Scott Deyette
New York State Department of Environmental Conservation
Division of Environmental Remediation
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Albany, New York 12233-7014

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ENVIRONMENT

Subject:
Monitoring Well Installation Work Plan
NYSEG Goshen Former MGP Site
Site No. 3-36-046

Date:
November 7, 2018

Contact:
Jason Golubski, PE

Phone:
315.671.9437

Email:
jason.golubski@arcadis.com

Our ref:
B0013080 #10

Dear Mr. Deyette:

This letter presents a work plan for replacing groundwater monitoring wells at the Goshen Former Manufactured Gas Plant (MGP) Site located in Goshen, New York (the site). Monitoring wells will be replaced to support of the forthcoming annual groundwater sampling event. Groundwater sampling will be conducted in accordance with the New York State Department of Environmental Conservation-(NYSDEC-) approved February 2017 Draft Site Management Plan (Draft SMP) and the March 2011 Record of Decision (ROD).

FIELD ACTIVITIES

The following groundwater monitoring wells (shown on Figure 1), that were identified in the Draft SMP as part of the monitoring well network, require replacement:

- MW08-04S and MW08-04D – confirmed to have been damaged/destroyed by facility operations
- MW08-08D – has not been located since 2016; presumed destroyed by facility operations

NYSEG proposes to install three new groundwater monitoring wells to re-establish the monitoring well network, at the approximate locations shown on Figure 1.

Monitoring Well Installation and Development

Replacement monitoring wells will be constructed and installed to the same depths, and with the same screened intervals, as the original wells (well construction logs are included as Attachment 1). Proposed monitoring wells MW18-08D and MW18-04D will be deep wells, extending to approximately 40

feet below ground surface (bgs). Proposed monitoring well MW18-04S will be a shallow well, extending to approximately 20 feet bgs.

Prior to drilling at each proposed well location, subsurface utility clearance will be performed to approximately 5 feet bgs using a vacuum truck/air knife or by manual clearing methods. Borings for the monitoring wells will be drilled using a conventional 4.25-inch hollow stem auger (HSA) drilling. Split-spoon sampling will not be conducted unless soil cuttings appear impacted by coal tar. If impacts are observed, split-spoon sampling will commence and continue to the base of the boring.

During drilling activities, community air monitoring for volatile organic compounds (VOCs) and particulates will be completed in accordance with New York State Department of Health's (NYSDOH's) May 2010 Generic Community Air Monitoring Plan (CAMP), using one upwind and one downwind monitoring station.

Monitoring wells will be installed in accordance with the Arcadis Technical Guidance Instruction (TGI) – Monitoring Well Installation (Attachment 2). Wells will be constructed using 2-inch diameter Schedule 40 polyvinyl chloride (PVC) casing fitted with a locking cap and up to 10-foot long, 0.010-inch slotted well screen. Well screens for replacement wells MW18-04D and MW18-08D will be installed from 30 to 40 feet bgs, while the well screen for MW18-04S will be installed from 10 to 20 feet bgs. A filter pack (#1 silica sand) will be placed in the annular space between the borehole wall and the well screen to a height of two feet above the top of the well screen. A minimum 2-foot thick hydrated bentonite seal will be installed immediately above the filter pack. The remaining annular space between the well casing and borehole will be grouted to grade.

Well surface completions will include stick-up protectors, surrounded by three bollards. Each well's location, ground surface elevation, and top of casing elevation will be surveyed once the wells are installed.

Following installation, Arcadis will develop each well in accordance with the Arcadis TGI – Monitoring Well Development (Attachment 3). Each of the new wells will be developed by alternately surging and pumping to remove sediment and improve hydraulic communication with the surrounding native formation materials.

Waste Management

All investigation-derived waste (IDW) generated, including drill cuttings and decontamination/well development water, will be placed in appropriately labeled NYSDOT-approved 55-gallon drums and stored in a designated on-site location. NYSEG's waste disposal vendor will subsequently transport drummed IDW off-site for appropriate treatment and/or disposal.

REPORTING

Following installation of the monitoring wells, a brief letter report will be prepared to summarize the completed field activities. The letter report will be supported by monitoring well construction/soil boring logs and an updated site plan illustrating the installed locations of the new wells. The letter report is anticipated to be submitted to NYSDEC as part of the 2018 annual site report, to be prepared following the annual groundwater sampling activities (discussed below).

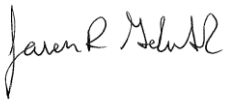
SCHEDULE

The new monitoring wells will be installed and developed during the week of December 10, 2018. As standard practice, groundwater sampling is typically completed at least two weeks following monitoring well installation and development. Therefore, the 2018 site-wide groundwater sampling, to be conducted in accordance with the Draft SMP, is anticipated to be completed during the week of December 31, 2018. The 2018 annual site report is anticipated to submitted to NYSDEC in Q1 2019.

Please contact Tracy Blazicek at 585.484.6839 or tlblazicek@nyseg.com with any questions or comments.

Sincerely,

Arcadis of New York, Inc.



Jason Golubski, PE
Senior Environmental Engineer

Copies:
Tracy Blazicek, CHMM, NYSEG
Jason Brien, PE, Arcadis

Enclosures:

