STA. 50120+00 TO STA. 50135+00 PLAN VIEW

SCALE: 1" = 50'

STA. 50135+00 TO STA. 50150+00 PLAN VIEW

SCALE: 1" = 50'

CHPE Champlain Hudson Power Express

PROJECT NO.: 21162 — Kiewit

PROJECT NO.: 120174 — KC Engineering and Land Surveying, P.C.

ALTERED ON: 03/13/2024

AFFIXED ON: 06/09/2023

IT IS A VIOLATION OF LAW FOR ANY PERSON, UNLESS THEY ARE ACTING UNDER THE DIRECTION OF A LICENSED PROFESSIONAL ENGINEER, ARCHITECT, LANDSCAPE ARCHITECT OR LAND SURVEYOR TO ALTER AN ITEM IN ANY WAY. IF AN ITEM BEARING THE STAMP OF A LICENSED PROFESSIONAL IS ALTERED, THE ALTERING ENGINEER, ARCHITECT, LANDSCAPE ARCHITECT OR LAND SURVEYOR SHALL STAMP THE DOCUMENT AND INCLUDE THE NOTATION "ALTERED BY" FOLLOWED BY THEIR SIGNATURE, THE DATE OF SUCH ALTERATION, AND A SPECIFIC DESCRIPTION OF THE ALTERATION.

No.	DATE	SUBMITTAL / REVISION DESCRIPTION	DB	APP
1	03/13/2024	NDC-0020: HDD 73A REDESIGN	JR	BD
0	06/09/2023	ISSUED FOR CONSTRUCTION SUBMISSION	MK	NH

CHAMPLAIN HUDSON POWER EXPRESS

SEGMENT 8 (PACKAGE 5A) - CSX: ROTTERDAM - BETHLEHEM

EROSION AND SEDIMENT CONTROL PLAN

STA. 50120+00 TO STA. 50150+00

DRAWN BY: MK DESIGNED BY: MK APPROVED BY: NH SCALE AS SHOWN DATE: 06/09/2023

PERMIT DRAWING NO. N/A

DRAWING NO. C-405

CHPE LLC
623 Fifth Avenue, 20th Floor
New York, NY 10022

Segment 8 (Package 5A)

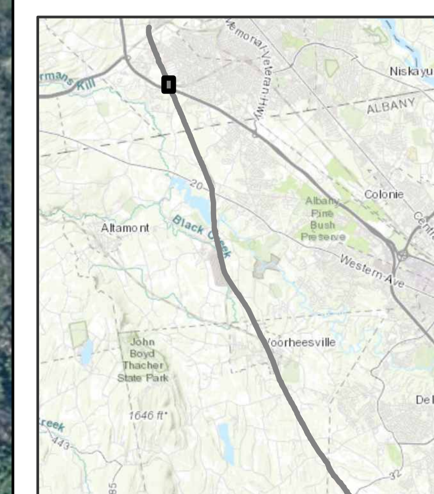
EM&CP Appendix E New Sheets

CHPE EM&CP

Schenectady and Albany County,
New York

Deviation Zone Analysis

- Mile Post
- Segment 8 Trench Excursion
- Segment 8 HDD Excursion
- Segment 8 Trench
- Segment 8 HDD
- Segment 8 (Previous Alignment)
- Delineated Wetlands
- Delineated Streams
- Deviation Zone



0 50 100 200
Feet

Prepared March 1, 2024
Basemap: Esri "World Imagery" map service

CHPE EM&CP

Schenectady and Albany County, New York

Deviation Zone Analysis

- Mile Post
- Segment 8 Trench Excursion
- Segment 8 HDD Excursion
- Segment 8 Trench
- Segment 8 HDD
- Segment 8 (Previous Alignment)
- Delineated Wetlands
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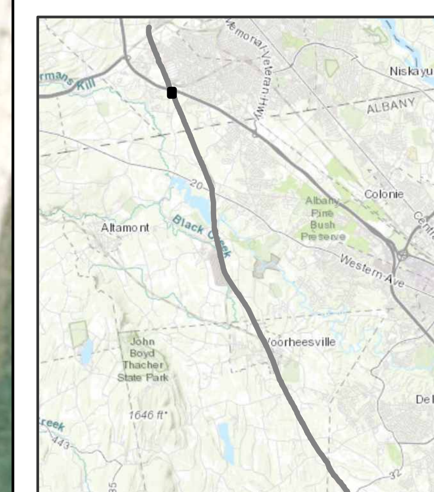
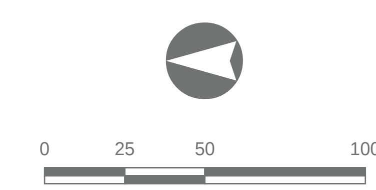




Prepared March 1, 2024
Basemap: Esri "World Imagery" map service

CHPE
Champlain Hudson Power Express

CHPE LLC
623 Fifth Avenue, 20th Floor
New York, NY 10022

Segment 8 (Package 5A)

EM&CP Appendix J Memo

BRIERLEY ASSOCIATES
Creating Space Underground

April 1, 2024
File No. 322004-000

Kiewit Engineering (NY) Corporation
470 Chestnut Ridge Rd, 2nd Floor
Woodcliff Lake, NJ 07677

Attention: Jason Neff, PE, PMP - Design Engineering Manager

Subject: HDD 73A,74 Design Revisions
Champlain Hudson Power Express – Segment 5b
Rotterdam to Fuera Bush, NY

Dear Mr. Neff:

At your request, we have modified HDD 73A,74 to accommodate minor alignment modifications. Specifically, these modifications include reversal of the drilling direction and shifting of the HDD entry and exit pits. Amended text and design calculations are attached. The following is noted:

- The duct pull forces have not changed significantly; and
- The risk of IR increases at the drill exit, as the revised geometry involves drilling downslope. The driller will also need to be prepared to contain the drill fluid which will flow downhill to the exit pit during drilling.

