APPENDIX J: INADVERTENT RELEASE PLAN AND HDD DESIGN SUMMARY REPORT CASE 10-T-0139

BRIERLEY ASSOCIATES
Creating Space Underground

March 23, 2023
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 Design Summary Report
Champlain Hudson Power Express – Segment 5B
Fuera Bush to Bethlehem, New York

Dear Mr. Neff:

Brierley Associates Underground Engineers, PLLC (Brierley) is pleased to provide this HDD Design Summary Report for Segment 5B of the Champlain Hudson Power Express Project. This work was conducted in general accordance with our contract with Kiewit Engineering (NY) Corporation (Kiewit).

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

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1.0 Introduction

The Champlain Hudson Power Express (CHPE) project will install a pair of HVDC electrical transmission cables with an associated telecommunications line from Canada to New York City, NY. This work includes approximately 126 crossings under roads, railroads, wetlands water bodies, and obstructions to be installed using horizontal directional drilling (HDD) methods to minimize interference with use or impacts to the surface environment. This Design Summary Report addresses the design for the HDD crossings in Package 5b which extends from Fuera Bush to Bethlehem. Package 5b includes a total of 4 crossings, which are summarized in Table 1, below.

Table 1: HDD Locations, Lengths, and Description

HDD #	Approx. Start Station*	Approx. End Station*	Approx. HDD Length, ft	Obstruction Crossed
87B	51106+47	51120+29	1,458	S. Albany St/Route 54, water main
88	51179+50	51194+20	1,467	Coeyman's Creek
89	51201+75	51225+45	2,369	Wetland, Stream
90	51235+05	51247+40	1,238	Route 396/Stream Bank

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

The purposes of this Design Summary Report are to provide the following:

- Review of the existing geological and geotechnical conditions for each HDD crossing.
- Provide a descriptive narrative of the HDD crossings in support of the design drawings and technical specifications.
- Present pipe stress and annular pressure analyses that support the proposed designs.
- Present construction considerations including inadvertent return mitigation.

2.0 Project Description

The proposed CHPE route follows the Hudson River Valley of New York. The new transmission line will be approximately 146 miles in length, extending from the south end of Lake Champlain to Astoria, NY. Project Maps showing the locations of the HDD crossings are presented in Figure 1.

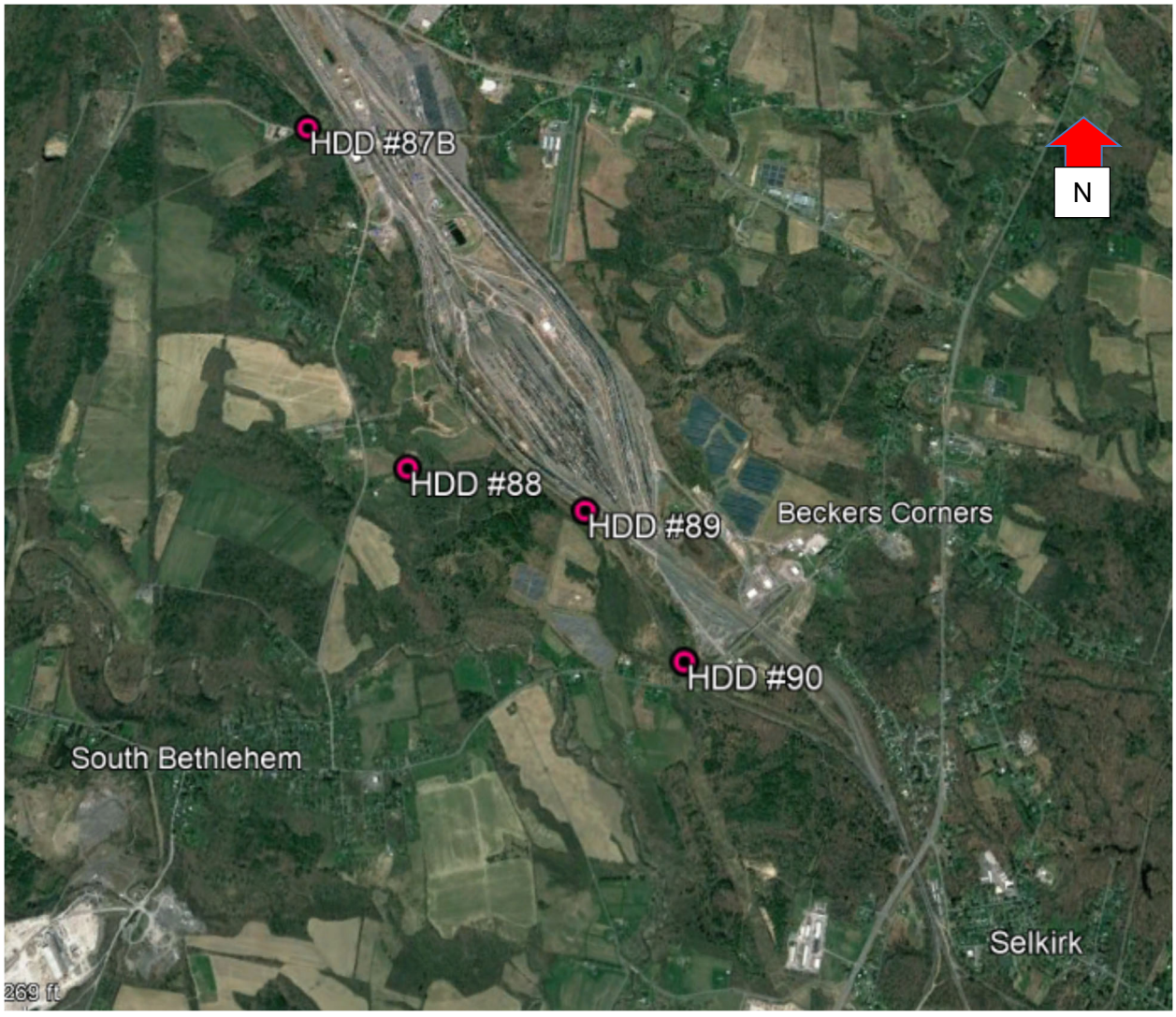


Figure 1 – Crossing Location Plan, HDD #87B through HDD #90. Photo from www.googleearth.com. Not to scale.

3.0 Background

The underground construction of two HVDC electrical transmission cables is proposed to be housed in individual 10-inch-diameter plastic conduit spaced approximately 15 feet apart. A third, minimum 2-inch-

diameter plastic conduit will be bundled with one of the 10-inch diameter conduits for a telecommunications line.

The proposal is to install the cable duct at least 25 feet below congested areas, roads, railroads, under/around other obstructions, 15 to 25 feet below wetland, and 35 to 45 feet below open bodies of water using horizontal directional drilling (HDD) methods.

HDD is a widely used trenchless construction method to install pipe and conduits with limited disturbance to the ground around the bore alignment. The goal for using HDD methods is to install the conduits while controlling and minimizing the amount of impact to congested areas, existing underground obstructions, and to the adjacent wetlands to the extent possible.

4.0 Surface Conditions

HDD #87B

HDD #87B passes below S. Albany St/Route 54 which curves from east-west to northwest-southeast in this vicinity. This roadway is supports two lanes of active traffic and is approximately 23-ft wide. The crossing also passes below a 48-in water main operated by the Albany Water Board, and numerous smaller utilities.

Southwest of S. Albany St/Route 54 (in the vicinity of the HDD alignment) the ground surface slopes downward toward the center of the alignment, from about El. 170 to El. 155. In this area, the crossing passes below a wetland and 60-in CMP culvert. This area is covered with brush and small trees.

The HDD Entry is located to the northwest, on the south side of S. Albany St/Route 54, adjacent to a small commercial facility (single-story buildings, unpaved parking). The ground surface in this area ranges from about El. 175 to El. 178. Overhead utility poles are located on the opposite (north) side of the road.

The HDD Exits are staggered and located in a grassy area on the northeast side of S. Albany St/Route 54. A paved parking area and a brick office building operated by CSX are located to the immediate east. Surface grades at the HDD exit range from about El. 175 to El. 177.

HDD #88

HDD #88 is located to the east of S. Albany St/Route 54 and passes below Coeyman's Creek and an adjacent wetland. The majority of the site vicinity is covered by trees and brush. Farmland is located to the northwest, southwest and northeast.

The HDD Entry is located to the southwest in an open field (farmland). Surface grades in this area range from about El. 163 to El. 165. The HDD exit is located to the northeast in an area covered by brush and small trees, which has been mapped as wetland. Surface grades in this area range from about El. 174 to El. 176.

Surface grades along the HDD alignment slope downward toward Coeyman's Creek at moderate grades from the northeast and southeast. The Creek is oriented approximately north-south, with a bottom elevation estimated at El. 124 to El. 125.

HDD #89

HDD #89 is located to the southwest of a single CSX rail (oriented northwest-southeast), and passes below a small stream, which is generally oriented north-south. The majority of the HDD alignment is covered by brush and small trees, and has been mapped as wetland. Overhead utility poles are located immediately adjacent to and parallel the northwest portion of the HDD alignment.

In general the surface grades slope downward gently toward the south-southwest. However, moderate slopes are located on either side of the stream. The stream bottom is estimated to be at about El. 149.

The HDD entry is located to the southwest, with a surface grade of about El. 158 to El. 160 The HDD exit is located to the northwest, with surface grades of about El. 174 to El. 175. Both the entry and exit areas are covered by brush and small trees and have been mapped as wetlands.

The entirety of the HDD #89 alignments are located within the CSX right-of-way.

HDD #90

HDD #90 is located to the southwest of a single CSX rail (oriented northwest-southeast), and passes below the bank and wetland of a small stream, which is generally oriented northwest-southeast. HDD #90 also passes below Route 396 which is about 27-ft wide and oriented northeast-southwest. In this vicinity the CSX rails are elevated, and pass over Route 396 by means of steel bridge with concrete wing walls to the northeast of the crossing. In general, the site grades along the alignment slope downward toward the stream to the southwest.

Two (2) separate, northeast-southwest oriented overhead power lines cross the alignment in the Route 396 vicinity. Numerous power poles associated with these lines are located along the southeast portion if the HDD alignment.

The HDD #90 entry area is located to the southeast. This area is covered by small trees and brush, and mapped wetland is locate to the northeast. Surface grades in this immediate area range from about El. 157 to El. 159.

The HDD #90 exit area is located to the northwest. This area is covered by small trees and brush, and has been mapped as wetland. Surface grades in this immediate area range from about El. 157 to El. 159.

The surface grade of the adjacent CSX rail (northeast) ranges from about El. 165 to El. 166. The entirety of the HDD #90 alignments are located within the CSX right-of-way.

5.0 Below-grade Structures

5.1 Utilities

The location of existing known below-grade utilities are shown on the design drawings. Additional soft dig information will be evaluated during final design and prior to issued-for-construction drawing submittal. Minimum offsets between the known utilities and the HDD borepaths are included on the profiles.

5.2 Foundations

The location of existing foundations (bridges, retaining walls) will be added to the issued-for-construction drawings based on as-built information provided by others, where available.

6.0 Subsurface Conditions

The subsurface conditions in the vicinity of the HDD crossings were investigated by subsurface investigations and laboratory testing completed by others. Subsurface investigations included sampled test borings and cone penetrometer testing.

In general, the subsurface conditions at each of the 5b crossings are generally similar, and consist of surficial fill overlying glacial lake deposits consisting of silt and clay (loose to medium dense and very soft to soft), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth. It should be also noted that the glacial lake deposits contain extensive amounts of “Weight-of-Hammer” materials.

7.0 HDD Process

HDD involves drilling a small diameter (4 to 9-in) "pilot hole" along a pre-established, design alignment from and entry pit to an exit pit. The pilot is then enlarged as necessary by a series of reaming passes, and the product pipe or duct bundle is pulled into place. HDD generally does not require pits (or shafts), or dewatering. The depth and trajectory of the HDD needs to be carefully designed to account for subsurface conditions and the bending tolerances of the drill rods, steering limits of the drill tools, anticipated reaction of the subsurface conditions, and bending tolerances and the product pipe/conduit. All stages of the HDD process involve pumping a bentonite-based, environmentally safe drilling fluid into the borehole through the drill rods. The drilling fluid travels back to the surface within the annular space between the drill rods and surrounding soil. The drilling fluid maintains borehole stability, removes cuttings, and cools the drilling tools. A common risk associated with HDD is release of drilling fluid to the ground surface, which is referred to as an inadvertent return (IR) or "frac-out". This may occur when the downhole drill fluid pressure exceeds the confining capability of the surrounding soil, or if zones of weakness or previous disturbance are present (e.g., existing utilities, utility poles, deep foundations). Drilling fluid and drilling fluid additives are chemically inert, biodegradable, and non-toxic. However, the occurrence of a frac-out typically requires cleanup, may result in surface heave or settlement, and may result in borehole instability (e.g., collapse, squeezing).

8.0 Design Components

8.1 HDD Geometry

The proposed bore path alignments, entry and exit locations, entry angle, exit angle, and a vertical and horizontal design radii of curvature for each HDD crossing in this segment are shown in the design drawings. The HDD technical specifications are found in Section 33 05 07.13 of the Technical Specifications. Inadvertent release prevention and mitigation plans for each HDD crossing are provided as separate documents.