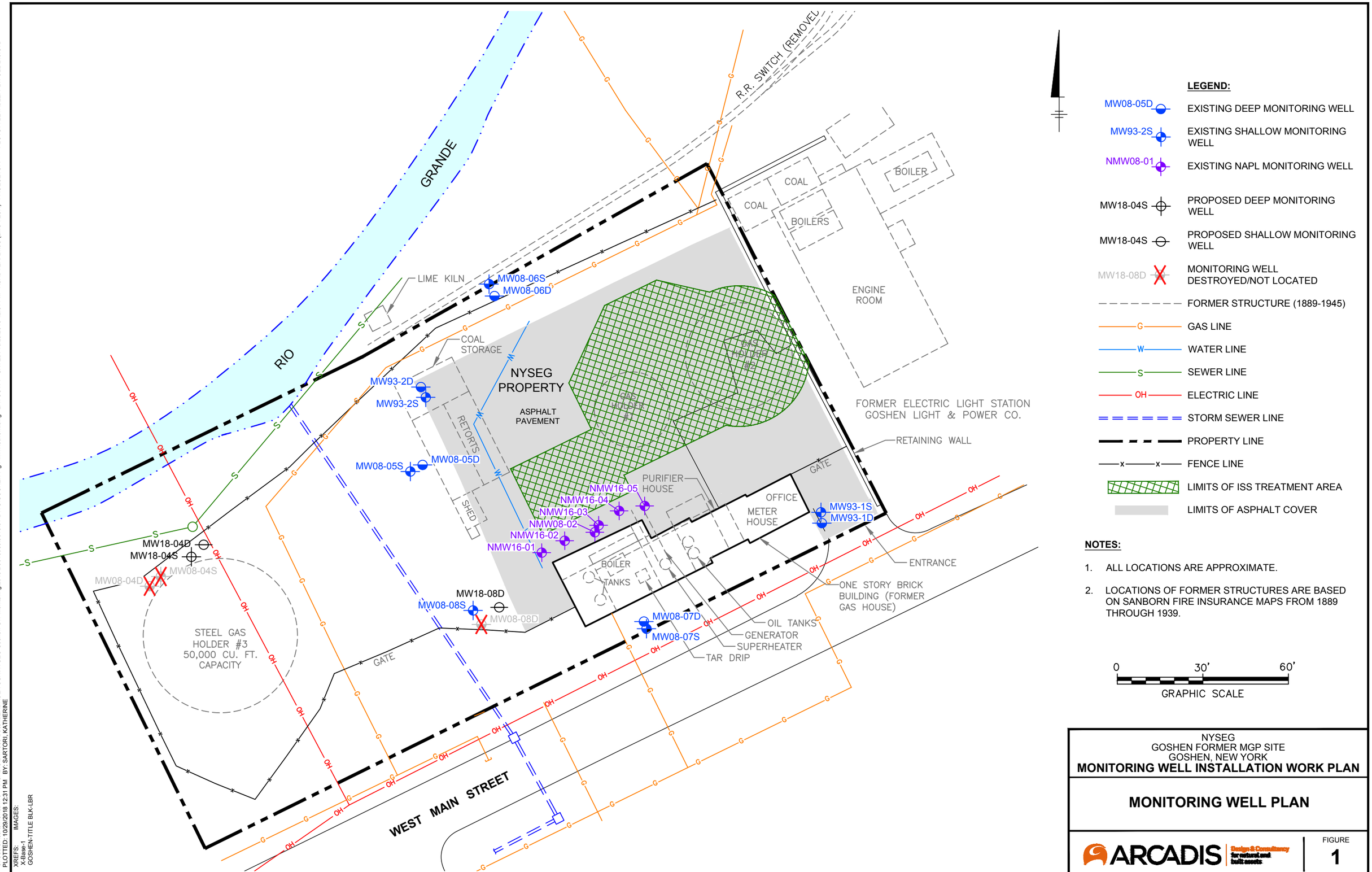
Figure

1 Monitoring Well Plan

Attachments

1 Monitoring Well Construction Logs
2 Arcadis TGI – Monitoring Well Installation
3 Arcadis TGI – Monitoring Well Development

FIGURE



LEGEND:

- MW08-05D — EXISTING DEEP MONITORING WELL
- MW93-2S — EXISTING SHALLOW MONITORING WELL
- NMW08-01 — EXISTING NAPL MONITORING WELL
- MW18-04S — PROPOSED DEEP MONITORING WELL
- MW18-04S — PROPOSED SHALLOW MONITORING WELL
- MW18-08D — MONITORING WELL DESTROYED/NOT LOCATED
- FORMER STRUCTURE (1889-1945)
- G — GAS LINE
- W — WATER LINE
- S — SEWER LINE
- OH — ELECTRIC LINE
- STORM SEWER LINE
- PROPERTY LINE
- x — x — FENCE LINE
- LIMITS OF ISS TREATMENT AREA
- LIMITS OF ASPHALT COVER

NOTES:

1. ALL LOCATIONS ARE APPROXIMATE.
2. LOCATIONS OF FORMER STRUCTURES ARE BASED ON SANBORN FIRE INSURANCE MAPS FROM 1889 THROUGH 1939.

0 30’ 60’

GRAPHIC SCALE

NYSEG
GOSHEN FORMER MGP SITE
GOSHEN, NEW YORK

MONITORING WELL INSTALLATION WORK PLAN

MONITORING WELL PLAN

ARCADIS Design & Consultancy for natural and built assets

FIGURE 1

CITY: SYRACUSE NY DIV/GROUP: ENV/CAD DB: E. KRAHMER, K.SARTORI PIC: PM: TM: TR: J.BISTROVICH LYR:(Opt)ON=*;OFF=*REF*
C:\Users\ksartori\OneDrive - ARCADIS\BIM 360 Docs\IBERDROLA USA\NYSEG Goshen GW Monitoring\2018\B0013080.0015\01-DWG\GOSHEN-Fig1-MWNetwork.dwg LAYOUT: 1 SAVED: 10/29/2018 12:31 PM ACADVER: 21.0S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: PLTFULL.240.CTB
PLOTTED: 10/29/2018 12:31 PM BY: SARTORI, KATHERINE
XREFS: IMAGES:
X-Base-1
GOSHEN-TITLE BLK-LBR

ATTACHMENT 1

Monitoring Well Construction Logs

Date Start/Finish: 11/12/08
Drilling Company: Parratt Wolff
Driller's Name: Jim Lansing
Drilling Method: Hollow Stem Auger
Auger Size: 4.25" ID
Rig Type: Ingersoll Rand A300
Sampling Method: 2' x 2" Split Spoon

Northing: 935176.8
Easting: 538358.5
Casing Elevation: 429.82' AMSL

Borehole Depth: 40' bgs
Surface Elevation: 430.18' AMSL

Descriptions By: Christin Cifelli

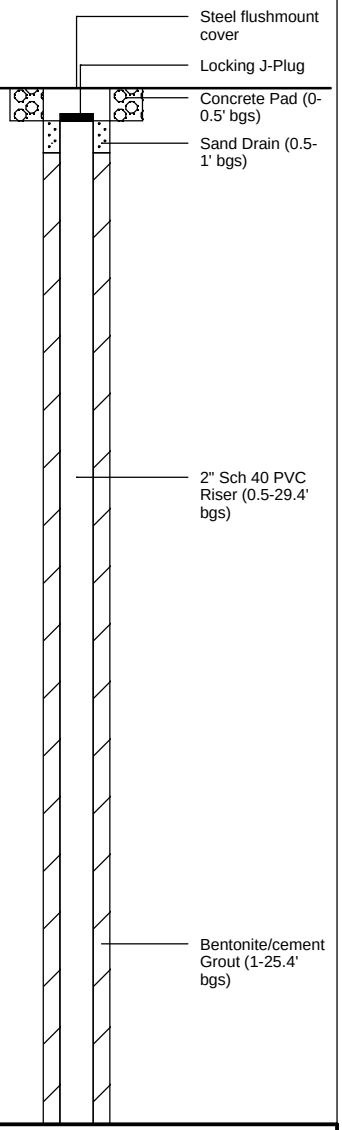
Well/Boring ID: **MW08-4D**

Client: New York State Electric and Gas

Location: West Main Street
Goshen, NY

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Geologic Column	Stratigraphic Description
0	430	1	0-2	1.1	4 3 4 3	7	0.0		Brown/black BRICK fragments, some fine to coarse Sand, little medium Gravel (Concrete and Brick), moist. Brown Silty CLAY, trace fine Gravel, moist.
		2	2-4	1.0	3 3 3 2	6	0.0		Brown fine to medium SAND, little fine to very coarse Gravel (brick fragments), moist.
5	425	3	4-6	1.0	2 3 2 3	5	0.0		Brown Silty CLAY, trace coarse Sand to medium Gravel, moist. Light brown/yellow CLAY, moist.
		4	6-8	1.5	4 5 10 10	15	0.0		Brown Silty CLAY, some coarse Sand and coarse Gravel, moist. Fine to medium SAND lense at 7' bgs.
		5	8-10	1.5	5 5 5 9	10	0.0		Brown Silty CLAY, trace coarse Sand, moist.
10	420	6	10-12	1.7	5 6 7 9	13	0.0		SAA. Brown fine SAND, wet.
		7	12-14	1.9	7 8 7 7	15	0.0		Brown CLAY and medium SAND, wet. Brown fine SAND, wet. Brown Silty CLAY and fine to medium GRAVEL, moist. Very coarse GRAVEL (shale) at 13.9' bgs.
15	415	8	14-16	1.3	6 7 8 8	15	0.0		Grey very fine SAND and SILT, trace fine to very coarse Gravel, moist.

