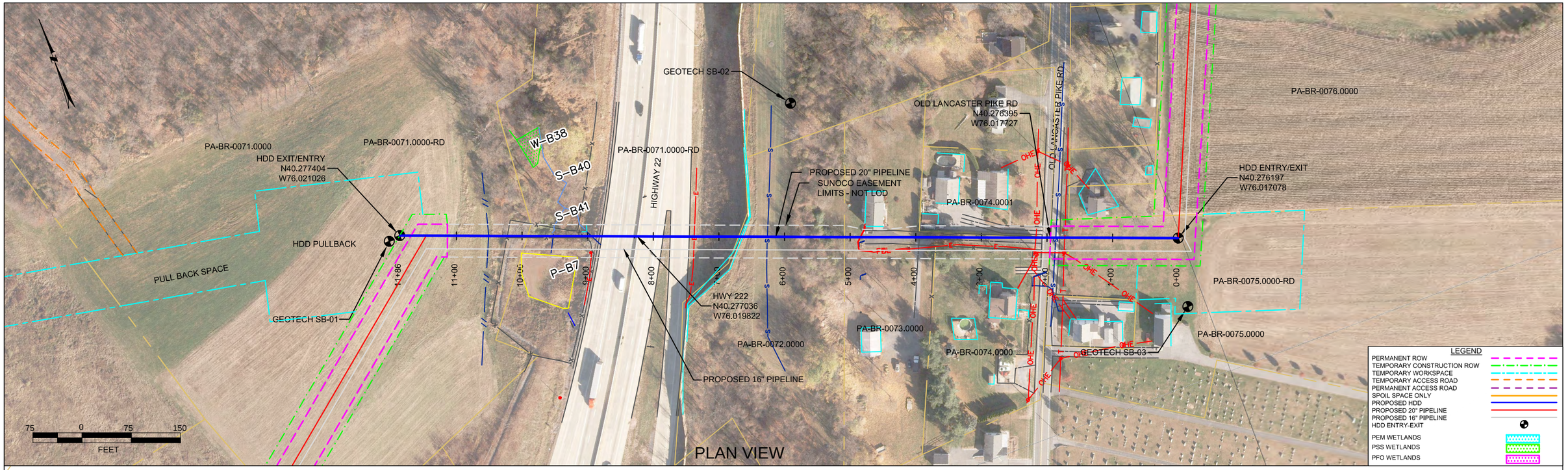
HDD PA-BR-0075.0000-RD (S-B41, S-B40)

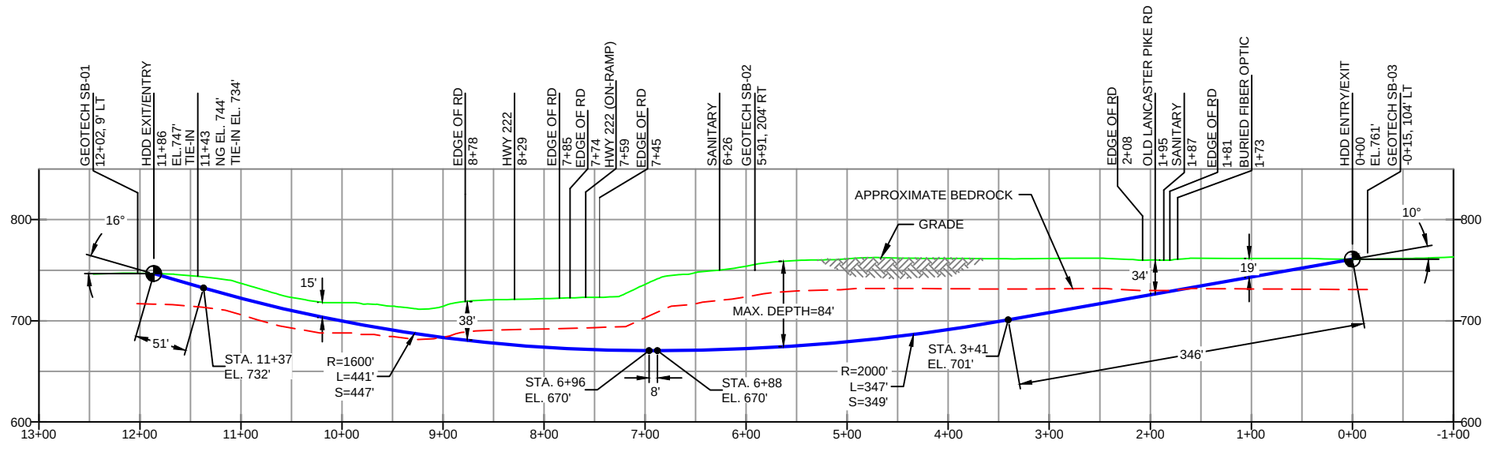
Given the design, the threat of inadvertent return has been reduced to the maximum extent practicable and in this case that threat is considered to be low. Implementing this design, along with adherence to the Pennsylvania Pipeline Project Inadvertent Return Contingency Plan will ensure inadvertent impacts, if they were to occur, are also minimized to the maximum extent.

