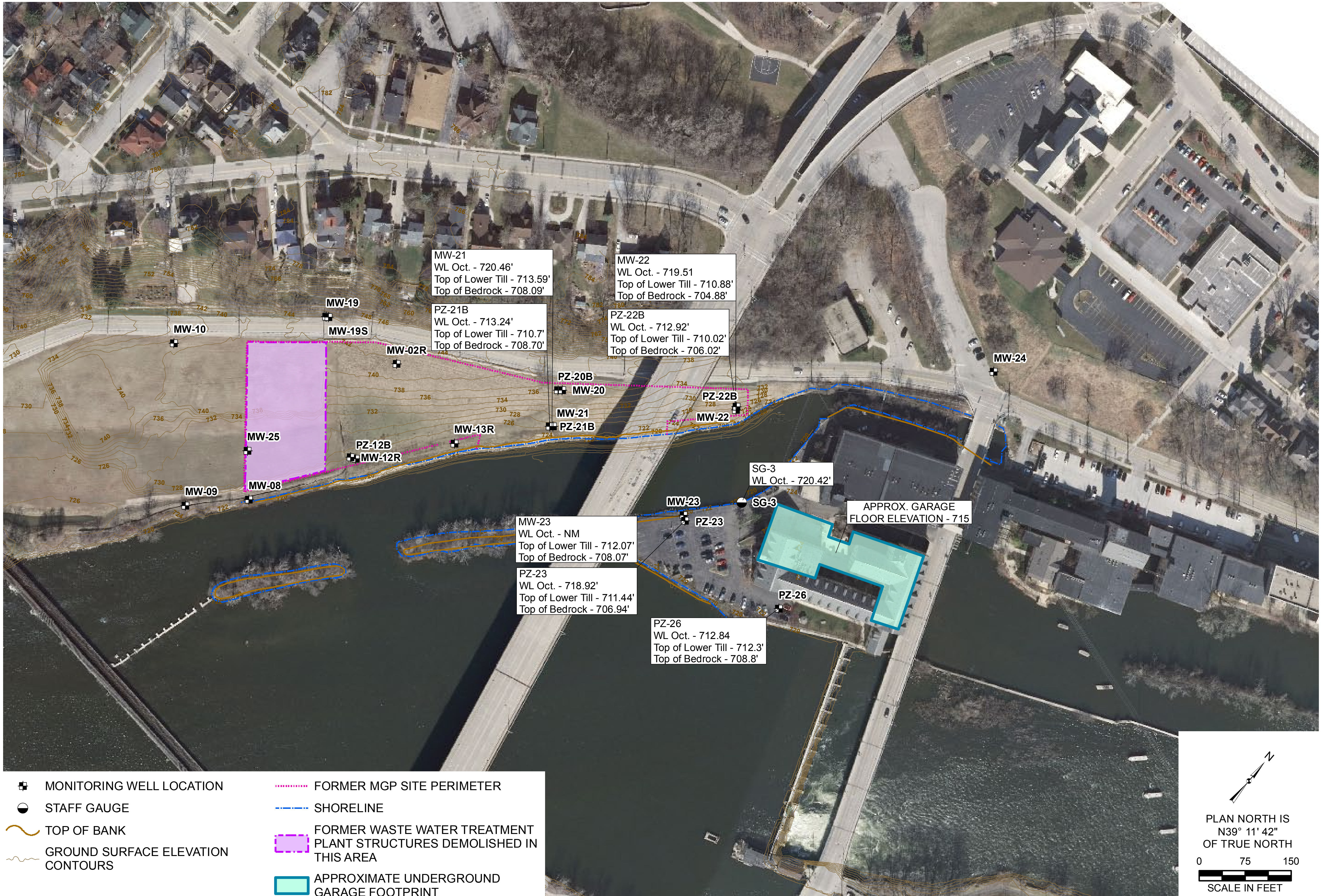
Y:\GIS\Projects\15\1508\MXD\SSWP\Figure 1_Proposed_Sampling_Locations.mxd Author: tcushman; Date/Time: 2/10/2015, 9:10:52 AM



DRAWN BY/DATE: TDC 2/3/15
REVIEWED BY/DATE: PMH 2/3/15
APPROVED BY/DATE: BGH 2/10/15

RELEVANT ELEVATIONS - OCTOBER WATER LEVELS

FORMER APPLETON MANUFACTURED GAS PLANT (MGP) FACILITY
WE ENERGIES
APPLETON, WISCONSIN

PROJECT NO: 1508

FIGURE NO: 2

NATURAL RESOURCE TECHNOLOGY

Y:\GIS\Projects\15\1508\MXD\SSWP\Figure 2_Site Features.mxd Author: tcushman; Date/Time: 2/10/2015, 9:15:19 AM

TABLES

Table 1 - Summary of Site Investigation Activity Location and Rationale

We Energies - Former Appleton Manufactured Gas Plant
WDNR BRRTS Activity #02-45-000042, FID #445033380

Location	Estimated Surface Elevation (NGVD)*	Estimated Top of Screen Elevation (NGVD)*	Screen Length (feet)	Estimated Groundwater Elevation (NGVD)*	Location Rationale	Monitoring Objectives
SB-2014	723.3	--	--	--	Up to 3 borings will be completed to evaluate the presence of a historical dam structure	Investigate the potential underground structure that could obstruct groundwater flow in this area.
MW-26	723.3	710.8	10	713.5	Nested with PZ-26	Provide water level data to determine GW flow and evaluate groundwater quality above bedrock at PZ-26.
MW-27	723.5	711	10	720.0	Between existing MW-23 and future MW-28 and nested with PZ-27	Provide water level data to determine GW flow and water quality data downstream of the PZ-23 area.
PZ-27	723.5	703.5	5	720.0	Between existing PZ-23 and future PZ-28 and nested with MW-27	Provide hydraulic gradient and water quality of the shallow bedrock in the PZ-23 area
MW-28	723.5	711	10	720.0	Southwest of existing MW-23 and future MW-27, directly adjacent to potential underground structure, and nested with PZ-28	Provide water level data to determine GW flow and water quality data in the PZ-23 area. To evaluate-hydraulic isolation of PZ-26.
PZ-28	723.5	703.5	5	720.0	Southwest of existing PZ-23 and future PZ-27, directly west adjacent to the potential underground structure, and nested with MW-28	Provide hydraulic gradient and water quality of the shallow bedrock in the PZ-23 area to evaluate hydraulic isolation of PZ-26.
SG-4	723	--	--	711.0	Bench mark or Staff Gauge installed to monitor tailwater elevation of the river exiting the hydroelectric unit	Provide low head elevation for evaluating vertical and horizontal gradients
SV-1	723.3	One SG probe to be placed 1-2ft above groundwater**	0.5	713.5	Along the southern face of the Fox River Apartments, east of PZ-26	Evaluate the presence/ absence of VOCs in soil gas above areas of known or suspected groundwater contamination in shallow bedrock.
SV-2	723.3	One SG probe to be placed 1-2ft above groundwater**	0.5	713.5	Along the southern face of the Fox River Apartments, near PZ-26	Evaluate the presence/ absence of VOCs in soil gas above areas of known or suspected groundwater contamination in shallow bedrock.
SV-3	723.3	One SG probe to be placed 1-2ft above groundwater**	0.5	713.5	Along the southern face of the Fox River Apartments, near the corner of the Southern and Western corners of the building	Evaluate the presence/ absence of VOCs in soil gas above areas of known or suspected groundwater contamination in shallow bedrock.
SV-4	723.5	One SG probe to be placed 1-2ft above groundwater**	0.5	720.0	Along the western face of the Fox River Apartments, near the elevator shaft.	Evaluate the presence/ absence of VOCs in soil gas above areas of known or suspected groundwater contamination in shallow bedrock.
SV-5	715	One SG probe to be placed 1-2ft above groundwater**	0.5	713.5 - 720	Inner courtyard area of Fox River Apartmetns between underground garage and townhomes	Investigate the lateral extent of the possible vapor intrusion pathways
SV-6	715	One SG probe to be placed 1-2ft above groundwater**	0.5	713.5 - 720	Inner courtyard area of Fox River Apartmetns between underground garage and townhomes	Investigate the lateral extent of the possible vapor intrusion pathways

Notes:

* Elevations are estimated based on survey data and general distance from locations MW-23, PZ-23, and PZ-26

** If conditions allow, a second soil gas probe will be installed at least 2 feet above the initial probe and 3 to 5-feet below ground surface.

Table 2 - Groundwater Sample Analysis Plan

We Energies - Former Appleton Manufactured Gas Plant

WDNR BRRTS Activity #02-45-000042, FID #445033380

	2014 Plan - Year 9 (July 2014 to October 2014)									Proposed Monitoring Plan (starting April 2015)								
						RNA Parameters									RNA Parameters			
Monitoring Well Location	VOCs (USEPA 8260B)	BTEX (USEPA 8260B)	Benzene (USEPA 8260B)	Naphthalene (USEPA 8260B)	Arsenic (USEPA 6020)	Geochemical Parameters[1] (Various)	Field Parameters[2]	DNAPL Measurement	Water Levels	VOCs (USEPA 8260B)	BTEX (USEPA 8260B)	Benzene (USEPA 8260B)	Naphthalene (USEPA 8260B)	Arsenic (USEPA 6020)	Geochemical Parameters[1] (Various)	Field Parameters[2]	DNAPL Measurement	Water Levels
Site Monitoring Wells (North of Fox River Canal)																		
MW-2R		S		S	A	A	S	A	S		S		S	A	A	S	A	S
MW-8									S									S
MW-9									S									S
MW-10									S									S
MW-12R		S		S	A	A	S	A	S		S		S	A	A	S	A	S
MW-13R		S		S	A	A	S	A	S		S		S	A	A	S	A	S
MW-19		S		S	A	A	S	A	S		S		S	A	A	S	A	S
MW-19S									S									S
MW-20		S		S	A	A	S	S	S		S		S	A	A	S	S	S
MW-21		S		S	A	A	S	S	S		S		S	A	A	S	S	S
MW-22		S		S	A	A	S	A	S		S		S	A	A	S	A	S
MW-24		S		S	A	S	S		S		S		S	A	S	S		S
MW-25		S		S	A	S	S		S		S		S	A	S	S		S
Site Bedrock Piezometers																		
PZ-12B			A	A			A		A			A	A			A		A
PZ-20B			A	A			A		A			A	A			A		A
PZ-21B			A	A			A		A			A	A			A		A
PZ-22B			A	A			A		A			A	A			A		A
Fox River Apartment Wells (South of Fox River Canal)																		
MW-23									Q									Q
PZ-23		Q		Q	A	A	Q	A	Q		Q		Q	A	Q	Q	A	Q
PZ-26[4]	1,2Q	Q		Q	AO	Q	Q	Q	Q	1,2Q	Q		Q	A	Q	Q	Q[3]	Q
MW-26										1,2Q	Q		Q	A	Q	Q	Q	Q
MW-27										1,2Q	Q		Q	A	Q	Q	Q	Q
PZ-27										1,2Q	Q		Q	A	Q	Q	Q	Q
MW-28										1,2Q	Q		Q	A	Q	Q	Q	Q
PZ-28										1,2Q	Q		Q	A	Q	Q	Q	Q
Staff Gauges																		
SG-3									Q									Q
SG-4																		Q

(PAR/CAR 061004)(RJC/CAR 071022)(BGH/CAR 250309)(BGH/CAR 290610)(BGH/CAR 2011)(BGH/CAR 2012)(U-BGH 6/6/613)(U-BGH 2/12/14)(C-PMH 3/20/14)(U-PMH 1/27/15)

Notes:

BTEX = Benzene, ethylbenzene, toluene, xylenes (total)

RNA = Remediation by Natural Attenuation

A = Annual Sampling Frequency (Apr)

S = Semi-Annual Sampling Frequency (Apr, Oct)

Q = Quarterly Sampling (Jan, Apr, Jul, Oct)

1. Geochemical parameters include: Nitrate, methane, manganese, dissolved iron, sulfate, and alkalinity.
2. Field parameters include: pH, dissolved oxygen, temperature, specific conductance, and oxidation/reduction potential.
3. Starting in April 2015, following each quarterly NAPL reading in 2015, NAPL will be removed from the well using a bailer (or other technique). Water level and NAPL thickness measurements will be collected before and after NAPL removal. The volume of NAPL recovered will also be estimated and recorded.
4. Water quality sampling will not be conducted at this location as long as NAPL remains present.

2015 Work Plan Additions

Table 3 - Soil Vapor and Waste Characterization Sample Analysis Plan

We Energies - Former Appleton Manufactured Gas Plant

WDNR BRRTS Activity #02-45-000042, FID #445033380

Sample Type/Location	Proposed Number of Samples	Parameter	Method	Field Duplicates[1]	Equipment Blanks	MS/MSD[2]	TOTAL	Container Type	Minimum Volume	Preservation (Cool to 4° ≥ 2°C All Samples)	Holding Time from Sample Date
Soil Gas	6	VI VOCs[3]	TO-15	1	--	1*	7	Summa Canister	1 L	--	30 days
	6	Other Gases (CO2, O2, CH4)	ASTM D1946 or EPA 3C	1	--	1*	7	Summa Canister	1 L	--	30 days

Notes:

1. Field duplicates will be collected at a frequency of one per group of ten or fewer
2. Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples will be collected at a frequency of one per group of twenty or fewer
3. Vapor VOCs include BTEX, and naphthalene

* MS/MSD Vapor samples do not require additional cannisters

Table 4 - January 2015 Calculated Residential Risk Screening Levels

We Energies - Former Appleton Manufactured Gas Plant
WDNR BRRTS Activity #02-45-000042, FID #445033380

Compound	Residential Indoor Air Vapor Action Levels ($\mu g/m^3$) [1]	Residential Attenuation Factor for Sub-Slab and Shallow Soil Gas[2,3]	Residential Vapor Risk Screening Level for Sub-Slab and Shallow Soil Gas ($\mu g/m^3$)
Benzene	3.6	0.1	36
Ethylbenzene	11	0.1	110
Naphthalene	0.83	0.1	8.3
Toluene	5,200	0.1	52,000
Xylene (mix)	100	0.1	1,000

[o-PMH, c-BGH 2/15]

Notes:

[1] Source - http://dnr.wi.gov/topic/Brownfields/documents/vapor/vapor-quick.pdf (Carcinogenic Risk of 1-in-100,000); based on most recent USEPA updates provided in November 2014.

[2] Source - http://dnr.wi.gov/files/PDF/pubs/rr/RR800.pdf

[3] Attenuation factors for residential buildings also apply to small commerical buildings.

ATTACHMENT A

DRILLING METHODS GENERAL, NRT 07-05-03

Prepared By:	RJC	Date Prepared:	04-05-13
Corporate Officer:	BRH	Date Approved:	02-26-14

DRILLING METHODS GENERAL

1.1. Scope and Application

This standard is applicable to subsurface drilling techniques through unlithified, lithified, and fill materials. This standard operating procedure (SOP) does not address specific drilling methods, which are implemented by the drilling contractor, rather this SOP summarizes drilling methods available for use at environmental sites. It is important for technical staff to be familiar with available drilling methods for discussions with drilling contractors (who can offer additional insight and advice when planning for and scoping a project). In addition, ASTM D6286 is a standard guide that also provides additional information regarding applicability of drilling methods when planning an environmental drilling project. Refer to the project-specific documents for variances to this SOP.

1.2. Health and Safety Warnings

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

Clear all underground utilities in accordance with SOP 07-05-01 prior to commencing sampling activities. Some states require the firm completing the drilling make the locate request for it to be valid and defensible, so check applicable state laws before clearing a site for underground utilities.

1.3. Drilling Types

1.3.1. Augers

Hollow-stem and solid-stem auger methods can be used in unconsolidated and semi-consolidated (weathered rock) materials, but not in competent rock. Each method can be used without introducing foreign materials into the borehole (such as drilling fluids), thus minimizing the potential for cross-contamination, an important consideration when selecting the drilling method(s) for a project.

1.3.1.1 Hollow-Stem Auger

A hollow-stem auger consists of a hollow steel stem or shaft with a continuous spiraled steel flight welded onto the exterior of the drill stem, connected to an auger bit, which when rotated, transports cuttings to the surface. This method is best suited in materials such as sand that have a tendency to collapse when drilled.

A monitoring well can be installed inside hollow stem augers with little concern for potential caving of the surrounding material. A center-rod bottom plug or pilot bit assembly can be used to keep most material out of the bottom of the auger during drilling. Potable water may be used inside the augers (where applicable) to equalize pressure if sand or other flowing material ("heaving sands" or "blow-in") enters the auger from the bottom. Watertight center plugs are not acceptable because they create suction when extracted from the augers, which can compound heaving sand issues. Auguring without a center plug or pilot bit assembly is permitted, provided the soil plug in the bottom of the auger is removed when sampling or constructing a well. Removing the soil plug from augers can be accomplished by introducing water into the auger. Retracting augers after constructing monitoring wells in lose soils that are prone to caving can be difficult because the augers are typically extracted without being rotated to avoid damage to the well; thus, a drill rig with sufficient power must be used to extract the augers without rotation. Boreholes can be augured to depths of 150 feet or more (depending on the auger and drill rig size), but generally boreholes are augured to depths less than 100 feet. ASTM D5784 is a standard for the performance of hollow-stem auger drilling and well installation which should be referred to if this method if drilling is being considered. Field personnel performing soil sampling or well construction with this method should read this guidance to ensure work is done in accordance with industry standards.