Well/Boring Construction



Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level; OLM = Oil-like material; TLM = Tar-like material

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Infrastructure, environment, buildings

Client: New York State Electric and Gas

Well/Boring ID: **MW08-4D**

Borehole Depth: 40' bgs

Site Location:
West Main Street
Goshen, NY

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Geologic Column	Stratigraphic Description	Well/Boring Construction
		9	16-18	0.8	7 8 8 9	16	0.0		Grey SILT, trace fine to coarse Sand and fine to medium Gravel, moist. Fine to medium SAND lense at 16.8' bgs.	
		10	18-20	1.0	18 17 10 12	27	0.0		Grey SILT, some Clay, little fine to medium Gravel, moist.	
20	410								Grey Silty CLAY, trace coarse Sand to fine Gravel, moist.	2" Sch 40 PVC Riser (0.5-29.4' bgs)
		11	20-22	1.0	18 17 10 12	27	0.0		Grey Silty CLAY, some fine to coarse Gravel, moist.	
		12	22-24	0.8	12 26 16 18	42	0.0		Grey SILT and CLAY, some medium to coarse Sand and fine Gravel, wet. Grey very fine SAND and SILT, little medium Gravel and Clay, moist. Very coarse GRAVEL (shale) at 22.8' bgs.	Bentonite/cement Grout (1-25.4' bgs)
25	405	13	24-26	1.5	12 14 14 10	28	0.0		Grey very fine SAND and SILT, some Clay and fine to medium Gravel, moist.	
		14	26-28	1.1	12 11 12 15	23	0.0		Grey fine to coarse GRAVEL, some very fine Sand and Silt, little Clay, wet. Grey fine to coarse SAND, trace very coarse Gravel, wet.	Bentonite Seal (25.4-27.4' bgs)
		15	28-30	1.0	13 12 13 31	25	0.0		Grey very fine SAND, some coarse Sand to medium Gravel, little Silt and Clay, moist.	
30	400	16	30-32	1.6	18 22 36 39	58	0.0		Black fine to coarse SAND (TILL), wet. Grey very fine SAND, some fine to medium Gravel (TILL), moist. Grey very fine SAND and SILT, some coarse Sand to fine Gravel, little Clay (TILL), moist.	#1 Silica Sand Pack (27.4-39.4' bgs)
		17	32-34	0.9	21 27 29 39	56	0.0		Grey very fine to coarse SAND (TILL), wet. Grey SILT and fine to medium GRAVEL, little Clay (TILL), moist.	2" Sch 40 PVC 0.010" Slot Screen (29.4-39.4' bgs)
35	395	18	34-36	1.4	22 25 32 41	57	0.0		Grey SILT and CLAY, some fine to very coarse Gravel (TILL), moist.	

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level; OLM = Oil-like material; TLM = Tar-like material

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Client: New York State Electric and Gas

Well/Boring ID: **MW08-4D**

Borehole Depth: 40' bgs

Site Location:
West Main Street
Goshen, NY

DEPTH / ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Geologic Column	Stratigraphic Description	Well/Boring Construction
	19	36-38	1.3	29 35 50 13	85	0.0		Grey SILT and CLAY, some fine to medium Gravel (TILL), moist. Wet from 36.3 - 37.0' bgs.	#1 Silica Sand Pack (27.4-39.4' bgs) 2" Sch 40 PVC 0.010" Slot Screen (29.4-39.4' bgs)
	20	38-40	1.2	27 29 31 36	60	0.0		Grey medium GRAVEL and very fine SAND, some Silt and Clay (TILL), wet. Grey SILT, some Clay, little fine to coarse Gravel (TILL), moist.	
40 / 390									
45 / 385									
50 / 380									
55 / 375									

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level; OLM = Oil-like material; TLM = Tar-like material

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Date Start/Finish: 11/12/08
Drilling Company: Parratt Wolff
Driller's Name: Jim Lansing
Drilling Method: Hollow Stem Auger
Auger Size: 4.25" ID
Rig Type: Ingersoll Rand A300
Sampling Method: 2' x 2" Split Spoon

Northing: 935180.2
Easting: 538362.4
Casing Elevation: 429.71' AMSL

Borehole Depth: 20' bgs
Surface Elevation: 430.20

Descriptions By: Christin Cifelli

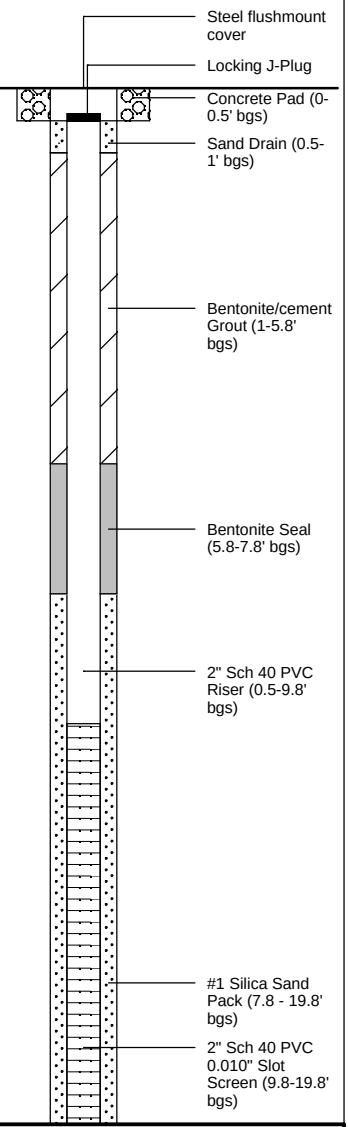
Well/Boring ID: **MW08-4S**

Client: New York State Electric and Gas

Location: West Main Street
Goshen, NY

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Geologic Column	Stratigraphic Description
0	430	1	0-2	1.1	4 3 4 3	7	0.0		Brown/black BRICK fragments, some fine to coarse Sand, little medium Gravel (Concrete and Brick), moist. Brown Silty CLAY, trace fine Gravel, moist.
		2	2-4	1.0	3 3 3 2	6	0.0		Brown fine to medium SAND, little fine to very coarse Gravel (brick fragments), moist.
5	425	3	4-6	1.0	2 3 2 3	5	0.0		Brown Silty CLAY, trace coarse Sand to medium Gravel, moist. Light brown/yellow CLAY, moist.
		4	6-8	1.5	4 5 10 10	15	0.0		Brown Silty CLAY, some coarse Sand and coarse Gravel, moist.
		5	8-10	1.5	5 5 5 9	10	0.0		Brown Silty CLAY, trace coarse Sand, moist.
10	420	6	10-12	1.7	5 6 7 9	13	0.0		SAA. Brown fine SAND, wet.
		7	12-14	1.9	7 8 7 7	15	0.0		Brown CLAY and medium SAND, wet. Brown fine SAND, wet. Brown Silty CLAY and fine to medium GRAVEL, moist.
15	415	8	14-16	1.3	6 7 8 8	15	0.0		Grey very fine SAND and SILT, trace fine to very coarse Gravel, moist.