The discussions and recommendations contained in the IFC HDD Basis of Design Report and IRR plan otherwise remain unchanged.

We thank you for this opportunity to be of service to you and your team on this project. Should you have any questions or require additional information, please do not hesitate to contact the undersigned at your convenience.

Sincerely,

Brierley Associates Underground Engineers, PLLC

Nick Strater, P.G.
Trenchless Design Manager

Brian C. Dorwart, P.E., P.G.
Sr. Consultant

1.0 Introduction

Table 1: HDD Locations, Lengths, and Description

HDD #	Approx. Start Station*	Approx. End Station*	Approx. HDD Length, ft	Obstruction Crossed
73A,74	**50100+00**	**50120+04**	**2,004**	NYS Throughway (I-90)

*Project stationing shown is approximate. Each HDD has its own independent stationing.

4.1 Surface Conditions

HDD #73A,74

HDD #73A,74 pass below an overhead electric cable easement (Niagara Mohawk) which is oriented approximately northwest-south, and about 100-ft wide. Power poles are located to the west of the HDD alignments.

The HDD #73A,74 alignments also pass below Interstate I-90 which is oriented approximately southeast-northwest, 115-ft wide, and located on an elevated embankment. Interstate I-90 passes over two (2) active CSX rails to the immediate east by means of a concrete deck bridge. The western bridge abutment is located to the immediate east of the HDD alignments. The areas to the north of I-90 and adjacent to Niagara Mohawk easements are heavily wooded.

The HDD #73A,74 exit (southeast) is located in a paved cul-de-sac at the northeast end of S Westcott Rd. The HDD #73A,74 entry (northwest) is located in a wooded area to the northwest of the Niagara Mohawk easement. The CSX rails are located approximately at-grade to the east-northeast, and are oriented northwest-southeast. The CSX rails rest on an elevated embankment which is approximately 4 to 5 feet higher than adjacent grades. Portions of the HDD #73A,74 alignments are located within the CSX right-of-way.

The surface grades in the site vicinity generally slope downward to the south, from about El. 326 to El. 314. The surface of I-90 is at about El. 350.

APPENDIX B
HDD Calculations Per Crossing

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

CROSSING: **HDD 73A-74 Conduit #1**
NY State Thruway(I-90)

ISSUE: **Issued for Construction (IFC)**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

STATE OF NEW YORK
BRIAN C DORWART
080342
LICENSED PROFESSIONAL ENGINEER

Brian C Dorwart
Digitally signed by Brian C Dorwart
DN: c=US, o=BRIERLEY ASSOCIATES CORPORATION, dnQualifier=A01410C000001881F68602400021945, cn=Brian C Dorwart
Date: 2024.04.02 11:31:03 -04'00'

Project No: 322004-000
Print Date: 1-Apr-2024

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/23/2023	1	Issued for Construction	ABL
8/29/2023	2	Profile Revisions	KRF
3?31/24	3	Plan Revisions	NHS

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	20+45.21	FT

Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)

	East	North	Elevation
Entry	629021.1198	1437814.4763	326.40 ft
Horizontal Curve PI	629520.3407	1436410.0486	
Exit	629890.9574	1435991.5954	311.00 ft
Depth to Mudline	16.40 ft	Clearance Depth =	36.40 ft
Measured Plan Length at ties =	2045.2102 ft		
Coordinate Length =	2045.2102 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation

Water Surface Elev.*	310.00 ft
Mudline Elev.*	310.00 ft
Lowest centerline Elev.	273.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	629021.1198	1437814.4763	13+15.88	629461.8497	1436574.5977	E 160.43163 N	1315.88		
Curve	13+15.88	629461.8497	1436574.5977	16+60.86	629636.1280	1436279.3164	E 138.46925 N	344.98	900.00	-21.962 deg.
Tangent	16+60.86	629636.1280	1436279.3164	20+45.21	629890.9574	1435991.5954	E 138.46925 N	384.35		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1315.88	Input Radius, ft.	900.00	Plan Length, ft.	384.35	
Entry Azimuth, deg.[5]	N 160.43163 E	Curve, deg	-21.962 deg.	Exit Azimuth, deg.[5]	N 138.46925 E	
Entry Azimuth, rad.[5]	2.80006	Curve, rad	-0.38332	Exit Azimuth, rad.[5]	2.41674	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	342.88	Easting	629890.9574	**Check**
PCH Easting	629461.8497	Arc Length, ft.	344.98	Northing	1435991.5954	**Delta**
PCH Northing	1436574.5977	Chord Azimuth, deg	149.4504			**0.0000**
		PI Easting =	629520.3407			**0.0000**
		PI Northing =	1436410.0486			**OK CALC**
		PTH Easting =	629636.1280			
		PTH Northing =	1436279.3164			**Exit Station**
						20+45.21
Cum Plan Length	1315.88	Cum Plan Length	1660.86	Cum Plan Length	2045.210223	**OK STA**