1.3.1.2 Solid-Stem Auger

Solid-stem augers have a solid stem or shaft with a continuous spiraled steel flight, welded onto the stem, and connected to an auger bit. This auger method is used in cohesive and semi cohesive soils that do not have a tendency to collapse when disturbed. Boreholes can be augured to depths of 200 feet or more (depending on the auger and drill rig size), but generally boreholes are augured to depths less than 150 feet.

1.3.2. Rotary Methods

This method consists of a drill stem coupled to a bit that rotates and cuts through soils and/or competent rock. The cuttings produced from the rotating drill bit are transported to the surface by the selected drilling fluid (water, drilling mud, or air) in all cases except for sonic rotary. Rotary sonic methods only require the addition of drilling fluid (typically water) to cool the drill bit.

For non-sonic rotary drilling, the water, drilling mud, or air is pumped down through the drill stem, out through the drill bit and is forced, along with the drill cuttings, to the surface between the borehole wall and drill stem. The drilling fluids also cool the drill bit. When considering this method, it is important to evaluate the potential for contamination when fluids and/or air are introduced into the borehole.

Sonic rotary is the preferred rotary drilling method, followed by water rotary, direct wireline rotary, air rotary, mud rotary, and dual-wall reverse circulation air rotary.

1.3.2.1. Rotary Sonic

This method advances two concentric drill stems using rotation in conjunction with axial vibration. After advancing the drill stem, the inner string is removed with a core of drill cuttings while the outer string remains in place to maintain an open borehole. The cuttings (generally intact) can be removed from the inner casing for examination of stratigraphy prior to disposal. Compared to hollow stem augurs,
1) the quantity of cuttings is minimized because the borehole diameter is reduced and 2) smearing of the formation materials on the borehole walls is reduced as well. This drilling method is useful in a variety of materials, from flowing sands to heavily consolidated formations.

In flowing sands, the drill casings can be filled and/or pressurized with potable water to prevent excess entry of formation materials into the drill string. The same QA/QC requirements for sampling of material introduced to the borehole apply as in other drilling methods. Because the amount of water introduced into the borehole can be significant, an approximation of the water used in the drilling process should be logged for use in estimating appropriate well development withdrawal.

Sonic drilling allows a larger diameter temporary casing to be set into a confining layer while drilling proceeds into deeper aquifers. This temporary casing is then removed during the grouting operation.
In many cases this will be acceptable technique. However, the level of contamination in the upper aquifer, the importance of the lower aquifers for drinking water uses, the permeability and continuity of the

confining layer, and state regulations should be taken into account when specifying this practice as opposed to permanent outer casing placed into the confining unit. Note that when using the temporary casing practice, it is critical that grout be mixed and placed properly as specified elsewhere in this section.

Because the total borehole diameter in sonic drilling is only incrementally larger than the inner casing diameter, particular care should be taken that the well casing is placed in the center of the drill stem while placing the filter pack. Centralizers may be required to facilitate this in the case of deep wells with PVC casing.

1.3.2.2. Water Rotary

When using water rotary, potable water should be used whenever possible. If potable water is not available, then options for transporting potable water to the site or alternative drilling methods should be evaluated. Water rotary is the preferred rotary method because potable water is the only fluid introduced into the borehole during drilling. Water does not clog the formation materials, thus reducing well development time. The potable water will, however, flow into the surrounding formation materials (if permeable) and mix with the natural formation water. This mixing of the drilling and natural formation water should be evaluated when determining the drilling method. Generally, most of the drilling water will be recovered during well development. ASTM D5783 is a standard for the performance of water-based rotary drilling and well installation which should be referred to if this method if drilling is being considered.

1.3.2.3. Mud Rotary

Mud rotary is the least preferred rotary method because chemical changes can be introduced into the borehole from the constituents in the drilling mud, and it is very difficult to remove the drilling mud from the borehole after drilling and during well development. The drilling mud can also carry contaminants from a contaminated zone to an uncontaminated zone, thereby cross contaminating the borehole. However, it is a preferred method among some drilling contractors because the drilling mud allows easy removal of the cuttings, cools the bit properly, and generally makes drilling easiest since the mud acts as a casing to hold the borehole open during drilling operations.

If mud rotary is selected, potable water is recommended whenever possible, and drilling muds need to be reviewed for potential environmental and chemical ramifications. ASTM D5783 is a standard for the performance of water-based rotary drilling and well installation which should be referred to if this method if drilling is being considered.

1.3.2.4. Direct Wireline Rotary

As with the water rotary method, potable water should be used, and if it is not available then consideration needs to be given to transporting potable water to the site or an alternative drilling method. This is the preferred method for coring bedrock because potable water is the only fluid introduced into the formation and it shares the same advantages and considerations of water rotary drilling. The difference between the two is that a continuous core sample may be recovered with wireline drilling. In comparison to air rotary, additional time may be required for borehole construction due to the core sample collection. ASTM D5876 is a standard for the performance of direct rotary wireline drilling and well installation which should be referred to if this method if drilling is being considered.

1.3.2.5. Air Rotary

Air rotary utilizes compressed air to cool the bit and remove the drill cuttings. When using air rotary, the air compressor must have an in-line organic air filter system connected between the compressor and rig. The organic filter system removes potential contaminants (such as oil or grease required for proper compressor operation) and should be regularly inspected to insure it is functioning properly. Air compressors that do not have in-line organic filter systems are not acceptable for use during drilling.

A cyclone velocity dissipater or similar air containment system should also be used to funnel the cuttings to one location instead of allowing them to be blown uncontrolled out of the borehole. An air rotary rig that allows cuttings to blow uncontrolled out of the borehole and does not direct them to a discharge point with minimal disturbance is not preferred. Air rotary that employs the dual tube (reverse circulation) drilling system is acceptable since the cuttings are contained in the drill stems and blown to the surface through the cyclone velocity dissipater and to the ground with little surface disturbance. ASTM D5782 is a standard for the performance of air rotary drilling and well installation which should be referred to if this method if drilling is being considered.

1.3.2.6. Dual-Wall Reverse Circulation Air Rotary

Dual-wall reverse circulation drilling air rotary is similar to regular air rotary with the exception that the flow of drill cuttings is from the casing into and through the drill bit rod. The method is extremely useful when ground-water sampling of an unconsolidated formation is desired during drilling. Samples can be collected while drilling proceeds and shipped to a laboratory for fast-turnaround to assess contaminant concentrations with depth. ASTM D5781 is a standard for the performance of dual-wall reverse circulation drilling and well installation which should be referred to if this method if drilling is being considered.

1.3.2.7. Other Methods

Other types of drilling procedures are also available, such as the cable-tool, the jetting method, and the boring (bucket auger) method. These methods are not common site investigation methods. Use of these methods may be appropriate based on site circumstances, if approved by the project manager before fieldwork is initiated.

1.4. Cased Boreholes

Casings are used to prevent cross-contamination when boreholes are drilled through contaminated intervals. A pilot borehole is bored through the overburden and/or contaminated zone into the underlying uncontaminated strata. An outer casing (sometimes called surface or pilot casing) is then placed into the borehole and sealed with grout. The borehole and outer casing extend a minimum of 5 feet into lower strata or 2 feet into competent bedrock. The total depths into underlying strata or bedrock will vary, depending on the physical characteristics of the underlying material and the extent of weathering and/or fracturing of the bedrock.

The size of the outer casing is of sufficient inside diameter (ID) to contain drilling equipment. The outer casing is grouted by the tremie method or pressure grouting to within 2 feet of the ground surface. The grout mixture used to seal the outer casing typically consists of Type I Portland cement/bentonite or cement/sand mixture to ensure the bottom plug is rigid enough to withstand drilling stresses. A minimum of 24 hours is allowed for grout curing before continuing drilling activities.

1.5. References

ASTM D2113-08 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

ASTM D5781-95(2006) Standard Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

ASTM D5782-95(2006) Standard Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

ASTM D5783-95(2006) Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

ASTM D5784-95(2006) Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

ASTM D5875-95(2006) Standard Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices

ASTM D6151-08 Standard Practice for Using Hollow Stem Augers for Geotechnical Exploration and Soil Sampling

ASTM D1452-09 Practice for Soil Investigation and Sampling by Auger Borings

ASTM D2113-08 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

ASTM D5872-95(2000) Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices

ASTM D6282-98(2005) Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations

ASTM D6286-98(2006) Standard Guide for Selection of Drilling Methods for Environmental Site Characterization

ATTACHMENT B

FIELD LOGGING OF SOIL AND SEDIMENT, NRT 07-06-03

Prepared By:	NDK/RJC	Date Prepared:	04-20-2014
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FIELD LOGGING OF SOIL AND SEDIMENT

1.1. Scope and Application

This standard operating procedure (SOP) is applicable to field logging of subsurface explorations of soil and sediment. This standard is established to indicate the process of logging in the field, to improve comprehension of the logging process, and to improve overall efficiency within the office when working with logging field notes. Refer to project-specific documents for variances from this SOP.

1.2. Health and Safety Warnings

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

Clear all underground utilities, private, commercial, and public in accordance with SOP 07-05-01 prior to commencing sampling activities. Screen each sample location with a metal detector or magnetometer prior to sampling to verify the absence buried metal, such as underground pipes.

1.3. Logging Procedure

Soil descriptions will be completed in accordance with ASTM Standard Practice for the Description and Identification of Soils (Visual-Manual Procedure), which is ASTM Standard D2488 – 09a. A copy of ASTM Standard D2488 – 09a is attached along with two summary sheets developed from this SOP. These two summary sheets describe in tabulated format how to identify fine- and course-grained soils in the field in accordance with ASTM SOP and they are entitled “Fine-Grained Soils Field Identification” and “Coarse-Grained Soils Field Identification”, respectively.

When logging soils, all contact depth shall be recorded in tenths of a foot. The general criteria for logging fine-grained and coarse-grained soils are listed below. Soil descriptions will be documented on field borehole logs and will describe material percentages of individual components that constituent the matrix of the soil sample and the soil classification guideline is based on ASTM D2488.

1.3.1. Sediment Classes

Granular sediment is comprised of three classes of material, biogenic, mineral/lithic, and glass. Glass is likely to be only a minimal component so it does not warrant further discussion. The descriptive classification for both mineral and biogenic types is based upon grain-size and sediment constituents.

1.3.1.1. Biogenic (Organic) Sediments

Biogenic sediments (organic origin) are those that contain remains or traces of once-living organisms in a concentration of greater than 50 percent. This class of sediment is often flocculent at the sediment/water interface and has a “pudding-like” texture due to its high content of organic material. Biogenic sediments are often dark brown to black in color, and have an organic odor. Basic components of those sediments include; shell fragments, fish parts, plant material, and fecal pellets.

1.3.1.2. Mineral Sediments

Mineral sediments consist of mineral grains derived from physically weathered rocks, precipitates, and antigenic sources in a concentration of greater than 50 percent (ASTM D2488 Section 3). If there are enough biogenic/organic constituents present to influence the soil properties (ASTM D2488 Section 14.8). Common components of mineral sediments include; quartz, feldspars, clay minerals, micas, and rock fragments.

1.4. Lithologic Description

A continuous log of encountered geologic materials from borehole cuttings, samples, and core should be recorded on a borehole field Log. Prior to creating a continuous log of geologic materials some terms, definitions, and descriptors are important to be aware while logging soil and sediment.

Physical descriptions derived from visual observation and manual testing can be used to classify soil and sediment origin (biogenic or mineral) as well as physical properties of the material. The physical soil and sediment description includes the following parameters:

- Color
- Odor

- Obvious materials
- Structure
- Consistency (including particle size, shape and angularity for course grained-soils/sediments)
- Gradation
- Dry Strength (manual test)
- Dilatency (manual test)
- Toughness (physical description)
- Plasticity (physical description)

The soil color should be identified using a Munsell soil color chart. Often organic sediments (biogenic) turn color after exposure to air, any such color change should be noted as well.

Any obvious material in samples, such as coal fines, metallic chips, wood, etc. should be noted, and depth of material recorded. Further, any sheen soil or water within the sample container should be recorded.

The odor of a sample needs to be described. The following table summarizes the terms that may be used to describe the strength or pungency of odors:

Strength of Odor	Comment
No odor	No detectable odor at close proximity
Faint	Barely perceptible under close proximity, may be difficult to characterize
Moderate	Perceptible odor under close proximity
Strong	Clearly perceptible odor from several feet, (e.g., standing over sample)

The following is a list of common odor characterizations (remember "-like" will follow each descriptor):

- Diesel
- Mothball
- Petroleum-gasoline
- Petroleum-diesel

- Petroleum-kerosene
- Sulfur
- Gasoline
- MGP
- Coal tar
- Creosote
- Paint
- Tar
- Solvent
- Oil-based Varnish
- Vinegar
- Rubber
- Kerosene
- Burnt
- Earthy
- Smokey
- Sour
- Sweet
- Fishy
- Fruity

Consider the following when classifying odors:

- Be safe! Use your hand to waft odors from the sample toward your nose initially. If you don't smell anything, then you can get closer. It may be helpful to take short quick breaths through the nose to help describe odors. DO NOT get your nose right up to a sample and take a deep breath as the contents of the sample is unknown and this work needs to be performed in a safe manner.
- Provide the sample interval(s) that the odor describes.

- Include negatives (i.e., descriptions of “No Odor”). The lack of odors can be just as important as the presence of odors. If there is no description of odor in the log, we cannot assume that there was no odor.

- Some samples may have very strong odors (saturate the nose) and make it difficult to discern the strength of the odors in later samples. Do not need to try and compensate for this, describe the odor as you perceive it at that time.

Structure of the soil should be described utilizing the following table taken from ASTM D2488.

Table 1: Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 millimeters thick
Laminated	Alternating layers of varying material or color with layers less than 6 millimeters thick
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken into small angular lumps resisting further breakdown
Lensed	Inclusion of small pockets of different soils, note thickness
Homogeneous	Same color and appearance throughout sample

Consistency for fine-grained soils (50% or more fines) of biogenic or mineral sources should be described as very soft to very hard utilizing the following table taken from ASTM D2488.

Table 2: Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very Hard	Thumbnail will not indent soil

Consistency for course-grained soils (less than 50 percent fines) should include several descriptive observations including particle size, particle shape, and angularity. Particle size differentiates between sand, silt, and clay (ASTM D2488 Section 3.1).

Particle shape refers to the length, width, and thickness of the individual particles. The description of particle shape should only be used in cases where the particle shape is flat, elongated, or flat and elongated (ASTM D 2488, Table 2).

Table 3: Criteria for Describing Particle Shape

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

The angularity refers to the overall shape or outline of a particle. The description should be angular, sub-angular, sub-rounded or rounded (ASTM D2488, Table 1).

Table 4: Criteria for Describing Angularity of Coarse-Grained Particles

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

Gradation refers to the distribution of grain sizes present in a sample and should be used where course-grained soils are encountered. The description should be either well-graded or poorly-graded as defined in ASTM D2488 (Sections 15.31 and 15.32). Sorting which is a Geologic Interpretation can often be confused with Gradation. When sorting is included while logging it should be printed in parentheses near the end of the log.

Table 5: Criteria for Describing Gradation

Description	Criteria
Poorly Graded	Predominately one particle size, wide range of sizes with some intermediate sizes missing (gap or skip graded)
Well Graded	Wide range of particle sizes and substantial amounts of the intermediate particles sizes

For fine-grained mineral soils, dry strength, dilatency, toughness, and plasticity should be used to classify the material as lean clay, fat clay, silt, or elastic silt (ASTM D2488 Section 14) and/or the NRT Fine-Grained Soils Field Identification Sheet, which is based on the ASTM standards.

Table 6: Criteria for Describing Dry Strength

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

Table 7: Criteria for Describing Dilatency

Description	Criteria
None	No visible change
Slow	Water appears/disappears slowly or does not disappear
Rapid	Water appears/disappears quickly

Table 8: Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

Table 9: Criteria for Describing Plasticity

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

1.4.1. Fine-Grained Sediment Description Format

The following format should be followed when logging fine-grained soil or sediment:

> **Group Name:** Soil color, preszence of organic material, particle descriptions, geotechnical description**,** dry strength, dilatency, toughness, plasticity, consistency, cementation, structure, odor, moisture, additional comments (geologic origin and/or descriptions).

Fine-Grained Sediment Description Example:

> **LEAN CLAY WITH SAND (CL)s**, reddish brown (5YR 4/4), few mottles greenish gray (10Y 5/1), 15% subrounded fine to medium sand, few subangular fine gravel, slow dilatency, medium toughness, medium plasticity, homogenous, blocky, no odor, moist, trace fine root material [TILL].