Well/Boring Construction



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Client: New York State Electric and Gas

Well/Boring ID: **MW08-4S**

Borehole Depth: 20' bgs

Site Location:
West Main Street
Goshen, NY

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Geologic Column	Stratigraphic Description	Well/Boring Construction
		9	16-18	0.8	7 8 8 9	16	0.0		Grey SILT, trace fine to coarse Sand and fine to medium Gravel, moist.	#1 Silica Sand Pack (7.8 - 19.8' bgs) 2" Sch 40 PVC 0.010" Slot Screen (9.8-19.8' bgs)
		10	18-20	1.0	18 17 10 12	27	0.0		Grey SILT, some Clay, little fine to medium Gravel, moist.	
20	410									
25	405									
30	400									
35	395									

Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level; OLM = Oil-like material; TLM = Tar-like material

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Date Start/Finish: 11/5/08
Drilling Company: Parratt Wolff
Driller's Name: Jim Lansing
Drilling Method: Hollow Stem Auger
Sampling Method: 4' x 2" Macrocore
Rig Type: Ingersoll Rand A300

Northing: 935163.4
Easting: 538474.8
Casing Elevation: 430.66' AMSL

Borehole Depth: 40' bgs
Surface Elevation: 431.08' AMSL

Descriptions By: Christin Cifelli

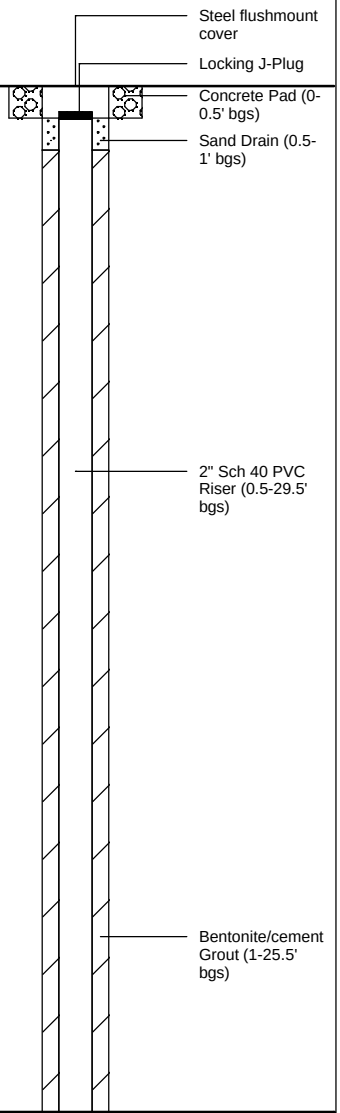
Well/Boring ID: **MW08-8D**

Client: New York State Electric and Gas

Location: West Main Street
Goshen, NY

DEPTH / ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Geologic Column	Stratigraphic Description
0 / 430	1	0-4	2.6	0.0		Grey coarse SAND and medium GRAVEL, moist.
				0.0		Brown very fine to fine SAND, moist.
				0.0		Brown Silty CLAY, moist. Coarse SAND to fine GRAVEL at 2.5-2.8' bgs.
5 / 425	2	4-8	3.7	0.0		Black medium to coarse SAND, moist. Brown Silty CLAY, trace medium Gravel, moist.
				0.0		
10 / 420	3	8-12	3.7	0.0		Grey fine to coarse SAND, some medium Gravel, moist. Brown Silty CLAY, some fine to medium Gravel, moist. Medium to very coarse GRAVEL (Shale) at 8.8-9.0' bgs.
				0.0		
15	4	12-16	3.8	0.0		Brown very fine SAND and SILT, little fine Gravel, wet. Grey/brown SILT and very fine SAND, trace Clay and fine to medium Gravel, moist.
				0.0		

Well/Boring Construction



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Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level; OLM = Oil-like material; TLM = Tar-like material

Client: New York State Electric and Gas

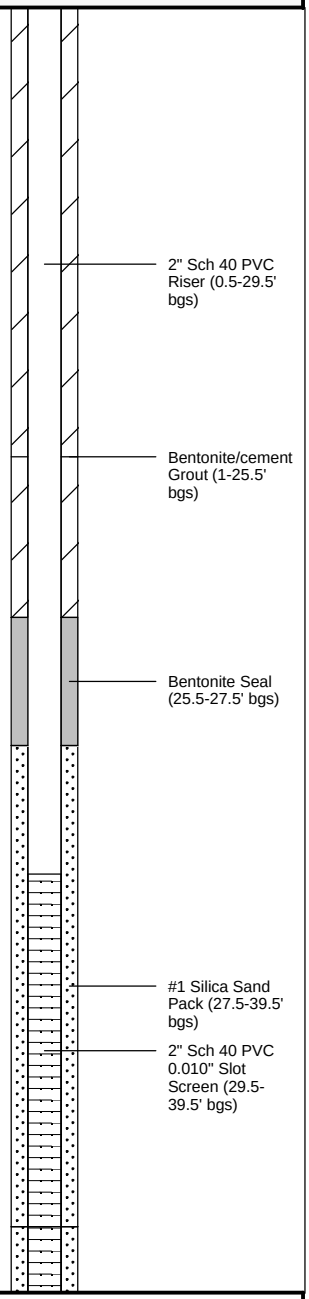
Well/Boring ID: **MW08-8D**

Borehole Depth: 40' bgs

Site Location:
West Main Street
Goshen, NY

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Geologic Column	Stratigraphic Description
	415				0.0		Grey very fine SAND and SILT, moist.
		5	16-20	2.8	0.0		Grey SILT, some very fine Sand, little fine to medium Gravel, moist.
20	410	6	20-24	3.3	0.0 0.0		Grey SILT and very fine SAND, some medium Sand to fine Gravel, trace Clay, moist.
25	405	7	24-28	2.7	0.0 0.0		SAA, wet throughout. Very coarse GRAVEL at 24.4' bgs.
30	400	8	28-32	1.9	0.0 0.0		Grey very fine SAND and SILT, little Clay, some coarse Sand to very coarse Gravel (TILL), moist.
		9	32-36	1.9	0.0		Grey very fine SAND and SILT, some Clay, trace fine to medium Gravel (TILL), moist.
35					0.0		Grey very fine SAND and SILT, trace Clay, some fine to very coarse Gravel (TILL), moist.

Well/Boring Construction



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Remarks: ags = above ground surface; bgs = below ground surface; NA = Not Applicable/Available; AMSL = Above Mean Sea Level; OLM = Oil-like material; TLM = Tar-like material

Client: New York State Electric and Gas

Well/Boring ID: **MW08-8D**

Borehole Depth: 40' bgs

Site Location:
West Main Street
Goshen, NY

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	PID Headspace (ppm)	Geologic Column	Stratigraphic Description	Well/Boring Construction
	395	10	36-38	0.3	0.0		Black/grey fine to coarse SAND and fine to coarse GRAVEL (TILL), wet.	#1 Silica Sand Pack (27.5-39.5' bgs); 2" Sch 40 PVC 0.010" Slot Screen (29.5-39.5' bgs)
							No Recovery.	
40	390							
45	385							
50	380							
55								

