November 13, 2015
103IP3406

Mr. Uriah Sowell
Rooney Engineering
115 Inverness Drive East, Suite 300,
Englewood, CO 80112

Subject: Infiltration Testing – Hopeland Road Valve Site
Sunoco Pennsylvania Pipeline Project
Lebanon County, Heidelberg Township

Dear Mr. Sowell:

Tetra Tech, Inc. (Tetra Tech) performed infiltration testing within proposed stormwater management feature areas at the proposed Hopeland Road Valve Site in Heidelberg Township, Commonwealth of Pennsylvania. This letter report summarizes results of the infiltration testing.

Two double-ring constant head infiltration tests were performed at the site on September 16, 2015, in accordance with ASTM International (ASTM) D3385; locations of the tests are shown in Attachment 1. The project Civil Engineer directed that infiltration testing occur near the existing ground surface, below the surficial topsoil horizon. Prior to infiltration testing, a hand auger soil boring was advanced adjacent to each test location to log lithology, inspect for evidence of seasonal high water table, and collect representative soil samples.

Soil borings were advanced by use of a hand-held auger, and subsurface conditions were logged. Boring logs (Attachment 2) include soil data obtained from the explorations. Bedrock and groundwater were not encountered within 2 feet of the infiltration test. The underlying geology is the Hammer Creek conglomerate, a very coarse quartz conglomerate with abundant pebbles and cobbles of gray quartzite. A soil sample was collected at each of the two infiltration test depths. The samples were inspected and described visually in Tetra Tech's geotechnical laboratory. A Percent Finer than a No. 200 Sieve Test (ASTM D1140) was performed to measure the amount of silt and clay particulate in the soil samples. An Atterberg Limit Test (ASTM D4318) was conducted to aid in classification of the soils. Results of the grain-size analysis and Atterberg Limits testing were referenced to determine the Unified Soil Classification System (USCS) designation for the soils encountered at the infiltration test depth. A summary of the laboratory testing results is in Attachment 3.

Infiltration testing via a double-ring, constant head testing method occurred at each test location; the procedure for this test method is described in Attachment 4. Results from the infiltration testing are summarized in the attached Infiltration Testing Tables (Attachment 5). Table 1 summarizes investigation and testing depths, results of the infiltration testing, and USCS classifications and descriptions of soils at the infiltration test depths.

TABLE 1
SUMMARY OF RESULTS FROM INFILTRATION INVESTIGATION

Infiltration Test Location	Infiltration Test Depth (inches)	Off-Set Soil Boring Depth (inches)	Infiltration Testing Results (inches/hour)	USCS Classification [(1)] at Test Depth	Generalized Description of Soils at Test Depth
IT-01	6	42	2.62	SM	Reddish brown fine to medium sand, some silt, trace fine to coarse gravel.
IT-02	6	36	0.07	CL	Reddish brown silty clay with some fine sand, trace fine gravel.

Tetra Tech's services accorded with generally accepted engineering practice. No warranty, expressed or implied, is given. We appreciate the opportunity to provide our professional services to you. If you have any questions regarding the testing we performed, please contact me at (302) 283-2274, or via E-mail at ralph.boedeker@tetratech.com.

Sincerely,

Ralph Boedeker

Ralph Boedeker, P.E.
Geotechnical Project Manager

cc: Karen Gleason (Tetra Tech – Pittsburgh)

Attachments
Attachment 1: Infiltration Test Locations
Attachment 2: Soil Boring Logs
Attachment 3: Laboratory Testing Summary
Attachment 4: Constant Head Double Ring Infiltration Test Procedures
Attachment 5: Infiltration Testing Tables