Pull Geometry

Pipe Entry	Exit	Enter the pipe entry location into the hole: Entry/Exit					
	Elevations		**Vertical Angle**			**Path**	**Curve**
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Length**	**Radius**
Entry Tangent	311.00 ft	291.47 ft	-9.90 deg	-9.90 deg	0.00 deg	113.60 ft	0.00 ft
Entry Curve	291.47 ft	273.60 ft	-9.90 deg	0.00 deg	9.90 deg	207.35 ft	1200.00 ft
Bottom Tangent	273.60 ft	273.60 ft	0.00 deg	0.00 deg	0.00 deg	1352.46 ft	0.00 ft
Exit Curve	273.60 ft	299.82 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	299.82 ft	326.40 ft	12.00 deg	12.00 deg	0.00 deg	127.83 ft	0.00 ft
					Total Check =	**2052.56 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	374.53	1315.88	No, Horiz > Entry V(Tan+Curve)
Exit	318.22	384.35	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	311.00	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	9.900 deg.	Design Exit Angle	9.90 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	125.036 ft	Plan Length	249.494 ft	Plan Length	1,352.45707 ft	Plan Length	206.315 ft	Plan Length	111.909 ft	2,045.210 ft
Rod Length	127.829 ft	Arc Rod Length	251.327 ft	Rod Length	1,352.45707 ft	Arc Rod Length	207.345 ft	Rod Length	113.600 ft	2,052.559 ft
Vertical Depth	-26.577 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	17.869 ft	Vertical Depth	19.531 ft	-15.400 ft
		Lowest Elevation	273.600 ft			Lowest Elevation	273.600 ft	CK Total Cum Depth	-15.400 ft	
Start Elevation	326.400 ft	Start Elevation	299.823 ft	Start Elevation	273.600 ft	Start Elevation	273.600 ft	Start Elevation	291.469 ft	
End Elevation	299.823 ft	End Elevation	273.600 ft	End Elevation	273.600 ft	End Elevation	291.469 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	9.900 deg	*Prop. Plan Length*	*2045.210223*	

Summary of Drill Calculations

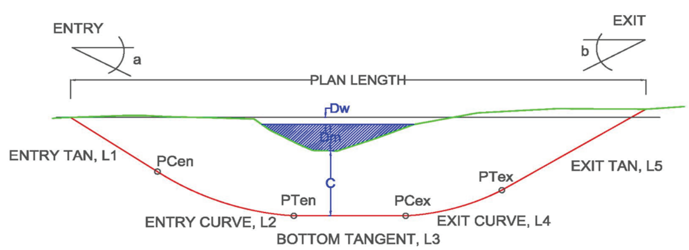
Entry to Exit Elevation Change =	-15.40 ft
Minimum Design Elevation =	273.60 ft
Invert Depth below exit =	37.40 ft
Invert Depth below entry =	52.80 ft
Path Length =	2,052.56 ft
Plan Length =	2,045.21 ft
Minimum Plan Length (No Tangent) =	692.75 ft
Entry Angle =	-12.00 deg
Exit Angle =	9.90 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	NO

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+25.04	Start Station	3+74.53	Start Station	17+26.99	Start Station	19+33.30	**Stationing Check**
PVC Station	1+25.04	PTV Station	3+74.53	PCV Station	17+26.99	PTV Station	19+33.30	Exit Station	20+45.210	**OK STATIONING**
Cum Plan Length	125.04	Cum Plan Length	374.53	Cum Plan Length	1726.99 ft	Cum Plan Length	1933.30	Cum Plan Length	2045.21	**Plan Length Check**
Cum Rod Length	127.83	Cum Rod Length	379.16	Cum Rod Length	1731.61 ft	Cum Rod Length	1938.96	Cum Rod Length	2052.56	**OK CALCULATION**
Cum Depth	-26.58	Cum Depth	-52.80	Cum Depth	-52.80 ft	Cum Depth	-34.9312	Cum Depth	-15.40	**Elevation Change Check**
										OK CALCULATION

NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise. Due East is defined as 0 degrees.
2. NAD83 New York State Plane East Zone
3. Elevations are referenced to NAVD88 Datum
4. All calculation locations represent the center of the drill hole.



(yellow)	Indicates inputs
(orange)	Indicates status on internal design checks

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"Creating Space Underground"
Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 2
DRILL PATH DESIGN CALCULATION
HDD 73A-74 Conduit #1
NY State Thruway(I-90)

Revision 3 TBD

D:\CHPE\[HDD#73A-74 CIR #1_APC_20240331.xlsb]F1A APCL

Pull Geometry

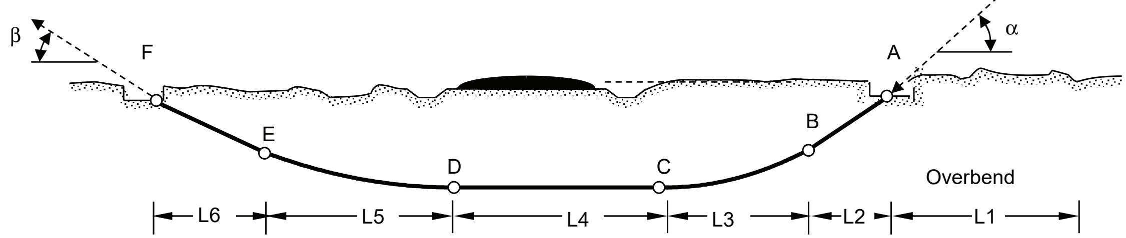
Lengths (Path)	Angles			Radius, R
L1 = 100.0 ft	Overbend	deg	radian	300.0 ft
L2 = 113.6 ft	α =	-9.9 °	-0.1728	
L3 = 207.3 ft				1,200.0 ft
L4 = 1352.5 ft	χ =	0.0 °	0.0000	
L5 = 251.3 ft				1,200.0 ft
L6 = 127.8 ft	β =	12.0 °	0.2094	
LT = 2152.6 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 326.40 ft