The drill will enter/exit 190 feet from the western edge of Stream B41 (S-B41) and enter/exit 960 feet from the eastern edge. The horizontal directional drill will enter/exit 240 feet from the western edge of Stream B40 (S-B40) and enter/exit 910 feet from the eastern edge. The drill will also enter/exit 270 feet from the western edge of Highway 222 and enter/exit 740 feet from the eastern edge. The drill will pass 15 feet underneath S-B41, 20 feet beneath S-B42, and 45 feet below Highway 222. The geotechnical results, as well as other data points, were used to determine the entry/exit angles, and depths to pass through the best substrates while maintaining the pipe integrity (e.g., no large bends). According to the geotechnical report the primary substrates being drilled through are fractured conglomerate of quartz and sandstone with layers of sandy clays and silts above the drill. Based on the geotechnical report and the drill profile minimal inadvertent returns are expected.

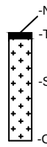


BERKS COUNTY, PENNSYLVANIA - CUMRU TOWNSHIP
S3-0200

PROFILE VIEW



GEOTECH SB-01

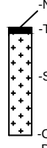


-NG EL. 747'
-TOPSOIL (0' - 1.0')
-SM (1.0' - 30.0')
-COMPLETION DEPTH EL. 717'

GEOTECH SB-02

-NG EL. 750'
-TOPSOIL (0' - 1.0')
-SM (1.0' - 11.0')
-SM/GM (11.0' - 24.0')
-FRACTURED CONGLOMERATE (24.0' - 32.0')
-COMPLETION DEPTH EL. 718'

GEOTECH SB-03



-NG EL. 767'
-TOPSOIL (0' - 0.7')
-SM (0.7' - 30.0')
-COMPLETION DEPTH EL. 737'

NOTE: REFER TO TEST BORING LOG S3-0290 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1186'
   HDD PIPE LENGTH (S=):1201'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-5.27	TO	ES-5.28	EROSION & SEDIMENT PLAN
SHEET 15	TO	SHEET 16	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/09/16	RMB	05/09/16	AAW	05/09/16
EP		MRS	11/23/15	RMB	11/23/15	AAW	11/23/15
C	ADDED GEOTECH INFO	MRS	09/25/15	RMB	09/25/15	AAW	09/25/15
B	ISSUED FOR BID	DLM	07/31/15	RMB	07/31/15	AAW	07/31/15
A	ISSUED FOR REVIEW	KB	04/15/15	RMB	04/15/15	AAW	04/15/15