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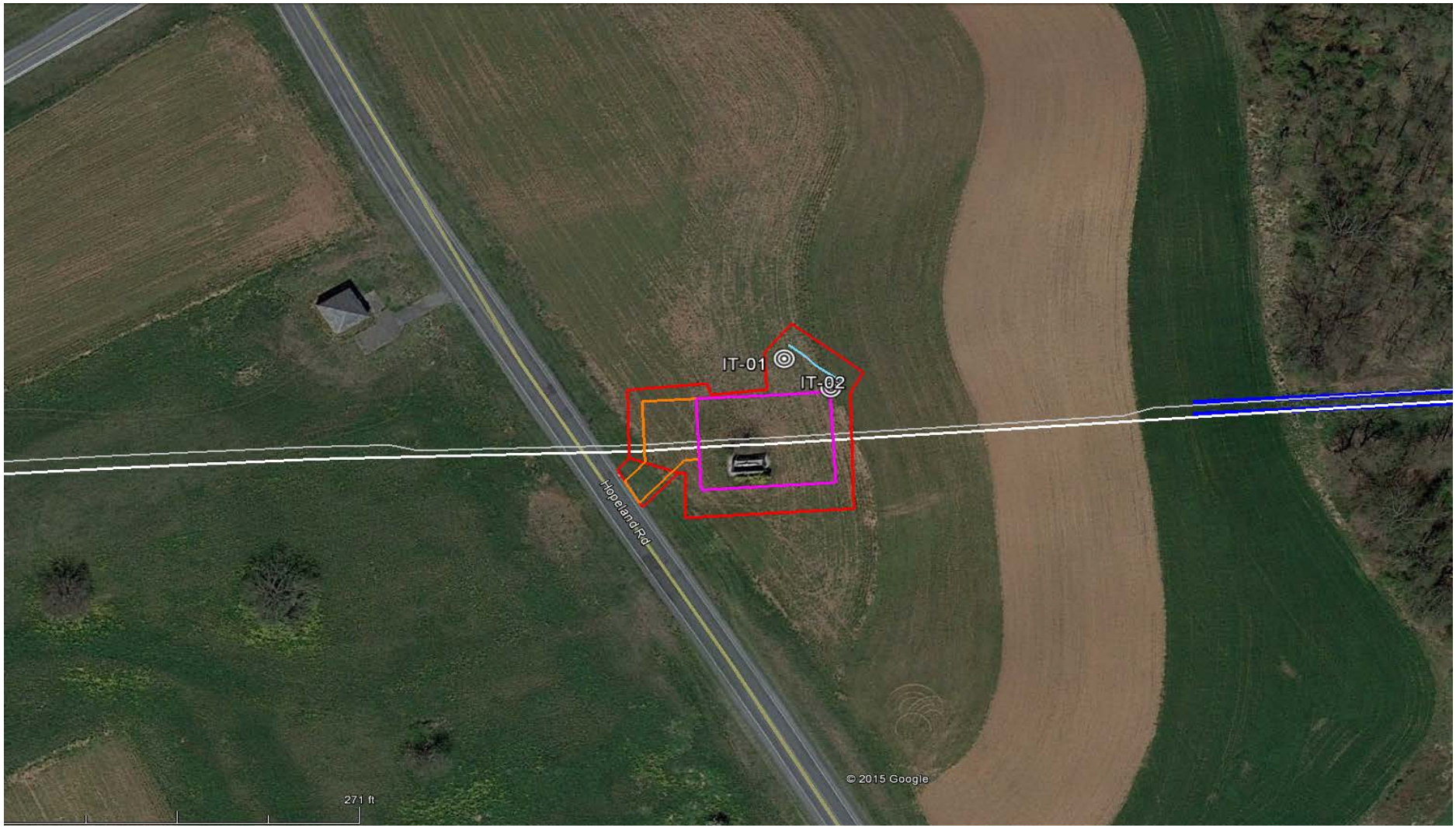
Attachment 1

Infiltration Test Locations



LEGEND:

Infiltration Test Locations (IT)

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INFILTRATION TEST LOCATIONS
HOPELAND ROAD VALVE SITE
LEBANON COUNTY, HEIDELBERG TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

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Attachment 2

Soil Boring Logs

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INFILTRATION TESTING SOIL LOG