Pipe Entry El = 311.00 ft



INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM} =	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	17.36 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,000 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	250 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	310.00 ft	
Ballast Water El., H_W =	310.00 ft	
Lowest Invert El., El_m =	273.60 ft	

Calculated Pull Force

POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	ASSESS F_x < SPS Air	ASSESS F_x < SPS Ballast
A	3,802 lb	225 psi	OK	3,802 lb	225 psi	OK	OK	OK
B	4,689 lb	118 psi	OK	4,893 lb	123 psi	OK	OK	OK
C	6,413 lb	194 psi	OK	5,729 lb	177 psi	OK	OK	OK
D	12,688 lb	320 psi	OK	12,004 lb	303 psi	OK	OK	OK
E	18,031 lb	487 psi	OK	14,932 lb	409 psi	OK	OK	OK
F	19,348 lb	488 psi	OK	15,686 lb	396 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_AF_R$ = 93.96 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.878323851	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.21219093	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	488 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	3.94	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	19.72	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.43 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

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Limited Liability Company
"Creating Space Underground"

Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 73A-74 Conduit #1
NY State Thruway(I-90)

Revision 3 TBD

D:\CHPE\[HDD#73A-74 CIR #1_APC_20240331.xlsb]F1A APCL

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem

Schenectady County, NY

HDD 73A-74 Conduit #1

NY State Thruway(I-90)

BRIERLEY ASSOCIATES Limited Liability Company

"Creating Space Underground"

INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Design Working Pressure, P_{WORK}	250 psi		Test Pressure, P_{TEST} 0 psig At high point
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification	445574C	Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	10		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	8.219 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	1.194 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	35.85681985	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	405.27 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.630 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.368 cf/LF	$V_{Di} = \pi*(D_i/2)^2/144$	
HDB =	1,600 psi	Based on PPI Publication TR-4/2015 and ASTM 2837	
Design Factor for HDB, DF =	0.625	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1000 psi	HDS = HDB*DF	
Environmental Factor, Af_e =	1	Reference 2: Use for pressure rating only	
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	15.68	Lb/LF	
Tensile Yield, Ty psi =	3,500 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	4%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-33.48 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.74 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.67 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.49 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, BB_{B2} =	-11.75 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.99 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	49.16 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	50.42 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

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HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem

Schenectady County, NY

BRIERLEY ASSOCIATES Limited Liability Company

"Creating Space Underground"

HDD 73A-74 Conduit #1

NY State Thruway(I-90)

1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	875 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE

OK — OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	250 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	500 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	375 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING

OK — OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe — Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert: 52.80 ft — Ballast depth to invert, H_B: 37.40 ft — Drill Fluid depth to invert, H_{DF}: 37.40 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	16.40 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	20.50 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	21.03 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	16.40 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	86.47 psi	12.41 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	85.95 psi	11.89 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.87 psi	28.82 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.35 psi	28.29 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	90.57 psi	16.51 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

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TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem

Schenectady County, NY

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

HDD 73A-74 Conduit #1

NY State Thruway(I-90)

3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr	Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5) / Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7	
Design Factor, DF = f_T*f_Y	0.4	**SAFE PULL STRENTH, SPS =**	**50,200 lb**
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	125,499 lb
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	3,500 psi		
Safe Allowable Stress, SAS =	1,400 psi	SAS = $Ty*f_{temp}*DF$ / Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	50,200 lb	**Using SSAS =**	**41,235 lb**

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR}*f_r$

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	1,400 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.87832		
r = σ_i/2*(SSAS) =	0.21219	Example from Table T5, σ_i =	488 psi
P_{CRR} =	234.9 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	117.4 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	96.95 psi	Pull Back Condition - Option 3	**OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	96.42 psi	Pull Back Condition - Option 4	**OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24