All geologic descriptions will be record as noted in the above examples when logging Fine-Grained Soil or Sediment. List below are more details on the noted criteria necessary for a complete description:

- Color - Soil color is coded using the Munsell Soil Color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded; for example, “reddish brown (5YR 4/4)”.
- Class type (Biogenic or Mineral)
- Size Distribution - approximate percentage of gravel, sand, fines (if possible, distinguish between silt and clay). Percentages should add up to 100%. For example, “80% silt, 20% f-sand”.
- Geotechnical Description-recording the blow counts for a specific split spoon while working with a Hollow Stem Auger, performing pocket penotrometer test, or a Torvane shear strength test (when applicable and available). Field Guides for testing soil strength using a pocket penetrometer or field vane are attached.
- Dry Strength, Dilatency, Toughness, and Plasticity tests should be completed to determine the fine-s] grained soil characteristics and type.
- Textural Classification - example “Sandy Silt”
- Group Symbol - USCS group symbol is written in parentheses after the textural classification. For example, “(sML)”
- Consistency/Penetration Resistance - use very soft, soft, medium, stiff, very stiff, and hard. These are estimated from drive sample hammer blows or other field tests. Blow counts may also be used, if reliable.
- Moisture Content - Dry, damp, moist, wet (saturated)
- Miscellaneous - odor, contact, and/or bedding dip, bedding features, cementation, structures, fractures, fracture fillings, fossils, formation name, minerals, oxidation, etc.

1.4.2. Coarse-Grained Sediment Description Format

The following format should be followed when logging coarse-grained soil or sediment:

Group Name: Soil color, presence of organic material, particle descriptions, geotechnical description**,** fine-grained soils, consistency, cementation, structure, odor, moisture, additional comments (geologic origin and/or descriptions).

Coarse-Grained Sediment Description Example:

POORLY GRADED SAND WITH SILT, (SP-SM) reddish brown (5YR 4/4), subrounded fine to medium sand, few subangular fine gravel, no cementation, homogenous no odor, moist.

All geologic descriptions will be record as noted in the above examples when logging Coarse-Grained Soil or Sediment. List below are more details on the noted criteria necessary for a complete description:

- Color - Soil color is coded using the Munsell Soil Color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded; for example, "reddish brown (5YR 4/4)".
- Class type (Biogenic or Mineral)
- Size Distribution - approximate percentage of gravel, sand, fines (if possible, distinguish between silt and clay). Percentages should add up to 100%. For example, "80% silt, 20% fine sand".
- Grain shape (angular, subangular, subrounded, rounded, or well-rounded)
- Geotechnical Description-recording the blow counts for a specific split spoon while working with a Hollow Stem Auger, performing pocketpenotrometer test, or a Torvane shear strength test (when applicable and available).
- Textural Classification - example "Sandy Silt"
- Group Symbol - USCS group symbol is written in parentheses after the textural classification. For example, "(sML)"
- Moisture Content - Dry, damp, moist, wet (saturated)
- Miscellaneous - odor, contact, and/or bedding dip, bedding features, cementation, structures, fractures, fracture fillings, fossils, formation name, minerals, oxidation, etc.

1.4.3. SOP Attachments

The following attachments are herein made part of the SOP for the purposes of logging soil and sediment samples appropriately and in accordance with this SOP:

- ASTM D2488
- NRT Fine-Grained Soils Field Identification Summary
- NRT Coarse-Grained Soils Field Identification Summary
- NRT Field Guide 001 Pocket Penetrometer (June 2012)
- NRT Field Guide 002 Field Vane (June 2012)

1.5. References

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

ASTM D5715, Test Method for Estimating the Degree of Humification of Peat and Other Organic Soils (Visual/Manual Method).

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

ASTM D5079, Practices for Preserving and Transporting Rock Core Samples.

ASTM D5434, Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM D4543, Practices for Preparing Rock Core Specimens and Determining Dimensional and Shape Tolerances.

ASTM D6236, Guide for Coring and Logging Cement - or Lime-Stabilized Soil.

ASTM D7099 ,Terminology Relating to Frozen Soil and Rock.

ASTM D0653, Terminology Relating to Soil, Rock, and Contained Fluids.

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

ASTM International, D2488-00 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

USEPA, 2001, Sediment Sampling guide and Methodologies (2nd Edition), Division of Surface Water, Cincinnati, Ohio, 2001.

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

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

ATTACHMENT 1

COARSE-GRAINED SOILS FIELD IDENTIFICATION

Coarse-Grained Soils Field Identification
(Particles are less than 50% silt and/or clay (< No. 200 sieve)
DO NOT include particles > 3" diameter to estimate particle %

(Description guidelines follow ASTM D2488 Standard, reference standard for additional detail on performance for soil descriptions)

GROUP NAME, soil color, particle descriptions, consistency, cementation, structure, odor, moisture, additional comments [geologic origin].

POORLY GRADED SAND WITH SILT,(SP-SM), reddish brown (5YR 4/4), subrounded fine to medium sand, few subangular fine gravel, no cementation, homogeneous, no odor, moist.

1

Group Name – Determine after completion of tests.

2

Soil Color (in moist condition) – Color name followed by Hue, Value, & Chroma (eg., Brown (7.5YR 5/3))
Mottled – Identify the percentage mottled and color
(e.g., Brown (7.5YR 5/3) 5% Gray (10YR 5/1) mottling)

3

Particle Descriptions (comments not required when not applicable)
1)**Percent cobbles/boulders** volume %
2)**Coarse Particle Size Range** (Maximum size, and range)
3)**Particle Shape and Angularity**
4)**% gravel/sand/fines** - % particle < 3" by dry weight basis
- Estimate percentage to the closest 5%.
- sum of % gravel/sand/fines must equal 100 (except trace)

General Particle ranges:

Trace	**< 5%**
Few	**5–10 %**
Little	**15–25 %**
Some	**30–45 %**
Mostly	**50–100 %**

5

Consistency Geotechnical Guide (not in ASTM)

Relative Density	SPT Blows/Foot
Very Loose	0-4
Loose	4-10
Medium Dense	10-30
Dense	30-50
Very Dense	>50

6

Describe Fine Grained Material – follow fine-grained description sheet.

7

Cementation Drop dilute HCl onto the soil, describe

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

8

Structure- note thickness for stratified, laminated, lensed.

Stratified	Alternating layers of material/color ≥ 6 mm
Laminated	Alternating layers of material/color < 6 mm
Fissured	Breaks on fracture(s) with little resistance
Lensed	Small pockets of different material
Homogeneous	Same color and appearance throughout

9

Odor –Appropriate terms listed on back.

10

Moisture -

Dry	Dry to touch, dusty.
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

11

Additional Comments – presence of roots or root holes, surface coatings on coarse-grained particles, etc.

GRADING

poorly graded	- Predominately one particle size (uniform) - Wide range of sizes with some intermediate sizes missing (gap or skip graded)
well graded	Wide range of particle sizes and substantial amounts of the intermediate particle sizes

Sorting entered under *Geologic Interpretation*
The geologic interpretation (including sorting) should printed in parentheses near the end of the log.

Sorting Class	
very well sorted	1 Wentworth size class
well sorted	1 Wentworth size class
moderately well sorted	2 Wentworth size classes
moderately sorted	3 Wentworth size classes
poorly sorted	4 Wentworth size classes
very poorly sorted	5-8 Wentworth size classes

Wentworth size classes are the geologic grain sizes shown on the next page.

FIELD IDENTIFICATION PROCEDURES (excluding particles > 3” and basing fractions on weights)			Group Symbol	NAMES
GRAVEL > 50% > No. 4 Sieve Size	Clean Gravel (little or no fines)	Wide range in grain size and substantial amounts of intermediate particle sizes	**GW**	WELL-GRADED GRAVEL (GW) WELL-GRADED GRAVEL WITH SAND (GWs)
		Predominately one size of range of sizes w/ some intermediate sizes missing	**GP**	POORLY-GRADED GRAVEL (GP) POORLY-GRADED GRAVEL WITH SAND (GPs)
	Well-Graded	fines = ML or MH	**GW-GM**	WELL-GRADED GRAVEL WITH SILT (GW-GM) WELL-GRADED GRAVEL WITH SILT AND SAND (GW-
		fines = CL or CH	**GW-GC**	WELL-GRADED GRAVEL WITH CLAY (GW-GM) WELL-GRADED GRAVEL WITH CLAY AND SAND (GW-
	Poorly-Graded	fines = ML or MH	**GP-GM**	POORLY-GRADED GRAVEL WITH SILT (GP-GM) POORLY-GRADED GRAVEL WITH SILT AND SAND (GP-
		fines = CL or CH	**GP-GC**	POORLY-GRADED GRAVEL WITH CLAY (GP-GC) POORLY-GRADED GRAVEL WITH CLAY AND SAND (GP-
	Gravel with Fines (Appreciable Fines)	Non-plastic fines (for identification, see ML)	**GM**	SILTY GRAVEL (GM) SILTY GRAVEL WITH SAND (GMs)
		Plastic fines (for identification, see CL)	**GC**	CLAYEY GRAVEL (GC) CLAYEY GRAVEL WITH SAND (GCs)
SAND 50% or more is < No. 4 Sieve Size	Clean Sand (little or no fines)	Wide range in grain size and substantial amounts of intermediate particle sizes	**SW**	WELL-GRADED SAND (SW) WELL-GRADED SAND WITH GRAVEL (SWg)
		Predominately one size or a range of sizes w/ some intermediate sizes missing	**SP**	POORLY-GRADED SAND (SP) POORLY-GRADED SAND WITH GRAVEL (SPg)
	Well-Graded	fines = ML or MH	**SW-SM**	WELL-GRADED SAND WITH SILT (SW-SM) WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SMg)
		fines = CL or CH	**SW-SC**	WELL-GRADED SAND WITH CLAY (SW-SC) WELL-GRADED SAND WITH CLAY AND GRAVEL (SW-
	Poorly-Graded	fines = ML or MH	**SP-SM**	POORLY-GRADED SAND WITH SILT (SP-SM) POORLY-GRADED SAND WITH SILT AND GRAVEL (SP-
		fines = CL or CH	**SP-SC**	POORLY-GRADED SAND WITH CLAY (SP-SC) POORLY-GRADED SAND WITH CLAY AND GRAVEL (SP-
	Sand with Fines (Appreciable Amount of Fines)	Non-plastic fines (for identification, see ML)	**SM**	SILTY SAND (SM) SILTY SAND WITH GRAVEL (SMg)
		Plastic fines (for identification, see CL)	**SC**	CLAYEY SAND (SC) CLAYEY SAND WITH GRAVEL (SCg)

Borderline Symbols:
Make every effort to place the soil in a single group. Use a borderline symbol when a soil falls in to one of two possible basic groups (i.e. SC/CL, CL/CH). A borderline symbol may be used under the following circumstances:

1) Fines 45-55%, one symbol represents coarse-grained soil with fines and the other a fine-grained soil (i.e. GM/ML, SC/CL).
2) % sand & gravel estimated to be approximately the same. GP/SP, SC/GC, GM/SM (it is practically impossible to have GW/SW).
3) If a soil could be well or poorly graded (GW/GP, SW/SP)

The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. (i.e. if surrounding soil is GM and your sample could be GM/ML or ML/GM, then GM/ML should be chosen.

Group Name for borderline symbols is the first symbol (i.e. GM/ML is (Silty Gravel or Silty Gravel With Sand (as appropriate)). The only exceptions are for fine-grained material.

Particle Sizes

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS - ASTM D****)				
Grain Size	**Relative Size**	**Inches**	**Millimeters**	**Sieve Size (mm, unless noted)**
Boulders	Basketball or larger	> 11.8"	> 300	Pass – n/a Retained on a 300
Cobbles	lemon to basketball	>3" - 11.8"	75 – 300	Pass a 300 mm sieve Retained on a 75
Coarse Gravel	grape to lemon	0.76" - 3"	19 – 75	Passes a 75 Retained on a 19
Fine Gravel	pea to grape	0.19" - 0.75"	5 – 19	Pass a 19 Retained on 4.75 (No. 4)
Coarse Sand	rock salt	0.08-0.19	2.00 - 4.75	Pass a 4.75 (No. 4) Retained on 2.00 (No. 10)
Medium Sand	sugar to table salt	0.02-.008	0.425 – <2.00	Pass a 2.00 (No. 10) Retained on 0.425 (No 40.)
Fine Sand	Fine sugar to sugar	0.003-0.02	0.075 – <0.425	Pass a 425 µm (No. 40) Retained on 0.075 (No. 200)
Silt			0.005 – 0.074	Pass a 0.075 (No. 200) Non-plastic
Clay			< 0.005	Pass a 0.075 (No. 200) Plastic

GEOLOGIC	
Grain Size	**Millimeters**
Boulder	> 256
Cobble	64 - 256
Pebble	4 - 64
Granule	2 - 4
Very Coarse Sand	1 - 2
Coarse Sand	0.5 - 1
Medium Sand	0.25 - 0.5
Fine Sand	0.125 - 0.25
Very Fine Sand	0.0625 - 0.125
Coarse Silt	0.031 - 0.0625
Medium Silt	0.016 - 0.031
Fine Silt	0.008 - 0.016
Very Fine Silt	0.004 - 0.008
Clay	< 0.004

Fine-Grained Soils Field Identification

(Particles are 50% or more silt and/or clay (< No. 200 sieve)

DO NOT include particles > 3" diameter to estimate particle %

Description guidelines follow ASTM D2488-00 Standard, reference standard for additional detail on performance for soil descriptions. Geologic descriptions may be added to the end of the description in brackets.

GROUP NAME, soil color, particle descriptions, dilatency, toughness, plasticity, consistency, cementation, structure, odor, moisture, additional comments, [geologic origin and/or descriptions].

LEAN CLAY WITH SAND (CL)s, reddish brown 5YR 4/4, few mottles greenish gray 10Y 5/1, 15 % subrounded fine to medium sand, few subangular fine gravel, slow dilatency, medium toughness, medium plasticity, homogenous, blocky, no odor, moist, trace fine root material [TILL].

1

Group Name: Determine after completion of tests listed below. Flow Chart for group names is on the back of this sheet.

2

Soil Color (moist condition) Color name with Hue, Value, & Chroma (e.g., Brown (7.5YR 5/3))
Mottled – Identify mottling percentage and color (e.g., Brown (7.5YR 5/3) 5% Gray (10YR 5/1) mottles)

3

Peat: Composed primarily of vegetable tissue in ranges of decomposition. Do not subject samples to field test procedures described beyond Item #4.
Color - Usually dark brown to black
Texture - Ranges from fibrous to amorphous
Consistency - Usually spongy

4

Particle Descriptions (comments not required when not applicable)
1) **Percent cobbles/boulders** volume %
2) **Coarse Particle Size Range** (Maximum size, and range)
3) **Particle Shape and Angularity**
4) **% gravel/sand/fines** - % particle < 3" by dry weight basis
Estimate percentage to the closest 5%. Sum of gravel/sand/fine %s must equal 100 % (except trace) - General Particle ranges:

Trace	**< 5%**	**Little**	**15–25 %**	**Mostly**	**50–100 %**
Few	**5–10 %**	**Some**	**30–45 %**		

Grain Size	Inch	Millimeter	relative size
Boulders	>11.8	>300	basketball or larger
Cobbles	2.9-11.8	75-300	Lemon - basketball
Coarse Gravel	0.75-2.9	19-75	grape to lemon
Fine Gravel	0.19-0.75	4.8-19	pea to grape
Coarse Sand	0.08-0.19	2.0-48	rock salt
Medium Sand	0.02-.008	0.43-2.0	sugar to table salt
Fine Sand	0.003-0.02	0.08-0.43	fine sugar to sugar
Silt / Clay	<0.003	<0.08	

5

Dilatency – Mold ½"diameter ball (remove all medium sand or larger), add water until soft (not sticky). Smooth ball into palm of one hand; vigorously shake hand horizontally, striking against other hand. Note water appearing on surface. Squeeze sample by closing the hand or pinching soil – note disappearance of water.

None	No visible change
Slow	Water appears/disappears slowly or does not disappear
Rapid	Water appears/disappears quickly

6

Toughness – Shape dilatency ball into a thread (1/8" (3 mm) diameter). Fold and re-roll until thread crumbles (near plastic limit). Note strength of thread. Lump pieces together and knead until lump crumbles.

Low	Slight pressure required to roll near plastic limit. Thread and lump are weak and soft.
Medium	Medium pressure required to roll near plastic limit. Thread and lump have medium stiffness.
High	Considerable pressure needed to roll near plastic limit.

7

Plasticity: On the basis of toughness test observations

Non	Thread cannot be rolled at any water content
Low	Thread is barely rolled, lump cannot be formed when drier than the plastic limit
Medium	Easily rolled thread, little time to reach plastic limit. Cannot re-roll. Lump crumbles when drier than plastic limit.
High	Considerable time to reach plastic limit. Thread can be re-rolled several times. Can form lump without crumbling when drier than plastic limit.