Project: Sunoco PPP - Hopeland Road Valve Site
Project No.: 103IP3406
Boring/Pit No.: IT-01
Tested by: Tetra Tech/Hynes

Equipment Used: Infiltration Testing Equipment/Hand Auger
Weather: Sunny
Geology:
Land Use: N/A

Horizon	Upper Boundary	Lower Boundary	Soil Textural Class	Description	Soil Color	Color Patterns	Pores, Roots, Rock Structure	Depth to Bedrock	Depth to Water	Comments
	0''	6"	topsoil	topsoil	brown	solid				
	6"	42"	SM	fine to medium sand, some silt, trace f-c gravel	reddish brown	solid		Not Encountered	Not Encountered	%<200: 27.9

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INFILTRATION TESTING SOIL LOG

Project: Sunoco PPP - Hopeland Road Valve Site
Project No.: 103IP3406
Boring/Pit No.: IT-02
Tested by: Tetra Tech/Hynes

Equipment Used: Infiltration Testing Equipment/Hand Auger
Weather: Sunny
Geology:
Land Use: N/A

Horizon	Upper Boundary	Lower Boundary	Soil Textural Class	Description	Soil Color	Color Patterns	Pores, Roots, Rock Structure	Depth to Bedrock	Depth to Water	Comments
	0''	6"	topsoil	topsoil	brown	solid				
	6"	36"	CL	silty clay with a little fine to medium sand, trace fine gravel	reddish brown	solid		Not Encountered	Not Encountered	%<200: 72.1

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Attachment 3

Laboratory Testing Summary

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HOPELAND ROAD VALVE SITE

Valve Site	Soil Boring No.	Sample No.	Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318)			USCS Classif. (ASTM D2487)
					Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	
Hopeland Road	IT-01	IT-01	4.0	27.9	NL	NP	NV	SM
	IT-02	IT-02	37.0	72.1	47	23	24	CL

Notes:

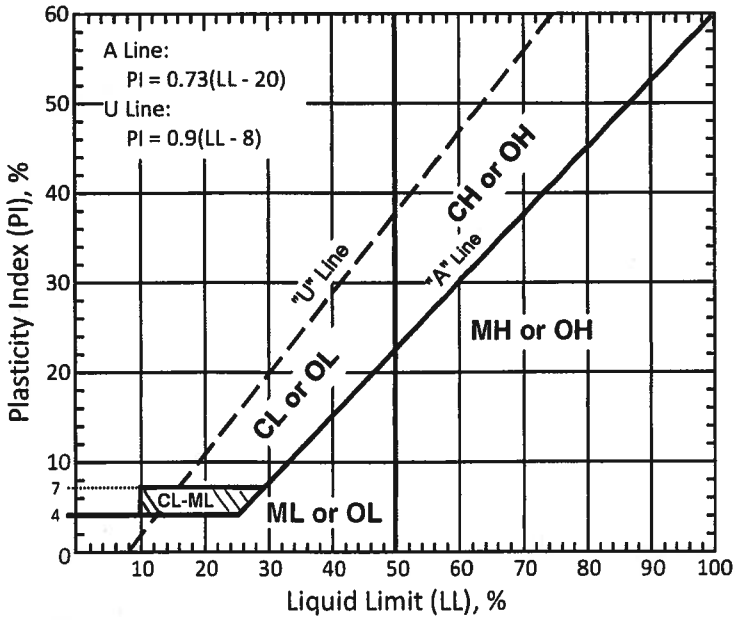
1) Sample depths based on feet below grade at time of exploration.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