The HDD design alignments for Package 5b have been developed in general accordance with the Project Design Criteria Manual (document entitled "Project Design Criteria", Champlain Hudson Power Express, 400kV HVDC Underground Transmission Line, KIEWIT PROJECT NO. 104809, Dated June 2022, herein referred to as the "Design Manual").

8.2 Annular Pressure Analysis

Drill fluid loss from the borehole typically occurs as a result of one or a combination of the following:

- Hydraulic Jacking: Hydraulic jacking occurs when there are existing cracks in the formation such as fractures within bedrock or stiff cohesive soils, or relatively high permeability zones contained within a relatively low permeability materials (e.g. a sand lense in clay). When the drill fluid pressure exceeds the weight or force restraining the materials on the sides of the fracture or higher permeability zone, the confining material will be hydraulically jacked open resulting in an enlarged opening with more fluid volume capacity and eventually, the possibility of a new flow path for the fluid. The Total Stress calculations provides a conservative method for assessment of this type of drill fluid loss.

- Hydraulic Fracturing. Hydraulic fracturing occurs when the drill fluid pressure exceeds the static stress state in the formation *plus* the strength of the formation material. The result is a fracturing of the formation providing access for the drill fluid to a path that will continue to grow until the drill fluid pressure is reduced or the formation strength increases. The stress plus strength and the Kirsch methods may be used to assess this type of drill fluid loss in rock. In soil formations the Delft may be used to model for drill fluid loss when hydraulic fracturing occurs.

- Leakage: Flow of the drill fluid into existing open space, such as open bedrock fractures and soil porosity.

It's common to loose upwards of 30% (or more) of the drill fluid to the adjacent formation (soil and bedrock) during HDD construction. If the drill fluid reaches to ground surface or water (river) mudline, it's referred to as a "fracout" or inadvertent drill fluid return ("IR"). This may require conditioning of the borehole to stop the drill fluid loss, and cleanup of the drill fluid, if accessible.

A preliminary annular pressure analysis was completed for the pilot hole for each of the currently proposed HDD borepath geometries, based on the currently available geotechnical data. This process compares the anticipated range of downhole annular drill fluid pressures required to complete the pilot bore to the estimated confining capabilities of the surrounding geologic materials. This exercise can be useful in the evaluation of risk of inadvertent returns (IR's, or "fracout") during drilling. The potential for an IR may be considered greatest at locations where the anticipated range of downhole drill fluid

pressures are close to or exceed the estimated confining capabilities of the surrounding materials. Note that the pilot hole (vs the reamed hole) is generally the most constrained, and presents the greatest risk of IR during the HDD construction process.

The following should be noted:

- HDD requires drill fluid pressures sufficient to stabilize the borehole and remove cuttings. In general, it may be possible to reduce the risk of drill fluid loss through careful drilling and drill fluid management, but IR risk cannot be completely eliminated.
- The annular pressure analysis is considered to be a tool to identify areas of potential risk. *It is not considered an exact predictor of the location or degree of an IR.*
- The annular pressure analysis does not account for existing pathways or zones of weakness in the subsurface, which may be related to existing utilities, foundations, utility poles and below-grade space. Where present, these features will *increase* the risk of drill fluid loss.
- The annular pressure analysis is not an accurate predictor of borehole leakage, where drill fluid leaks to the adjacent materials through existing porosity or fractures.
- Drill fluid loss from the borehole may not migrate to the surface. In some cases, the drill fluid may escape to the surrounding formation through localized fractures, porosity, or dilation.

The anticipated range of downhole drill fluid pressures (combined static and dynamic) for each HDD crossing in Package 5b are shown in Appendix B along with a generalized subsurface profile for each bore. The static drill fluid pressure is a function of the density of the drill fluid at a specific location and depth below the drill entry elevation. The dynamic pressure is the pressure required to move the drill fluid (and cuttings) up the borehole annulus, and is a function of pump rates, hole geometry, fluid density, fluid velocity, and fluid rheology. The estimated annular pressures included in Appendix B are based on the API-13D method using a Power Law to model the dynamic pressure of a visco-plastic fluid.

Geotechnical parameters used in the analysis were derived through evaluation of laboratory testing and engineering judgement. The confining capability of the native materials was approximated using a variety of methods, which include the following:

- **Total Stress Model**: The Total Stress Model is based on the dead weight of the formation material above the drill path and excludes the potential strength of the formation. This method is considered *conservative* but is considered a reasonable approximation for the formation pressure capacity of bedrock and very dense soil.

- **Cavity Expansion Model (Delft Equation)**: This method considers the strength of the formation along with the total stress (above) and is based on Ko = 1 conditions. The initial equation was derived from the Mohr-Coulomb failure model adjusted by Delft University for low angle cylindrical cavity expansion in a host material when subjected to internal pressure. This method has been found more realistic in sand, silt, and stiffer cohesive formations than the Total Stress Model. However the method require assumptions of a horizontal surface with homogeneous isotropic soil. Additionally, the equations require significant property assumptions such as the Shear Modulus, G. *This model is not generally appropriate for most bedrock, particularly hard sedimentary bedrock, and metamorphic and igneous lithologies.*

- **Stress plus Strength Model**: This method was initially implemented by the US Corps of Engineers to assess the damage potential to levees from the HDD fluids during drilling. This model adds the strength of the formation material to the total stress though results are generally considered to be conservative. The basis of the model, like the cavity expansion model is the Mohr-Coulomb failure approach. This model is generally appropriate for soil or bedrock.

- **Queens Model**: The Queens model was developed at Queens University. This model also adds the strength of the formation material to the total stress. The basis of this model, similar to the cavity expansion model is the Mohr-Coulomb failure approach. The difference between this model and the Delft model is that the Queens approach permits variation in the Ko of the soil and is considered more realistic in softer cohesive soils.

Additional input assumptions included:

- Jetting tools will be used for fill, lacustrine and glaciofluvial deposits.
- A mud motor will be used to complete the pilot hole for bores encountering glacial till and bedrock.
- A drill fluid pump rate of 150 gpm for pilots using jetting and a drill fluid pump rate 400 gpm for mud motors.

- An average drill fluid density of 78 pcf, and maximum drill fluid density of 94 pcf.
- An estimated drill bit diameter of 8.16 inches and a drill rod diameter of 3.5 inches.

The results of the annular pressure analyses included in Appendix B suggest that each of the 5b HDD centerlines will encounter very soft silty fat clays with very low strength characteristics, Weight of Hammer (W.O.H.) materials, with a stronger lean clay layer above, providing some pressure capacity for the drills.

- For these 4 crossings, there is an apparent risk of IR for the entire length of each bore. This is due to the poor strength characteristics (W.O.H. material) of the formation and equates to limited confining capabilities. At these locations careful consideration during drilling operations needs to be given to maintain borehole stability.
- In W.O.H materials, it is common to lose returns without IR, as the formation dilates. However, this may require additional drill fluid volumes and hole conditioning.
- HDDs #89 and #90 have critical areas with Factors of Safety below 1.0.
    - Contingency plans for track movement and impact should be developed in coordination with the Owner prior to executing the work.
    - The adjacent railroad tracks should be monitored in close coordination with the Owner prior to, continuously throughout operations, and 1-2 weeks post installation.

The HDD contractor(s) should be prepared to monitor the downhole drill fluid pressures in each bore, and respond to elevated pressures and drill fluid loss. The Inadvertent Return Contingency Plan details additional methods for mitigating inadvertent returns.

8.3 Conduit Material Selection

The conduit installed by HDD for the CHPE project must be plastic to satisfy cable ampacity requirements. The conduit must also be designed to withstand the short-term installation (pullback) loads, and the long-term external loads.

The conduit selected for the Package 5b HDD installations is PE4710 DR9 High Density Polyethylene (HDPE), consistent with the requirements of the Design Manual. Note that we have assumed that the telecommunications conduit will be minimum 3-in diameter (versus 2-in) to improve pullback survivability.

Pullback calculations for each HDD crossing are included in Appendix B, along with the conduit details. These will be updated during final design. These calculations have been developed in general accordance with ASTMF-1962 as modified to account for invert tangent section, independent vertical curves, and fluid drag. The safe pull force has been calculated in accordance with recommendations of the Plastic Pipe Institute. Both water ballasted and unballasted conduit have been considered. Water ballasting is recommended to reduce the pull force in each case.

It should be noted that HDPE is assembled through butt-fusion, which creates an internal "bead" which must be removed during fusion ("debeading") to reduce risk of cable damage during cable pulling.

9.0 Construction Considerations

The following construction considerations are presented for discussion purposes.

9.1 Subsurface Conditions

The following soils encountered along the package 5b alignment present specific construction considerations:

- Fill: Fill soils were encountered at each of the HDD crossing locations. These materials are expected to be uncontrolled, and could contain obstructions to HDD construction, including debris, abandoned utilities, cobbles and boulders, and trash. In addition, fill soils located within and adjacent to railway easements may contain contamination which could impact the performance of HDD drill fluid, requiring more frequent replacement. Drill fluid containing contamination may require specialized disposal.
- Glacial Lake Deposits: Glacial Lake Deposits (fine sand, silt, clay) were encountered at numerous HDD crossing locations. Where soft to very soft, fine grained soils are present, squeezing behavior may result in choking of the hole and increased risk of downhole pressure spikes and inadvertent drill fluid returns. Drill fluid additives and frequent hole conditioning may be required to control this behavior. In addition, very soft soils may present difficulties in maintaining the drill tool alignment.
    - In W.O.H materials, it can be common to lose returns without IR, as the formation dilates. However, this may require additional drill fluid volumes and hole conditioning.

9.2 Steering Tools

A downhole steering tool will be required for each HDD to maintain the desired alignment, and offsets from adjacent sensitive structures. Walkover steering tools are not considered appropriate to potential magnetic interference associated adjacent utilities and railroad structures, and (depending on the crossing) the depth of the installation.

9.3 Drill Fluid Pressure Monitoring

The HDD contractor should employ a downhole pressure tool during pilot hole drilling to monitor and the annular drill fluid pressures. This will help maintain pressure levels below an established threshold, reduce risk of IR's, and may provide details on locations where drilling fluid is lost.

9.4 Conduit Laydown and Pullback

As-noted, butt-fused plastic conduit (HDPE) used for cable raceway must be completely assembled and de-beaded prior to pullback. This will require significant work space in each case. The conduit is typically assembled during drilling, and will need to be protected prior to installation.

In each case, pullback of the conduit should be completed without interruption to reduce the risk of the conduit becoming stuck and damaged. We recommend that the conduit be fully water-ballasted to reduce the pullback forces.

10.0 References

American Petroleum Institute (API) API Specification 13A, Specification for Drilling-Fluid Materials - Sixteenth Edition, ANSI/API 13A/ISO 13500, July 2004.

ASTM 1962-20: Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings, ASTM 2005

Kennedy, M., Skinner, G and I Moore, 2004, Elastic Calculations of Limiting Mud Pressures to Control Hydro-fracturing During HDD, NASTT No-Dig 2004 Proceedings.

Mayne, P.W., and Kulhawy, F.H. (1990). Manual on Estimating Soil Properties for Foundation Design. Electric Power Research Institute (EPRI).

Mechanics of Hydraulic Fracturing, 1957, M.K. Hubert and D.W. Willis, Shell Development Co., AIME Petroleum Transactions.

Plastic Pipe Institute, Handbook of PE Pipe - Second Edition, https://plasticpipe.org/publications/pe-handbook.html.

US Army Corps of Engineers EM 1110-2-2902a December 31, 2020, Conduits, Pipes, and Culverts Associated with Dams and Levee Systems.

APPENDIX A
GEOTECHNICAL DATA

Kiewit

MEMORANDUM

DATE: November 7, 2022

TO: Nick Strater; Brierley Associates Underground Engineers, PLLC

FROM: Matthew Hawley, P.E.; Kiewit Engineering (NY) Corp. MKH
Jaren Knighton; Kiewit Engineering (NY) Corp.

SUBJECT: Geotechnical Data: Segment 9 - HDD Crossing 87.B – Revision 1
Champlain Hudson Power Express Project
Schenectady, New York

Kiewit Engineering is providing the attached geotechnical data for use in the horizontal direction drill (HDD) design for the Champlain Hudson Power Express project in Upstate New York. This HDD crossing is located south of Schenectady, New York. The approximate station for the start of HDD crossing Number 87.B is STA 51111+00 (42.5604° N, 73.8506° W).

The geotechnical data at this HDD crossing is attached. The available data is from the recent investigation by Terracon, referenced below.

- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express-Package 5, Schenectady through Selkirk, dated April 4, 2022.

Contact us if you have questions or require additional information.