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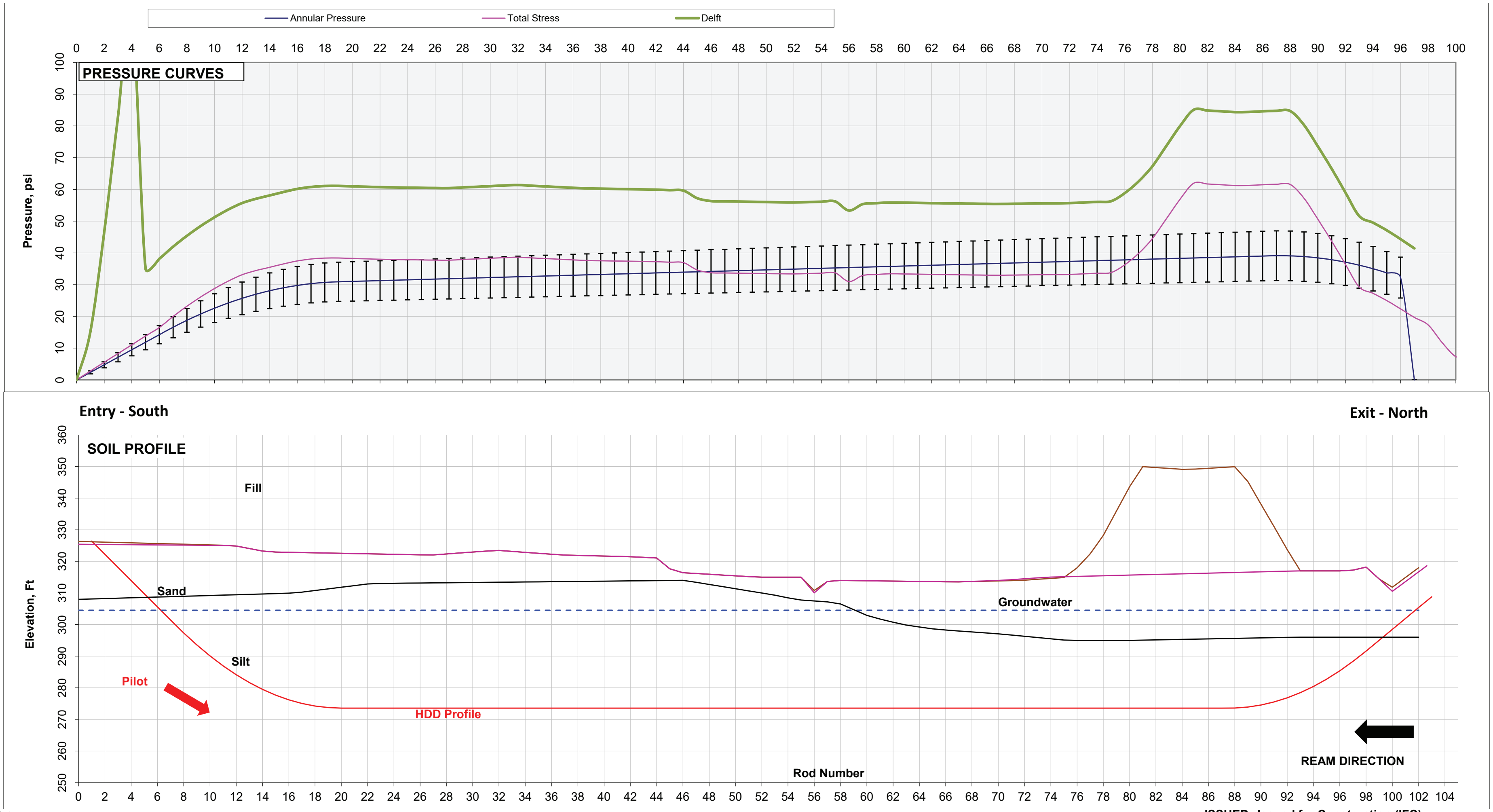

Notes:
1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

9.00 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs
K178.7A
K178.7B
K178.8
K178.96
B178.9-1
RS-2

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Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 73A-74 Conduit #1
NY State Thruway(I-90)

Revision 3

FIGURE 1

BRIERLEY ASSOCIATES

Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

CROSSING: **HDD 73A-74 Conduit #2**
NY State Thruway (I-90)

ISSUE: **Issued for Construction (IFC)**

Contents:

Prepared For: Kiewit

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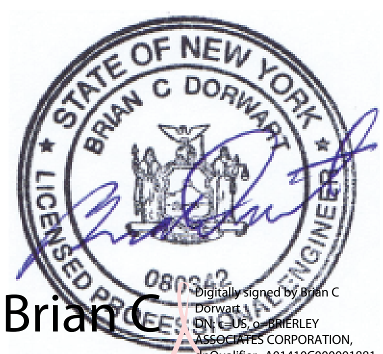


Brian C Dorwart

Digitally signed by Brian C Dorwart
DN: c=US, o=BRIERLEY ASSOCIATES CORPORATION, dnQualifier=A01410C000001881F68602400021945, cn=Brian C Dorwart
Date: 2024.04.02 11:29:50 -04'00'

Project No: 322004-000
Print Date: 1-Apr-2024

Date	ID	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/23/2023	1	Issued for Construction	ABL
8/29/2023	2	Profile Alterations	KRF
4/1/2024	3	Plan Revision	NHS

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	20+37.76	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	629035.3157	1437819.6222	325.80 ft
Horizontal Curve PI	629546.9663	1436408.1216	
Exit	629902.4145	1436001.2771	311.30 ft
Depth to Mudline	15.80 ft	Clearance Depth =	36.20 ft
Measured Plan Length at ties =	2037.7571 ft		
Coordinate Length =	2037.7571 ft		
	OK-HORIZONTAL CURVE		

*If no water or mudline then use lower of entry or exit elevation	
Water Surface Elev.*	310.00 ft
Mudline Elev.*	310.00 ft
Lowest centerline Elev.	273.80 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	629035.3157	1437819.6222	13+32.80	629489.5177	1436566.6062	E 160.07508 N	1332.80		
Curve	13+32.80	629489.5177	1436566.6062	16+66.09	629657.8784	1436281.1720	E 138.85723 N	333.29	900.00	-21.218 deg.
Tangent	16+66.09	629657.8784	1436281.1720	20+37.76	629902.4145	1436001.2771	E 138.85723 N	371.67		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1332.80	Input Radius, ft.	900.00	Plan Length, ft.	371.67	
Entry Azimuth, deg.[b]	N 160.07508 E	Curve, deg	-21.218 deg.	Exit Azimuth, deg.[b]	N 138.85723 E	
Entry Azimuth, rad.[b]	2.79384	Curve, rad	-0.37032	Exit Azimuth, rad.[b]	2.42352	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	331.39	Easting	629902.4145	**Check**
PCH Easting	629489.5177	Arc Length, ft.	333.29	Northing	1436001.2771	**Delta**
PCH Northing	1436566.6062	Chord Azimuth, deg	149.4662			**0.0000**
		PI Easting =	629546.9663			**0.0000**
		PI Northing =	1436408.1216			**OK CALC**
		PTH Easting =	629657.8784			
		PTH Northing =	1436281.1720			**Exit Station**
						20+37.76
Cum Plan Length	1332.80	Cum Plan Length	1666.09	Cum Plan Length	2037.75707	**OK STA**