7

Geo-Technical	Pocket Penet	Blows / foot	ASTM Consistency	ASTM Criteria (press thumb/thumbnail)
Very soft	0-0.25	0-2	Very soft	Penetrates > 1"
Soft	0.25-0.5	2-4	Soft	Penetrates about 1"
Firm	0.5-1.0	4-8	Firm	Indents about ¼"
Stiff	1.0-2.0	8-15	- -	No ASTM Description
Very Stiff	2.0-4.0	15-30	Hard	Thumbnail only indents
Hard	>4.0	>30	Very hard	Thumbnail will not indent

8

Cementation Drop dilute HCl onto the soil, describe

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

9

Structure- note thickness for stratified, laminated, lensed.

Stratified	Alternating layers of material/color ≥ 6 mm
Laminated	Alternating layers of material/color < 6 mm
Fissured	Breaks on fracture(s) with little resistance
Slickensided	Polished/glossy fracture plane(s), sometimes striated
Blocky	Can be broken into small angular lumps which resist further breakdown
Lensed	Small pockets of different material
Homogeneous	Same color and appearance throughout

10

Odor –Appropriate terms listed on back.

11

Moisture -

Dry	Dry to touch, dusty.
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

12

Comments – diamicton, roots or root holes, surface coatings, etc…

13

Geologic Interpretations

Deposition add *possible* if unsure	alluvial, lacustrine, colluvial, sediment flow, mass slump, subglacial, supraglacial, glaciaofluvial, glaciolacustrine, aeolian (loess), outwash, proglacial

Dilatency	Toughness	Plasticity	Soil Identification
No	Low	Low	Elastic Silt (MH)
	Low / Medium	Low / Medium	Elastic Silt (MH)
	Medium	Medium	Lean Clay (CL) or Elastic Silt (MH)
No	High	High	Fat Clay (CH)
Slow	Medium	Medium	Lean Clay (CL)
	Low	Non / Low	Silt (ML)
	Low / Medium	Low / Medium	Elastic Silt (MH)
Rapid	Low	Non / Low	Silt (ML)

If properties do not flow, texture again.
- Use borderline texture if soil cannot be differentiated after multiple texture procedures
- MH / CL properties are similar. If MH / CL are indistinguishable use MH/CL or CL/MH.

Note - MH will dry quickly with a smooth, silky feel on your hands.

	Dilatency	Toughness	Plasticity
ML	slow - rapid	low	non - low
CL	no - slow	medium	medium
MH	no - slow	low - medium	low - medium
CH	no	high	high

				GROUP NAME	
CL	<30% sand / gravel	<15% sand / gravel		Lean Clay	(CL)
		%sand ≥ %gravel		Lean Clay With Sand	(CL)s
		%sand < %gravel		Lean Clay With Gravel	(CL)g
	≥ 30% sand / gravel	%sand ≥ %gravel	<15% gravel	Sandy Lean Clay	s(CL)
			≥15% gravel	Sandy Lean Clay With Gravel	s(CL)g
		%sand < %gravel	<15% sand	Gravelly Lean Clay	g(CL)
			≥15% sand	Gravelly Lean Clay With Sand	g(CL)s
ML	<30% sand / gravel	<15% sand / gravel		Silt	(ML)
		%sand ≥ %gravel		Silt With Sand	(ML)s
		%sand < %gravel		Silt With Gravel	(ML)g
	≥ 30% sand / gravel	%sand ≥ %gravel	<15% gravel	Sandy Silt	s(ML)
			≥15% gravel	Sandy Silt With Gravel	s(ML)g
		%sand < %gravel	<15% sand	Gravely Silt	g(ML)
			≥15% sand	Gravely Silt With Sand	g(ML)s
CH	<30% sand / gravel	<15% sand / gravel		Fat Clay	(CH)
		%sand ≥ %gravel		Fat Clay With Sand	(CH)s
		%sand < %gravel		Fat Clay With Gravel	(CH)g
	≥ 30% sand / gravel	%sand ≥ %gravel	<15% gravel	Sandy Fat Clay	s(CH)
			≥15% gravel	Sandy Fat Clay With Gravel	s(CH)g
		%sand < %gravel	<15% sand	Gravelly Fat Clay	g(CH
			≥15% sand	Gravelly Fat Clay With Sand	g(CH)s
MH	<30% sand / gravel	<15% sand / gravel		Elastic Silt	(MH)
		%sand ≥ %gravel		Elastic Silt With Sand	(MH)s
		%sand < %gravel		Elastic Silt With Gravel	(MH)g
	≥ 30% sand / gravel	%sand ≥ %gravel	<15% gravel	Sandy Elastic Silt	s(MH)
			≥15% gravel	Sandy Elastic Silt With Gravel	s(MH)g
		%sand < %gravel	<15% sand	Gravely Elastic Silt	g(MH)
			≥15% sand	Gravely Elastic Silt With Sand	g(MH)s
OL/ OH					
OL					
OH					
PT				Peat	(PT)

"**Sandy**" indicates coarse particles are =/> 30% and less than 50%.

"**Sandy**" indicates sand % > gravel %

"**with Gravel**" indicates the % of gravel is =/> 15%.

Borderline Symbols:
Every effort shall be made to place the soil in a single group. A borderline symbol is used when a soil that may fall in to one of two possible basic groups (e.g., SC/CL, CL/CH). A borderline symbol may be used under the following circumstances:

1) Fines 45-55%, one symbol represents coarse-grained soil with fines and the other a fine-grained soil (e.g., GM/ML, CL/SC).
2) If a soil could either be a silt or clay (CL/ML, CH/MH)
3) Fine-grained soil at low/high compressibility boundary (CL/CH, MH/ML)

The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. (e.g., if surrounding soil is GM and your sample could be GM/ML or ML/GM, then GM/ML should be chosen. Group Names for borderline symbols are the group name for the first symbol except:

CL/CH – LEAN TO FAT CLAY
ML/CL – CLAYEY SILT
CL/ML – SILTY CLAY

Designation: D2488 – 09a

Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)[1]

This standard is issued under the fixed designation D2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (either intact or disturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (see Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.6 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:
Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 *clay*—soil passing a No. 200 (75-µm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D2487).

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

fine—passes a No. 40 (425-µm) sieve and is retained on a No. 200 (75-µm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Fig. 1a and Fig. 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols.*

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

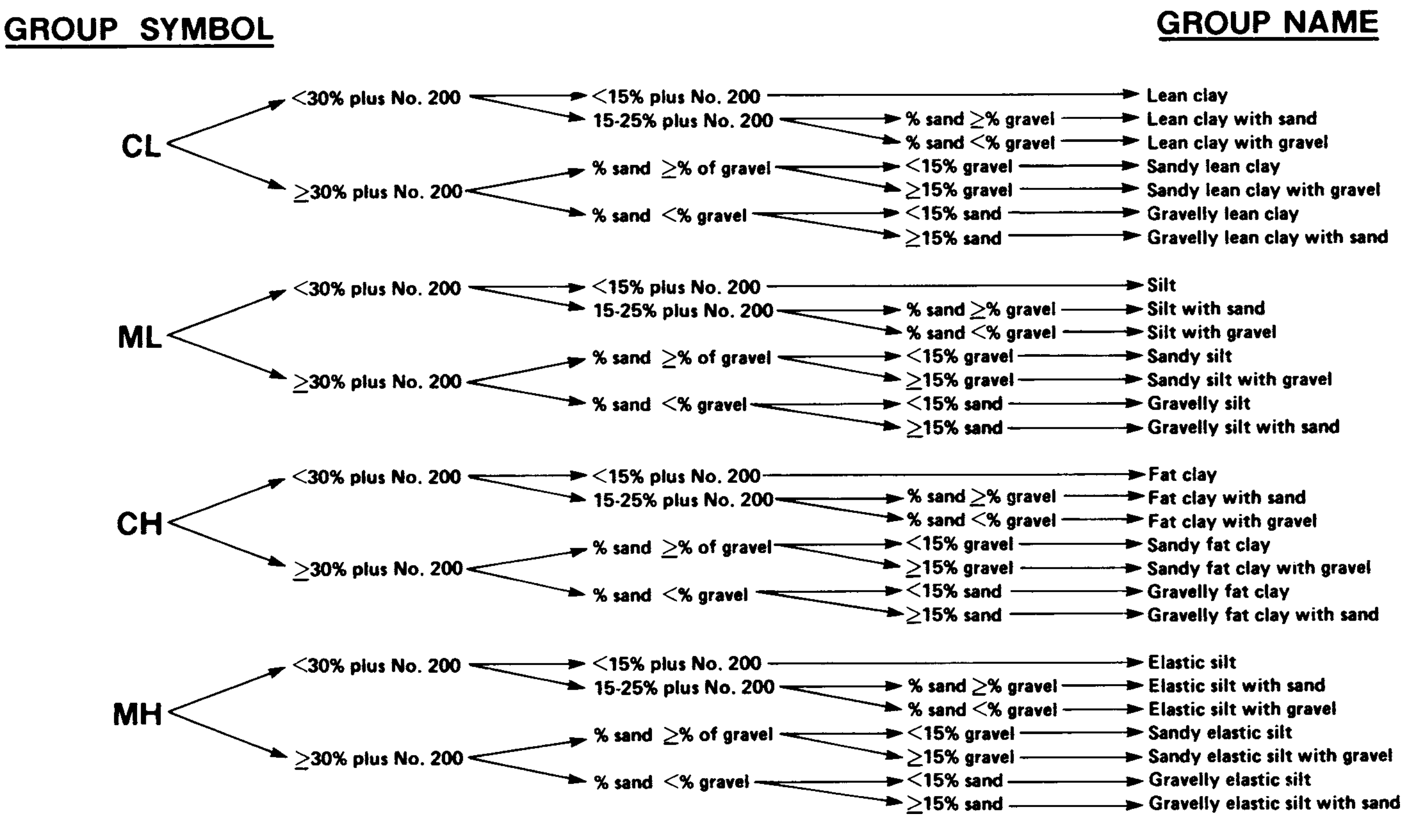
5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

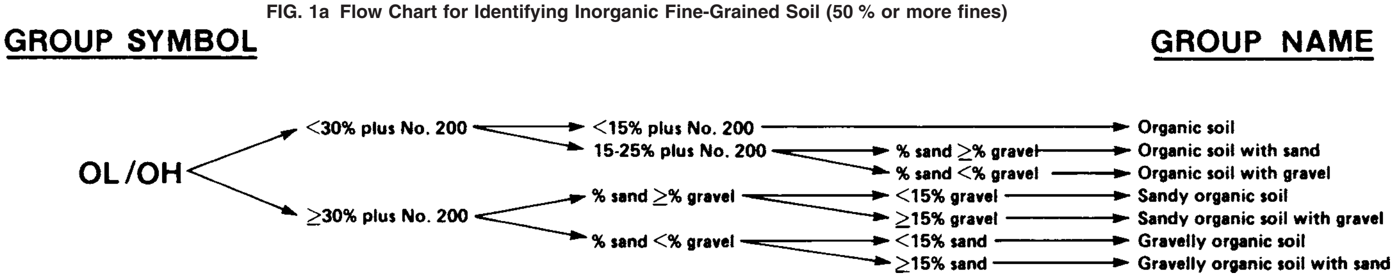
5.7 This practice may be used in combination with Practice D4083 when working with frozen soils.

NOTE 5—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D3740 provides a means for evaluating some of those factors.



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1 b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)

6. Apparatus

6.1 *Required Apparatus*:

6.1.1 *Pocket Knife or Small Spatula*.

6.2 *Useful Auxiliary Apparatus*:

6.2.1 *Test Tube and Stopper* (or jar with a lid).

6.2.2 *Hand Lens*.

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 *N*) to three parts water (This reagent is optional for use with this practice). See Section 8.

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 *N*) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 **Caution**—Do not add water to acid.

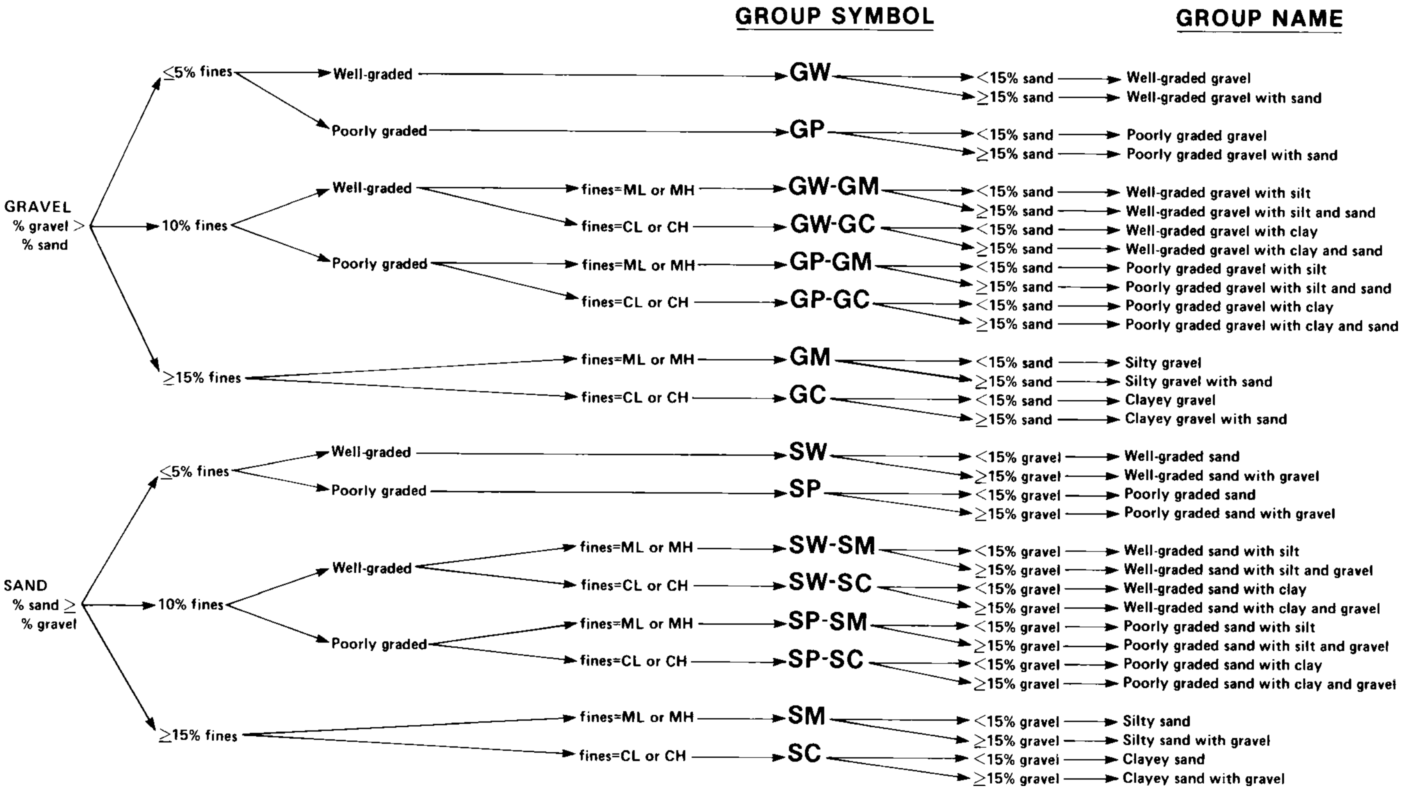
9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 6—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D1452, D1587, or D2113, or Test Method D1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 7—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

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

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3⁄8 in.)	200 g (0.5 lb)
19.0 mm (3⁄4 in.)	1.0 kg (2.2 lb)
38.1 mm (11⁄2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 8—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceeding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