Major Divisions			Group Symbols	Typical Descriptions	Laboratory Classifications		
Coarse Grained Soils (More than half of material is larger than No. 200 sieve)	Gravels More than half of coarse fraction is larger than No. 4 sieve	Clean gravel (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine Percentage of sand and gravel from grain size curve. Depending on Percentage of fines (fraction smaller than No. 200 sieve), coarse-grained soils are classified as follows: Less than 5 percent GW, GP, SW, SP; More than 12 percent GM, GC, SM, SC; 5 to 12 percent Borderline cases requiring dual symbols[1]	$C_u=\frac{D_{60}}{D_{10}}$ greater than 4: $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting C_u or C_c requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 Sieve)	Clean sands (Little or no fines)	SW	Well graded sands, gravely sands, little or no fines		$C_u=\frac{D_{60}}{D_{10}}$ greater than 6: $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting C_u or C_c requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits Plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	

Major Divisions		Group Symbols	Typical Descriptions
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays , sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays (Liquid limit greater than 50)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
	Highly organic soils	Pt	Peat and other highly organic soils

For soils plotting nearly on A line use dual symbols i.e ., I_p = 29.5, w_L=60 gives CH-MH. When w_L is near 50 use CL-CH or ML-MH. Take near as ± 2 percent.



(1) Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GW-GC. well-graded gravel-sand mixture with clay binder.

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Attachment 4

Constant Head Double Ring Infiltration Test Procedures

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Constant Head
Double Ring Infiltration Test

Tools and Supplies:

- ☐ 125 gallons of clean water per test
- ☐ Two infiltrometers per test
- ☐ One 12" ring per test
- ☐ One 24" ring per test
- ☐ Splash Guard
- ☐ Shovels Flat/Round
- ☐ Hand Rake
- ☐ Sledge Hammer
- ☐ Driving Block and Cap
- ☐ Purge Pump and tubing
- ☐ Battery
- ☐ Backhoe (for tests greater than 2 feet)
- ☐ Gator/ATV (as necessary
- ☐ Hand Auger (with extensions)
- ☐ Thermometer
- ☐ Supply bucket (1/2 inch PVC, tubing, funnel extra valves…..)

Procedure:

A. Unless directed otherwise, advance one soil boring at each test location. The boring should extend to groundwater. Accurately measure depth to groundwater and depth of each soil change. Pay close attention to soils for mottling. Contact office to determine test depth. Note this step can be omitted if test borings were advanced during a previous site visit.

B. Excavate test pit to specified test depth. Test pit should be sloped or benched in accordance with OSHA standards. (For safety two people will be onsite for tests deeper than 4 feet).

C. Use Flat point shovel to grade bottom of test pit. Bottom of excavation should be flat but not compacted. Check boring log to ensure that soil at bottom of excavation is soil type to be tested. (Collect and bag sample of soil at the bottom of the excavation) Include soil description and classification on worksheet.

D. Set up infiltrometer:

1. Set 24" ring at bottom of excavation.
2. Using driving block drive (ring) 3 to 4 inches into the ground (Record penetration depth).
3. Set 12" ring at bottom of excavation centered in 24" ring.
4. Using driving block drive (ring) 2 to 3 inches into the ground (Leave 12" ring approximately 1 inch higher than 24" ring.) (Record penetration depth)
5. Lightly tamp disturbed soil along inside and outside edges of rings. Do not compact soil at the bottom of the hole.
6. Use hand rake to scarify soils within the test rings.
7. Install drop tubes on infiltrometers.
8. Measure distance from bottom of drop tube to soil. Should be 5 to 6 inches. Record on attached form. Should be $\pm$ ¼ inch between two rings

Constant Head
Double Ring Infiltration Test

9. Set stand and infiltrometer on each ring.
    a. Make sure infiltrometers are oriented so that bottom valve is easy to reach.
    b. Measure distance from bottom of drop tube to soil. Should be 5 to 6 inches. Record as Hc on attached form.

E. Fill infiltrometer and ring.

1. Use pump, battery to transfer water to test set up as necessary.
2. Be sure bottom valves are closed and all top valves are open.
3. Fill infiltrometers through top valve to 0 L mark.
4. Place splash guard within rings to prevent soil scouring.
5. Fill rings until water reaches the bottom of the drop tube.
6. Water level should be $\pm$ ¼ inch between two rings.
7. Remove splash guard.