Pull Geometry

Pipe Entry: **Exit** — Enter the pipe entry location into the hole: Entry/Exit

	Elevations		Vertical Angle			Path	Curve
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Length**	**Radius**
Entry Tangent	311.30 ft	292.03 ft	-10.00 deg	-10.00 deg	0.00 deg	110.97 ft	0.00 ft
Entry Curve	292.03 ft	273.80 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	273.80 ft	273.80 ft	0.00 deg	0.00 deg	0.00 deg	1349.33 ft	0.00 ft
Exit Curve	273.80 ft	300.02 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	300.02 ft	325.80 ft	12.00 deg	12.00 deg	0.00 deg	123.98 ft	0.00 ft
					Total Check =	**2045.05 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	370.77	1332.80	No, Horiz > Entry V(Tan+Curve)
Exit	317.66	371.67	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*	
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	311.30
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	121.272 ft	Plan Length	249.494 ft	Plan Length	1,349.33176 ft	Plan Length	208.378 ft	Plan Length	109.282 ft
Rod Length	123.981 ft	Arc Rod Length	251.327 ft	Rod Length	1,349.33176 ft	Arc Rod Length	209.440 ft	Rod Length	110.967 ft
Vertical Depth	-25.777 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	19.269 ft
		Lowest Elevation	273.800 ft			Lowest Elevation	273.800 ft	CK Total Cum Depth	-14.500 ft
Start Elevation	325.800 ft	Start Elevation	300.023 ft	Start Elevation	273.800 ft	Start Elevation	273.800 ft	Start Elevation	292.031 ft
End Elevation	300.023 ft	End Elevation	273.800 ft	End Elevation	273.800 ft	End Elevation	292.031 ft	Ck Exit Elevation	
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*2037.75707*

SUMS
2,037.757 ft
2,045.047 ft
-14.500 ft

SUMMARY VERTICLE CURVE CALCULATIONS

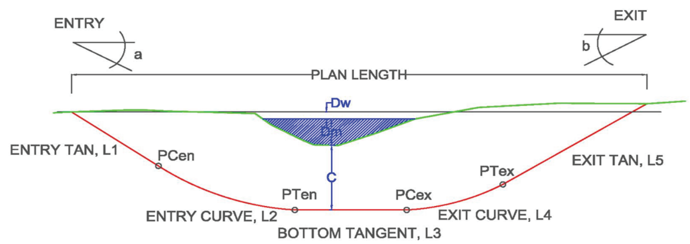
Start Station	0+00.00	Start Station	1+21.27	Start Station	3+70.77	Start Station	17+20.10	Start Station	19+28.48
PVC Station	1+21.27	PTV Station	3+70.77	PCV Station	17+20.10	PTV Station	19+28.48	Exit Station	20+37.757
Cum Plan Length	121.27	Cum Plan Length	370.77	Cum Plan Length	1720.10 ft	Cum Plan Length	1928.48	Cum Plan Length	2037.76
Cum Rod Length	123.98	Cum Rod Length	375.31	Cum Rod Length	1724.64 ft	Cum Rod Length	1934.08	Cum Rod Length	2045.05
Cum Depth	-25.78	Cum Depth	-52.00	Cum Depth	-52.00 ft	Cum Depth	-33.7693	Cum Depth	-14.50

Stationing Check
OK STATIONING
Plan Length Check
OK CALCULATION
Elevation Change Check
OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-14.50 ft**
Minimum Design Elevation =	**273.80 ft**
Invert Depth below exit =	**37.50 ft**
Invert Depth below entry =	**52.00 ft**
Path Length =	**2,045.05 ft**
Plan Length =	**2,037.76 ft**
Minimum Plan Length (No Tangent) =	**688.43 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

NOTES:
1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.
2. NAD83 New York State Plane East Zone
3. Elevations are referenced to NAVD88 Datum
4. All calculation locations represent the center of the drill hole.



Indicates inputs
Indicates status on internal design checks

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Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 73A-74 Conduit #2
NY State Thruway (I-90)

Revision 3 TBD

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Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	111.0 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	1349.3 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	124.0 ft	β =	12.0 °	0.2094	
LT =	2145.0 ft				

INPUT: Assumed Friction Factors

μ_G =	0.10	dry + rollers
μ_b =	0.25	drill fluid in hole
μ_c =	0.30	in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 10.75	PIPE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	10.75	Pipe or Bundle	
Pipe Dry Weight, W_P =	15.70 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	8.22 in	Bundle Multiplier F_D	1.0000
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,000 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	250 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	310.00 ft	
Ballast Water El., H_W =	310.00 ft	
Lowest Invert El., El_m =	273.80 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	33.77 in	
Wall Section Area, A_W	37.70738915	
Volume Outside, V_{DO}	0.630 cf/LF	
Volume Inside, V_{DI}	0.368 cf/LF	
q_d =	2.03 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.32 lb/ft	Comparison Only @ 8psi

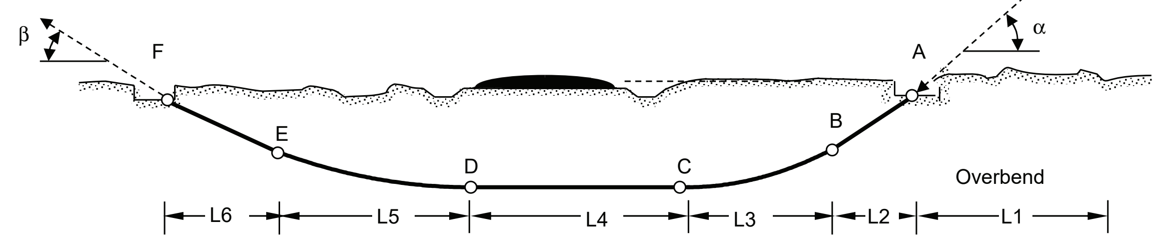
Calculated Buoyant Forces

Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 325.80 ft — Pipe Entry El = 311.30 ft