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

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the critera in Table

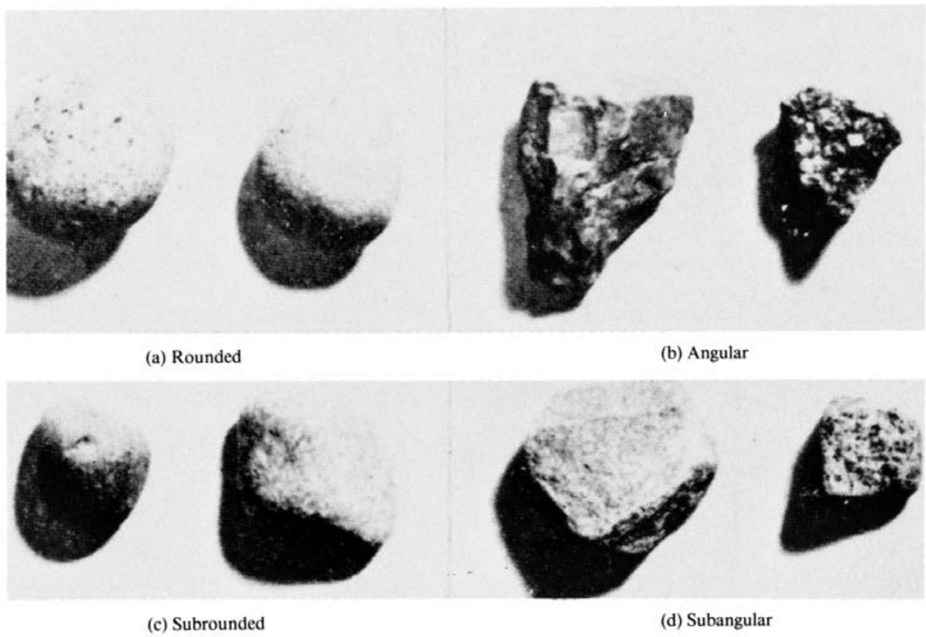


FIG. 3 Typical Angularity of Bulky Grains

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

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

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

4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maxi-

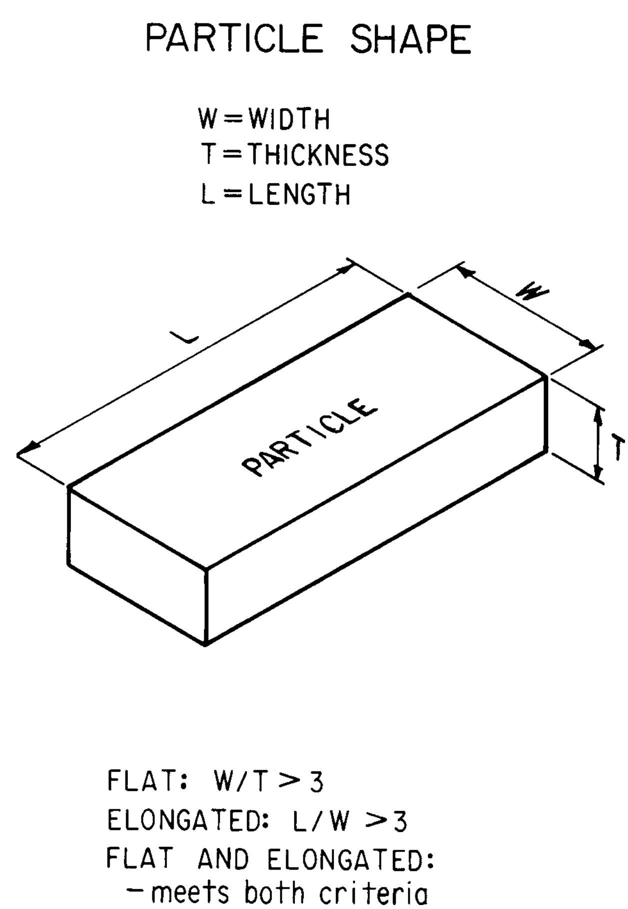


FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

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

TABLE 4 Criteria for Describing the Reaction With HCl

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

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

TABLE 6 Criteria for Describing Cementation

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

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

mum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

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

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

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

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 9—Since the percentages of the particle-size distribution in Test Method D2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 10—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

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

14.2 *Dry Strength*:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 11—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accorance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy*:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness*:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about ⅛ in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about ⅛ in. The thread will crumble at a diameter of ⅛ in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils*:

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 12—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 *Identification of Organic Fine-Grained Soils*:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and

TABLE 8 Criteria for Describing Dry Strength

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

TABLE 9 Criteria for Describing Dilatancy

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

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A ⅛-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

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

may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 13—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 14—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 15—Other examples of soil descriptions and identification are given in Appendix X1 and Appendix X2.

NOTE 16—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
   Gravel—fine, coarse
   Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

For intact samples:

18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

17. Precision and Bias

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

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft^3; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incororated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown.

X2.4.3 *Broken Shells*—About 60 % uniformly graded gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % nonplastic fines; "Poorly Graded Gravel with Silt and Sand (GP-GM)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix:	Suffix:
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D2488 – 09) that may impact the use of this standard. (Approved June 15, 2009.)

(*1*) Revised Section 1.2.3.

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ATTACHMENT C

BOREHOLE AND MONITORING WELL ABANDONMENT, NRT 07-05-07

Prepared By:	RJC	Date Prepared:	05/31/2013
Corporate Officer:	BRH	Date Approved:	02-27-14

BOREHOLE AND MONITORING WELL ABANDONMENT

1.1. Scope and Application

This standard is applicable to abandonment of monitoring wells and boreholes. The objective of this standard operating procedure (SOP) is to assure that the monitoring well or borehole is abandoned such that it cannot act as a conduit for migration of water from the ground surface to the water table or between aquifers. Many states have requirements for well abandonment; however, these requirements are sometimes not explicit. A technically sound well abandonment method is based on the site geology, well casing materials, and general condition of the well(s). To comply with state requirements, the appropriate state agency must be notified (if applicable) of well abandonment. Refer to the project-specific documents for specific requirements for well and borehole abandonment and variances to this SOP.

1.2. Health and Safety Warnings

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

1.3. Abandonment

When feasible, the preferred 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 down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing is then removed from the hole with the drill rig. The borehole is then backfilled with the appropriate grout material. The backfill material is placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (e.g., tremie method). The top two feet of the borehole is filled with concrete or material similar to surrounding features (e.g., asphalt or topsoil) to ensure a secure surface seal. If the area has heavy traffic use, and/or the well locations need to be permanently marked, then a protective surface pad(s) and/or steel bumper guards may be installed.
The concrete surface plug can be recessed below ground surface if the potential for construction activities

exists. This abandonment method is appropriate for one to four inch diameter wells. Planning is required for wells having six-inch or larger diameters and the abandonment of these wells should only be completed after review of the appropriate state regulations and discussions with the well driller that will be retained for the abandonment.

Wells constructed of PVC may be more difficult to remove from the borehole than metal casings because of its brittleness. If the PVC well casing breaks during removal it may be abandoned if cut off (or broken) below the required depth for abandonment. However, if state regulations require the entire well string to be removed, then these wells can be abandoned 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 from 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 on the rotating flights. After the casing materials have been removed from the borehole, the borehole is cleaned out and pressure grouted with the approved grouting materials.

1.4. References

ASTM International, D5299 Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities

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

ATTACHMENT D

MONITORING WELL CONSTRUCTION AND DEVELOPMENT, NRT 07-05-05

Prepared By:	RJC	Date Prepared:	04-05-13
Corporate Officer:	BRH	Date Approved:	02-27-14

MONITORING WELL CONSTRUCTION AND DEVELOPMENT

1.1. Scope and Application

This standard is applicable to construction and development of groundwater monitoring wells. Refer to the project-specific documents for variances to this standard operating procedure (SOP).

1.2. Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. Project Health and Safety Plans will contain additional practices, if necessary, to mitigate site-specific hazards. Clear all underground utilities in accordance with SOP 07-05-01 prior to commencing sampling activities.

1.3. Considerations

Design and installation of permanent monitoring wells involves drilling boreholes into various geologic formations with differing subsurface conditions and may require several drilling methods and installation procedures (NRT SOP 07-05-03). State well construction methods and requirements should be reviewed and incorporated into scope development to ensure applicable regulations are satisfied.

Selection of drilling methods and installation procedures shall be based on field data collected during a hydrogeologic site investigation and/or a search of existing data. Each permanent monitoring well will be designed and installed to function properly throughout the entire anticipated life of the monitoring program.

When designing monitoring wells the following issues need to be considered:

- Short- and long-term objectives
- Potential length of the monitoring program
- Contaminants to be monitored/analyzed

- Type of well construction materials to be used and size of borehole required
- Surface and subsurface geologic conditions
- Aquifer(s) to be monitored
- Length and placement of the well screen(s) and anticipated depth of the well(s)
- General site conditions and drill rig accessibility
- Potential health and safety hazards
- Whether the wells will serve more than one purpose (e.g., monitoring, pump test, extraction)

Each issue can be expanded into many subtopics depending on the project complexity. The drilling method(s) is selected once the data have been assembled and reviewed.

1.4. Drilling Methods for Monitoring Well Installation

For many sites, hollow-stem auger is the preferred drilling procedure for installing wells (typically based on cost, depth, and well constructability). However, site conditions may require other methods and alternate methods will be review/selected that will perform acceptably under anticipated or known site conditions. It is advisable to consider several different drilling alternatives and be prepared to use them if problems occur that warrants a drilling method change.

The following drilling methods are available for monitoring well construction purposes. Selection of a drilling method should consider how the drilling method will affect well development and quality of connection to the aquifer. Refer to SOP 07-05-03 for a summary of specific drilling procedures.

- Hollow-Stem Auger
- Solid-Stem Auger
- Rotary Sonic
- Water Rotary
- Mud Rotary
- Direct Wireline Rotary
- Air Rotary

- Dual-Wall Reverse Circulation Air Rotary
- Hydraulic Push
- Cable-Tool (not recommended)
- Jetting Method (not recommended)
- Bucket Auger (not recommended)
- The project manager in consultation with a senior staff geologist if necessary shall approve the use of non-recommended methods before fieldwork is initiated. In addition, it is anticipated the drilling subcontractor will procure the appropriate materials based on the number of boreholes and the expected depths.

1.5. Borehole Requirements

1.5.1. Borehole Diameter

The borehole will be of sufficient diameter to 1) satisfy state regulations and 2) so well construction can proceed as needed. For example, regulations for many states require a borehole diameter of at least 4 inches greater than the well casing (e.g., a 6-inch borehole is required to install a 2-inch outside diameter (OD) casing). A borehole diameter less than 4 inches larger than the well casing will not be acceptable in these states. This “4-inch” requirement allows an annular space around the well casing large enough to install the required filter pack and annular seal. In addition, this annular space will allow up to a 1.5-inch diameter tremie pipe for placing the filter pack, seal, and/or grout at the appropriate intervals. In addition, the borehole(s) shall be advanced as close to vertical as possible and checked with a plumb bob or level. Slanted boreholes are not acceptable unless specified in the design.

1.5.2. Overdrilling the Borehole

Sometimes it is necessary to overdrill the borehole (drill deeper than required to set the well) to set the well screen and filter pack at the target depth or to place a sump beneath the well. Typically, overdrilling by just a few feet is sufficient for this purpose. If the borehole is overdrilled it can be backfilled to the designed depth, either with bentonite pellets or the filter pack. The need to overdrill a borehole or use bentonite below the well screen should only be done in consultation with a Senior Geologist.

1.6. Monitoring Well Construction Methods

1.6.1. Monitoring Well Construction and Installation

Following borehole completion, the well string is constructed by securing the PVC riser to the well screen by flush-jointed threads. Lubricating oils and grease are not to be used on casing threads. Teflon tape can be used to wrap the threads to insure a tight fit and minimize leakage. No glue of any type shall be used to secure casing joints. Teflon® O-rings can also be used to insure a tight fit and minimize leakage; however, O-rings made of other materials are not acceptable if the well is going to be sampled for organic compounds.

Six to twelve inches of clean filter pack sand is placed at the bottom of the borehole before the well string is lowered into the borehole. The well string is placed into the borehole through the hollow-stem auger or temporary casing. Centralizers can be used to plumb a well, but may interfere with filter pack or annular space seal placement or may cause bridging during material placement. Monitoring wells less than 50 feet deep usually do not need centralizers. If centralizers are used they should be placed below the well screen and above the bentonite pellet seal. The specific placement intervals are determined based on site conditions.

When installing the well string through hollow-stem augers, the augers are slowly extracted as the sand pack, bentonite seal (if necessary), and annular space seal are tremied and/or poured into place. The extraction of the augers allows the materials being placed through the augers to flow below the augers, rather than up into the augers causing the augers to become stuck in the borehole.

After the well string is plumb, the filter material is poured or tremie-piped around the well screen up to the designated depth (generally six inches to two feet above the well screen). After the filter pack has been installed, six inches to two feet of fine sand is typically placed on top of the filter pack as a filter pack seal unless the well is too shallow to allow placement of this fine sand layer. Next, the bentonite seal, consisting of bentonite chips, bentonite pellets, or bentonite granules, depending on site conditions, is placed, if necessary. The bentonite seal extends from the top of the filter pack seal to the bottom of the annular space seal, typically two to five feet above the filter pack seal. The annular space seal, consisting of bentonite granules, chips, grout, or slurry, depending on site conditions, is then pumped by the tremie method or poured into the annular space around the PVC casing up to one foot bgs for a flush-mounted protective cover or two inches bgs for a stick-up protective cover. Bentonite is not placed between the well casing and protective cover pipe; sand or native soil is used to allow water to drain away from the well. If grout is used, it is allowed to set for a minimum of 24 hours before the surface seal and protective cover pipe are installed.

Following placement of the annular space seal, the protective cover pipe is installed. A stick-up protective cover pipe will have a lockable cap. The stick-up protective cover extends at least two feet bgs, and does not extend below the annular space seal into the filter pack. The protective cover has a weep hole (minimum ¼ inch diameter) for drainage placed just above the top of the well pad or ground surface to prevent water from remaining inside the cover. A protective cover made of aluminum or other soft metals is not acceptable because it is not strong enough to resist tampering. Concrete or soil is placed on top of the bentonite annular space seal/ surface seal to prevent drying and cracking, depending on site conditions and state requirements.

A flush-mounted protective cover pipe extends at least one foot bgs. It is made of material that will withstand traffic and have a watertight seal. The PVC well casing is cut low enough so a lockable cap may be secured over the casing to prevent tampering with or filling of the well. Concrete surface seals are installed around flush-mounted protective covers, and extend to the bottom of the cover. The flush-mounted cover is installed slightly (1/2 to 1 inch) above the surrounding ground surface and the concrete pad installed sloping away from the cover to facilitate drainage away from the well and reduce ponding of water over the well, especially if there is a potential for it to freeze in winter.

After the surface pad and protective cover are installed, bumper posts may be installed (if needed). Bumper posts are typically steel pipes of 3- to 4-inch diameter and a minimum 5-foot length. They are installed to a minimum depth of 2 feet below ground surface, extend a minimum of 3 feet above ground surface, and are filled with either sand or concrete once installed (to provide additional strength). The bumper posts are placed around the monitoring wells in a configuration that provides maximum protection for the well.

After the wells have been installed, they are permanently marked with the well number on either the cover or an appropriate place that will not be easily obscured by weather, damaged, or vandalized.

1.6.2. Cased Wells

Double cased wells are constructed when:

- There is reason to believe interconnection of two aquifers by well construction may cause cross-contamination.
- Flowing sands make it impossible to install a monitoring well using conventional methods.
- In special areas designated by a governmental agency.

A pilot borehole is drilled through the overburden and/or contaminated zone to a pre-determined depth. An outer casing is then placed into the borehole and sealed with grout. The outer casing diameter is of sufficient diameter to contain the inner casing and the required minimum annular space. The outer casing is grouted by the tremie method or pressure grouting to within 2 feet of the ground surface. The grout is pumped into the annular space between the outer casing and the borehole wall by placing the tremie tube in the annular space and pumping the grout from the bottom of the borehole to the surface, or placing a grout shoe or plug inside the casing at the bottom of the borehole and pumping the grout through the bottom grout plug and up the annular space on the outside of the casing. If the outer casing is set into very tight clay, both of the above methods might have to be used, because the clay usually forms a tight seal in the bottom and around the outside of the casing preventing grout from flowing freely during injection. Conversely, outer casing set into bedrock normally will have space enough to allow grout to flow freely during injection.

The grout mixture used to seal the outer annular space can be neat cement, cement/bentonite, or cement/sand. The seal or plug at the bottom of the borehole and outer casing consists of a Type I Portland cement/bentonite or cement/sand mixture. The use of a pure bentonite grout for a bottom plug is not acceptable because the bentonite grout cures to a gel and is not rigid enough to withstand the stresses of drilling. At least 24 hours are required for the grout plug to cure before attempting to drill through it.

When drilling through the seal, care must be taken to avoid cracking, shattering, and/or washing out the seal. Removal of outer casings, which are sometimes called temporary surface casings, after well screens and casings have been installed and grouted is not performed. Trying to remove outer surface casings after the inner casings have been grouted may jeopardize the structural integrity of the well.

Potentially contaminated zones can also be isolated by telescoping smaller diameter hollow stem augers inside larger ones. However, this is typically limited by the large diameters required at the surface, which make use of rotary drilling methods advantageous based on costs and generation of drilling spoils.

1.6.3. Bedrock Wells

The preferred method of advancing the borehole into the bedrock is rock coring. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking and/or shattering the seal. Roller cone bits are used in soft bedrock, but caution must be taken when using a roller cone bit to advance through the grout seal in the bottom of the borehole because excessive water and "down" pressure can cause cracking, eroding(washing), and/or shattering of the seal. Low volume air hammers have been used to advance the borehole, but they have a tendency to shatter the seal because of the hammering action. Any proposed method will be evaluated on its own merits, and will have to be approved by a senior staff geologist before drilling activities begin.

The installation of monitoring wells into bedrock can be accomplished in at least two ways:

1 Open Bedrock Well: The finished well consists of an open borehole from the base of the surface casing to the well bottom. The surface casing extends from the ground surface into bedrock and prevents the hole from collapsing. If the protective casing integrity is compromised, the well is open to direct contamination and will have to be repaired or abandoned. A limitation to the open bedrock well is the entire bedrock interval serves as the monitoring zone. In this situation, it is very difficult or even impossible to monitor a specific zone and contaminants, if present, could be diluted. The use of open bedrock wells is generally not acceptable in the Superfund and RCRA programs because of the uncontrolled monitoring intervals. However, some site-specific conditions or objectives may warrant open bedrock wells.