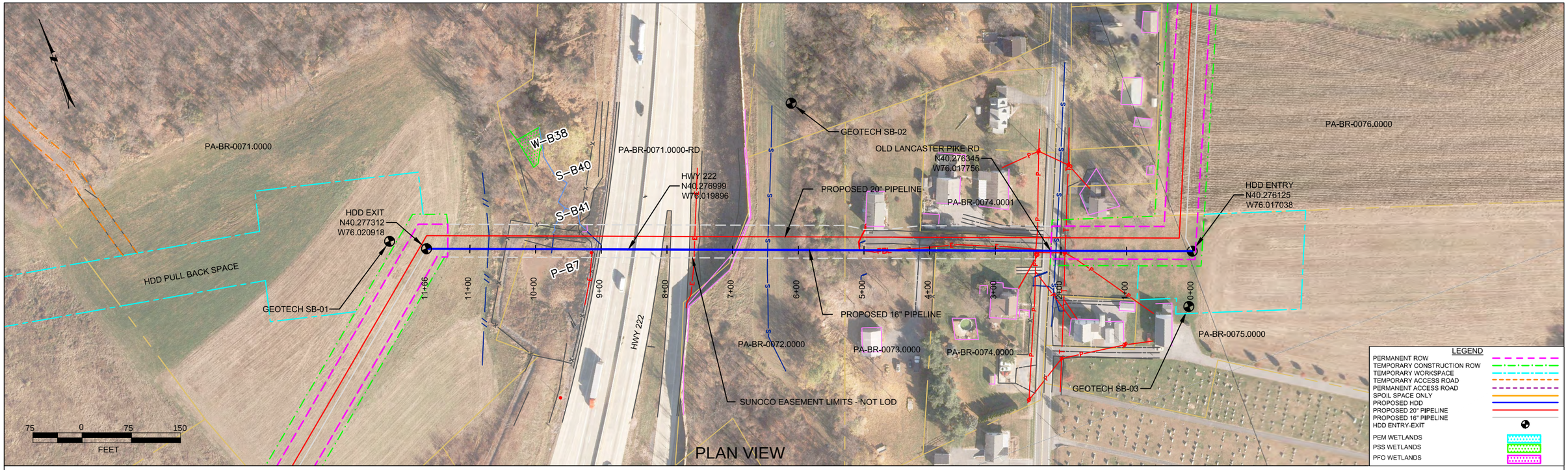
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

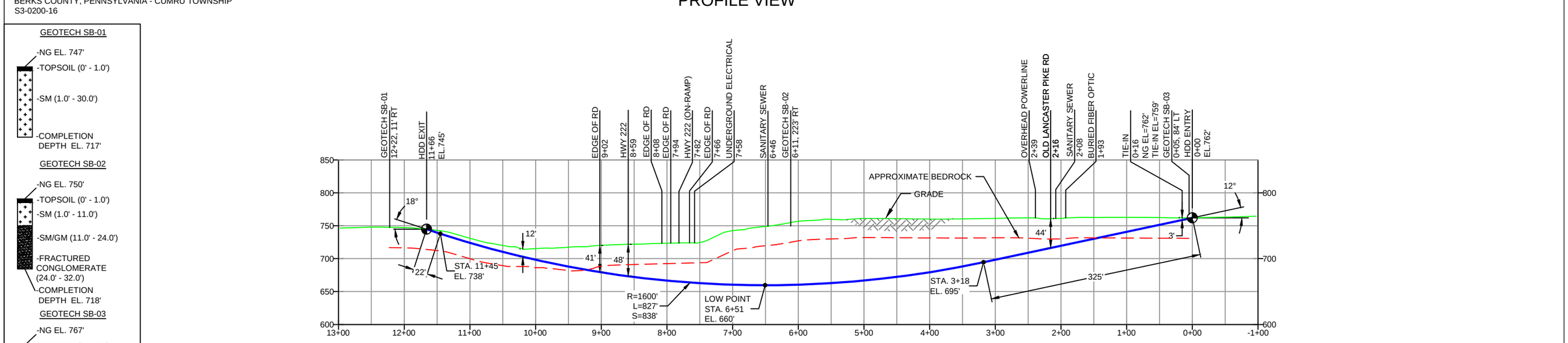
20-INCH HORIZONTAL DIRECTIONAL DRILL
HWY 222
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150' | DWG. NO: PA-BR-0075.0000-RD



BERKS COUNTY, PENNSYLVANIA - CUMRU TOWNSHIP
S3-0200-16

PROFILE VIEW



GEOTECH SB-01
-NG EL. 747'
-TOPSOIL (0' - 1.0')
-SM (1.0' - 30.0')
-COMPLETION DEPTH EL. 717'