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ATTACHMENT 2

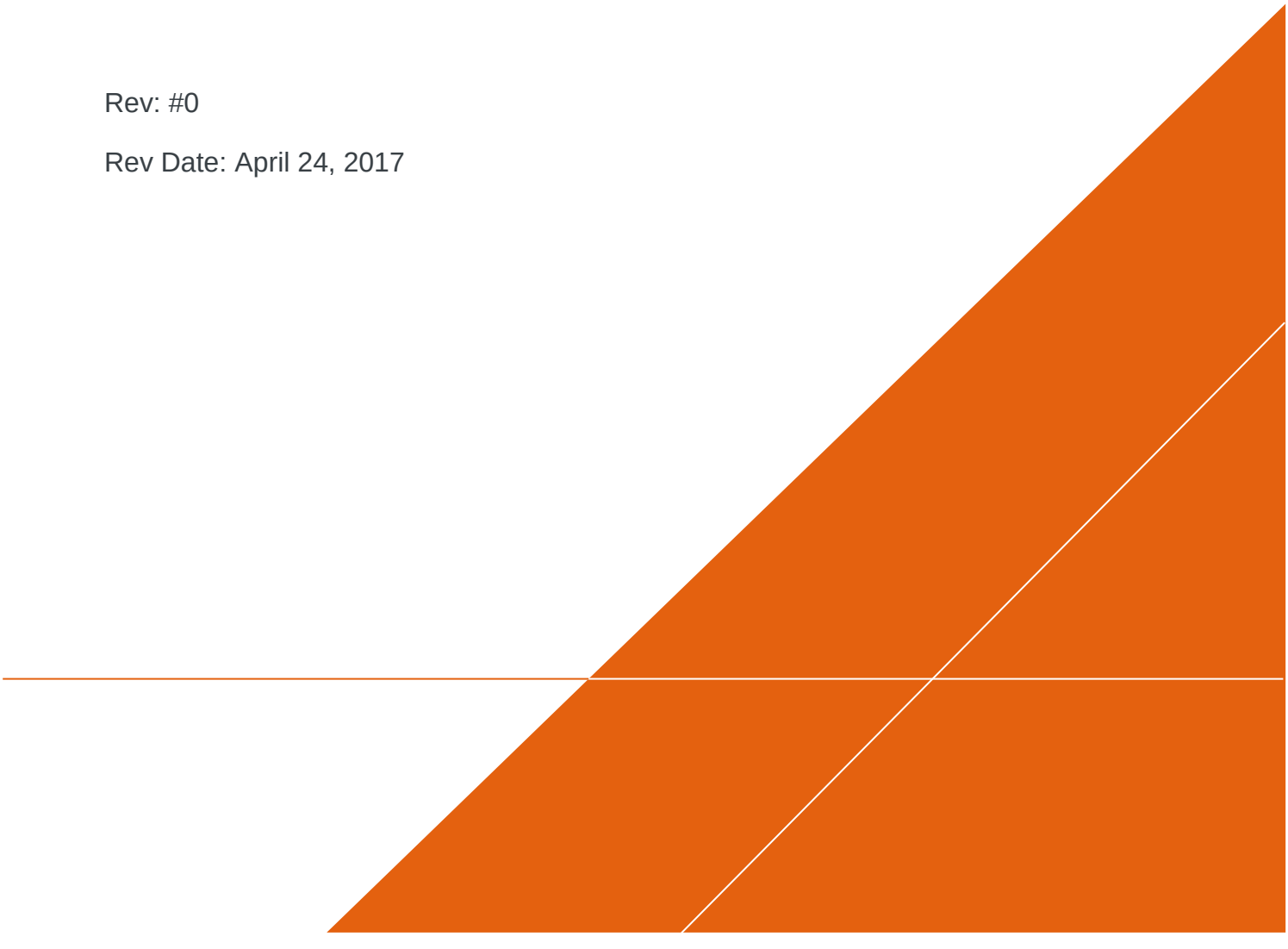
Arcadis TGI – Monitoring Well Installation

ARCADIS Design & Consultancy for natural and built assets

TECHNICAL GUIDANCE INSTRUCTION - MONITORING WELL DEVELOPMENT

Rev: #0

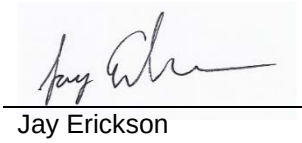
Rev Date: April 24, 2017



VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	4/24/2017	All	Re-written as TGI	Marc Killingstad

APPROVAL SIGNATURES

Prepared by:		4/24/2017
	Jay Erickson	Date:
Technical Expert Reviewed by:		4/24/2017
	Marc Killingstad	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) covers the development of screened wells used for obtaining representative groundwater information and samples from granular aquifers (i.e., monitoring wells). Note that this TGI only applies to monitoring well development and not remediation (injection/extraction) well development.

The purposes of Monitoring Well Development are:

1. Repair damage to the borehole wall from drilling that can include clogging, smearing or compaction of aquifer materials;
2. Remove fine grained sediment from the formation and filter pack that may result in high turbidity levels in groundwater samples;
3. To re-sort formation and filter pack material adjacent to the well screen;

4. To recover any drilling fluids (if used) that may affect the permeability of the formation and filter pack or alter the water quality around the well; and
5. To optimize the well efficiency and hydraulic communication between the well screen and the formation.

Successful monitoring well development is dependent on the following:

1. Hydrostratigraphy – Permeable formations containing primarily sand and gravel are more easily developed due to lower percentages of silt and clay material. Water in permeable formations can be moved in and out of the screen and/or through the formation easier than in less permeable deposits
2. Well Diameter – Development tooling including brushes, surge blocks, pumps and jetting tools are more readily available for wells 4 inches in diameter and greater.
3. Well Design – Wells with filter packs and screens designed to match the formation through the analysis of formation sieve samples are easier to develop. An important aspect to well design is to minimize the size of the annular space between the formation and well screen. Adequate room must be allowed for the proper installation of well materials, but not too large as to prevent/reduce communication with the surrounding formation.
4. Drilling Methods – Different drilling methods result in varying amount of borehole damage and, therefore, impact the degree to which development will be successful.

Well development methods for monitoring wells include the following:

1. Bailing – use of a bailer to remove water and sediment from the well casing. This technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow in only in one direction, toward the well screen.
2. Pumping/overpumping – use of a pump to remove water and sediment from the well casing, overpumping involves pumping the well at a rate that exceeds the design capacity of the well. Similar to bailing, this technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow in only in one direction, toward the well screen. Small diameter monitoring wells have the additional constraint on pump size and flow rates.
3. Backwashing (rawhiding) – consists of starting and stopping a pump intermittently to produce rapid pressure changes in a well. This method can produce better results than pumping alone since the procedure involves movement of the water in and out of the screen and formation. However, in many cases the surging action is not rigorous enough to fully develop the well.
4. Surging/swabbing – use of a mechanical surge block or swabbing tool to operate like a piston with an up and down motion. The downstroke causes a backwash action that breaks up bridged sediment and the upstroke pulls the dislodged sediment into the well. This method works well for small and large diameter wells. Care should be taken on the downstroke so as not to force fines back into the formation, frequent pumping/purging during surging help to keep fines out of the well. Double surge blocks are recommended.
5. Jetting – use of a tool fitted with nozzles that direct streams of water horizontally into well screens at high velocity. Due to the size of the tooling, this method is better suited for wells 4 inch in diameter and larger. The method is also more effective with wire-wrapped/continuous slot screens due to the

increased open area. Jetting requires specialized equipment and concurrent pumping to prevent reintroducing fines into the filter pack. Additionally, jetting requires subsequent surging to remove fines dislodged in the filter pack and formation.

For most situations, gentle surging coupled with bailing or pumping to remove dislodged materials is recommended.

Well development for properly designed and constructed monitoring wells may begin after the annular seal materials have been installed and allowed to cure, since these wells are designed to retain 90-99% of the filter pack material. This cure time is typically at least 24 to 48 hours after the sealing materials have been installed.

This TGI is meant to provide a general guide for proper monitoring well development. A site-specific field implementation plan for well installation and development detailing the specific methods and tools should be developed to provide site-specific instruction and guidance.

3 PERSONNEL QUALIFICATIONS

Monitoring well development activities will be performed by persons who have been trained in proper well development procedures under the guidance of an experienced field geologist, engineer, or technician.

4 EQUIPMENT LIST

Required equipment depends on the selected method and should be detailed in the site-specific field implementation plan. However, the following are typically required.

- Health and safety equipment, as required by the site Health and Safety Plan (HASP):
- Cleaning equipment
- Field notebook and/or personal digital assistant (PDA)
- Monitoring well keys
- Water level indicator
- Field parameter meter (YSI)
- Well Development Logs
- Well construction logs/diagrams
- Weighted tape (measure depth)
- Turbidity meter
- Camera
- Watch/timing device.