2. Cased Monitoring Well: This well has an inner well screen and casing with filter pack, bentonite seal, and annular grout like monitoring wells constructed in unlithified materials. This well installation method gives the flexibility of isolating the monitoring zone(s) and minimizing inter-aquifer flow. The filter pack also serves as a barrier between the bentonite seal and the screened interval. Rubber inflatable packers are not acceptable alternatives to filter packs because the packers have to remain in the well permanently and, over a period of time, will decompose and possibly contribute contaminants to the monitoring zone.

1.6.4. Placing Well Materials

Acceptable methods for placing well materials, including the filter pack and annular seal, include positive displacement and the tremie method. Use of the tremie method minimizes the risk of bridging in the borehole and ensures the placement at the proper intervals. Pouring materials (filter pack and bentonite seal) is acceptable in shallow boreholes less than 50 feet where the annular space is large enough to prevent bridging and allow measuring (with a tape measure) to ensure the materials are placed at the proper intervals. The proper placement depth is documented by measuring and not by estimating. Also, to insure the materials are placed at the proper intervals, they should be tamped with an appropriate tool while measuring. Tamping minimizes the potential for bridging by forcing the materials that have lodged against the borehole wall and/or the well casing to the proper interval.

1.7 Well Development

Completed monitoring wells can be developed immediately unless constructed and sealed with a liquid grout seal. Wells constructed with grout seals, (and all other wells, if possible), should not be developed for at least 12 hours after they are installed. This allows sufficient time for the well materials to set and cure before development procedures are initiated. The purpose of developing new wells is to remove residual materials remaining in the wells after installation has been completed, and to try to re-establish the natural hydraulic flow conditions of the formation around the immediate vicinity of the well. New wells are developed until the column of water in the well is free of visible sediment, and the pH, temperature, and specific conductivity have stabilized. Refer to ASTM Standard Practices D5521/D5521M for more details on development criteria.

In most cases the above criteria can be satisfied; however, in some cases the pH, temperature, and specific conductivity stabilize while the water remains turbid. In this case the well may still contain well construction materials, such as drilling mud in the form of a mud cake and/or formation soils that have not been washed out of the borehole. Excessive or thick drilling mud cannot be flushed out of a borehole with one or two well volumes of purge water, agitation and continuous flushing for several days may be necessary to complete the well development under this condition. Repeated cycles of development over several hours or days may also be necessary for low-yield wells which pump dry or nearly dry during development.

Caution should be taken when using high rate pumps and/or large volume air compressors during well development because excessive pumping or high air pressures can damage the well screen and filter pack. The on-site geologist will make the decision as to the development completion of each well. All field decisions will be documented in the field logbook.

The following methods are used to develop monitoring wells:

- Pumping
- Compressed air (with the appropriate organic filter system)
- Bailing
- Surging
- Backwashing ("rawhiding")
- Jetting

These methods can be used, both individually and in combination, to achieve effective well development. The selected development method(s) will be approved by a senior staff geologist before well installation activities are initiated.

1.8 References

ASTM D5092-04(2010)e1 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers

D5521/D5521M-13 Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers

ASTM D6001-05 Standard Guide for Direct-Push Ground Water Sampling for Environmental Site Characterization

ASTM D6724-04(2010) Standard Guide for Installation of Direct Push Ground Water Monitoring Wells

ASTM D6725-04(2010) Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers

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

ATTACHMENT E

SOIL VAPOR SAMPLING, NRT 07-09-07

Prepared By:	SGW	Date Prepared:	07/03/2013
Corporate Officer:	JMN	Date Approved:	07/18/2014

SOIL VAPOR SAMPLING

1.1. Scope and Application

This standard is applicable for soil vapor sampling of soil vapor probes. This standard describes the procedures for the monitoring of permanent and semi-permanent soil vapor probes for the evaluation of subsurface vapor migration. Refer to project-specific documents for variances to this SOP. Note that these methods may be modified as necessary to meet State or Federal guidelines for sample collection.

1.2. Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety standard operating procedures when working with potentially hazardous material or with material of unknown origin. In addition follow all safety procedures when using electric tools, compressed gases, and generators. Project Health and Safety Plans will contain additional practices, as necessary, to mitigate site-specific hazards.

1.3. Soil Vapor Sampling Equipment

The following sections describe the equipment, set-up, sampling procedures, and post-sampling handling of soil vapor samples.

1.3.1. Soil Vapor Sampling Equipment

The following equipment is required to collect a soil vapor sample:

- Landtec GEM 2000 Plus or equivalent landfill gas meter (methane, carbon dioxide, oxygen, and nitrogen)
- Dielectric Technologies MGP 2002 helium detector
- Helium. Technical Grade (99% purity) is the standard. Use of lower grade helium must be evaluated on a site specific basis and may require agency approval prior to sample collection.
- Plastic shroud to cover probe
- 1-liter Tedlar™ bags

- Tygon™ or silicone tubing (cut to length)
- ¼-inch O.D. inert tubing (e.g., Teflon™) cut to length
- Peristaltic pump
- BIOS DC-LITE flow calibrator, calibrated rotometer, or equivalent
- Calibrated vacuum gauge for measuring initial and final vacuum readings. Digital is preferred though analog is acceptable, especially when working outside operational temperatures for digital gauge. Vacuum gauges will be calibrated according to manufacturer's instructions and will be submitted for recalibration a minimum of once per year. Gauges will be sent to a certified facility to be checked against masters traceable to the National Institute of Standards and Technology (NIST).
- Clean (dedicated) 3/16-inch hose barb
- New or dedicated 3-way valves and 2-way valves for purging and sampling
- 1-liter or 6-liter SUMMATM canisters or equivalent (batch certified); confirm the laboratory can meet applicable screening levels with selected canister size
- "T"-fitting for collection of duplicate samples (supplied by the lab)
- SUMMATM canister regulator set at approximately 150 to 200 milliliters per minute (mL/min)
- ¼-inch O.D. Teflon or stainless-steel compression fittings
- Probe location maps
- Chain of custody forms and seals
- Field logbook and field data air sampling forms
- Eye protection and Nitrile (or equivalent) gloves
- Instrument calibration forms
- Health and Safety Plan

1.3.2. Soil Vapor Sample Set Up

Field sampling staff shall complete the sample set-up of a SUMMA™ (or equivalent) canister prior to sample collection. Each SUMMA™ (or equivalent) canister shall be vacuum tested with a calibrated digital or analog vacuum gauge attached to the canister inlet. The canister vacuum is checked by opening the canister valve and noting the initial vacuum reading. The vacuum should indicate between 25 and

30-inches of mercury. The canister shall not be used if the starting vacuum is less than 25-inches of mercury. If the vacuum does not stabilize, the gauge or associated fittings are leaking. Upon completion of the vacuum check, close the SUMMA™ canister valve and remove the vacuum gauge. Attach the sample regulator to the SUMMA™ canister. This regulator need not be dedicated if zero grade laboratory air is available to purge/decontaminate it between samples.

When probe installation is complete, inert tubing will extend from the probe to the ground surface and be capped by a dedicated 3-way stopcock with the valve position closed to the vapor probe. Detailed directions on the use of the 3-way valve are provided in Attachment A of this SOP "Guide to the 3-way micro-valve". A helium shroud, consisting of a solid plastic container with a recommended height of less than 6 inches and a volume less than 6L, will be placed over the 3-way stopcock around the exposed portion of the soil vapor probe. Inert tubing will be connected to the other two ends of the stopcock and pass through ¼-inch holes in the helium shroud sealed with a pass-through compression fitting (or some other material to prevent the helium from escaping the shroud). One length of tubing will connect with the summa canister and the other length will attach to a purge apparatus. All fittings and tubing will be dedicated to avoid cross-contamination between probes.

The helium shroud will contain two additional holes no more than three inches above the base of the shroud for connections to the helium source and helium detector. It is especially important that the hole for the helium detector is near the base of the shroud to get an accurate reading of the percentage of helium near the surface seal of the vapor probe. Lengths of inert tubing will be inserted into the side of the shroud and sealed using a compression fitting or other inert material to prevent helium from escaping the shroud. One length of tubing will be connected to the helium cylinder and the other to the helium detector outside of the shroud.

The tubing coming out from the shroud connected to one outlet of the 3-way stopcock will be connected directly to the flow controller and Summa™ canister assembly. The tubing coming out from the shroud connected to the other outlet of the 4-way stopcock will be connected to a 2-way stopcock with the valve position closed to the vapor probe. The 2-way stopcock will then be connected to a purge apparatus that will fill a 1L Tedlar™ (or equivalent) bag. The purge apparatus must be able to fill the Tedlar™ bag at a rate similar to grab sample collection (100 to 200 milliliters per minute).The preferred purge apparatus is to connect the Tedlar™ bag.to a peristaltic or gas sampling pump and directly fill the Tedlar™ bag. An alternate purge apparatus may include the use of a lung box. Details of sample purging are discussed in

Section 1.3.4 below. A new pair of Nitrile gloves should be worn while connecting the sample assembly for each soil vapor probe. The total length of inert tubing should not exceed 5 feet.

1.3.3. Summa Canister Preparation and Quality Assurance/Quality Control

A SUMMA™ canister is a stainless steel container which has had its internal surfaces passivated (at the laboratory) using the "Summa" process. The process uses an electro-polishing step in conjunction with chemical deactivation. The overall process results in a chemically inert interior surface of the media which allows for the collection and subsequent analysis of samples containing very low concentrations of VOCs. The SUMMA™ media is available in a number of different sizes. Note that water should never be allowed to enter a SUMMA™ canister because it may render the canister unusable.

Once the laboratory cleaning process is completed, the SUMMA™ canisters are prepared by the laboratory for use in the field. Each canister is evacuated to achieve a vacuum pressure of approximately 30-inches of mercury. The pressure differential between the canister and atmosphere allows for the SUMMA™ canister to sample without the use of a separate sample pump. Depending on the project requirements, either grab or integrated samples may be collected. The holding time (shelf life) for SUMMA™ canisters that have been prepared for use in the field is 30-days. If the canister has not been used within this time-period, it shall be returned to the contracted laboratory for re-conditioning.

SUMMA™ canisters undergo either an individual or batch certification process. The individual certification process requires that each canister undergo a comprehensive Quality Assurance/Quality Control (QA/QC) procedure that results in analysis documentation for each canister, verifying that there are no residual compound concentrations above a pre-determined level. Individual certifications add greatly to the cost. Typically, individually certified canisters are used for indoor and ambient air sampling programs that require very low method detection limits. Batch certified canisters undergo the same re-conditioning process as the individually certified canisters. However, only 5-percent of randomly chosen canisters are analyzed for residual constituents. If any of the selected canisters do not meet specific certification criteria, all of the canisters in that batch are required to undergo the entire cleaning and QA/QC process again. This process is repeated until all QA/QC re-conditioning criteria are met.

A typical 6-liter SUMMA™ canister and a 30-minute sample flow controller are depicted below. One-liter canisters are smaller, but have the same general appearance. Flow controllers may vary significantly in appearance.

30-Minute Flow Controller with Vacuum Gauge

Summa Canister (6-Liter)

1.3.4. Sampling Probe Purging

Upon completion of any vacuum/pressure measurements and prior to soil vapor sample collection, each probe shall be purged a predetermined volume (in liters or milliliters) based on the volume of the probe riser (tubing length). The purge volume shall be equivalent to a minimum of three tubing volumes. Volume of air in the tubing will be calculated using the formula: πr2l, where r is the inside radius of the tubing and l is the length of tubing. For typical ¼-inch outer diameter 3/16–inch inner diameter tubing, there will be 5.4 milliliters of air per foot of tubing. Multiplying that volume by 3, results in a purge volume of 16.3 mL of air per foot of tubing. The total purge volume can be calculated by multiplying the length of tubing (in feet) from the Tedlar™bag to the top of the vapor probe by 16.3 mL. Typically, the 1-liter volume removed during the chemical leak test is more than adequate to also purge the sample probe.

As discussed above, a purging apparatus will be connected to the 2-way stopcock. The purpose of the 2-way stopcock is to prevent the vapor probe from coming into contact with the ambient atmosphere. For this reason, the two way stopcock should always be closed to the vapor probe except during sample purging. Once sample purging is complete, the valve must be closed prior to stopping the vacuum/air pump to prevent backflow of ambient air into the vapor probe. Note, if any portion of the sample train is exposed to ambient air after purging, the sample train must be resealed and allowed to re-equilibrate for 30 minutes and be repurged prior to sampling.

Using the preferred purging apparatus, the inlet of the gas sampling pump will connect to the outlet of the 2-way stopcock. The outlet of the gas sampling pump will be connected to the inlet of a flow meter (rotameter) to monitor the rate at which the probe is purged. Then the outlet of the rotameter will be connected to the inlet of the Tedlar™ bag.

Alternatively, if a lung box is used, the inlet of the Tedlar™ bag will be connected to the outlet of the 2-way stop cock and the Tedlar™ bag will be placed in a lung box large enough to collect the requisite volume of purged soil gas. The gas sampling pump will be connected to the rotameter to monitor the flow rate and evacuate the air inside the lung box to collect soil gas into the 1L Tedlar™ bag.

Purging will be conducted using a flow rate of 100 to 200 mL/min consistent with the rate of sample collection. Given the small volume of the sample probes, purge air can be discharged to the outside atmosphere. Note that Tedlar™ bags should not be discharged within buildings, especially during concurrent indoor air sampling. Care shall be taken to prevent the purged air from being reintroduced into the sampling probe.

1.3.5. Chemical (Helium) Leak Testing

The purpose of the chemical leak test is to ensure that the sample port and probe assembly is properly set and not leaking. A leaking probe assembly could result in a leakage of ambient air into the sample, potentially biasing the sample. Prior to sampling, a chemical leak test will be performed using helium as a tracer gas. A shroud will be placed over the soil vapor probe. The ambient air inside the shroud will be replaced with helium graded at 99 percent purity or higher until the atmosphere consists of a minimum of 20 percent helium. The concentration of helium under the shroud shall be continuously monitored and maintained above 20% during purging of the vapor probe. It should be noted that concentrations of 60 percent to 80 percent helium have routinely been observed in the shroud during prior field testing. This will be accomplished by inserting Teflon™ tubing through a ¼ inch hole in the shroud and attaching the other end to the helium canister. The helium canister will then be opened, and the shroud atmosphere will be continuously monitored by a Dielectric Technologies Model MGD-2002 Multi-Gas Detector (or equivalent) until the percentage of helium inside the shroud reaches a minimum of 20 percent. The final helium concentration inside the shroud will be recorded on the Field Data Air Sampling Form. The final helium concentration inside the shroud will be multiplied by 10 percent (0.1) to determine the allowable concentration of helium in the Tedlar™ bag sample. Both the final helium concentration inside the shroud and the calculated allowable concentration in the Tedlar™ bag will be recorded on the Field Data Air Sampling Form (Attachment B).

After the target atmosphere is established (and maintained throughout the period of the chemical leak test), the 3-way stopcock will be opened to the purge apparatus, which fills a 1-liter Tedlar™ bag attached via inert tubing to the sample probe/port. An in-line flow meter will be used to monitor/adjust the air flow of air being removed by the purge apparatus. Once filled, the 2-way and 3-way valves between the sampling port and the 1-liter Tedlar bag will be closed to prevent the vapor probe from being exposed to the atmosphere and then the 1-liter Tedlar™ bag will be disconnected. The air inside Tedlar bag will be measured using the Model MGD-2002 Multi-Gas Detector (or equivalent) for the presence of helium. The concentration of helium measured inside the Tedlar™ bag will be recorded on the Field Data Air Sampling Form. If the concentration of helium in the sample is below the calculated allowable concentration (i.e., less than 10 percent of the concentration inside the helium shroud), proceed with the mechanical leak test and sample collection as described in Section 1.3.6. Note that the allowable concentration can vary depending upon the agency that you are working with (e.g., WDNR draft guidance suggests a 5% allowable concentration). The recommended allowable concentration should be confirmed prior to entering the field. Typically, the Tedlar™ bag of air also serves as the required three volume purge of the probe or port.

Corrective actions to mitigate leaks in the soil vapor probe will be performed when the helium concentration in the Tedlar™ bag sample exceeds the allowable concentration in the helium shroud. Corrective actions will be performed in the field and will include checking and tightening all connections. Samples will not be collected for laboratory analysis when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the helium concentration in the shroud.

1.3.6. Mechanical Leak Testing

The mechanical leak test will be performed immediately after completing the helium leak test. Since the mechanical leak test is performed using the vacuum of the SUMMA™ canister, it is preferred to complete the chemical leak test before the mechanical leak test to potentially identify leaks in the sample train prior to opening the canister. This reduces the risk of exposing a canister during a failed mechanical leak test. The mechanical leak test will be completed by keeping the 2-way valve closed to the atmosphere and turning the valve on the 3-way valve to close the connection to the soil vapor probe.