HDD 87.B
Borings K-194.0-2.2A,
K-194.0-2.2B
Segment 9 - Design Package 5

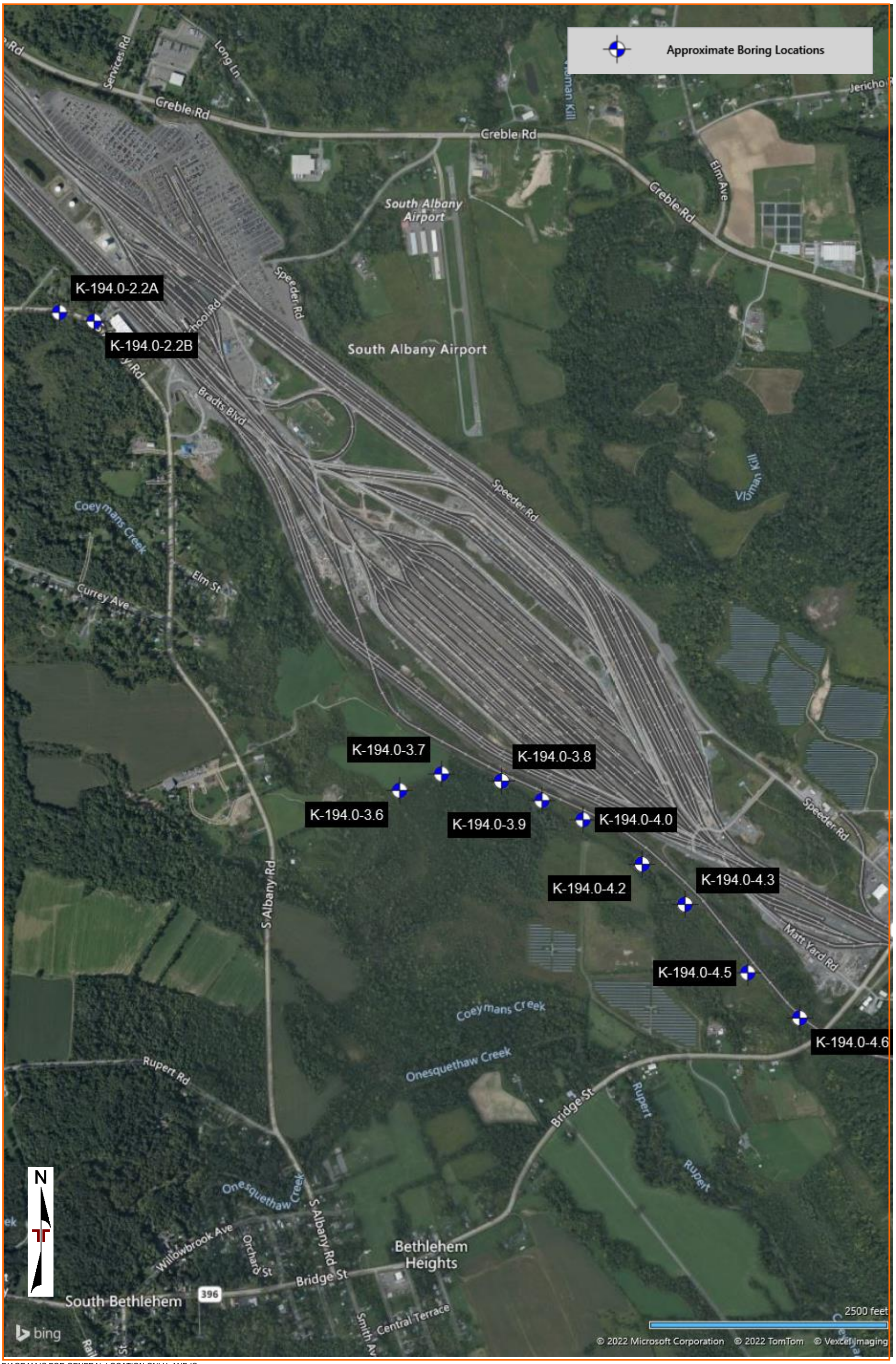


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. K-194.0-2.2A

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.560366° Longitude: -73.849816°

Surface Elev.: 164.02 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.2	164	**TOPSOIL**
		FILL - SANDY SILT WITH GRAVEL (ML), brown, stiff
2.0	162	**SILT AND CLAY (CL-ML)**, brown, medium stiff to stiff
		grades with sand
12.0	152	**SILT AND CLAY (CL-ML)**, gray, very soft to stiff

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		18	12-11-7-9 N=18				
		18	10-5-4-4 N=9	2.75 (HP)			
5		16	3-2-3-3 N=5	2.25 (HP)			
		20	5-5-6-7 N=11	2.5 (HP)			
		20	5-6-6-7 N=12	2.0 (HP)	34.3	40-25-15	82
10		22	3-3-4-4 N=7	1.75 (HP)			
	▽						
15		24	2-1-1-2 N=2	< .25			
20		8	4-3-9-10 N=12	< .25	26.7		
25		24	WOH-WOH-WOH-WOH	< .25			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *At completion of drilling*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-03-2022 | Boring Completed: 02-03-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-2.2A

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.560366° Longitude: -73.849816°

Surface Elev.: 164.02 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		SILT AND CLAY (CL-ML), gray, very soft to stiff *(continued)*									
			30								
	32.0	132				24	WOH-WOH-WOH-WOH 3" Splt Spoon With Ring Samplers	< .25	36.4	33-19-14	93
		Boring Terminated at 32 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *At completion of drilling*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-03-2022 | Boring Completed: 02-03-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-2.2B

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings
Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.560181° Longitude: -73.848449°

Surface Elev.: 173.65 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.8	173	**FILL - POORLY GRADED GRAVEL**, gray, very dense
1.0	172.5	**FILL - ASPHALT FRAGMENTS**, black, very dense
2.0	171.5	**FILL - POORLY GRADED GRAVEL WITH SILT AND SAND**, brown, very dense
		FILL - SILT AND CLAY, brown, very stiff to very hard
		Gravel seam at 4 feet
6.0	167.5	**SILT AND CLAY (CL-ML)**, brown, stiff to very stiff
12.0	161.5	**SILT AND CLAY (CL-ML)**, gray, very soft
		silt seam noted

DEPTH (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	20	25-85-69-31 N=154				
	20	8-9-8-8 N=17				
		100/4"				
5	22	2-4-6-6 N=10	2.5 (HP)			
	24	8-10-11-12 N=21		25.9	36-21-15	93
10	24	4-5-7-7 N=12				
15	24	WOH-WOH-WOH-WOH	< .25	31.9		
20	24	WOH-WOH-WOH-WOH	< .25			
25	24	WOH-WOH-WOH-WOH	< .25			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

While drilling

At completion of drilling

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-03-2022 | Boring Completed: 02-03-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-2.2B

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.560181° Longitude: -73.848449°

Surface Elev.: 173.65 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		SILT AND CLAY (CL-ML), gray, very soft *(continued)*	30			24	WOH-WOH-WOH-WOH 3" Split Spoon With Ring Samplers	< .25	33.9	34-19-15	86
	35.0	138.5	35			24	WOH-WOH-WOH-WOH	< .25			
		Boring Terminated at 35 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

While drilling

At completion of drilling

Terracon
30 Corporate Cir Ste 201
Albany, NY

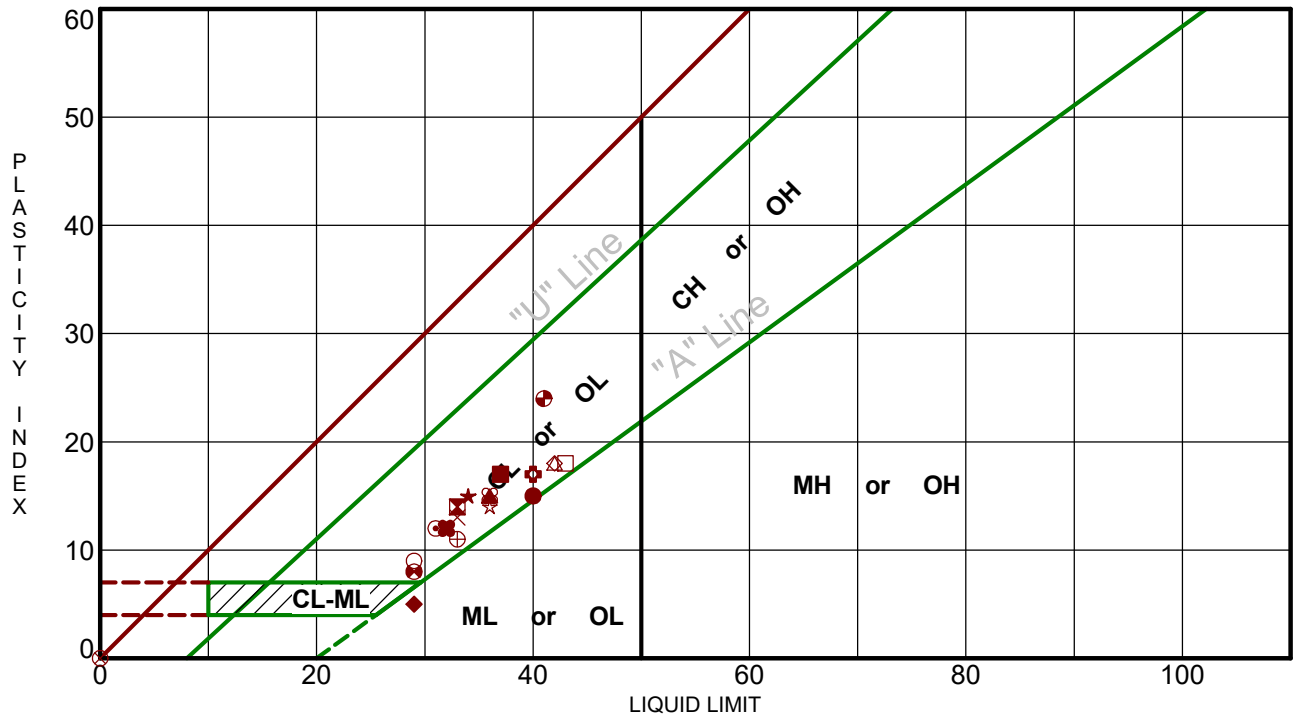
Boring Started: 02-03-2022 | Boring Completed: 02-03-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	K-194.0-2.2A	8 - 10	40	25	15	82.2	CL	LEAN CLAY with SAND
⊠	K-194.0-2.2A	30 - 32	33	19	14	92.9	CL	LEAN CLAY
▲	K-194.0-2.2B	8 - 10	36	21	15	92.5	CL	LEAN CLAY
★	K-194.0-2.2B	29 - 31	34	19	15	86.5	CL	LEAN CLAY
⊙	K-194.0-3.8	10 - 12	31	19	12	94.8	CL	LEAN CLAY
✿	K-194.0-3.8	38 - 40	40	23	17	81.8	CL	LEAN CLAY with SAND
○	K-194.0-3.9	15 - 17	29	20	9	94.3	CL	LEAN CLAY
△	K-194.0-3.9	33 - 35	42	24	18	89.9	CL	LEAN CLAY
⊗	K-194.0-4.0	8 - 10	NP	NP	NP	79.8	ML	SILT with SAND
⊕	K-194.0-4.0	28 - 30	33	22	11	94.4	CL	LEAN CLAY
□	K-194.0-4.2	8 - 10	43	25	18	75.7	CL	LEAN CLAY with SAND
⊠	K-194.0-4.2	28 - 30	29	21	8	94.5	CL	LEAN CLAY
◕	K-194.0-4.3	8 - 10	41	17	24	85.3	CL	LEAN CLAY
☆	K-194.0-4.3	19 - 21	36	22	14	95.8	CL	LEAN CLAY
⊠	K-194.0-4.3	35 - 37	36	21	15	94.7	CL	LEAN CLAY
■	K-194.0-4.5	15 - 17	37	20	17		CL	LEAN CLAY
◆	K-194.0-4.5	29 - 31	29	24	5	98.7	ML	SILT
◇	K-194.0-4.6	15 - 17	42	24	18	67.4	CL	SANDY LEAN CLAY
✕	K-194.0-4.6	30 - 32	33	20	13	95.1	CL	LEAN CLAY
■	K-194.0-4.6	43 - 45	32	20	12	98.0	CL	LEAN CLAY