5 CAUTIONS

Where surging is performed to assist in removing fine-grained material from the sand pack, surging must be performed in a gentle manner. Excessive suction could promote fine-grained sediment entry into the outside of the sand pack from the formation.

Avoid using development fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

In some cases, it may be necessary to add potable water to a well to allow surging and development, especially for new monitoring wells installed in low permeability formations. Before adding potable water to a well, the Certified Project Manager (CPM) and/or Project Hydrogeologist must be notified and the CPM shall make the decision regarding the appropriateness and applicability of adding potable water to a well during well development procedures. If potable water is to be added to a well as part of development, the potable water source should be sampled and analyzed for constituents of concern, and the results evaluated by the CPM prior to adding the potable water to the well. If potable water is added to a well for development purposes, at the end of development the well will be purged dry to remove the potable water, or if the well no longer goes dry then the well will be purged to remove at least three times the volume of potable water that was added.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with monitoring well development will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

7 PROCEDURE

As indicated above, for most monitoring wells, gentle surging coupled with bailing or pumping to remove dislodged sediment is recommended.

1 Ensure sufficient time has passed to allow for proper curing of the well seal.

2 Don appropriate PPE (as required by the site-specific HASP).

3 Place plastic sheeting around the well.

4 Clean all equipment entering each monitoring well, except for new, disposable materials that have not been previously used.

5 Open the well cover while standing upwind of the well, remove well cap. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field notebook. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the PID reading in the breathing zone is below 5 PID units, proceed. If the PID reading is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don the appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings.

6 Obtain an initial measurement of the depth to water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book. It is recommended to use a weighted tape for the total well depth measurement.

7 The depth to the bottom of the well should be sounded and then compared to the completion form or construction diagram for the well. Any discrepancies should be reported immediately to the CPM and/or Project Hydrogeologist. If sand or sediment is present inside the well, it should first be removed by bailing. Do not insert bailers, pumps, or surge blocks into the well if obstructions, parting of the casing, or other damage to the well is suspected. Instead report the conditions to the CPM and/or Project Hydrogeologist and obtain approval to continue or cease well development activities.

8 Lower a double surge block into the screened portion of the well. Starting from the bottom of the screen using 2 foot throws, gently raise and lower the surge block to force water in and out of the screen slots and sand pack. Continue surging for 15 to 30 minutes.

9 Lower a bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well and gently bounce on the bottom of the well to collect/remove accumulated sediment, if any. Remove and empty the bailer, if used. Repeat until the bailed/pumped water is free of excessive sediment and contact at the bottom of the well feels solid. Alternatively, measurement of the well depth with a weighted tape can be used to verify that sediment and/or silt has been removed to the extent practicable, based on a comparison with the well installation log or previous measurement of total well depth.

10 After surging the well for a minimum of two cycles and removing excess accumulated sediment from the bottom of the well, re-measure the depth-to-water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book.

11 Remove formation water by pumping/bailing. Where pumping is used, measure and record the pre-pumping water level. Operate the pump at a relatively constant rate. Measure the pumping rate using a calibrated container and stop watch, and record the pumping rate in the field log book. Measure and record the water level in the well at least once every 5 minutes during pumping. Note any relevant observations in terms of water color, visual level of turbidity, sheen, odors, etc. Pump or bail until termination criteria specified in the Site-Specific Field Implementation plan are reached. Note: the project-specific field implementation plan may also specify a maximum turbidity requirement for completion of development. Unless otherwise specified the maximum turbidity should be 50 NTUs or less. Record the total volume of water purged from the well.

12 While developing, take periodic water level measurements (at least one every five minutes) to determine if drawdown is occurring and record the measurements on the Well Development Log.

13 While developing, calculate the rate at which water is being removed from the well. Record the volume on the Well Development Log.

14 While developing, water is also periodically collected directly from the well or bailer discharge and readings taken of the indicator parameters: pH, specific conductance, and temperature. Development is considered complete when the indicator parameters have stabilized (i.e., three consecutive pH, specific conductance, and temperature readings are within tolerances specified in the project work plans or within 10% if not otherwise specified), the extracted water is clear and free

of fine sediment and most importantly, when acceptable volume of water has been removed and/or a sufficient amount of surging has been performed.

15 In certain instances, for slow recharging wells, the parameters may not stabilize. In this case, well development is considered complete when minimal amounts of fine-grained sediments are recovered and acceptable volume of water has been removed.

16 If the well goes dry, stop pumping or bailing. Note the time that the well went dry. After allowing the well to recover, note the time and depth to water. Resume pumping or bailing when sufficient water has recharged the well.

17 Contain all development water in appropriate containers.

18 When complete, secure the lid back on the well.

19 Place disposable materials in plastic bags for appropriate disposal and decontaminate reusable, downhole pump components and/or bailer

8 WASTE MANAGEMENT

Materials generated during monitoring well installation and development will be placed in appropriate labeled containers and disposed of as described in the Work Plan/Field Implementation Plan or Field Sampling Plan.

9 DATA RECORDING AND MANAGEMENT

All well development activities should be documented on appropriate log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site; times of arrival and departure; significant weather conditions; timing of well development activities; development method(s); observations of purge water color, turbidity, odor, sheen, etc.; purge rate; and water levels before, during, and after pumping.

10 QUALITY ASSURANCE

All reused, non-disposable, downhole well development equipment should be cleaned in accordance with the procedures outlined in the project documents.

11 REFERENCES

American Society for Testing Materials (ASTM), Designation D5521-05. *Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

ATTACHMENT 3

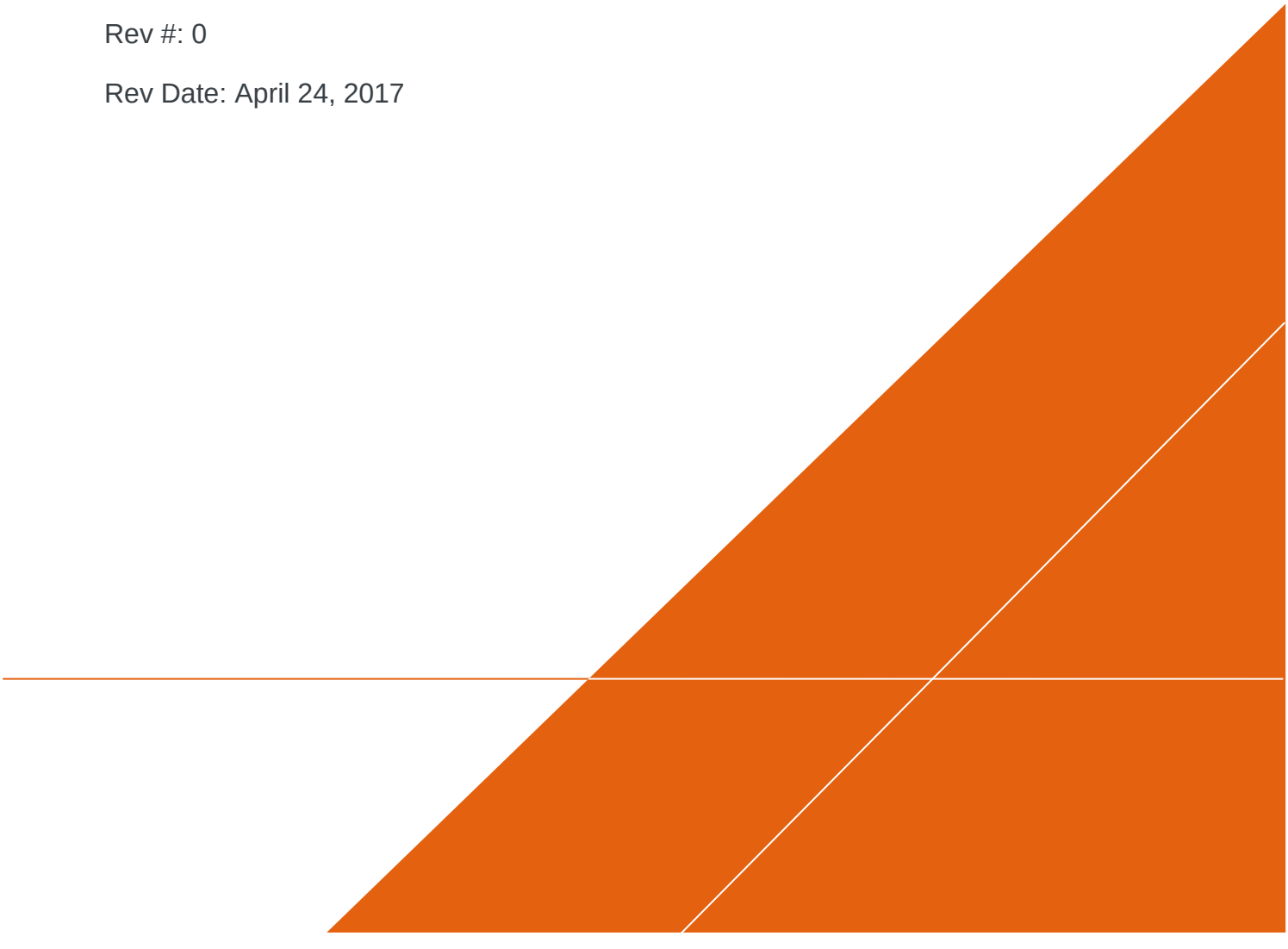
Arcadis TGI – Monitoring Well Development