Calculated Pull Force							ASSESS	
POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	F_x < SPS Air	F_x < SPS Ballast
A	3,427 lb	193 psi	OK	3,427 lb	193 psi	OK	OK	OK
B	4,257 lb	119 psi	OK	4,429 lb	124 psi	OK	OK	OK
C	5,738 lb	184 psi	OK	5,104 lb	167 psi	OK	OK	OK
D	11,404 lb	318 psi	OK	10,770 lb	300 psi	OK	OK	OK
E	16,126 lb	474 psi	OK	13,307 lb	396 psi	OK	OK	OK
F	17,269 lb	482 psi	OK	13,952 lb	389 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert — $P_{PA} = P_AF_R$ = 94.15 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_TD_{OD}/2R$ — PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.880121965	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.209468908	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	482 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	3.92	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	19.61	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

D_O<8" Use $D_H=D_O+4$"; 8"<D_O<24" Use $D_H=1.5*D_O$; D_O>24" Use $D_H=D_O+12$"

NOTES: 1 - Calculations were done in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. ASTM applies hydrokinetic pressure as shear per unit pipe length requiring a back calculation to determine actual pull force based on average pipe area.

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Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 73A-74 Conduit #2
NY State Thruway (I-90)

Revision 3 — TBD

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TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem

Schenectady County, NY

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

HDD 73A-74 Conduit #2

NY State Thruway (I-90)

INPUTS

Pipe Material Properties

Sources: ASTM D3350 and Plastic Pipe Institute Publications and as referenced

Test Pressure, P_{TEST} 0 psig At high point

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification	445574C	Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	10		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	8.219 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	1.194 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	35.85681985	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	405.27 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.630 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.368 cf/LF	$V_{Di} = \pi*(D_i/2)^2/144$	
HDB =	1,600 psi	Based on PPI Publication TR-4/2015 and ASTM 2837	
Design Factor for HDB, DF =	0.625	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1000 psi	HDS = HDB*DF	
Environmental Factor, Af_e =	1	Reference 2: Use for pressure rating only	
Density =	59.28 pcf	1.410 g/cc	Average from WL Plastics WL122 for PE4710
Weight Dry, W =	15.68	Lb/LF	
Tensile Yield, Ty psi =	3,500 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	4%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.6	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2
	γ_{INT}	γ_{EXT1}	γ_{EXT2}
Density, γ =	62.4	78	80

Buoyant Unballasted Fluid 1, B_{B1} =	-33.48 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.74 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.67 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.49 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.75 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.99 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	49.16 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	50.42 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

HDPE PROPERTIES

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1. ASSESS PIPE PRESSURE RATING

Failure mode: Short term = burst; Long term = slow crack growth

Short Term (<10 hours)

Design Temperature, °F =	73 deg F	
Ultimate Internal Pressure, P_U =	875 psi	$P_U = 2*Ty*f_t/(DR-1)$
Allowable Internal Pressure, P_A =	400 psi	$P_A = 2*HDB*f_t/(DR-1)$

ASSESSMENT TEST PRESSURE	
OK	OK if P_A >= to P_{TEST}

Long Term Design for operating conditions

Design Temperature, °F =	73 deg F	
Pressure Rating, PR =	250 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	500 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	375 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
OK	OK if PR >= to P_{WORK}

2. ASSESS PIPE UNCONSTRAINED BUCKLING CAPACITY FOR CONSTRUCTION PRESSURES

CALCULATE: Unconstrained Buckling Capacity of pipe Unconstrained buckling ASTM F1962 EQ 5

Critical Pressure, $P_{CR} = f_o*[2*E/(1-\upsilon^2)]*[(1/(DR-1))^3]$

	Short Term	Long Term
Design Temperature, F =	73 deg F	73 deg F
P_{CR} =	267.4 psi	82.3 psi
$P_a = P_{CR}/FS$	107.0 psi	32.9 psi

CALCULATE: internal and external pressure for deepest pipe invert depth and construction conditions

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	52.00 ft	Ballast depth to invert, H_B	37.50 ft	Drill Fluid depth to invert, H_{DF}	37.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	16.44 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	20.56 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	21.08 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	16.44 psi

Unconstrained buckling occurs when DIFFERENTIAL PRESSURE between the inside pressure plus pipe capacity is less than the outside pressure. $(P_I + P_a) - P_E <= 0$

Differential Pressures	Short Term	Long Term	
Internal Air and External Fluid 1 = $(P_A+P_a)-P_{DF1}$	86.42 psi	12.36 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	85.89 psi	11.83 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.86 psi	28.80 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.34 psi	28.28 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	32.92 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	90.53 psi	16.47 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

Pipe installation pressure differential does not require ballasting the pipe during pull-back

Pipe may be fully dewatered for operational conditions providing there is no soil loading. Soil loads not assessed.

Engineer to assess any dewatering of the pipe in the future for stability based on actual project conditions and time duration.