GEOTECH SB-02
-NG EL. 750'
-TOPSOIL (0' - 1.0')
-SM (1.0' - 11.0')
-SM/GM (11.0' - 24.0')
-FRACTURED CONGLOMERATE (24.0' - 32.0')
-COMPLETION DEPTH EL. 718'

GEOTECH SB-03
-NG EL. 767'
-TOPSOIL (0' - 0.7')
-SM (0.7' - 30.0')
-COMPLETION DEPTH EL. 737'

NOTE: REFER TO TEST BORING LOG S3-0290 FOR COMPLETE SOIL MATERIAL DESCRIPTION

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3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1166'
   HDD PIPE LENGTH (S=):1185'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
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5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

ES-5.27	TO	ES-5.28	EROSION & SEDIMENT PLAN	
SHEET 15	TO	SHEET 16	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/09/16	RMB	05/09/16	AAW	05/09/16
EP		MRS	11/23/15	RMB	11/23/15	AAW	11/23/15
B	ADDED GOETECH INFO	MRS	09/25/15	RMB	09/25/15	AAW	09/25/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

Sunoco Logistics Partners L.P.

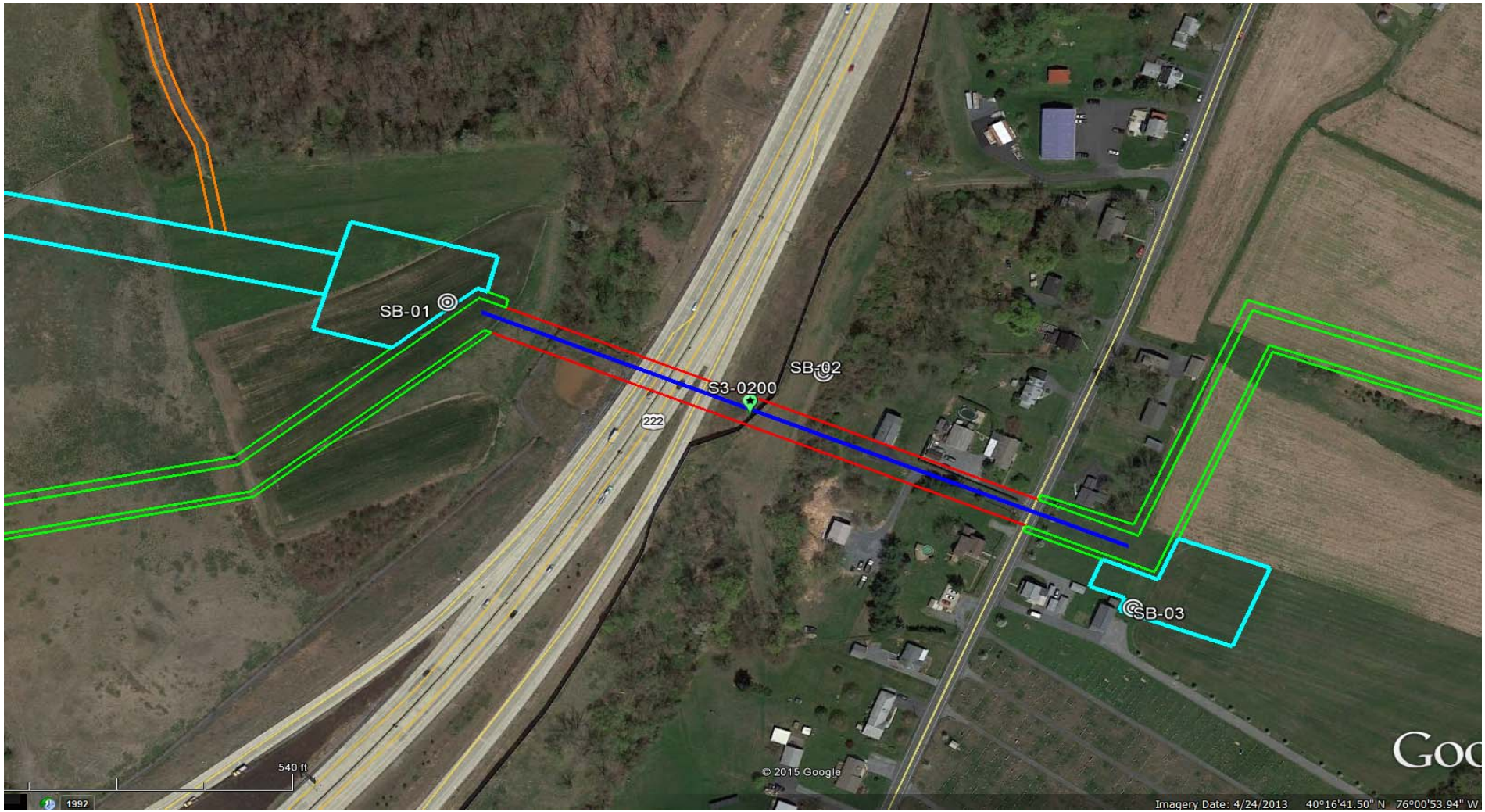
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