ARCADIS Design & Consultancy for natural and built assets

TGI - MONITORING WELL INSTALLATION

Rev #: 0

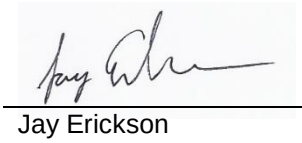
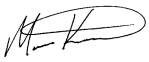
Rev Date: April 24, 2017



VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	4/24/2017	All	Re-written as a TGI	Marc Killingstad Peter C. Frederick

APPROVAL SIGNATURES

Prepared by:		4/20/17
	Jay Erickson	Date:
Technical Expert Reviewed by:		4/24/17
	Marc Killingstad	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) describes methods used to install groundwater monitoring wells in granular aquifers. It is assumed that the monitoring well has been properly designed, including sizing of the filter pack and screen, the length of the screen, total depth of the well, material strength and compatibility and surface completion. Typical monitoring wells are constructed of manufactured screen and engineered filter pack and are generally suitable for formations with granular materials having a grain size distribution with up to 50% passing a #200 sieve and up to 20% clay-sized material. Monitoring wells installed in formations finer than this may not be able to produce turbidity free water.

The monitoring well installation procedures set forth herein are consistent with the approach and methods presented in the American Society of Testing and Materials (ASTM) D5092 – *Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM D5092). As such, following this TGI in combination with proper well design (see appropriate TGI), well development (see appropriate TGI), groundwater sampling procedures (see appropriate TGI), and well maintenance and rehabilitation (see appropriate TGI), will result in a monitoring well suitable for: (1) collection of groundwater samples

representative of the surrounding formation and free of artificial turbidity; (2) measurement of accurate groundwater levels; and (3) hydraulic conductivity testing of formation sediments immediately adjacent to the open interval of the well (e.g., slug testing).

Monitoring well boreholes in unconsolidated (overburden) materials are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions or project objectives, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and driven well points may also be used in some cases within the overburden. Monitoring wells to be installed within consolidated materials such as fractured bedrock are commonly drilled using water-rotary (coring or tri-cone roller bit), air rotary or Rotasonic methods. For guidance when installing monitoring wells in consolidated materials, please refer to the appropriate document. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, project objectives, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No polyvinyl chloride (PVC) glue/cement will be used in constructing or retrofitting monitoring wells that will be used for water-quality monitoring. No coated bentonite pellets will be used in the well drilling or construction process. Specifications of materials to be installed in the borehole will be obtained prior to mobilizing onsite; these materials generally include:

- Well casing (length, material, and diameter);
- Well screen (length, material, diameter, and slot size);
- Bentonite (type, as applicable, chips, non-coated and granular bentonite are acceptable);
- Filter pack (filter pack type and fine sand seal type, as applicable); and
- Grout (type, as applicable).

Well materials will be inspected and, if needed, cleaned or replaced prior to installation.

3 PERSONNEL QUALIFICATIONS

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Where field sampling is performed for soil or bedrock characterization, field personnel will have undergone in-field training in soil or bedrock description methods, as described in the appropriate Standard Operating Procedures (SOPs) and/or TGIs for those activities.

4 EQUIPMENT LIST

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;

- Work Plan (or equivalent), Field Sampling Plan (FSP), and site-specific Health and Safety Plan (HASP);
- Personal protective equipment (PPE), as required by the HASP;
- Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if such are not provided by drillers;
- Appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- Soil and/or bedrock logging equipment as specified in the appropriate project documents;
- Appropriate sample containers and labels;
- Drum labels as required for investigation derived waste handling;
- Chain-of-custody forms;
- Insulated coolers with ice, when collecting samples requiring preservation by chilling;
- Photoionization detector (PID) or flame ionization detector (FID);
- Ziplock style bags;
- Water level or oil/water interface meter;
- Locks and keys for securing the well after installation;
- Decontamination equipment (bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels);
- Engineer's tape/measuring wheel;
- Weighted tape;
- Disposable bailers;
- Digital camera (or phone with camera)
- Field notebook or Personal Digital Assistant (PDA); and
- Appropriate field forms, consider including a photo of the well head and a Google Earth map showing the well location.

Prior to mobilizing to the site, Arcadis personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling and well installation equipment will be provided. Specifications of the sampling and well installation equipment are expected to vary by project, and so communication with the driller is necessary to ensure that the materials provided will meet the project objectives. Equipment/materials typically provided by the driller could include:

- Drilling equipment required by the ASTM standard guidance document D1586, when performing split-spoon sampling;
- Disposable plastic liners (when drilling with direct-push equipment);
- Drums for investigation derived waste;

- Drilling and sampling equipment decontamination materials;
- Decontamination pad materials, if required; and
- Well construction materials.

5 CAUTIONS

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See appropriate guidance for proper utility clearance protocol.

Prior to beginning field work, contact the project technical team to ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members.

Some regulatory agencies require a minimum annular space between the well or permanent casing and the borehole wall. When specified, the minimum clearance is typically 2 inches on all sides (e.g., a 2-inch diameter well requires a 6-inch diameter borehole). In addition, some regulatory agencies have specific requirements regarding grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan.

If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the project specific documents for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquids (LNAPLs) are known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Similarly, consider the compatibility between the well materials and the surrounding environment. For example, PVC well materials are not preferred when DNAPL is present. In addition, some groundwater conditions leach metals from stainless steel or are corrosive to metal well materials. If questions arise, contact the CPM and/or project technical lead to discuss.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

As noted above, coated bentonite pellets will not be used in monitoring well construction, as the coating could impact the water quality in the completed well.

