November 13, 2015
103IP3406

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

Subject: Infiltration Testing – Schaefferstown Tie-In 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 Schaefferstown Tie-In 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 15, 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 an undifferentiated Limestone fanglomerate, Triassic limestone and dolomite pebbles and fragments in a red, very fine grained quartz matrix. 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.

Tetra Tech, Inc.
240 Continental Drive, Suite 200, Newark, DE 19713
Tel 302-738-7551 Fax 302-454-5988 www.tetratech.com

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	5	40	5.51	SM	Reddish brown fine to medium sand, some silt, trace fine to coarse gravel.
IT-02	5	43	3.97	SM	Reddish brown fine to medium sand, some silt, tract fine to coarse 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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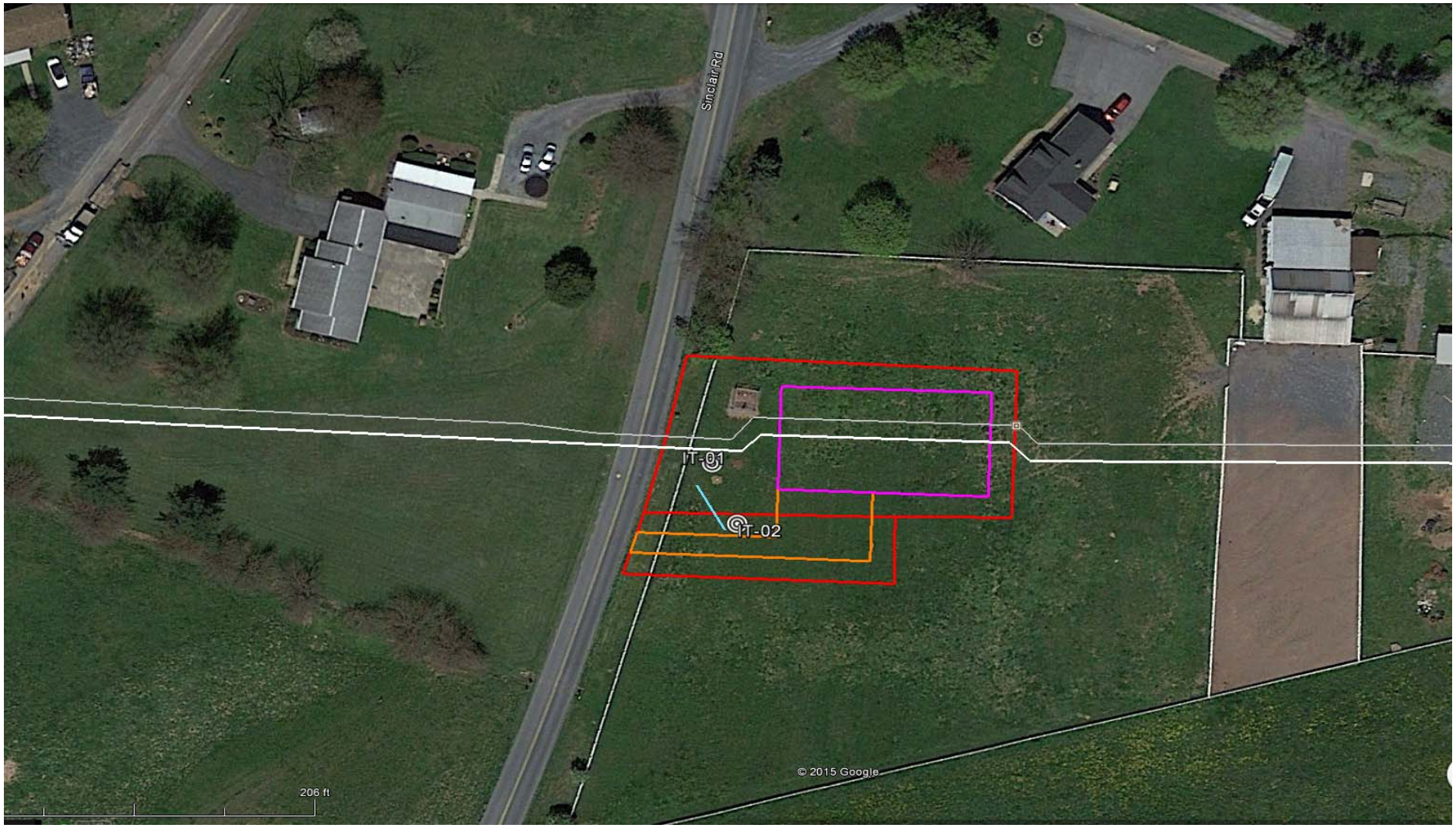
Attachment 1