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

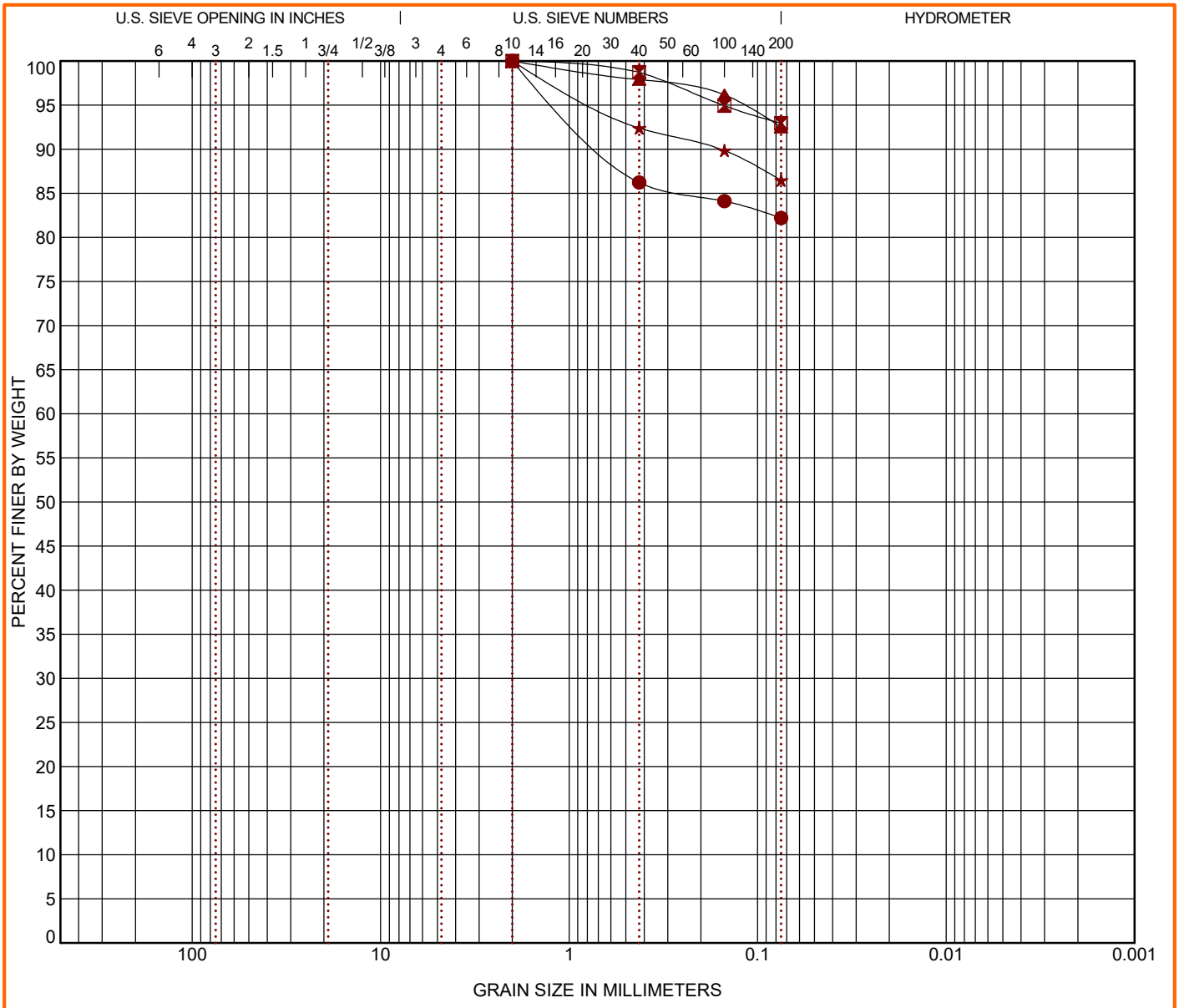
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-2.2A	8 - 10	LEAN CLAY with SAND (CL)	34.3	40	25	15		
⊠	K-194.0-2.2A	30 - 32	LEAN CLAY (CL)	36.4	33	19	14		
▲	K-194.0-2.2B	8 - 10	LEAN CLAY (CL)	25.9	36	21	15		
★	K-194.0-2.2B	29 - 31	LEAN CLAY (CL)	33.9	34	19	15		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-2.2A	8 - 10	2				0.0	0.0	17.8		82.2	
⊠	K-194.0-2.2A	30 - 32	2				0.0	0.0	7.1		92.9	
▲	K-194.0-2.2B	8 - 10	2				0.0	0.0	7.5		92.5	
★	K-194.0-2.2B	29 - 31	2				0.0	0.0	13.5		86.5	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 3/30/22

Kiewit

MEMORANDUM

DATE: February 13, 2023

TO: Nick Strater; Brierley Associates Underground Engineers, PLLC

FROM: Matthew Hawley, P.E.; Kiewit Engineering (NY) Corp. MKH
Jaren Knighton; Kiewit Engineering (NY) Corp.

SUBJECT: Geotechnical Data: Segment 9 – Package 5 – HDD Crossing 88 – Revision 1
Champlain Hudson Power Express Project
Selkirk, New York

Kiewit Engineering is providing the attached geotechnical data for use in the horizontal direction drill (HDD) design for the Champlain Hudson Power Express project in Upstate New York. This HDD crossing is located south of Schenectady, New York. The approximate station for the start of HDD crossing Number 88 is STA 51179+50 (42.5454° N, 73.8403° W).

The geotechnical data at this HDD crossing is attached. The available data is from the previous investigation by AECOM and the recent investigations by Terracon, referenced below.

- AECOM, Geotechnical Data Report, Upland Segments, Champlain Hudson Power Express, dated May 28, 2021.
- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express-Package 5, Schenectady through Selkirk, dated April 4, 2022.
- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express – Additional HDD Borings – Phase 3, Fort Ann to Coxsackie, dated November 3, 2022.

Contact us if you have questions or require additional information.

HDD 88
Borings SY-7,SY-8,
K-194.0-3.6, K-194.0-3.7,
KB-194.0-3.6B
Segment 9 - Design Package 5

CHPE Segment 8 & 9 - Package 5
HDD Soil Boring Coordinates and Elevations

Firm	Boring	Northing (feet)	Easting (feet)	Ground Surface Elevation (feet)
TRC*	A179.6-1	1433335.8	631009.7	332.5
	A182.4-1	1420048.2	636557.9	291.5
	A187.65-1	1394856.5	644775.4	327.7
	A191.05-1	1378814.5	652321.0	274.7
	A191.82-1	1375154.9	654314.3	257.1
	A192.9-1	1370644.3	657458.6	232.8
	B177.1-1	1445275.2	626125.8	347.3
	B177.6-1	1442944.0	627003.0	346.5
	B178.01-1	1440838.2	627828.3	368.5
	B178.9-1	1436461.4	629767.4	322.1
	B180.1-1	1431140.9	631965.3	310.4
	B180.9-1	1427158.5	633611.8	307.5
	B182.9-1	1417657.6	637123.9	291.5
	B183.2-1	1415871.4	637202.5	290.2
	B184.3-1	1410133.0	637597.6	324.0
	B184.8-1	1408223.8	638230.4	323.1
	B185.6-1	1403875.9	639489.9	328.2
	B188.0-1	1392812.4	645793.4	330.9
	B188.35-1	1391616.5	646333.6	333.4
	B188.51-1	1390815.1	646697.7	340.2
	B190.0-1	1383732.6	649743.4	296.3
	B190.1-1	1383134.9	649975.5	294.6
	B190.8-1	1379726.2	651827.2	282.3
	B192.4-1	1372732.4	655878.1	239.3
	B193.5-1	1367919.2	659547.5	218.6
AECOM**	RS-2	1436092.2	629800.7	315.6
	RS-3	1418336.4	636985.0	303.2
	RS-4	1414567.4	637285.8	302.2
	RS-5	1411399.1	637471.6	319.0
	RS-7A	1391599.9	646333.6	340.5
	RS-9	1372089.8	656230.9	238.7
	SY-7	1353089.8	670133.9	159.8
	SY-8	1353716.5	671626.7	175.0
	SY-9	1353046.4	673133.41	163.1
	SY-9A	1351940.0	674314.3	158.3
	SY-10	1350838.3	675488.6	166.0
	SCH-19	1446199.8	625927.0	333.8
	SCH-19A	1445712.1	626032.4	343.1

Notes:

- Northings and Eastings are provided in NAD83 New York State Plane East Zone.
- Elevations are referenced to the NAVD88 datum.

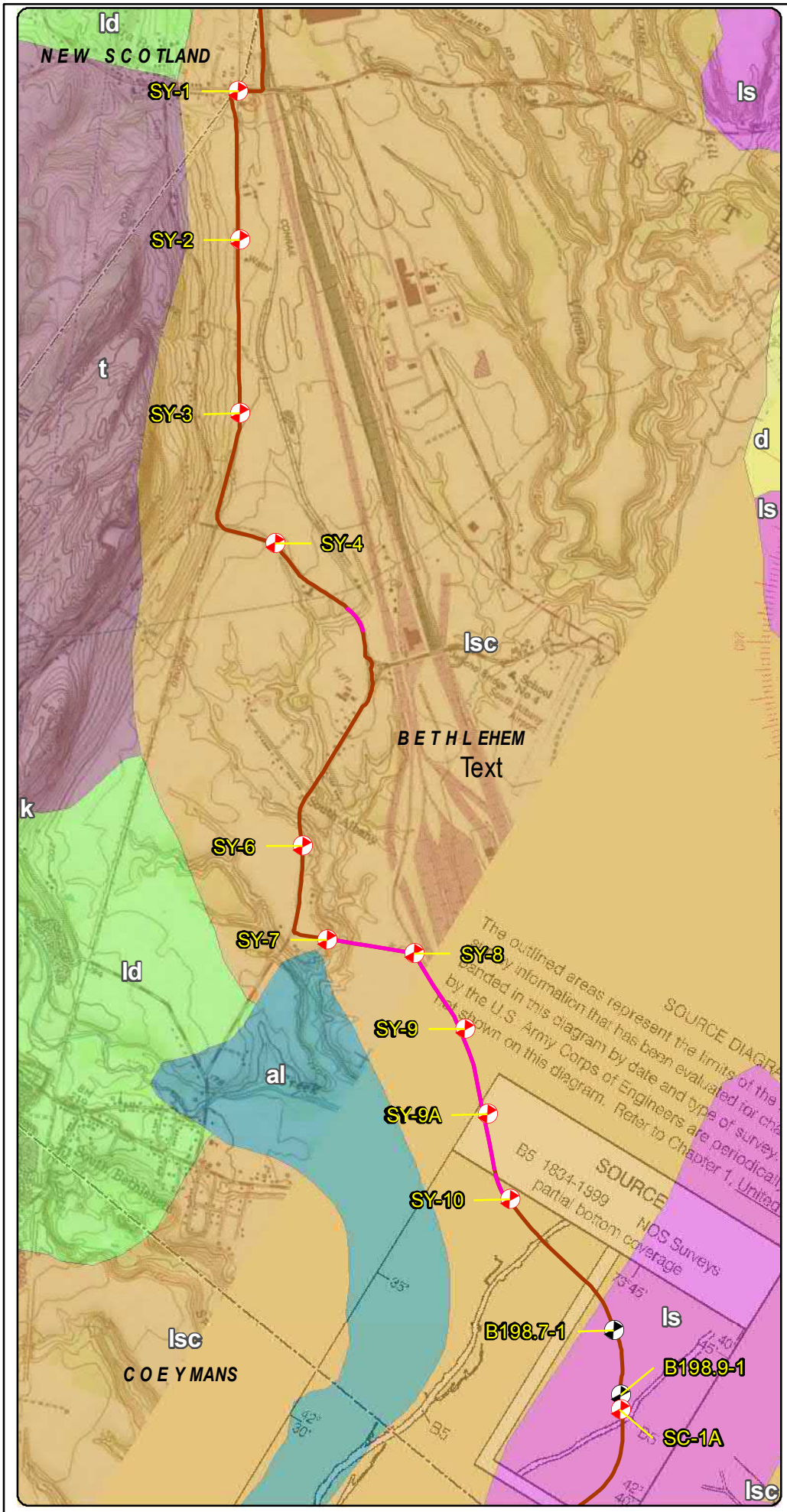
* TRC boring coordinates as shown in Table 1-6 in AECOM report (reference below). Boring elevations estimated from November 2021 topographic survey by Williams Aerial.

** AECOM boring coordinates and elevations as shown in Table 1-6 in AECOM report.

*** Kiewit boring coordinates and elevations are noted on the boring logs.

Reference:

AECOM, Geotechnical Data Report, Upland Segments: Putnam Station, Washington County, to Cementon, Green County, NY, Champlain Hudson Power Express, dated May 28, 2021.