Heat of hydration during neat cement grout curing must be considered to avoid damage to PVC well materials. The annular space for a typical monitoring well is small enough that heat of hydration should not create excessive temperature increases which may damage PVC well material. However, washouts in the borehole can lead to thick accumulations of grout which can produce enough heat during curing to weaken and potentially damage PVC casing. If heat of hydration is a concern, contact the project technical lead to address the issue.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

7 PROCEDURE

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Prior to monitoring well installation, determine the expected volumes of filter pack and seal materials including bentonite (if applicable) and grout (neat cement or cement-bentonite).
2. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.
3. Advance boring to desired depth. Collect soil and/or bedrock samples at appropriate interval as specified in the Work Plan (or equivalent) and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. Decontaminate equipment between samples in accordance with the Work Plan (or equivalent) and/or FSP. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is described in ASTM D1586 – *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D1586). Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks. Dual-rotary removes cuttings by compressed air or water/mud and allow only a general assessment of geology.
4. Describe each soil sample as outlined in the appropriate project records. Record descriptions in the field notebook and/or personal digital assistant (PDA). It is also beneficial to photo document the samples. It should be noted that PDA logs must be electronically backed up and transferred to a location accessible to other project team members as soon as feasible to retain and protect the field data. During soil boring advancement, document all drilling events in field notebook, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if Rotasonic, dual-rotary, or direct-push methods are used.

5. If it is necessary to install a monitor well into a permeable zone below a confining layer, particularly if the deeper zone is believed to have water quality that differs significantly from the zone above the confining layer, then a telescopic well construction should be considered. In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer, and a permanent casing (typically PVC, black steel or stainless steel) is installed into the socket drilled into the top of the confining layer. The casing is then grouted in place. The preferred methods of grouting telescoping casings include: pressure-injection grouting using an inflatable packer installed temporarily into the base of the casing, such that grout is injected out the bottom of the casing until it is observed at ground surface outside the casing; displacement-method grouting (also known as the Halliburton method), which entails filling the casing with grout and displacing the grout out the bottom of the casing by pushing a drillable plug, typically made of wood to the bottom of the casing, following by tremie grouting the remainder of the annulus outside the casing; or tremie grouting the annulus surrounding the casing using a tremie pipe installed to the base of the borehole. In all three cases, the casing is grouted to the ground surface, and the grout is allowed to set prior to drilling deeper through the casing. Site-specific criteria and work plans should be created for the completion of non-standard monitoring wells, including telescopic wells.

6. Before installing a screened, it is important to confirm that the borehole has been advanced into the targeted saturated zone. This is particularly important for wells installed to monitor the water table and/or the shallow saturated zone, as the capillary fringe may cause soils above the water table to appear saturated. If one or more previously installed monitoring wells exist nearby, use the depth to water at such well(s) to estimate the water-table depth at the new borehole location.

   To verify that the borehole has been advanced into the saturated zone, it is necessary to measure the water level in the borehole. For boreholes drilled without using water (e.g., hollow-stem auger, cable-tool, air rotary, air hammer), verify the presence of groundwater (and /or LNAPL, if applicable) in the borehole using an electronic water level probe, oil-water interface probe, or a new or decontaminated bailer. For boreholes drilled using water (e.g., drive and wash, spun-casing with roller-bit wash, Rotasonic, or water rotary with core or roller bit), monitor the water level in the borehole as it re-equilibrates to the static level. In low-permeability units like clay, fine-grained glacial tills, shale and other bedrock formations, it may be necessary to wait overnight to allow the water level to equilibrate. Document depth to water in the borehole on the appropriate field forms and field notebook. If there are questions concerning the depth of the well/screen interval, consult with the project technical lead prior to finalizing well depth/screen interval. To the extent practicable, ensure that the depth of the well below the apparent water table is deep enough so that the installed well can monitor groundwater year-round, accounting for seasonal water-table fluctuations. When in doubt, err on the side of slightly deeper well installation.

7. Upon completing the borehole to the desired depth, if a screened well construction is desired, install the monitoring well by lowering the screen and casing assembly with sump through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter (although sometimes 4-inch), flush-threaded PVC or stainless steel slotted or wire wrapped well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole. The screen length will be specified in the Work Plan (or equivalent) or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick

geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation and will (in most cases) be determined prior to the field mobilization.

The slot size and filter pack gradation should be predetermined in the Work Plan (or equivalent) or FSP and based on site-specific grain-size analysis (sieve analysis) or other geologic considerations or monitoring objectives. Typically, slot sizes for monitoring wells will range from 0.010 inches to 0.020 inches while the filter pack will be 20-40, Morie No. 0, or equivalent. In very fine-grained formations where sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and 30-65, Morie No. 00, or equivalent filter pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and 10-20, Morie No. 1, or equivalent filter pack may be preferred. If the screen slot size and filter pack have not been based on site-specific grain-size analysis, consider collecting soil samples during well installation so future wells can be properly designed.

A blank sump may be attached below the well screen if the well is being installed for DNAPL recovery/monitoring purposes. If so, the annular space around the sump may be backfilled with neat cement grout using a tremie to the bottom of the well screen prior to placing the filter pack around the screen. A blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well. For wells greater than 50 feet deep, centralizers may be desired to assist in centering the monitoring well in the borehole during construction.

8. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica filter pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen (following specifications in the Work Plan) using a tremie. The filter pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. Verify that the expected volume of filter pack matches with the actual amount installed. There can be differences due to irregularities in the borehole. Washout of the borehole will result in the need for greater than calculated well materials. If a difference of more than 10% is noted, consult with the project technical team. The filter pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan (or equivalent) or FSP. The well should be gently surged to prevent filter pack material bridging and to settled the filter pack prior to well seal installation.
9. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack (alternatively, in some cases a fine sand seal may be installed instead of bentonite—follow the specifications in the Work Plan). If non-hydrated bentonite is used, the bentonite should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. *No coated bentonite pellets will be used in monitoring well drilling or construction*. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure.
10. During the extraction of the augers or casing, a cement/bentonite or neat cement grout will be placed in the annular space from the bentonite seal to a depth approximately 2 ft. below groundwater surface (bgs) or as specified in the Work Plan (or equivalent). As with the filter pack, it is recommended that seal material be placed with a tremie pipe. Ensure that seal materials are mixed at the proper ratios with water following manufacturer's recommendations.

11. Install the monitoring well completion as specified Work Plan (or equivalent). Typical completions are a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing, and should slope gently away to promote drainage away from the well.
12. Monitoring wells should be labeled using indelible ink or paint with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.
13. When an above-grade completion is used, the riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the riser will be sealed using an unvented, expandable locking plug.
14. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook as well as appropriate field forms.
15. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 7 below.

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and install monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system, GeoProbe®, or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches. The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells. The procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment decontamination area.
2. Advance soil boring to designated depth, collecting samples at intervals specified in the Work Plan (or equivalent). Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 3 above. Collect samples for laboratory analysis as specified in the Work Plan (or equivalent) and/or FSP.
3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC or stainless steel slotted screen and blank riser. The sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Steps 9 through 11 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 12 above. During well installation, record construction details and tabulate materials used in field notebook as well as appropriate field forms.
5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 8 below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout.

8 WASTE MANAGEMENT

Investigation-derived wastes (IDW), including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan (or equivalent), FSP, and/or IDW management guidance document.

9 DATA RECORDING AND MANAGEMENT

Drilling activities should be documented on appropriate field/log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used. In addition, the locations of newly-installed wells will be documented photographically or in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

The well location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the site Work Plan (or equivalent). Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 or 1988 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest 0.01 foot. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

10 QUALITY ASSURANCE

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate SOP. Well materials will also be cleaned prior to well installation.

11 REFERENCES

American Society for Testing Materials (ASTM) D5092 - *Standard Practice for Design and Installation of Ground Water Monitoring Wells*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

American Society of Testing and Materials (ASTM) D1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

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