Vacuum test the connections between the Summa™ canister and 3-way valve by opening the canister valve to place a test vacuum on the assembly for 10 minutes. The start time and initial vacuum, as well as the stop time and final vacuum, will be recorded on the Field Data Air Sampling Form and in the field logbook. If gauge vacuum cannot be maintained for 10 minutes, work shall be suspended and all fittings in the sample assembly will be checked and corrective actions taken. The initial Summa™ canister that failed shall be discarded and a new canister will be connected to the sample train. Once the sample train is reassembled, the sample assembly will be re-tested. If vacuum still cannot be maintained for 10 minutes, sampling activities will be discontinued until the leak can be identified and addressed.

If gauge vacuum was maintained for 10 minutes, proceed with sample collection as described in Section 1.3.7. Note that some agencies may request the vacuum for the mechanical test to be introduced using a separate pump and vacuum gauge (rather than use the SUMMA™ canister to supply the vacuum). In this instance the apparatus used to create the vacuum may be attached to the 2-way valve. Confirm acceptable methods for mechanical leak detection prior to entering the field.

1.3.7. Sample Collection with SUMMA™ Canisters

Sample location information and meteorological conditions (temperature, barometric pressure, wind speed/direction, and relative humidity) shall be recorded on a Field Data Air Sampling Form. Meteorological data will be obtained online from the nearest National Weather Service measuring station. Digital photos may be taken of each sample location and sample assembly. Record ambient air measurements of carbon dioxide, oxygen, methane, and nitrogen during sampling in the field form using the Landtec Gem 2000 Plus (or equivalent) meter. These measurements may be required for comparison to concentrations measured in the sample.

Open the 3-way stopcock connecting the SUMMA™ canister assembly to the soil vapor probe/port. The canister valve will already be open if sampling immediately follows the mechanical leak test. The time and initial vacuum when sample collection starts shall be recorded on the Field Data Air Sampling Form. In addition record the elapsed time and vacuum periodically until sampling is completed. The laboratory-provided flow regulators will have been calibrated for a 5 to 10-minute sample duration, which correlates to a flow rate of 150 to 200 mL/min. Close the summa canister valve when the vacuum gauge indicates approximately 5 inches Hg (mercury) of vacuum remain in the canister. Sample collection should take approximately 5 to 10 minutes for a 1-liter SUMMA™ canister (depending on the regulator flow rate). Care should be taken to prevent the vacuum to approach ambient pressure. If the final pressure is near ambient (less than 1 in Hg), it must be considered an invalid sample. If the vacuum inside the canister approaches ambient pressure, consider completing the sample (closing the valve) and submitting the sample, as collected, to the laboratory for analysis. Final pressure inside the canister before and after sample collection must be recorded and is typically submitted to the laboratory at the time of analysis.

The time sample collection was stopped and final vacuum shall be recorded on the Field Data Air Sampling Form. Remove the flow regulator/particulate filter assembly. Attach either the digital or analog vacuum gauge to the canister and record the final vacuum on the Field Data Air Sampling Form. Remove the vacuum gauge and replace the laboratory-supplied brass plug on the canister. Disconnect the sample tubing assembly and replace the protective cover on the soil vapor probe. If water and/or product are encountered during sample collection, this observation shall be documented in the field logbook and/or on the appropriate field form and on the sample tag.

Label the sample canister tag and record on the COC the sample identification, date and time the sample was collected, the canister and flow controller serial numbers, and the final vacuum gauge reading. Samples shall not be chilled or subjected to extreme temperature or pressure fluctuations. Samples will be shipped to the laboratory for analysis of VOC contaminants of concern (as identified in a site specific work plan) by USEPA approved methods, such as Method TO-15. When appropriate, include analysis of carbon dioxide, oxygen, methane, and nitrogen by ASTM Method D1946 or EPA 3C.

1.3.8. Tedlar™ Bag Sample Media

Soil vapor samples for on-site analysis/field screening shall be collected using a Tedlar™ bag media and a peristaltic pump. A sample collected in a Tedlar bag will follow the same procedure followed for the chemical leak test described in Section 1.3.5.

Sample location information and meteorological conditions (temperature, barometric pressure, wind speed/direction, and relative humidity) shall be recorded on a Field Data Air Sampling Form. Meteorological data will be obtained online from the nearest National Weather Service measuring station. Digital photos may be taken of each sample location and sample assembly. Record measurements of carbon dioxide, oxygen, methane, and nitrogen during sampling using the Landtec Gem 2000 Plus (or equivalent) meter. These measurements may be required for comparison to concentrations measured in the sample.

1.3.9. Post-Sample Collection

The sample train shall be dismantled and all non-dedicated lines used for sample collection shall be disposed of. New sample lines at each sample location shall be used, except for dedicated equipment (3-way valves, fittings, and coupling bodies, etc.). The valve shall remain attached to soil vapor probes however; the valve shall be configured so that the probe is closed to atmosphere *(see Attachment A: Guide to the 3-way Micro-Valve)*. Non-dedicated, reusable equipment such as the flow regulators and sample T.s (for duplicate sample collection) shall be decontaminated by purging with laboratory supplied air.

1.3.10. Quality Control

Field duplicates will be collected during soil vapor sampling activities. Field duplicates will be collected at the rate of one duplicate sample per 20 soil vapor samples (i.e., 5 percent). Duplicate samples shall be collected by repeating the procedure detailed above, with the addition of a “T” splitter, and one canister attached to each end of the “T” Swagelok (compression) or equivalent fitting. A picture of a typical set-up for the collection of a duplicate sample is provided below.

Trip blanks typically will not be analyzed when using SUMMATM canisters. Trip blanks shall be utilized if they become a requirement of the sample collection method or as requested in a site specific work plan. Trip blanks can consist of either unopened fully evacuated canisters or canisters that have been fully charged with zero grade air by the laboratory. Since a fully charged canister has no vacuum with which to pull contaminants into the canister, a fully evacuated canister has a better likelihood of capturing potential transit-related contamination. If requested, the trip blank will be provided by the laboratory.

1.3.11. Soil Vapor Sample Handling

Tedlar™ bag samples shall be transported to the onsite field screening location. The holding time for a Tedlar™ bag sample shall not exceed thirty-six (36) hours.

Summa canisters samples shall be shipped to the contracted laboratory under chain of custody procedures for offsite laboratory analysis. The holding time for a Summa sample shall not exceed laboratory requirements or fourteen (14) days.

1.4. Data Management

Upon return to the office the following field measurements shall be included in electronic format (electronic sample control log) for capture in the NRT database:

- Sample Data
  - Sample ID

  - Date
  - Sample location
  - Canister serial number
  - Flow regulator
  - Sample depth
  - Sample time
  - QC information
- Initial conditions
  - Start time
  - Initial Field Canister Vacuum
  - Initial Air Temperature
  - Initial Barometric Pressure
- Final conditions
  - Stop time
  - Final Field Canister Vacuum
  - Final Air Temperature
  - Final Barometric Pressure
- Field Instrument Readings
  - O2
  - CO2
  - CH4

1.5. References

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

California Environmental Protection Agency, 2012, Advisory – Active Soil Gas Investigations, Department of Toxic Substances Control and California regional Water Quality Board, Los Angeles and San Francisco Regions, April 2012.

Department of Toxic Substance Control-California Environmental Protection Agency, 2011, Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance) October 2011.

H&P Mobile Geochemistry, Inc., March 2013, Soil Vapor Sampling Evaluation of Leak Check Procedures. Study presented at the Annual International Conference on Soil, Water, Energy and Air, San Diego, California.

ITRC (Interstate Technology & Regulatory Council). 2007. *Vapor Intrusion Pathway: A*

Practical Guideline. VI-1. Washington, D.C.: Interstate Technology & Regulatory Council, Vapor Intrusion Team. www.itrcweb.org.

Illinois Environmental Protection Agency (IEPA) Tiered Approach to Corrective Action Objectives, 35 Ill. Adm. Code 742 (TACO) amendments regarding the addition of the indoor inhalation exposure route issued May 16, 2013, effective July 15, 2013.

San Diego County, 2004, Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods."

San Diego County, 2002, Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" Final Draft 8/20/2002.

USEPA, 1994, SOP # 1703, Rev #: 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP #1704, Rev. #: 0.0, Summa Canister Sampling.

USEPA, 1996, SOP # 2042, Rev. #: 0.0, Soil Gas Sampling.

USEPA, 1999, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry GC/MS) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

United States Environmental Protection Agency (USEPA), 2002. Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). Office of Solid Waste and Emergency Response. November 29.

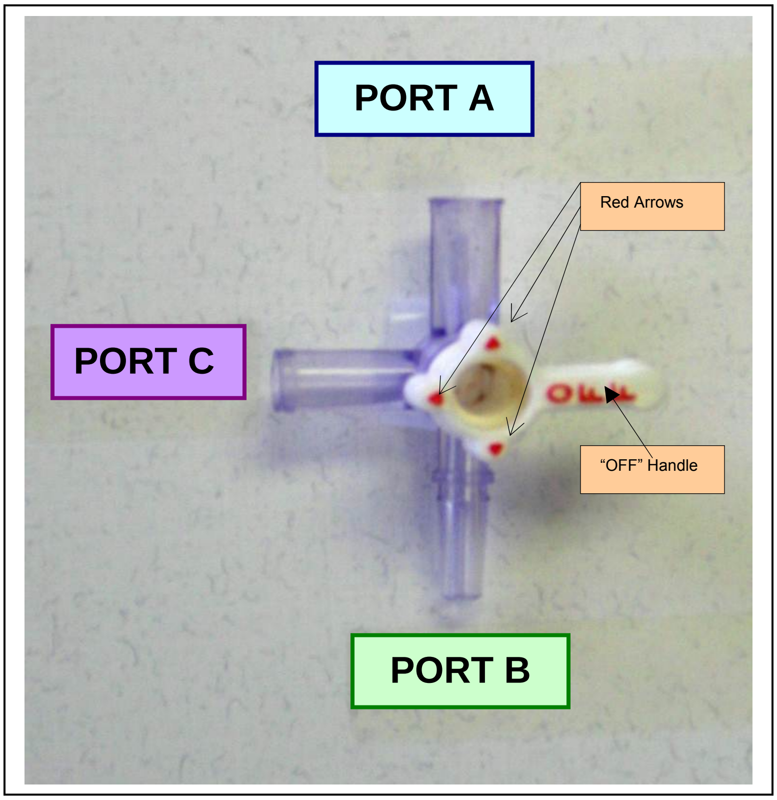
USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Wisconsin Department of Natural Resources (WDNR), 2010, Addressing Vapor Intrusion at Remediation & Redevelopment Sites in Wisconsin, PUB-RR-800.

ATTACHMENT A

GUIDE TO THE 3-WAY MICRO-VALVE

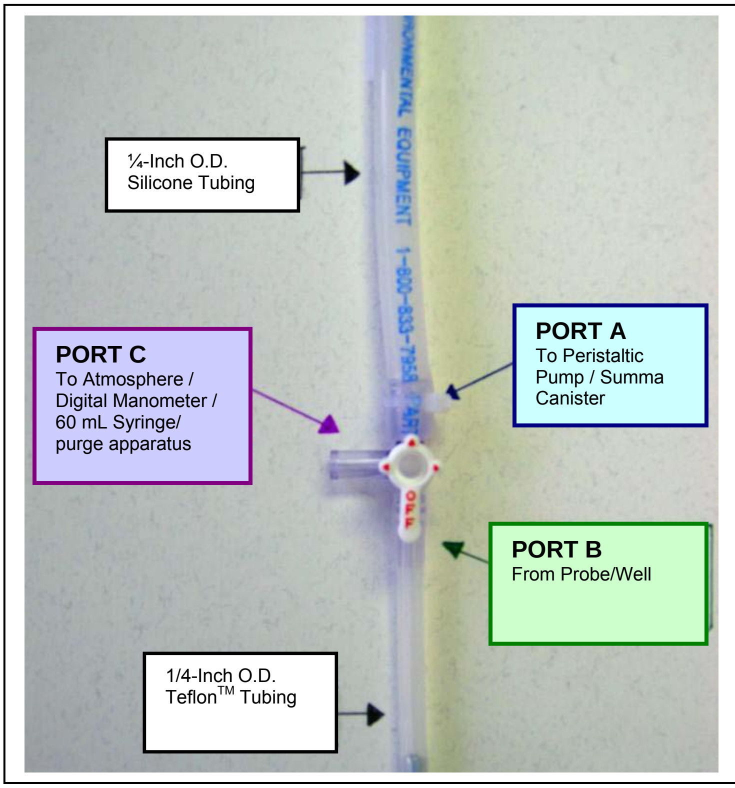
GUIDE TO THE 3-way MICRO-VALVE

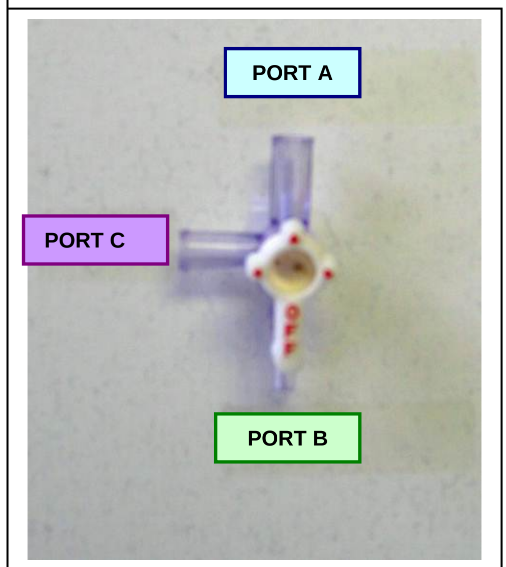


Notes:

1. Red arrows on the 3-waymicro-valve indicate the ports that are currently open.
2. The "OFF" handle indicates the port that is currently closed.
3. The designation of ports is alphabetical from the top (opposite the probe) going in a clockwise direction.

Valve Position #1: Closed to Probe/Well





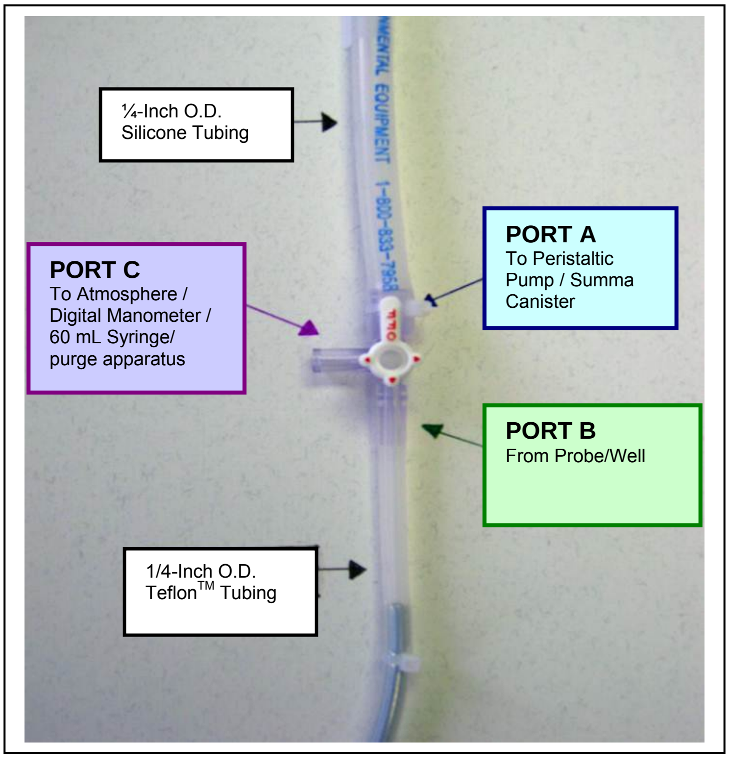
Valve Position #1:

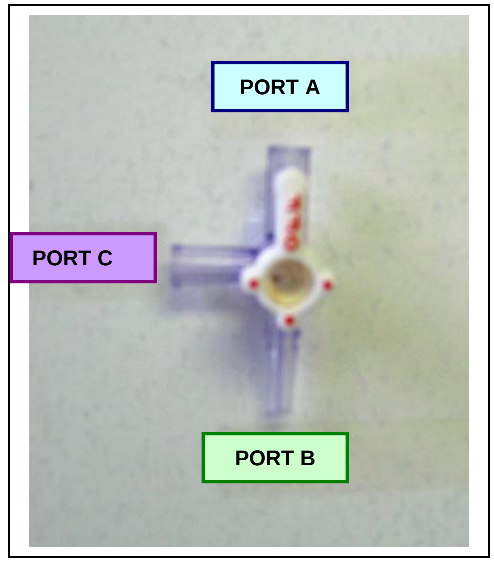
Closed to Port B (Probe/Well);
Open to Port A (Peristaltic Pump / SUMMA™ Canister)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is directly over Port B. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & C).