LEGEND

- 2021 Boring Location
- Previous (2013) Boring Location
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- Town Boundary
- County Boundary

Surficial Geology

- al - Recent alluvium
- d - Dunes
- k - Kame deposits
- ld - Lacustrine delta
- ls - Lacustrine sand
- lsc - Lacustrine silt and clay
- t - Till

0.25 0.125 0 0.25 Miles

Transmission

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

Surficial Geology and Geotechnical Borings
Selkirk Rail Yard Bypass
Figure 3-9

Prepared on 4/30/2021
by: AECOM

DATA SOURCES: ESRI, NYSDOT, NOAA, USACE, NYDOS, TDI, TRC

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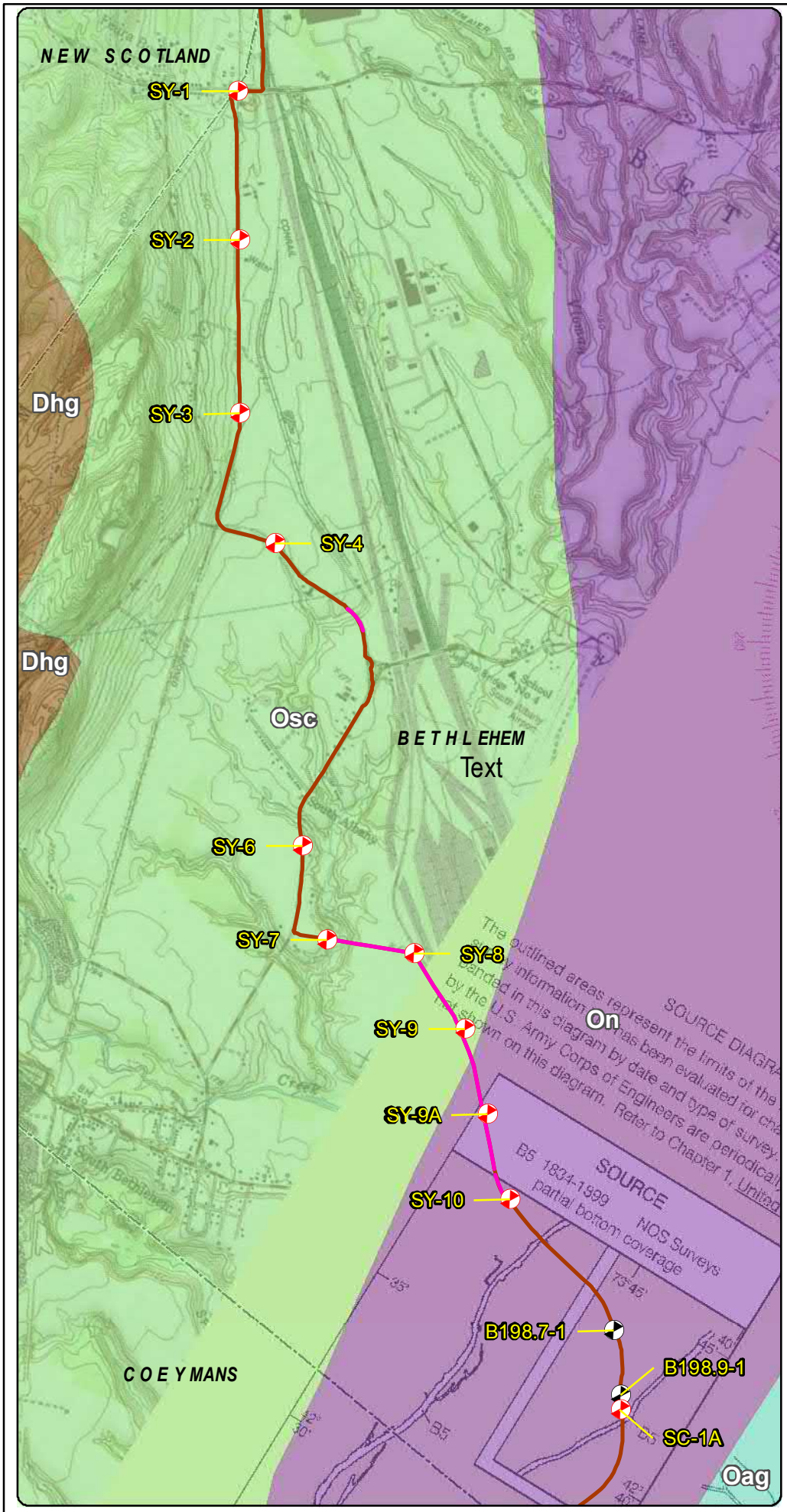

LEGEND

- 2021 Boring Location
- Previous (2013) Boring Location
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- Town Boundary
- County Boundary

Bedrock Geology

- Dhg - Port Ewen Formation
- Oag - Austin Glen Formation
- On - Normanskill Shale
- Osc - Schenectady Formation

* Schenectady Formation includes: graywacke, sandstone, siltstone, shale

0.25 0.125 0 0.25 Miles

Transmission

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

Bedrock Geology and Geotechnical Borings
Selkirk Rail Yard Bypass
Figure 4-9

Prepared on 4/30/2021
by: AECOM

DATA SOURCES: ESRI, NYSDOT, NOAA, USACE, NYDOS, TDI, TRC

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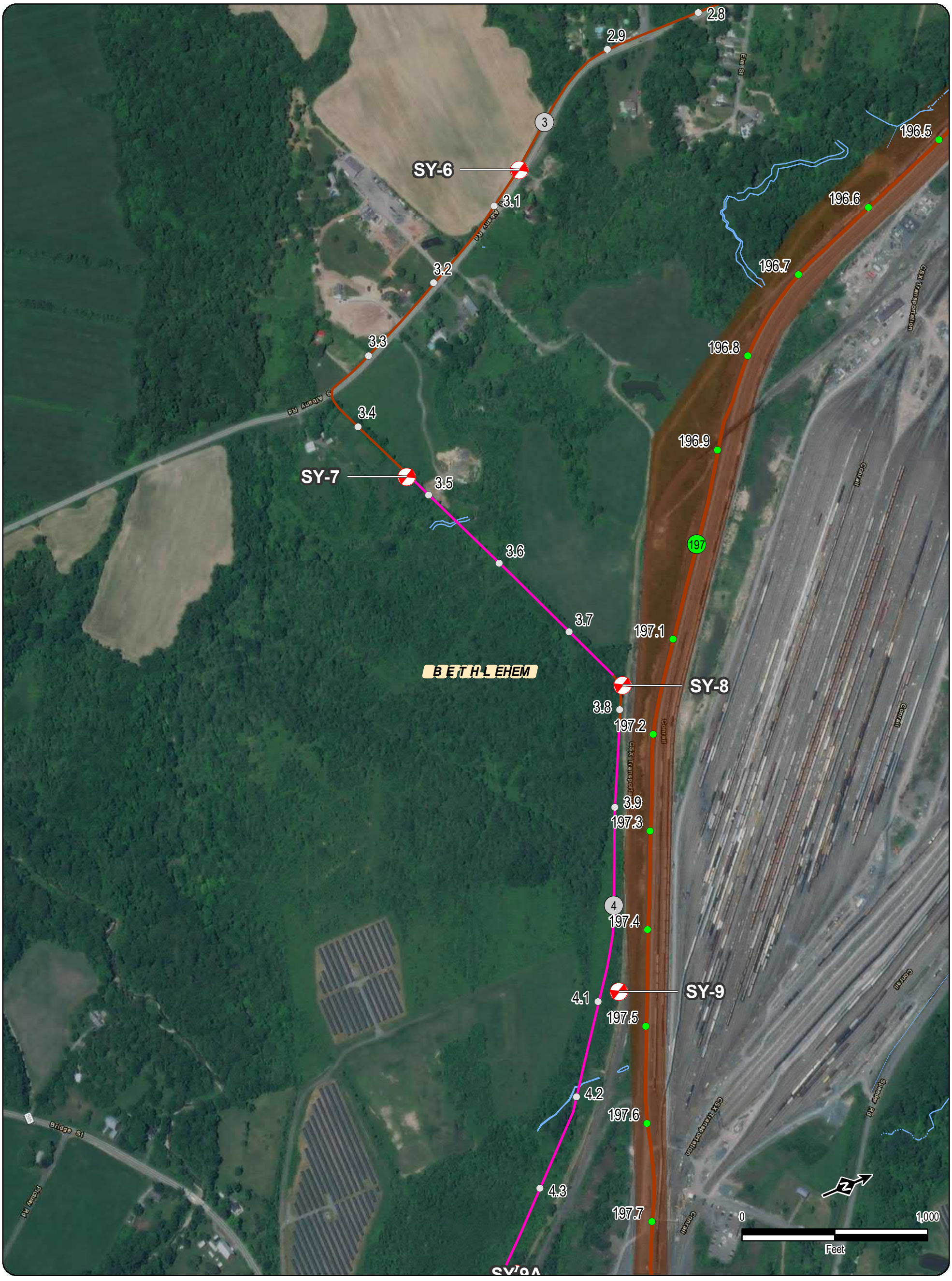

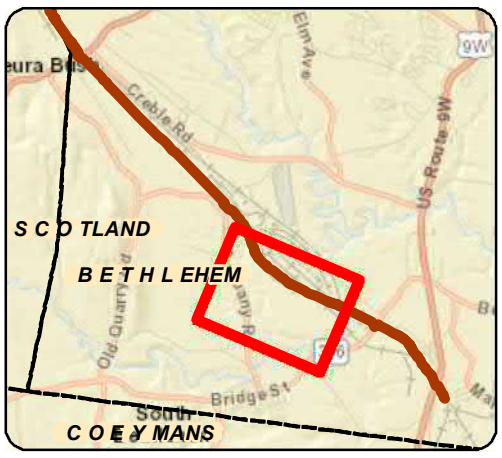

LEGEND

- 111.8 Certified Milepost - Tenths
- 135 Certified Milepost
- 111.8 Preferred Alternative Milepost - Tenths
- 135 Preferred Alternative Milepost
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- 2021 Boring Location
- Previous (2013) Boring Location
- Streams/Ditches
- Railroad ROW
- Deviation Zone
- Deviation Zone Outside ROW
- Preferred Alternative Deviation Zone
- Preferred Alternative Deviation Zone Outside ROW
- Town Boundary
- Village Boundary
- State Park (OPRHP)
- Reported Buried Structure

Parcel Ownership: TOWN NAME

Road Name: Village Name

Transmission Developers Inc.

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

BORING LOCATION PLAN

Selkirk Rail Yard Bypass

Figure A-9

Sheet 3 of 4

Prepared by: AECOM 5/19/2021

DATA SOURCES: ESRI, NETWORK MAPPING 2010, NYSDOT, OPRHP, TDI, TRC

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BORING CONTRACTOR: ADT														SHEET 1 OF 2	
DRILLER: Chris Chaillou														PROJECT NAME: CHPE -	
SOILS ENGINEER/GEOLOGIST: Chris French														PROJECT NO.: 60323056	
LOCATION: Selkirk, NY - MP 3.50														HOLE NO.: **SY-7**	
GROUND WATER OBSERVATIONS				CASING		SAMPLER		DRILL BIT		CORE BARREL				START DATE: 2/15/21	
Water at 8' (inferred)			TYPE	Flush Joint Steel		California Modified		Tricone Roller Bit						FINISH DATE: 2/15/21	
			SIZE I.D.	4"		2.5"		- -						OFFSET: N/A	
			SIZE O.D.	4.5"		3"		3 7/8"						DRILL RIG: CME LC-55	
			HAMMER WT.	140 lbs		140 lbs								BORING TYPE: SPT	
			HAMMER FALL	30"		30"								BORING O.D.: 4.5"	
														SURFACE ELEV.:	
														LONGITUDE:	
														LATITUDE:	

DEPTH	CORING RATE MIN/FT	SAMPLE DEPTHS FROM - TO (FEET)	SAMPLE TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.(2)	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		0'-5'				Hand Cleared					OL		0'-1.1'; Black SILT, some fine-medium sand, organics; medium stiff, moist
1.0											ML		1.1'-5.0'; Brown clayey SILT, little fine sand; medium stiff, moist
2.0													
3.0													TR-1; (3.0'-5.0')
		3'-5'	S-1										
4.0													
5.0													
		5'-7'	S-2	24"	24"	9	15	18	17	21	ML		Brown clayey SILT, trace fine sand; stiff, moist
6.0													
7.0													
		7'-9'	S-3	24"	24"	12	15	16	21	10	ML		Brown clayey SILT; stiff, moist
8.0													TR-2; (8.0'-8.5')
9.0													
		9'-11'	S-4	24"	24"	6	9	11	10	13	ML	Clayey SILT	Brown clayey SILT; medium stiff, moist
10.0													
11.0													
		11'-'13'	S-5	24"	24"	6	8	10	11	12	ML		SAA
12.0													TR-3; (12.0'-12.5')
13.0													
		13'-15'	S-6	24"	24"	5	7	7	7	9	ML		SAA
14.0													
15.0													
		15'-17'	S-7	24"	24"	5	5	7	8	8	MH		Brown clayey SILT; soft, saturated
16.0													16.0'-17.0'; Gray CLAY and silt; soft, wet
17.0													
18.0													18.5' (*inferred*)
19.0												CLAY and SILT	
20.0													

NOTES:

(1) Thick-wall ring lined drive sampler (California sampler) used for SPT samples. Rings dimensions = 2-1/2" O.D. by 2-7/16" I.D. by 6" length.

(2) Correction factor: $Ncorr=N*(2.0^2-1.375^2)in./(3.0^2-2.4^2)in. = N*0.65$.