Infiltration Test Locations



LEGEND:

Infiltration Test Locations (IT)

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INFILTRATION TEST LOCATIONS
SCHAEFFERSTOWN TIE IN 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 - Schaefferstown Tie In 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''	5"	topsoil	topsoil	brown	solid	roots present			
	5"	40"	SM	fine to medium sand, some silt, trace f-c gravel	reddish brown	solid		Not Encountered	Not Encountered	%<200: 24.1 at test depth

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INFILTRATION TESTING SOIL LOG

Project: Sunoco PPP - Schaefferstown Tie In 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''	5"	topsoil	topsoil	brown	solid	roots present			
	5"	43"	SM	fine to medium sand, some silt, trace f-c gravel	reddish brown	solid		Not Encountered	Not Encountered	%<200: 23.4 at test depth

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Attachment 3

Laboratory Testing Summary

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
SCHAEFFERSTOWN TIE IN 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, %	
Gates Road	IT-01	IT-01	11.8	24.1	29	24	5	SM
	IT-02	IT-02	9.8	23.4	NL	NP	NV	SM

Notes:

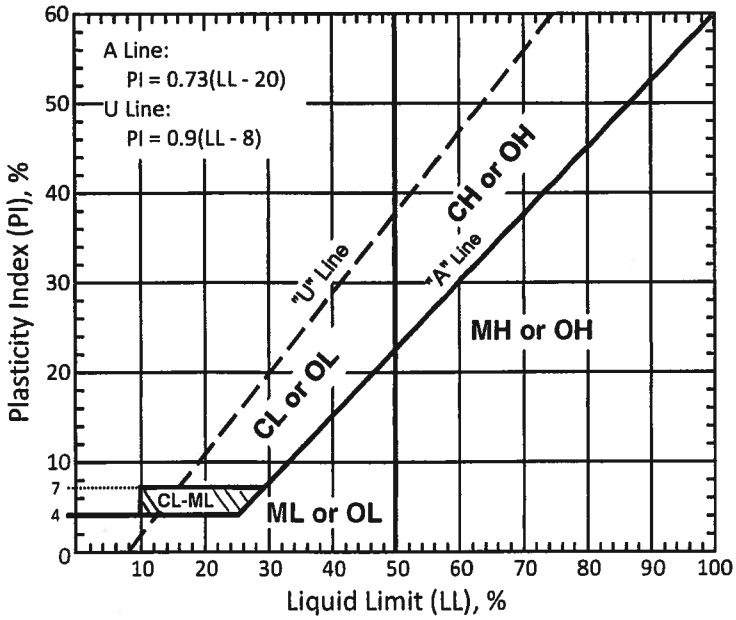
1) Sample depths based on feet below grade at time of exploration.

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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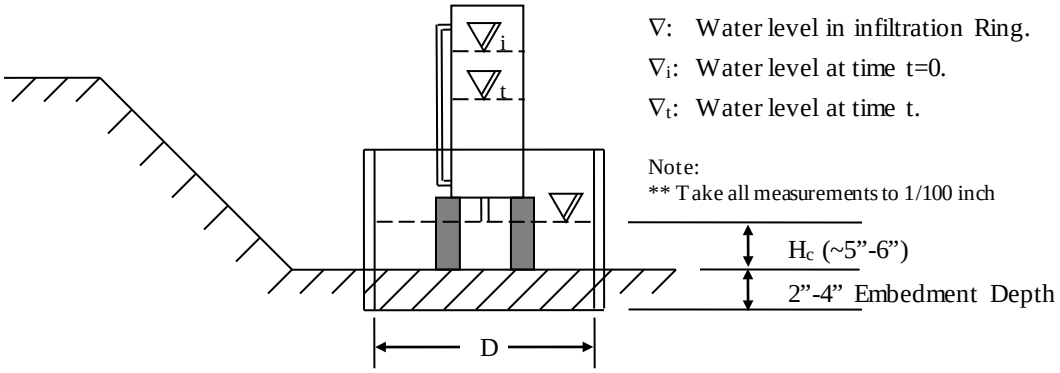
Constant Head
Double Ring Infiltration Test