In this valve position, the probe/well is not open to the atmosphere and, therefore, will not vent. If the valve is not in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #2: Open for Vacuum/Pressure Gauging & Purging





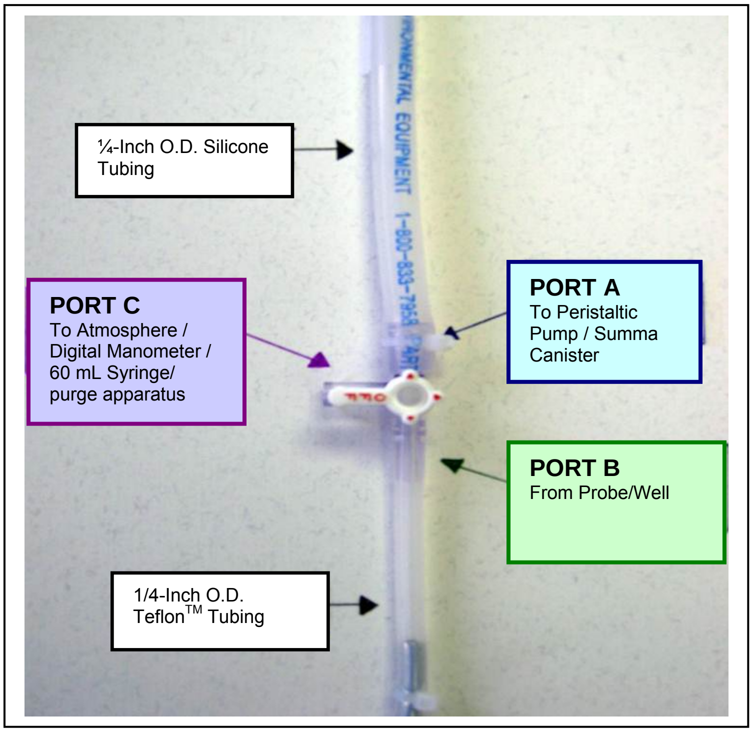
Valve Position #2:

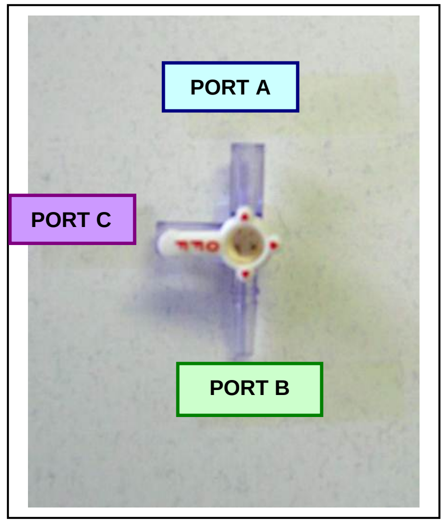
Closed to Port A (Peristaltic Pump / SUMMA™ Canister);
Open to Port B (Probe/Well)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is directly over Port A. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports B & C).

In this valve position when the digital manometer is connected to Port C, a vacuum/pressure reading can be obtained from the probe/well. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #3: Open for Soil Vapor Sample Collection





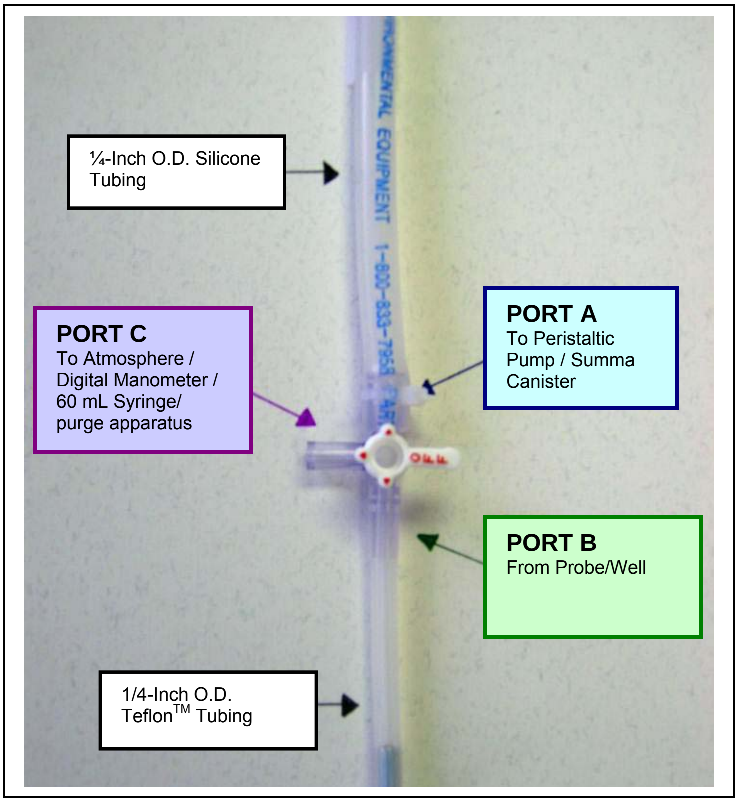
<u>Valve Position #3</u>:

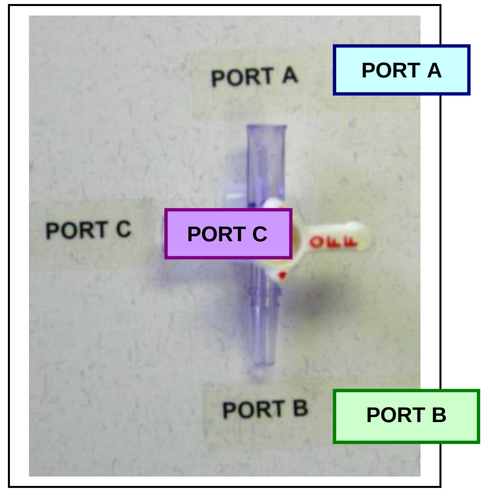
Closed to Port C (Atmosphere / Digital Manometer / 60 mL Syringe);
Open to Port A (Peristaltic Pump / SUMMA™ Canister)
Open to Port B (Probe/Well)

The "OFF" handle is turned in such a way that it is directly over Port C. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & B).

In this valve position, a soil vapor sample can be collected from the probe/well using the peristaltic pump and Tedlar™ bag or a summa canister. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #4: Improper Valve Position





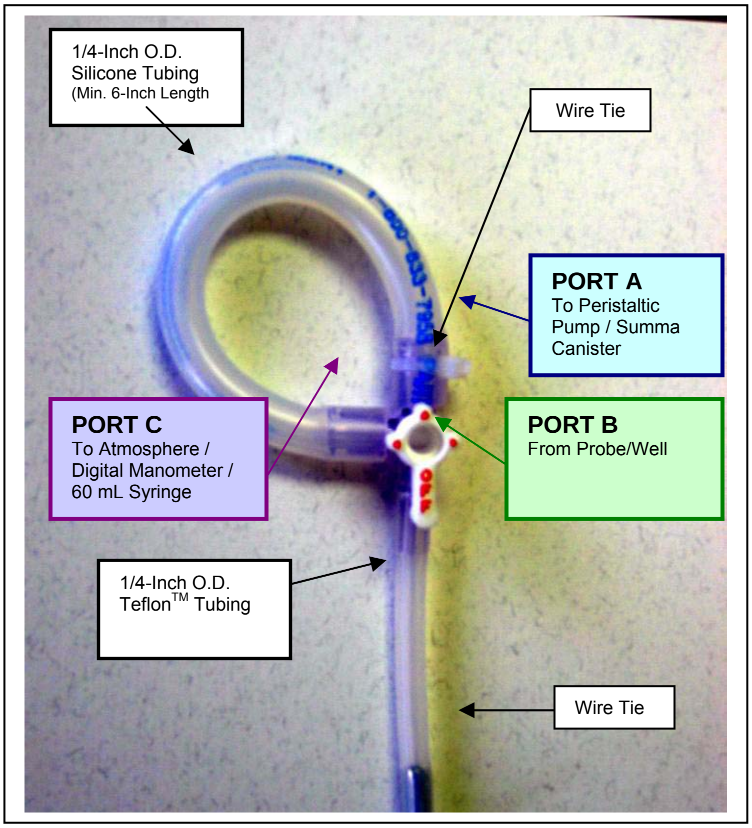
<u>Valve Position #4</u>:

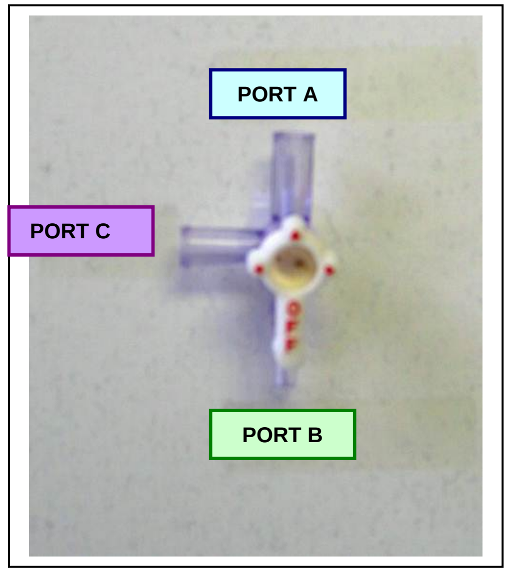
Open to Port A (Peristaltic Pump / Summa Canister);
Open to Port B (Probe/Well)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is opposite of Port C. The three small, red arrows opposite the "OFF" handle indicate all ports are open (Ports A, B & C).

In this valve position, the probe/well is open to the atmosphere and, therefore, will vent. In addition, this valve position will allow ambient air into the sample train and invalidate the data. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later. The valve should never be in this position.

Post-Monitoring Valve and Tubing Configuration





Post-Monitoring Valve and Tubing Configuration:

Closed to Port B (Probe/Well)
Open to Port A (Peristaltic Pump / SUMMA™ Canister);
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The 3-way micro-valve is set to position #1. The “OFF” handle is turned in such a way that it is directly over Port B. The three small, red arrows opposite the “OFF” handle indicate which ports are open (Ports A & C). In addition, the silicone tubing (minimum length of six (6) inches) is configured such that it forms a loop between Port A and Port C and a wire tie is used to secure the silicone tubing to Port A.

In this configuration, the probe/well is not open to the atmosphere and, therefore, will not vent. In addition, this configuration minimizes the water infiltration into the 3-way micro-valve. The valve and tubing should be placed in this configuration following vacuum/pressure gauging and soil vapor sample collection.

ATTACHMENT B

FIELD DATA AIR SAMPLING FORM

FIELD DATA AIR SAMPLING FORM

Site Name:___________________________________ Sampler:_________________

Sample Identification:_____________/____________ Date Sampled:_____________

Sample Location(s):____

____

Canister Serial
#:______________/_______________

Flow Regulator Serial
#:_______________/______________

Environmental Conditions

Outdoor Temperature:______ Barometric Pressure:______ Relative Humidity:______

Wind Speed/Direction:____________ Comments:____

Preliminary Screening

Instrumentation:_________ Calibration Date:___________ Time:_______am/pm

Field Reading(s):_______(ppm)/_______(ppm)/_______(ppm)/_______(ppm)

Location(s):____

____

Mechanical Leak Test

Time	Pressure
Start:________am/pm	_______"Hg
Stop:________am/pm	_______"Hg

Chemical Leak Test

Leak Test Compound:________________

Field Reading(s):______(%) (shroud)

______(%) (Tedlar bag)

Air Sampling

Time	Pressure	Controller Flow
Start: _______am/pm	_________"Hg	_____________
Stop: _______am/pm	_________"Hg	_____________
Start: _______am/pm	_________"Hg	_____________
Stop: _______am/pm	_________"Hg	_____________

ATTACHMENT F

CHAIN OF CUSTODY, NRT 07-03-03

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

CHAIN-OF-CUSTODY

1.1. Scope and Application

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

1.2. Health and Safety Warnings

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

1.3. Sample Custody

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

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

1.4. Chain-of-Custody Procedures

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

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

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

1.4.1. Chain-of-Custody Errors

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

1.5. Commercial Shipping

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

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

1.5.1. Multiple Cooler Shipments

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

1.6. References

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

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

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

ATTACHMENT G

INDOOR AIR VAPOR ACTION LEVELS FOR VARIOUS VOCS QUICK LOOK-UP TABLE

Indoor Air Vapor Action Levels for Various VOCs
Quick Look-Up Table[1]
Based on **November 2014** Regional Screening Level Summary Table

Chemical	Non-Residential (1-in-100,000 risk for carcinogens)		Residential (1-in-100,000 risk for carcinogens)		Molecular Weight (MW)	Basis of RSL[2]
	ppbV*	µg/m³	ppbV*	µg/m³	g/mole	
Benzene	4.9	16.0	1.1	3.6	78.11	c
Carbon Tetrachloride	3.1	20	0.73	4.7	153.82	c
Chloroform	1.1	5.3	0.24	1.2	119.38	c
Chloromethane	190	390	45	94	50.49	n
Dichlorodifluoromethane	88	440	20	100	120.91	n
1,1 – Dichloroethane (1,1-DCA)	19	77	4.4	18	98.96	c
1,2-Dichloroethane (1,2-DCA)	1.1	4.7	0.27	1.1	98.96	c
1,1 -Dichloroethylene (1,1-DCE)	220	880	52	210	96.94	n
1,2-Dichloroethylene (cis and mixed)	NA	NA	NA	NA	96.94	n
1,2-Dichloroethylene (trans)	NA	NA	NA	NA	96.94	n
Ethylbenzene	11	49	2.5	11	106.17	c
Methylene Chloride	740	2600	180	630	84.93	n
Methyl Tert-Butyl Ether (MTBE)	130	470	30	110	88.15	c
Naphthalene	0.68	3.6	0.16	0.83	128.18	c
Tetrachloroethylene	27	180	6.2	42	165.83	n
Toluene	5700	22,000	1400	5200	92.14	n
1,1,1 - Trichloroethane	4000	22,000	940	5200	133.41	n
Trichloroethylene	1.6	8.8	0.39	2.1	131.39	n
Trichloroflurومethane (Halocarbon 11)	540	3100	130	730	137.37	n
Trimethylbenzene (1,2,4)	6.2	31	1.5	7.3	120.2	n
Trimethylbenzene (1,3,5)	NA	NA	NA	NA	120.2	n
Vinyl Chloride	11	28	0.65	1.7	62.5	c
Xylene (mix)	100	440	23	100	106.17	n
Xylene (n,m,o separately)	100	440	23	100	106.17	n

[1] Regional Screening Tables: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm
[2] Basis for Regional Screening Level – n = non-carcinogen; c = carcinogen. Non-carcinogen RSL table values are based on a HI = 1; therefore, no multiple should be applied to the table values. Carcinogen RSL (cRSL) table values are listed for 1-in-1,000,000; in Wisconsin, 1-in-100,000 excess lifetime cancer risk is used for screening indoor air. **This table of Vapor Action Levels was developed by multiplying the cRSL values by 10 or applying HI=1 for non-carcinogens.** Screening levels are rounded to 2 significant digits.
* Conversions from µg/m³ to ppbV in this table based on T = 20ºC or 68 ºF; P = 1 atm or 101.325 kPA (see next page)

Update: December 4, 2014

Convert $\mu g/m^3$ to ppbV

On-line calculator: Indoor Air Unit Conversion
http://www.epa.gov/athens/learn2model/part-two/onsite/ia_unit_conversion.html
At 20ºC and 1 atm:

$$ppbV = \frac{\mu g / m^3}{MW} \times 8.3144 \left[\frac{L \cdot kPa}{mol \cdot {}^\circ K} \right] \times \left[T_{^\circ C} + 273.15 \right] {}^\circ K \times \frac{1}{101.325\, kPa}$$

OR ppbV = ($\mu g/m^3$ x **24.05**)/molecular weight

Using indoor vapor action levels (VAL) to determine vapor risk screening levels (VRSL)

Vapor risk screening levels are used to estimate indoor air concentrations from sub-slab vapor, soil gas or groundwater concentrations. Standard attenuation factors are applied to each media. This table lists the attenuation factor (AF = C_{IA}/C_{source}) and the dilution factor (inverse of the AF). The VAL is divided by the AF or multiplied by the dilution factor to calculate the vapor risk screening level.

Media Screened	Residential / Small Commercial Buildings		Large Commercial / Industrial Buildings	
	Attenuation Factor	*Dilution Factor*	*Attenuation Factor*	*Dilution Factor*
Sub-slab vapor	0.1	10	0.01	100
Deep soil gas	0.01	100	0.001	1000
Groundwater	0.001	1000	0.0001	10,000

Determining the Vapor Risk Screening Level for Groundwater

(at what concentration would groundwater potentially cause an indoor air exceedance)

$$C_{gw} = \left(\frac{C_{IA}}{H \times AF_{gw} \times 1000\, L / m^3} \right)$$

Where: C_{gw} = groundwater concentration (**µg/L**)
C_{IA} = indoor air concentration (from Quick look-up table, **$\mu g/m^3$**)
H = Henry's Law constant (dimensionless) from Chemical Specific Parameter Table: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
AF_{gw} = attenuation factor between groundwater and indoor air

Note: **The groundwater VRSL should NOT be relied upon to screen for vapor risk from PCE and TCE. Use groundwater Enforcement Standards to screen for vapor risk for these compounds.** If the contaminated groundwater is located near the building foundation, the attenuation factor should be increased to 0.1 (i.e., treated as a sub-slab concentration).

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