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HDPE PROPERTIES

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3. ASSESS ULTIMATE PULL STRENGTH (UPS) AND SAFE PULL STRENGTH (SPS)

Source PPI PE Handbook Ch 12 Formula 17 $SPS = \pi*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))$

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**SAFE PULL STRENTH, SPS =**	**50,200 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	125,499 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	3,500 psi			
Safe Allowable Stress, SAS =	1,400 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	50,200 lb	**Useing SSAS =**	**41,235 lb**	

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR}*f_r$

(ASTM F-1962 EQ. 22)

Pull Duration Time =	12 Hr	Pcr =	267.4 psi	
SAS =	1,400 psi	Design Depth in DF, H_{MDF} =	0.0 ft	
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum		
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.88012			
r = σ_i/2*(SSAS) =	0.20947	Example from Table T5, σ_i =	482 psi	
P_{CRR} =	235.4 psi			
FS =	2.0			
$P_{ACRR} = P_{CRR}/FS$ =	117.7 psi	Allowable Reduced Short Term Buckling pressure during pull		
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	97.13 psi	Pull Back Condition - Option 3	**OK as >0**	
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	96.61 psi	Pull Back Condition - Option 4	**OK as >0**	

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

f_T	Time factor for pull	
1.00	Up to 1 hour pull	1
0.95	Up tp 12 hours pull	12
0.91	Up to 24 hours	24

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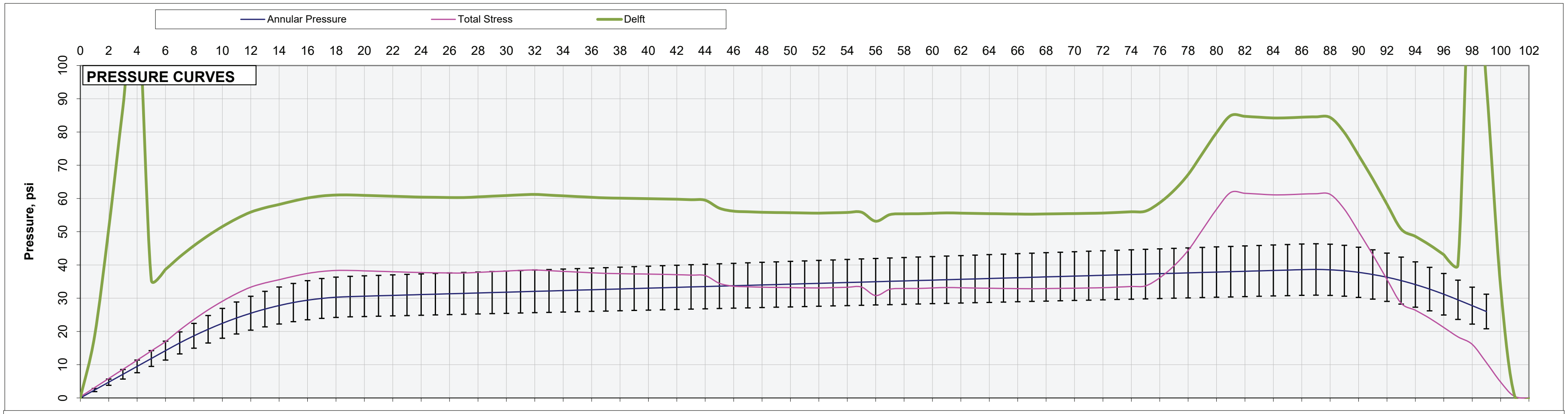

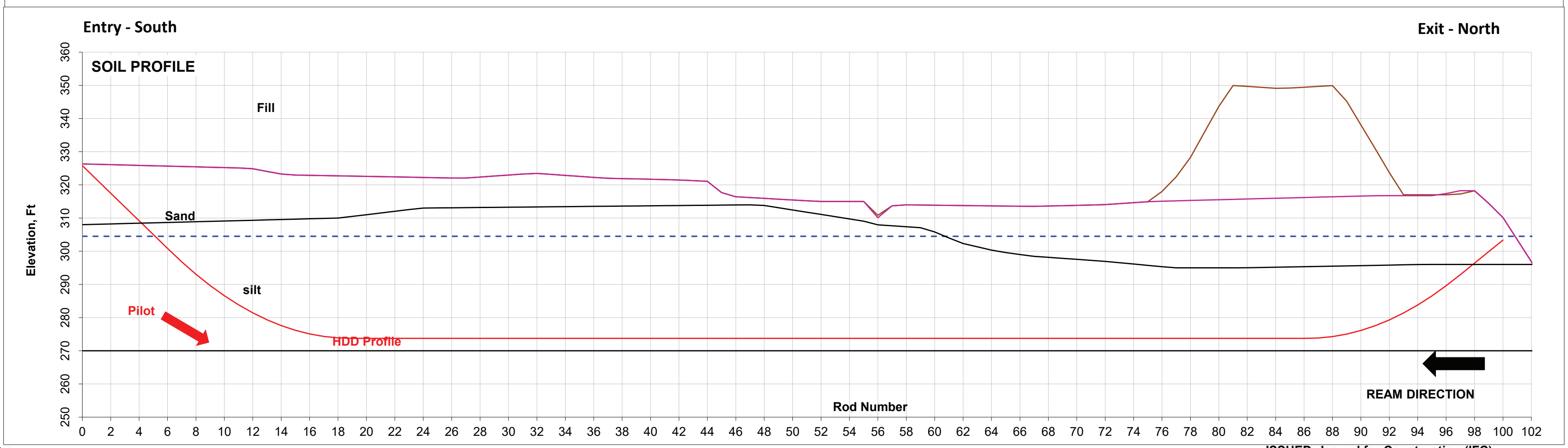

ISSUED: Issued for Construction (IFC)

Notes:

1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report.

Basis of annulur pressure calculations

9.00 in	Pilot Hole Diameter
78.0 pcf	Unit Weight Drill Fluid
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs

K178.7A
K178.7B
K178.8
K178.96
B178.9-1
RS-2

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ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 73A-74 Conduit #2
NY State Thruway (I-90)

Revision 3

FIGURE 1