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT	AECOM		SHEET 2 OF 2
			PROJECT NAME: CHPE -
DRILLER: Chris Chaillou			PROJECT NO.: 60323056
			HOLE NO.: **SY-7**
SOILS ENGINEER: Chris French			START DATE: 2/15/21
			FINISH DATE: 2/15/21
LOCATION: Selkirk, NY - MP 3.50			OFFSET: N/A

DEPTH	CORING RATE MIN/FT	DEPTHS FROM - TO (FEET)	TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		20'-22'	S-8	24"	24"	1	3	4	4	5	CH		Gray CLAY and silt; soft, wet
21.0													
22.0													
23.0													
24.0													
25.0													
		25'-27'	S-9	24"	24"	WOH	4	4	5	5	CH		SAA
26.0													
													TR-4; (26.0'-26.5')
27.0													
28.0													
29.0													
30.0													
		30'-32'	S-10	24"	24"	WOH/9"	2	6	7	5	CH	CLAY and SILT	Gray silty CLAY; soft, wet
31.0													
32.0													
33.0													
34.0													
35.0													
		35'-37'	S-11	24"	24"	WOH/9"	2	4	5	4	CH		SAA
36.0													
													TR-5; (36.0'-36.5')
37.0													
38.0													
		38'-40'	S-12	24"	24"	WOH/19"		2	6	1	CH		SAA
39.0													
40.0													
													SY-7 terminated at 40', grouted to surface
41.0													
42.0													
43.0													
44.0													
45.0													

NOTES:

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER/GEOLOGIST: Chris French

LOCATION: Selkirk Yard MP - 3.78

AECOM

Boring Log

SHEET 1 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-8**

START DATE: 02/26/2021

FINISH DATE: 02/26/2021

OFFSET: N/A

DRILL RIG: CME LC-55

BORING TYPE: SPT

BORING O.D.: 4.5"

SURFACE ELEV.:

LONGITUDE:

LATITUDE:

GROUND WATER OBSERVATIONS		CASING	SAMPLER	DRILL BIT	CORE BARREL
	TYPE	Flush Joint Steel	California Modified	Tricone Roller Bit	
	SIZE I.D.	4"	2.5"	- -	
	SIZE O.D.	4.5"	3"	3 7/8"	
	HAMMER WT.	140 lbs	140 lbs		
	HAMMER FALL	30"	30"		

DEPTH	CORING RATE MIN/FT	SAMPLE DEPTHS FROM - TO (FEET)	SAMPLE TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.(2)	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		0'-5'				Hand Cleared					CL		Brown CLAY and SILT, trace fine sand, trace organics, medium stiff, moist
1.0													1.1': Brown CLAY and SILT, trace fine sand, medium stiff, moist
2.0													
											CL		
3.0													TR-1; (3.0'-5.0')
		3'-5'	S-1										
4.0													
5.0													
		5'-7'	S-2	24"	19"	5	12	8	18	13	ML	SILT AND CLAY	Brown SILT and CLAY, stiff, moist
6.0													
7.0													
		7'-9'	S-3	24"	24"	13	14	16	13		ML		Brown clayey SILT, stiff, moist
8.0													TR-2; (8.0'-8.5')
9.0													
		9'-11'	S-4	24"	24"	4	8	9	11		ML		SAA
10.0													
11.0													
		11'-'13'	S-5	24"	24"	6	8	10	11				Brown clayey SILT and gray silty CLAY, medium stiff, moist
12.0													TR-3;(12.0'-12.5')
13.0													
		13'-15'	S-6	24"	24"	1	2	3	4		CH		Gray silty CLAY, some gray silt and clay, soft, wet
14.0													
15.0													
		15'-17'	S-7	24"	24"	2	3	4	4		CH		SAA
16.0												Silty CLAY	
17.0													
18.0													
19.0													
20.0													

NOTES:

(1) Thick-wall ring lined drive sampler (California sampler) used for SPT samples. Rings dimensions = 2-1/2" O.D. by 2-7/16" I.D. by 6" length.

(2) Correction factor: $N_{corr}=N*(2.0^2-1.375^2)in./(3.0^2-2.4^2)in. = N*0.65$.

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER: Chris French

LOCATION: Selkirk Yard MP - 3.78

AECOM

Boring Log

SHEET 2 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-8**

START DATE: 02/26/2021

FINISH DATE: 02/26/2021

OFFSET: N/A

DEPTH	CORING RATE MIN/FT	DEPTHS FROM - TO (FEET)	TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		20'-22'	S-8	24"	24"	WOH	3	3	5	4	CH		Gray silty CLAY, soft, wet
21.0													
22.0													
23.0													
24.0													
25.0													
		25'-27'	S-9	24"	24"	WOH	2	4	4	4	CH		SAA
26.0													TR-4; (26.0'-26.5')
27.0													
28.0													
29.0													
30.0													
		30'-32'	S-10	24"	24"	WOH	1	4	4	3	CH	Silty CLAY	SAA
31.0													
32.0													
33.0													
34.0													
35.0													
		35'-37'	S-11	24"	24"	WOH	WOH	4	5	3	CH		SAA
36.0													TR-5; (36.0'-36.5')
37.0													
38.0													
		38'-40'	S-12	24"	24"	WHO/8"	2	4	6	4	CH		SAA
39.0													
40.0													
													SY-8 terminated at 40 fbg
41.0													
42.0													
43.0													
44.0													
45.0													

NOTES:

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

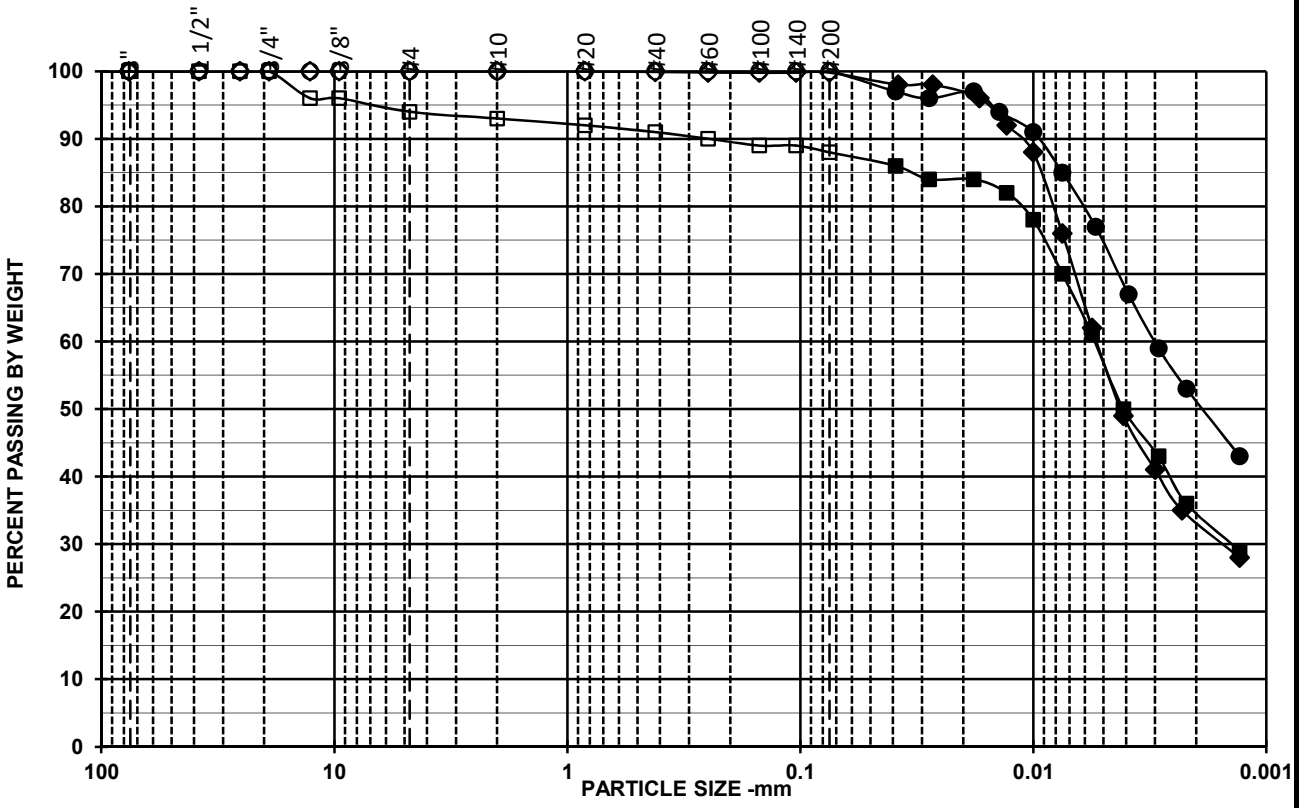
SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

Aquifer
CHPE- Selkirk Bypass Borings
LABORATORY SOIL TESTING DATA SUMMARY

BORING NO.	SAMPLE NO.	DEPTH (ft)	IDENTIFICATION TESTS							REMARKS
			WATER CONTENT (%)	LIQUID LIMIT (-)	PLASTIC LIMIT (-)	PLAS. INDEX (-)	USCS SYMB. (1)	SIEVE MINUS NO. 200 (%)	HYDROMETER % MINUS 2 μm (%)	
SY-1	S-2	5-7	25.6	34	20	14	CL	97	26	
SY-1	S-4	9-11	23.4	37	20	17	CL	88	33	
SY-3	S-2	5-7	33.3	60	25	35	CH	88	48	
SY-3	S-4	9-11	24.3	46	22	24	CL	65	30	
SY-6	S-3	7-9	20.5				SC	35	18	
SY-6	S-5	11-13	24.4				CL	91	35	
SY-7	S-2	5-7	26.1	41	21	20	CL	88	35	
SY-7	S-7	15-17	33.5	33	19	14	CL	99.8	33	
SY-7	S-10	30-32	39.4	43	20	23	CL	100	51	
SY-8	S-3	7-9	30.6	41	23	18	CL	99.5	39	
SY-8	S-8	20-22	42.7	46	20	26	CL	100	56	
SY-8	S-10	30-32	41.3	45	20	25	OL	100	45	
SY-9A	S-3	7-9	28.1	41	19	22	CL	99.7	44	
SY-9A	S-8	20-22	35.6	37	18	19	CL	100	47	
SY-9A	S-11	35-37	30.9	33	19	14	OL	100	27	
SY-10	S-3	7-9	31.6	40	19	21	CL	94.6	34	
SY-10	S-8	20-22	26.6	44	20	24	CL	99.9	49	
SY-10	S-10	30-32	33.8	30	19	11	CL	99.9	31	

Note: (1) USCS symbol based on visual observation and Sieve and Atterberg limits reported.



Open Symbols: Sieve analysis by ASTM D6913
Filled symbols: Hydrometer analysis by ASTM D7928 corrected for complete sample

SYMBOL	w (%)	LL	PL	PI	USCS	AASHTO	USCS DESCRIPTION AND REMARKS	DATE
□	26.1	41	21	20	CL		Brown, Lean clay, Insufficient sample size	04/09/21
◇	33.5	33	19	14	CL		Gray, Lean clay	04/09/21
○	39.4	43	20	23	CL		Gray, Lean clay	04/09/21

Aquifer

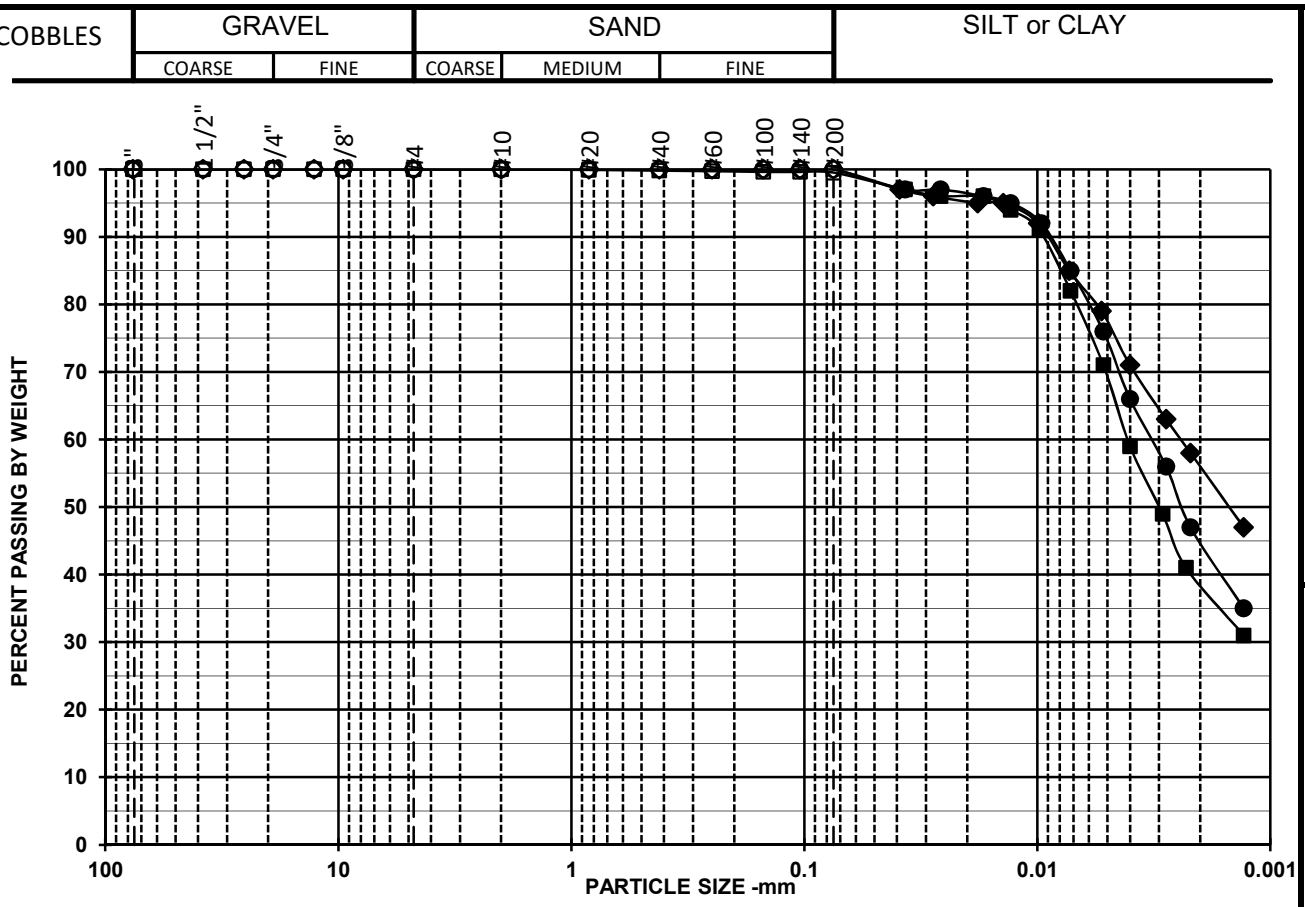
TerraSense, LLC #7853-21010

CHPE- Selkirk Bypass Borings

Symbol	□	◇	○
Boring	SY-7	SY-7	SY-7
Sample	S-2	S-7	S-10
Depth	5-7	15-17	30-32
% +3"	0	0	0
% Gravel	6	0	0
% SAND	6	0.2	0
%C SAND	1	0	0
%M SAND	2	0.1	0
%F SAND	3	0.1	0
% FINES	88	99.8	100
D_{100} (mm)	19.1	2	0.075
D_{60} (mm)	0.005	0.005	0.003
D_{30} (mm)	0.001	0.002	
D_{10} (mm)			
Cc			
Cu			