F. Start Test

1. Close all upper valves.
2. Open bottom valves.
3. Record water level (in milliliters) in sight windows on attached form. Observe water from vantage point that is approximately level with the water in the sight glass. Please note that markings on PVC casing are for reference only. Do not use these marks when observing water level.
4. Record time on attached form.

G. Monitor Test

1. Record water level in sight window and time on attached form.
2. Readings should be taken every 15 minutes for the 1st hour, 30 minutes for the second hour and every hour there after.
3. Do not allow water to drop below sight window at any time during testing.
4. Test duration is a minimum of 5 hours.
5. Refill test set up as necessary (When the water level reaches a point which will not allow another reading without running out.)
    a. Close bottom valves.
    b. Open top valves.
    c. Fill infiltrometers through top valve to 0 L mark.
    d. Record time and water level before and after filling.
    e. Close top two valves.
    f. Open bottom valve.
6. Test can be terminated when two successive permeability rates do not vary by more than 10%.

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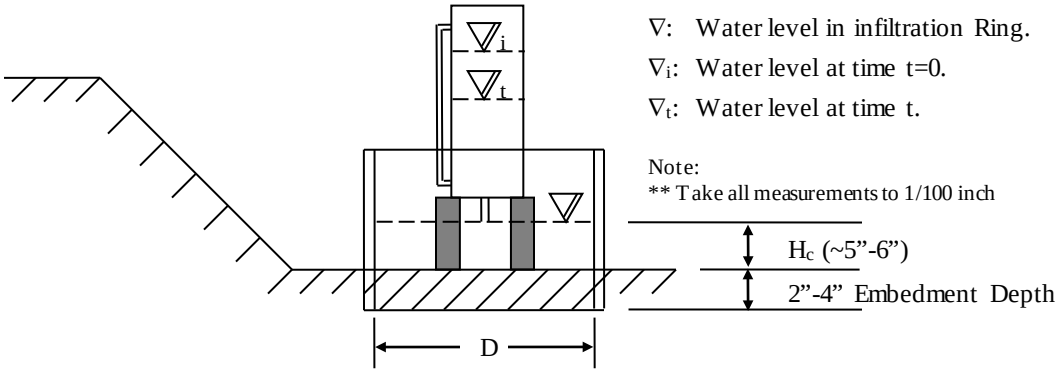
Constant Head
Double Ring Infiltration Test

H. Calculations

Inner Ring: $V_{IR} = \Delta V_{IR} / (A_{IR} * \Delta T)$
Annular Space: $V_A = \Delta V_A / (A_A * \Delta T)$
V= infiltration velocity (cm/h)
ΔV = volume of liquid used during time interval (cm^3)
ΔT= time interval in h
A= internal area of ring or annular space (cm^2)



D: Diameter of Ring.
H_c: Distance from bottom of Drop Tube to Soil.
∇: Water level in infiltration Ring.
∇_i: Water level at time t=0.
∇_t: Water level at time t.

Note:
** Take all measurements to 1/100 inch

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Attachment 5

Infiltration Testing Tables

Tt Double Ring Infiltration Test

Location:	IT-01		Project Name:	PPP - Hopeland Road Valve Site		Date:	September 16, 2015	
Inner Ring Diameter:	12	inch	Soil Temperature:	77	degrees	Outer Ring Penetration:	2.00	inches
Inner Ring Area:	729.7	cm^2	Water Temperature:	64	degrees	Inner Ring Penetration:	3.00	inches
Outer Ring Diameter:	24	inch	Inner Ring Liquid Depth:	5.00	inches	Test Depth:	0.5	feet
Annular Space Area:	2189	cm^2	Annular Space Liquid Depth:	5.00	inches	Technician:	JR	