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-Schaefferstown Tie In Valve Site		Date:	September 15, 2015	
Inner Ring Diameter:	12	inch	Soil Temperature:		degrees	Outer Ring Penetration:	2.00	inches
Inner Ring Area:	729.7	cm^2	Water Temperature:		degrees	Inner Ring Penetration:	3.00	inches
Outer Ring Diameter:	24	inch	Inner Ring Liquid Depth:	3.00	inches	Test Depth:	0.5	feet
Annular Space Area:	2189	cm^2	Annular Space Liquid Depth:	2.50	inches	Technician:	JR/AB	

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	9/15/15	7:30	15	15	8250	1750	11750	3,750	0.00	0.00	
	E	9/15/15	7:45			10,000		15,500				
2	S	9/15/15	7:45	15	30	10,000	3,250	15,500	3,750	7.0144	2.6978	
	E	9/15/15	8:00			13,250		19,250				
3	S	9/15/15	8:00	15	45	13,250	2,500	0	9,000	5.3957	6.4748	Refilled Outer Annulus to 0 mL
	E	9/15/15	8:15			15,750		9,000				
4	S	9/15/15	8:15	15	60	15,750	2,750	9,000	7,500	5.9353	5.3957	
	E	9/15/15	8:30			18,500		16,500				
5	S	9/15/15	8:30	15	75	0	2,750	16,500	3,250	5.9353	2.3381	Refilled Inner Ring to 0 mL
	E	9/15/15	8:45			2,750		19,750				
6	S	9/15/15	8:45	15	90	2,750	4,000	0	2,500	8.6331	1.7986	Refilled Outer Annulus to 0 mL
	E	9/15/15	9:00			6,750		2,500				
7	S	9/15/15	9:00	15	105	6,750	1,750	2,500	6,250	3.7770	4.4964	
	E	9/15/15	9:15			8,500		8,750				
8	S	9/15/15	9:15	15	120	8,500	750	8,750	10,250	1.6187	7.3741	
	E	9/15/15	9:30			9,250		19,000				
9	S	9/15/15	9:30	15	135	9,250	1,000	0	4,000	2.1583	2.8777	Refilled Outer Annulus to 0 mL
	E	9/15/15	9:45			10,250		4,000				
10	S	9/15/15	9:45	15	150	10,250	3,500	4,000	5,750	7.5540	4.1367	
	E	9/15/15	10:00			13,750		9,750				
11	S	9/15/15	10:00	15	165	13,750	3,250	9,750	6,250	7.0144	4.4964	
	E	9/15/15	10:15			17,000		16,000				
12	S	9/15/15	10:15	15	180	17,000	2,500	16,000	3,000	5.3957	2.1583	
	E	9/15/15	10:30			19,500		19,000				
13	S	9/15/15	10:30	15	195	0	1,250	0	1,500	2.6978	1.0791	Refilled Inner Ring to 0 mL, Outer Annulus to 0 mL
	E	9/15/15	10:45			1,250		1,500				
14	S	9/15/15	10:45	15	210	1,250	2,750	1,500	6,750	5.9353	4.8561	
	E	9/15/15	11:00			4,000		8,250				
15	S	9/15/15	11:00	15	225	4,000	2,500	8,250	5,000	5.3957	3.5971	
	E	9/15/15	11:15			6,500		13,250				
16	S	9/15/15	11:15	16	241	6,500	3,000	13,250	6,250	6.0701	4.2154	
	E	9/15/15	11:30			9,500		19,500				
17	S	9/15/15	11:30	15	256	9,500	3,500	0	5,250	7.5540	3.7770	Refilled Outer Annulus to 0 mL
	E	9/15/15	11:45			13,000		5,250				
18	S	9/15/15	11:45	15	271	13,000	3,250	5,250	4,250	7.0144	3.0576	
	E	9/15/15	12:00			16,250		9,500				
19	S	9/15/15	12:00	15	286	16,250	2,500	9,500	5,250	5.3957	3.7770	
	E	9/15/15	12:15			18,750		14,750				
20	S	9/15/15	12:15	15	301	18,750	500	14,750	3,000	1.0791	2.1583	
	E	9/15/15	12:30			19,250		17,750				

Note: mL is equal to cm^3.