16-INCH HORIZONTAL DIRECTIONAL DRILL
HWY 222
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

DWG. NO: PA-BR-0075.0000-RD-16



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S3-0200
BERKS COUNTY, CUMRU TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	OLD LANCASTER PIKE, CUMRU, PA		Page 1 of 1
HDD No.:	S3-0200	Dates(s) Drilled: 12-11/12-14	Inspector: E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 16' 38.638" N	76° 1' 15.864" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	1.0			TOPSOIL (12")					
1	3.0	5.0	1.0		17	SM	MAROON FINE TO COARSE SAND WITH A LITTLE FINE TO COARSE	8	14	22	15	**36**
							GRAVEL/CONGLOMERATE MATRIX, SOME SILT.					
2	8.0	8.7			6		MAROON FINE TO COARSE SAND WITH A LITTLE FINE TO COARSE	50	50/2"			**>50**
							GRAVEL/CONGLOMERATE MATRIX, SOME SILT.					
3	13.0	13.9			8		MAROON FINE TO COARSE SAND WITH A LITTLE FINE TO COARSE	16	50/5"			**>50**
							GRAVEL/CONGLOMERATE MATRIX, A LITTLE SILT.					
4	18.0	18.8			5		MAROON FINE TO COARSE SAND WITH A LITTLE FINE TO COARSE	50	50/3"			**>50**
							GRAVEL/CONGLOMERATE MATRIX, A LITTLE SILT.					
5	23.0	25.0			24		MAROON FINE TO COARSE SAND WITH A LITTLE FINE TO COARSE	3	31	48	25	**79**
							GRAVEL/CONGLOMERATE MATRIX, A LITTLE SILT.					
6	28.0	28.4			6		MAROON FINE TO COARSE SAND WITH A LITTLE FINE TO COARSE	50/5"				**0**
				30.0			GRAVEL/CONGLOMERATE MATRIX, SOME SILT.					
							AUGERED TO 30'.					
							GRINDING BEGINS 5' TO 6', THEN OFF AND ON BETWEEN					
							10 TO 28'.					
							CAVED AND DRY AT 27'.					