Sieve Size/ID #	Percent Finer Data		
6"	100	100.0	100.0
4"	100	100.0	100.0
3"	100	100.0	100.0
1 1/2"	100	100.0	100.0
1"	100	100.0	100.0
3/4"	100	100.0	100.0
1/2"	96	100.0	100.0
3/8"	96	100.0	100.0
#4	94	100.0	100.0
#10	93	100.0	100.0
#20	92	100.0	100.0
#40	91	99.9	100.0
#60	90	99.8	100.0
#100	89	99.8	100.0
#140	89	99.8	100.0
#200	88	99.8	100.0
5μ m	57	57	75
2μ m	35	33	51
1μ m	26	25	38

PARTICLE SIZE DISTRIBUTION
ASTM D6913 & ASTM D7928



Open Symbols: Sieve analysis by ASTM D6913
Filled symbols: Hydrometer analysis by ASTM D7928 corrected for complete sample

SYMBOL	w (%)	LL	PL	PI	USCS	AASHTO	USCS DESCRIPTION AND REMARKS	DATE
□	30.6	41	23	18	CL		Brown, Lean clay	04/12/21
◇	42.7	46	20	26	CL		Gray, Lean clay	04/12/21
○	41.3	45	20	25	OL		Gray, Organic silt	04/12/21

Aquifer

TerraSense, LLC #7853-21010

CHPE- Selkirk Bypass Borings

Symbol	□	◇	○
Boring	SY-8	SY-8	SY-8
Sample	S-3	S-8	S-10
Depth	7-9	20-22	30-32
% +3"	0	0	0
% Gravel	0	0	0
% SAND	0.5	0	0
%C SAND	0	0	0
%M SAND	0.2	0	0
%F SAND	0.3	0	0
% FINES	99.5	100	100
D_{100} (mm)	2	0.075	4.75
D_{60} (mm)	0.004	0.002	0.003
D_{30} (mm)			
D_{10} (mm)			
Cc			
Cu			

Sieve Size/ID #	Percent Finer Data		
6"	100.0	100.0	100
4"	100.0	100.0	100
3"	100.0	100.0	100
1 1/2"	100.0	100.0	100
1"	100.0	100.0	100
3/4"	100.0	100.0	100
1/2"	100.0	100.0	100
3/8"	100.0	100.0	100
#4	100.0	100.0	100
#10	100.0	100.0	100
#20	99.9	100.0	100
#40	99.8	100.0	100
#60	99.7	100.0	100
#100	99.6	100.0	100
#140	99.6	100.0	100
#200	99.5	100.0	100
5μ m	69	77	75
2μ m	39	56	45
1μ m	26	42	29

PARTICLE SIZE DISTRIBUTION
ASTM D6913 & ASTM D7928

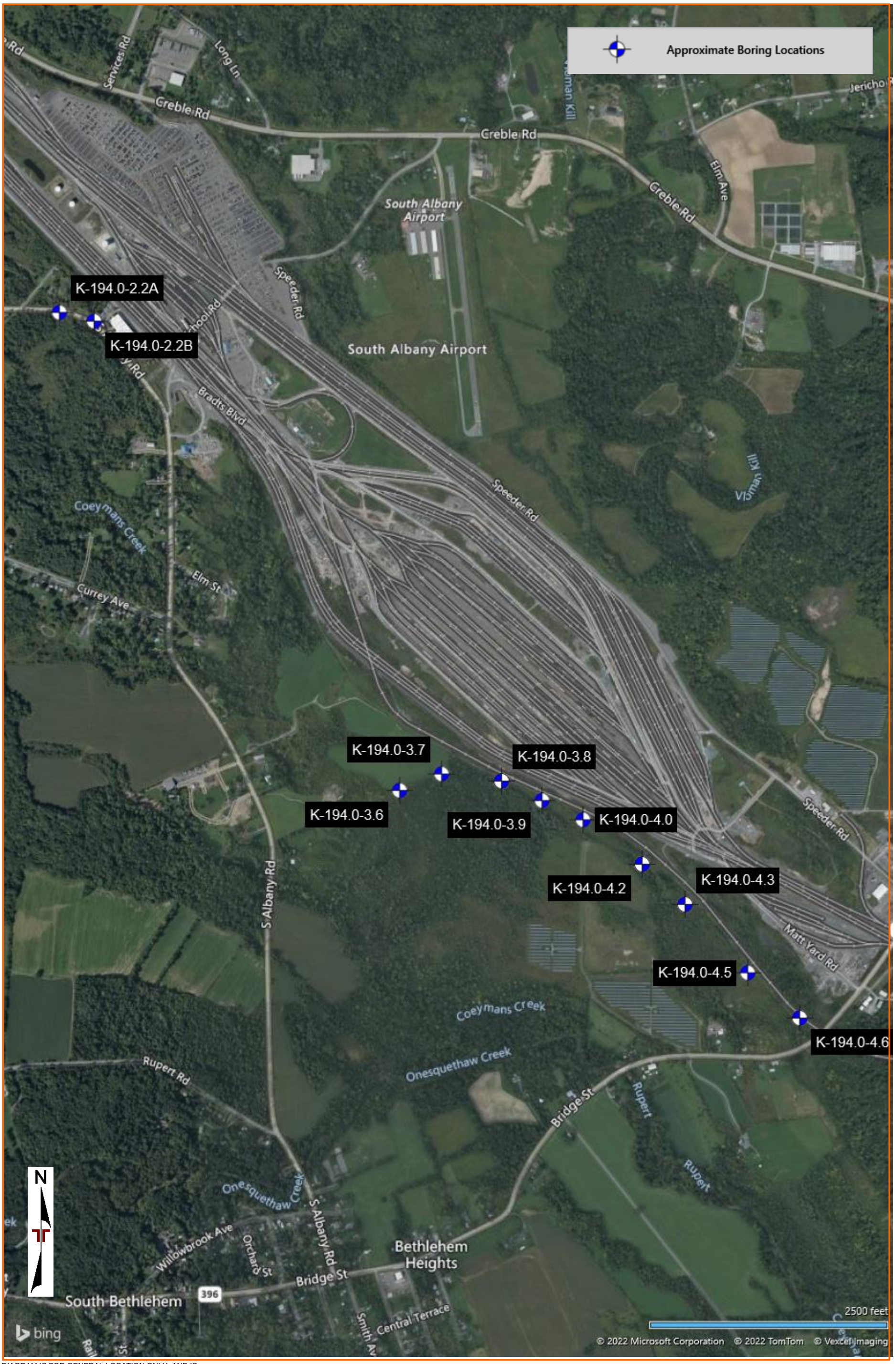


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. K-194.0-3.6

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.546540° Longitude: -73.836487°

Surface Elev.: 174.15 (Ft.)

DEPTH	ELEVATION (Ft.)	DESCRIPTION
0.3	174	**TOPSOIL**
		SANDY LEAN CLAY (CL), occasional sand partings, brown, soft to stiff
16.0	158	**LEAN CLAY WITH SAND (CL)**, varved, gray, very soft to soft

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
			15	1-1-2-4 N=3				
			18	4-6-8-9 N=14	4.5 (HP)	30.5	35-24-11	63
5			19	5-3-5-5 N=8	4.0 (HP)			
			20	5-6-8-8 N=14	4.5 (HP)			
			22	7-6-6-6 N=12	2.0 (HP)			
10			24	2-2-3-4 N=5	2.0 (HP)			
15	▽		24	2-2-2-2 N=4	1.5 (HP)			
20			24	WOH/24"	1.0 (HP)	42.6	43-24-19	79
25			24	WOH/24"	1.25 (HP)			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: SP
Hammer Efficiency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *While drilling*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 03-21-2022 | Boring Completed: 03-21-2022

Drill Rig: Deiedrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-3.6

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.546540° Longitude: -73.836487°

Surface Elev.: 174.15 (Ft.)

DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
LEAN CLAY WITH SAND (CL), varved, gray, very soft to soft *(continued)*											
31.0	143		30			24	WOH/24"	1.5 (HP)			
FAT CLAY WITH SAND (CH), varved, gray, very soft						24	WOH/24" 3" Split Spoon With Ring Samplers	.5 (HP)	43.1	54-23-31	72
			35			24	WOH/24"	.5 (HP)			
			40			24	WOH/24"	.5 (HP)			
			45			24	WOH/24"	.5 (HP)			
			50			24	WOH/24"	.5 (HP)			
52.0	122										
Boring Terminated at 52 Feet											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: SP
Hammer Efficiency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

While drilling

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 03-21-2022 | Boring Completed: 03-21-2022

Drill Rig: Deiedrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-3.7

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.547037° Longitude: -73.834820°

Surface Elev.: 175.01 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.3	174.5	**TOPSOIL**
		FILL - LEAN CLAY, organics noted, orange to gray, soft
2.0	173	
		LEAN CLAY (CL), brown, medium stiff to stiff
		dropstones noted between 8' and 10'
12.0	163	
		LEAN CLAY WITH SAND (CL), varved, gray, very soft to soft

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
			19	WOH/12"-4-5				
			18	6-5-8-9 N=13		29.4		
5			20	3-4-5-7 N=9				
			20	4-5-5-7 N=10				
			17	5-4-4-5 N=8		32.4	30-22-8	98
10	▽		21	2-2-3-4 N=5				
15			18	1-2-1-2 N=3				
20			22	WOH/18"-1				
			24	WOH/24" 3" Split Spoon With Ring Samplers		45.6	42-25-17	74
25			24	WOH/24"				

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: SP
Hammer Efficiency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *While drilling*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 03-22-2022 | Boring Completed: 03-22-2022

Drill Rig: Deiedrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-3.7

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.547037° Longitude: -73.834820°

Surface Elev.: 175.01 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	LEAN CLAY WITH SAND (CL), varved, gray, very soft to soft *(continued)*										
			30		X	22	WOH/24"				
			35		X	22	WOH/24"				
			40		X	24	WOH/24"				
			45		X	24	WOH/24"		39.3		
			50		X	24	WOH/24"				
	52.0	123									
	Boring Terminated at 52 Feet										

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: SP
Hammer Efficiency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *While drilling*

Terracon
30 Corporate Cir Ste 201
Albany, NY

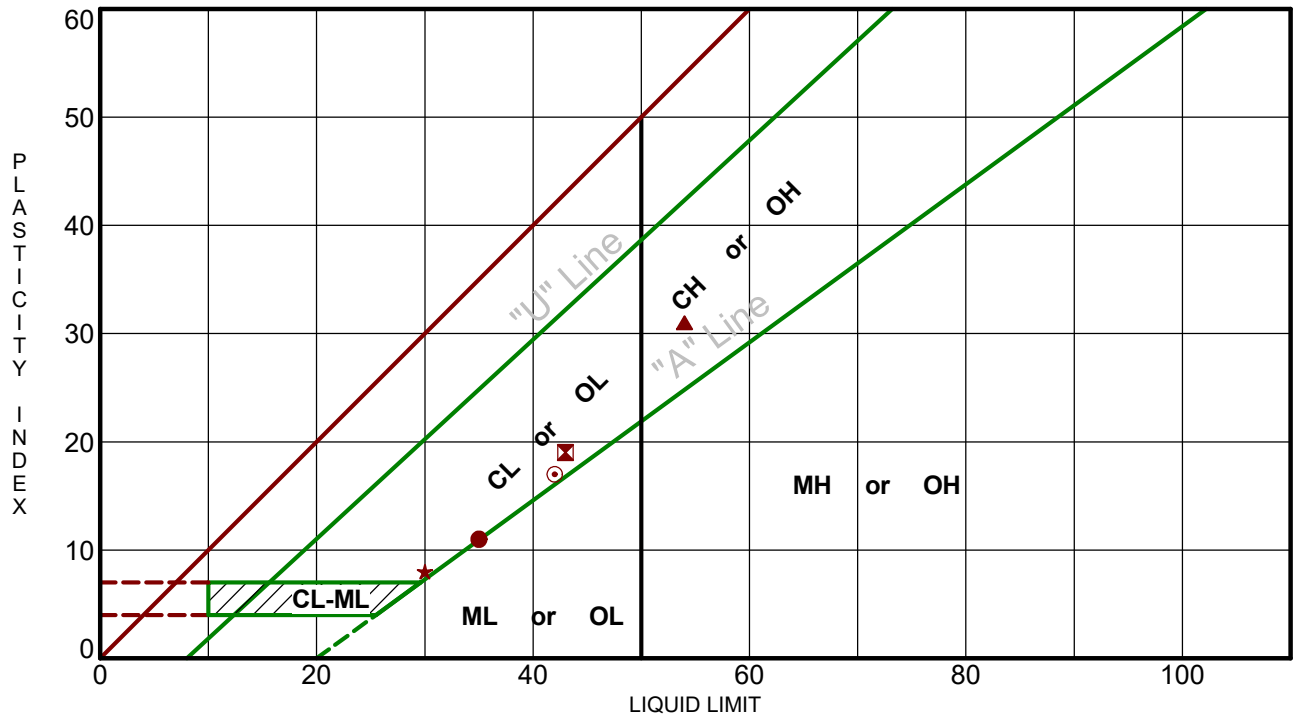
Boring Started: 03-22-2022 | Boring Completed: 03-22-2022