Trial	Start/End	Date	Time	delta-Time (min)	Elapsed Time (min)	Flow Readings				Incremental Infiltration		Notes
						Inner Ring		Annular Space		Inner Ring (in/hr)	Outer Ring (in/hr)	
						Reading (ml)	Flow (ml)	Reading (ml)	Flow (ml)			
1	S	9/16/15	13:00	15	15	10,000	1250	0	3,250	0.00	0.00	
	E	9/16/15	13:15			11,250		3,250				
2	S	9/16/15	13:15	15	30	11,250	750	3,250	1,250	1.6187	0.8993	
	E	9/16/15	13:30			12,000		4,500				
3	S	9/16/15	13:30	15	45	12,000	500	4,500	1,000	1.0791	0.7194	
	E	9/16/15	13:45			12,500		5,500				
4	S	9/16/15	13:45	15	60	12,500	500	5,500	1,000	1.0791	0.7194	
	E	9/16/15	14:00			13,000		6,500				
5	S	9/16/15	14:00	15	75	13,000	1,250	6,500	1,750	2.6978	1.2590	
	E	9/16/15	14:15			14,250		8,250				
6	S	9/16/15	14:15	15	90	14,250	750	8,250	1,500	1.6187	1.0791	
	E	9/16/15	14:30			15,000		9,750				
7	S	9/16/15	14:30	15	105	15,000	2,000	9,750	2,000	4.3165	1.4388	
	E	9/16/15	14:45			17,000		11,750				
8	S	9/16/15	14:45	15	120	17,000	1,000	11,750	2,250	2.1583	1.6187	
	E	9/16/15	15:00			18,000		14,000				
9	S	9/16/15	15:00	15	135	18,000	1,000	14,000	1,500	2.1583	1.0791	
	E	9/16/15	15:15			19,000		15,500				
10	S	9/16/15	15:15	15	150	0	500	0	750	1.0791	0.5396	
	E	9/16/15	15:30			500		750				
11	S	9/16/15	15:30	15	165	500	1,250	750	1,500	2.6978	1.0791	
	E	9/16/15	15:45			1,750		2,250				
12	S	9/16/15	15:45	15	180	1,750	1,250	2,250	2,250	2.6978	1.6187	
	E	9/16/15	16:00			3,000		4,500				
13	S	9/16/15	16:00	15	195	3,000	1,750	4,500	2,250	3.7770	1.6187	
	E	9/16/15	16:15			4,750		6,750				
14	S	9/16/15	16:15	15	210	4,750	1,750	6,750	2,250	3.7770	1.6187	
	E	9/16/15	16:30			6,500		9,000				
15	S	9/16/15	16:30	15	225	6,500	1,750	9,000	2,500	3.7770	1.7986	
	E	9/16/15	16:45			8,250		11,500				
16	S	9/16/15	16:45	16	241	8,250	1,500	11,500	1,250	3.0351	0.8431	
	E	9/16/15	17:00			9,750		12,750				
17	S	9/16/15	17:00	15	256	9,750	1,250	12,750	1,750	2.6978	1.2590	
	E	9/16/15	17:15			11,000		14,500				
18	S	9/16/15	17:15	15	271	11,000	1,250	14,500	1,500	2.6978	1.0791	
	E	9/16/15	17:30			12,250		16,000				
19	S	9/16/15	17:30	15	286	12,250	750	16,000	1,000	1.6187	0.7194	
	E	9/16/15	17:45			13,000		17,000				
20	S	9/16/15	17:45	15	301	13,000	1,250	17,000	500	2.6978	0.3597	
	E	9/16/15	18:00			14,250		17,500				

Note: mL is equal to cm^3.