Notes/Comments:
Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	OLD LANCASTER PIKE, CUMRU, PA		Page 1 of 1
HDD No.:	S3-0200	Dates(s) Drilled: 02-10-15	Inspector: E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 32.0
Boring Location Coordinates:		40° 16' 38.348" N	76° 1' 7.530" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.7			TOPSOIL (8")					
1	3.0	5.0	0.7		17	SM	MAROON FINE TO COARSE SAND WITH A LITTLE SILT, AND WITH	19	26	21	42	**47**
							SOME FINE TO COARSE GRAVEL.					
2	8.0	8.7			6		REDDISH BROWN MEDIUM COARSE SAND WITH SOME CONGLOMERAT	34	50/2"			**>50**
				11.0			GRAVEL, AND A LITTLE SILT.					
							AUGER REFUSAL AT 10'. OFFSET 8' NORTH AND CONTINUOUSLY					
							AUGERED TO NEXT SAMPLE INTERVAL.					
3	13.0	13.7	11.0		8	SM/ GM	REDDISH BROWN MEDIUM TO COARSE SAND WITH SOME	10	50/3"			**>50**
							CONGLOMERATE GRAVEL, TRACE ROCK FRAGMENTS, LITTLE SILT.					
4	18.0	18.3			5		REDDISH BROWN MEDIUM TO COARSE SAND WITH SOME	50/4"				**>50**
							CONGLOMERATE GRAVEL, TRACE ROCK FRAGMENTS, LITTLE SILT.					
5	23.0	23.1		24.0	24		REDDISH BROWN CONGLOMERATE GRAVEL.	50/1"				**>50**
							AUGER REFUSAL AT 24'.					
							ROCK CORING					
RUN 1	24.0	27.0	24.0	27.0	21	CONGLOM.	REDDISH BROWN INTENSELY FRACTURED CONGLOMERATE.	TCR: 58%, SCR: 8%, RQD: 0%				
RUN 1	27.0	32.0	27.0	32.0	22		REDDISH BROWN INTENSELY FRACTURED CONGLOMERATE.	TCR: 37%, SCR: 17%, RQD: 0%				
							CAVED AND DRY AT 23'.					

Notes/Comments:
Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	OLD LANCASTER PIKE, CUMRU, PA		Page 1 of 1
HDD No.:	S3-0200	Dates(s) Drilled: 12-11-14	Inspector: E. WATT
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 16' 33.303" N	76° 1' 1.736" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.7			TOPSOIL (8")					
1	3.0	5.0	0.7		10		MAROON FINE SAND AND SILT, TRACE CONGLOMERATE MATRIX.	2	9	9	12	**18**
2	8.0	10.0			11		MAROON FINE TO MEDIUM SAND WITH SOME SILT, TRACE FINE	1	5	15	20	**20**
							TO COARSE GRAVEL.					
3	13.0	14.5			15		MAROON FINE TO MEDIUM SAND AND SILT, WITH A LITTLE FINE	312	35	35		**70**
						SM	TO COARSE GRAVEL. (USCS: SM).					
4	18.0	19.4			15		MAROON FINE TO MEDIUM SAND AND SILT, WITH A LITTLE FINE	7	8	50/5"		**>50**
							TO COARSE GRAVEL.					
5	23.0	23.8			7		MAROON FINE TO MEDIUM SAND AND SILT, WITH A LITTLE FINE	20	50/3"			**>50**
							TO COARSE GRAVEL.					
6	28.0	28.7			5		MAROON FINE TO MEDIUM SAND WITH SOME SILT, WITH A LITTLE FINE	30	50/2"			**>50**
				30.0			TO COARSE GRAVEL.					
							AUGERED TO 30'.					
							CAVED AND DRY AT 20'.					

Notes/Comments:
Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0200

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.) From	Depth of Sample (ft.) To	Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318) Liquid Limit, %	Atterburg Limits (ASTM D4318) Plastic Limit, %	Atterburg Limits (ASTM D4318) Plasticity Index, %	USCS Classif. (ASTM D2487)
S3-0200	SB-01	2	8.0	8.7	8.5	24.0	-	-	-	-
		3	13.0	13.9	5.8	16.8	-	-	-	-
		5	23.0	25.0	7.3	19.3	-	-	-	-
		6	28.0	28.4	8.7	31.9	-	-	-	-
	SB-02	1	3.0	5.0	6.3	19.3	-	-	-	-
		2	8.0	8.7	5.7	12.6	-	-	-	-
		3	13.0	13.7	9.6	20.2	-	-	-	-
	SB-03	1	3.0	5.0	11.6	47.1	-	-	-	-
		2	8.0	10.0	8.4	28.2	-	-	-	-
		3	13.0	14.5	8.4	40.6	33	25	8	SM
		5	23.0	23.8	8.0	38.7	-	-	-	-
		6	28.0	28.7	4.5	26.8	-	-	-	-

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0200

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S3-0200	Hwy 222 - Lancaster Pike	SB-01	**Hammer Creek Conglomerate** - very coarse quartz conglomerate having abundant pebbles and cobbles of gray quartzite.	level-rolling upland	Hammer Creek Conglomerate	quartz conglomerate; reddish brown cross-bedded sandstone	2,580	10-60	
		SB-02							
		SB-03							

Note : Source of well log data - http://www.dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm. All other sources as referenced in comments section.

ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0200

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
S3-0200	SB-2	1	24	27	58	8	0	24	27	Slight to moderate	Conglomerate	Massive	Light Red	Heavily fractured in bottom half of core; fractures ranging from 0° to 65°, Avg. 25°
		2	27	32	37	17	0	27	32	Slight to moderate	Conglomerate	Massive	Light Red	Fractures ranging from 0° to 30°, Avg. 9°

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

Density	***N (blows)****
Very Loose	5 or less
Loose	6 to 10
Medium Dense	11 to 30
Dense	31to 50
Very Dense	51 or more

Relative Proportions

Description Term	*Percent*
Trace	1 - 10
Little	11 - 20
Some	21 - 35
And	36 - 50

Particle Size Identification

Boulders	8 in. diameter or more	
Cobbles	3 to 8 in. diameter	
Gravel	Coarse (C)	3 in. to ¾ in. sieve
	Fine (F)	¾ in. to No. 4 sieve
Sand	Coarse (C)	No. 4 to No. 10 sieve (4.75mm-2.00mm)
	Medium (M)	No. 10 to No. 40 sieve (2.00mm – 0.425mm)
	Fine (F)	No. 40 to No. 200 sieve (0.425 – 0.074mm)
Silt/Clay	Less Than a No. 200 sieve (<0.074mm)	

COHESIVE SOILS

(Silt, Clay & Combinations)

Consistency	***N (blows)****
Very Soft	3 or less
Soft	4 to 5
Medium Stiff	6 to 10
Stiff	11 to 15
Very Stiff	16 to 30
Hard	31 or more

Plasticity

Degree of Plasticity	*Plasticity Index*
None to Slight	0 - 4
Slight	5 - 7
Medium	8- 22
High to Very High	> 22

ROCK

(Rock Cores)

Rock Quality Designation (RQD), %	***Rock Quality Description***
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

N - Standard Penetration Resistance. Driving a 2.0" O.D., 1-3/8" I.D. sampler a distance of 18 inches into undisturbed soil with a 140 pound hammer free falling a distance of 30.0 inches. The number of hammer blows to drive the sampler through each 6 inch interval is recorded; the number of blows required to drive the sampler through the final 12 inch interval is termed the Standard Penetration Resistance (SPR) N-value. For example, blow counts of 6/8/9 (through three 6-inch intervals) results in an SPR N-value of 17 (8+9).

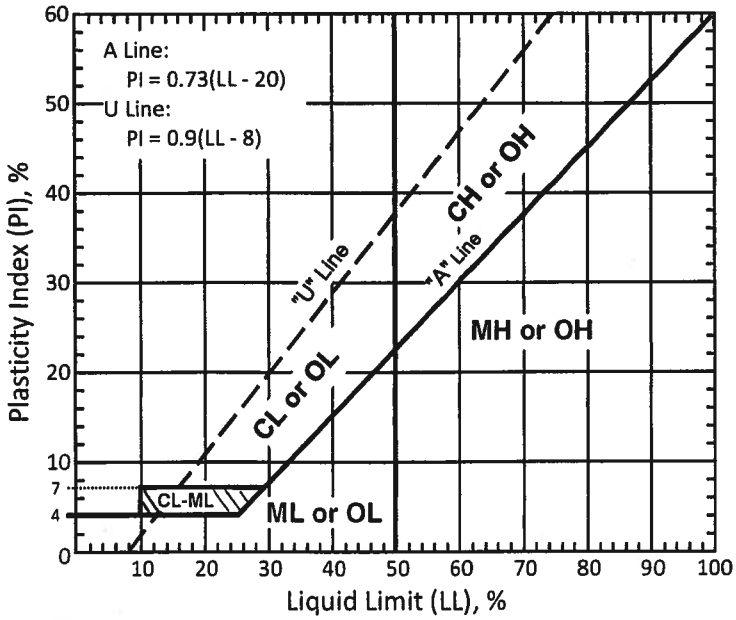
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

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.