Average Hourly infiltration rate (inches per hour) = 5.5053

Tt Double Ring Infiltration Test

Location:	IT-02		Project Name:	PPP-Schaefferstown Tie In Valve Site		Date:	September 15, 2015	
Inner Ring Diameter:	12	inch	Soil Temperature:		degrees	Outer Ring Penetration:	2.00	inches
Inner Ring Area:	729.7	cm^2	Water Temperature:		degrees	Inner Ring Penetration:	3.00	inches
Outer Ring Diameter:	24	inch	Inner Ring Liquid Depth:	3.00	inches	Test Depth:	0.5	feet
Annular Space Area:	2189	cm^2	Annular Space Liquid Depth:	4.00	inches	Technician:	JR/AB	

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	9/15/15	7:30	15	15	9500	750	7500	9,500	0.00	0.00	
	E	9/15/15	7:45			10,250		17,000				
2	S	9/15/15	7:45	15	30	10,250	1,750	0	12,500	3.7770	8.9928	Refilled annulus to 0 mL
	E	9/15/15	8:00			12,000		12,500				
3	S	9/15/15	8:00	15	45	12,000	1,500	12,500	7,250	3.2374	5.2158	
	E	9/15/15	8:15			13,500		19,750				
4	S	9/15/15	8:15	15	60	13,500	1,500	0	19,500	3.2374	14.0288	Refilled annulus to 0 mL
	E	9/15/15	8:30			15,000		19,500				
5	S	9/15/15	8:30	15	75	15,000	2,000	0	19,750	4.3165	14.2086	Refilled annulus to 0 mL
	E	9/15/15	8:45			17,000		19,750				
6	S	9/15/15	8:45	15	90	17,000	1,500	0	2,000	3.2374	1.4388	Refilled annulus to 0 mL
	E	9/15/15	9:00			18,500		2,000				
7	S	9/15/15	9:00	15	105	0	250	2,000	4,250	0.5396	3.0576	Refilled inner ring to 0 mL
	E	9/15/15	9:15			250		6,250				
8	S	9/15/15	9:15	15	120	250	750	6,250	4,750	1.6187	3.4173	
	E	9/15/15	9:30			1,000		11,000				
9	S	9/15/15	9:30	15	135	1,000	500	11,000	8,000	1.0791	5.7554	
	E	9/15/15	9:45			1,500		19,000				
10	S	9/15/15	9:45	15	150	1,500	0	0	8,250	0.0000	5.9353	Refilled annulus to 0 mL
	E	9/15/15	10:00			1,500		8,250				
11	S	9/15/15	10:00	15	165	1,500	1,000	8,250	10,750	2.1583	7.7338	
	E	9/15/15	10:15			2,500		19,000				
12	S	9/15/15	10:15	15	180	2,500	2,500	0	7,000	5.3957	5.0360	Refilled annulus to 0 mL
	E	9/15/15	10:30			5,000		7,000				
13	S	9/15/15	10:30	15	195	5,000	1,000	7,000	12,000	2.1583	8.6331	
	E	9/15/15	10:45			6,000		19,000				
14	S	9/15/15	10:45	15	210	7,000	1,500	0	6,000	3.2374	4.3165	Refilled annulus to 0 mL
	E	9/15/15	11:00			8,500		6,000				
15	S	9/15/15	11:00	15	225	8,500	4,500	6,000	6,250	9.7122	4.4964	
	E	9/15/15	11:15			13,000		12,250				
16	S	9/15/15	11:15	16	241	13,000	5,000	12,250	6,500	10.1169	4.3840	
	E	9/15/15	11:30			18,000		18,750				
17	S	9/15/15	11:30	15	256	11,000	4,750	0	4,000	10.2518	2.8777	Refilled inner ring to 11000 mL, Annulus to 0 mL
	E	9/15/15	11:45			15,750		4,000				
18	S	9/15/15	11:45	15	271	15,750	2,500	4,000	5,250	5.3957	3.7770	
	E	9/15/15	12:00			18,250		9,250				
19	S	9/15/15	12:00	15	286	18,250	500	9,250	5,250	1.0791	3.7770	
	E	9/15/15	12:15			18,750		14,500				
20	S	9/15/15	12:15	15	301	11,250	0	14,500	3,500	0.0000	2.5180	Refilled inner ring to 11250 mL
	E	9/15/15	12:30			11,250		18,000				

Note: mL is equal to cm^3.

Average Hourly infiltration rate (inches per hour) = 3.9709