Average Hourly infiltration rate (inches per hour) = 2.6177

Tt Double Ring Infiltration Test

Location:	IT-02		Project Name:	PPP - Hopeland Road Valve Site		Date:	September 16, 2015	
Inner Ring Diameter:	12	inch	Soil Temperature:	77	degrees	Outer Ring Penetration:	2.00	inches
Inner Ring Area:	729.7	cm^2	Water Temperature:	64	degrees	Inner Ring Penetration:	3.00	inches
Outer Ring Diameter:	24	inch	Inner Ring Liquid Depth:	3.50	inches	Test Depth:	0.5	feet
Annular Space Area:	2189	cm^2	Annular Space Liquid Depth:	5.00	inches	Technician:	JR	

Trial	Start/End	Date	Time	delta-Time	Elapsed Time	Flow Readings				Incremental Infiltration		Notes
						Inner Ring		Annular Space		Inner Ring	Outer Ring	
				(min)	(min)	Reading (ml)	Flow (ml)	Reading (ml)	Flow (ml)	(in/hr)	(in/hr)	
1	S	9/16/15	13:00	15	15	9,500	500	1025	725	0.00	0.00	
	E	9/16/15	13:15			10,000		1,750				
2	S	9/16/15	13:15	15	30	10,000	500	1,750	250	1.0791	0.1799	
	E	9/16/15	13:30			10,500		2,000				
3	S	9/16/15	13:30	15	45	10,500	0	2,000	0	0.0000	0.0000	
	E	9/16/15	13:45			10,500		2,000				
4	S	9/16/15	13:45	15	60	10,500	250	2,000	250	0.5396	0.1799	
	E	9/16/15	14:00			10,750		2,250				
5	S	9/16/15	14:00	15	75	10,750	0	2,250	0	0.0000	0.0000	
	E	9/16/15	14:15			10,750		2,250				
6	S	9/16/15	14:15	15	90	10,750	0	2,250	0	0.0000	0.0000	
	E	9/16/15	14:30			10,750		2,250				
7	S	9/16/15	14:30	15	105	10,750	0	2,250	2,500	0.0000	1.7986	
	E	9/16/15	14:45			10,750		4,750				
8	S	9/16/15	14:45	15	120	10,750	250	4,750	1,750	0.5396	1.2590	
	E	9/16/15	15:00			11,000		6,500				
9	S	9/16/15	15:00	15	135	11,000	0	6,500	1,250	0.0000	0.8993	
	E	9/16/15	15:15			11,000		7,750				
10	S	9/16/15	15:15	15	150	11,000	0	7,750	1,750	0.0000	1.2590	
	E	9/16/15	15:30			11,000		9,500				
11	S	9/16/15	15:30	15	165	11,000	0	9,500	2,250	0.0000	1.6187	
	E	9/16/15	15:45			11,000		11,750				
12	S	9/16/15	15:45	15	180	11,000	0	11,750	2,500	0.0000	1.7986	
	E	9/16/15	16:00			11,000		14,250				
13	S	9/16/15	16:00	15	195	11,000	0	14,250	1,750	0.0000	1.2590	
	E	9/16/15	16:15			11,000		16,000				
14	S	9/16/15	16:15	15	210	11,000	0	16,000	1,500	0.0000	1.0791	
	E	9/16/15	16:30			11,000		17,500				
15	S	9/16/15	16:30	15	225	11,000	0	17,500	1,750	0.0000	1.2590	
	E	9/16/15	16:45			11,000		19,250				
16	S	9/16/15	16:45	16	241	11,000	0	10,000	250	0.0000	0.1686	
	E	9/16/15	17:00			11,000		10,250				
17	S	9/16/15	17:00	15	256	11,000	0	10,250	500	0.0000	0.3597	
	E	9/16/15	17:15			11,000		10,750				
18	S	9/16/15	17:15	15	271	11,000	0	10,750	500	0.0000	0.3597	
	E	9/16/15	17:30			11,000		11,250				
19	S	9/16/15	17:30	15	286	11,000	0	11,250	250	0.0000	0.1799	
	E	9/16/15	17:45			11,000		11,500				
20	S	9/16/15	17:45	15	301	11,000	0	11,500	0	0.0000	0.0000	
	E	9/16/15	18:00			11,000		11,500				

Note: mL is equal to cm^3.

Average Hourly infiltration rate (inches per hour) = 0.0674