Drill Rig: Deiedrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	K-194.0-3.6	2 - 4	35	24	11	62.7	CL	SANDY LEAN CLAY
⊠	K-194.0-3.6	20 - 22	43	24	19	79.3	CL	LEAN CLAY with SAND
▲	K-194.0-3.6	31 - 33	54	23	31	71.7	CH	FAT CLAY with SAND
★	K-194.0-3.7	8 - 10	30	22	8	98.2	CL	LEAN CLAY
⊙	K-194.0-3.7	23 - 25	42	25	17	73.5	CL	LEAN CLAY with SAND

PROJECT: Champlain-Hudson Power Express
Package 5

SITE: Champlain to Hudson HDD Crossings
Schenectady, NY

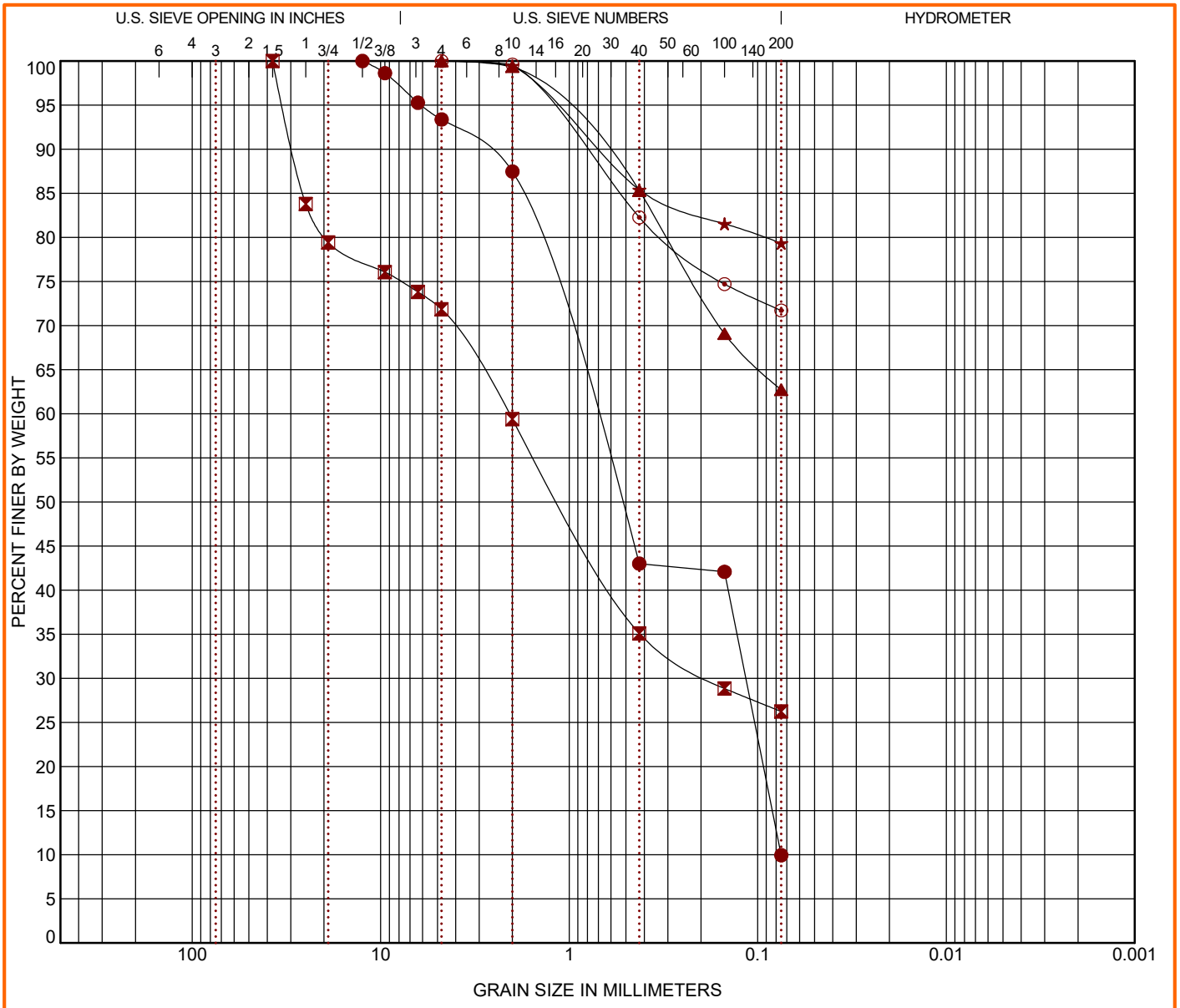
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-169.0-9.6	4 - 6	POORLY GRADED SAND with SILT (SP-SM)	6.9				0.23	10.23
⊠	K-169.0-9.6	55 - 57	SILTY SAND with GRAVEL (SM)	10.1					
▲	K-194.0-3.6	2 - 4	SANDY LEAN CLAY (CL)	30.5	35	24	11		
★	K-194.0-3.6	20 - 22	LEAN CLAY with SAND (CL)	42.6	43	24	19		
⊙	K-194.0-3.6	31 - 33	FAT CLAY with SAND (CH)	43.1	54	23	31		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-169.0-9.6	4 - 6	12.5	0.768	0.116	0.075	0.0	6.6	83.4		9.9	
⊠	K-169.0-9.6	55 - 57	37.5	2.087	0.182		0.0	28.1	45.6		26.2	
▲	K-194.0-3.6	2 - 4	4.75				0.0	0.0	37.3		62.7	
★	K-194.0-3.6	20 - 22	4.75				0.0	0.0	20.7		79.3	
⊙	K-194.0-3.6	31 - 33	4.75				0.0	0.0	28.3		71.7	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

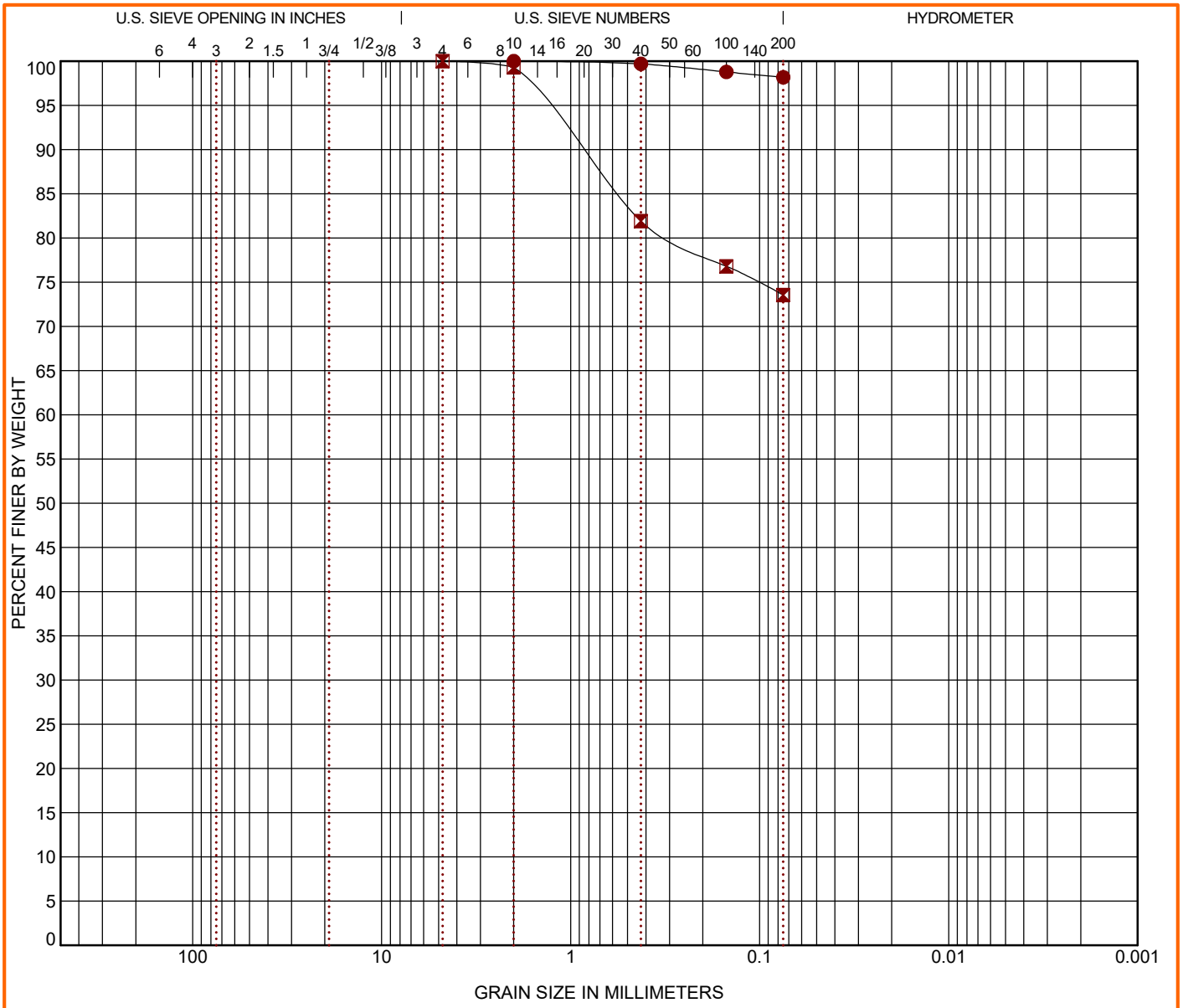
PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 4/29/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-3.7	8 - 10	LEAN CLAY (CL)	32.4	30	22	8		
⊠	K-194.0-3.7	23 - 25	LEAN CLAY with SAND (CL)	45.6	42	25	17		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-3.7	8 - 10	2				0.0	0.0	1.8		98.2	
⊠	K-194.0-3.7	23 - 25	4.75				0.0	0.0	26.5		73.5	

PROJECT: Champlain-Hudson Power Express
Package 5

SITE: Champlain to Hudson HDD Crossings
Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 4/29/22

CHEMICAL LABORATORY TEST REPORT

Project Number: JB215256
Service Date: 04/12/22
Report Date: 04/14/22

Terracon
10400 State Highway 191
Midland, Texas 79707
432-684-9600

Client

Kiewit Engineering (NY) Corp
1055 Trainstation Cicle
Lone Tree, CO 80124

Project

Champlain-Hudson Power Express Project
Champlain to Hudson HDD Crossings
Schenectady, NY

Sample Location	K-194.0-3.6
Sample Depth (ft.)	6-10
pH Analysis, ASTM - G51-18	7.8
Water Soluble Sulfate (SO4), ASTM C 1580 (mg/kg)	158
Sulfides, ASTM - D4658-15, (mg/kg)	nil
Chlorides, ASTM D 512 , (mg/kg)	50
RedOx, ASTM D-1498, (mV)	+457
Total Salts, ASTM D1125-14, (mg/kg)	429
Resistivity, ASTM G187, (ohm-cm)	4,543

Analyzed By: Zach Robertson

Zach Robertson
Engineering Technician III

Approximate Boring Locations

KB-192.4

KB-192.8B

KB-194.0-3.9B

KB-194.0-3.6B

KB-194.0-4.4

KB-194.0-4.6B

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DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. KB-194.0-3.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546299° Longitude: -73.836627°

Surface Elev.: 172.9310 (Ft.)

DEPTH	ELEVATION (Ft.)
0.5	172.4

TOPSOIL

LEAN CLAY (CL), varved silt and clay, brown, very soft to very stiff

grades gray

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		24	3-4-4-5 N=8			
		24	3-4-7-11 N=11			
5		24	7-8-8-9 N=16	31.0	36-24-12	89
10		24	3-3-4-4 N=7			
15						
20		24	WH-WH-WH-WH			
25						

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4 1/4"HSA
Cased to 10'
Mud Rotary to 97

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by AB
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-15-2022 | Boring Completed: 09-15-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

BORING LOG NO. KB-194.0-3.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546299° Longitude: -73.836627°

Surface Elev.: 172.9310 (Ft.)

DEPTH ELEVATION (Ft.)

GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
LEAN CLAY (CL), varved silt and clay, brown, very soft to very stiff *(continued)*								
	30			24	WH-WH-WH-WH	37.9	36-22-14	96
	35							
	40			24	WR-WR-WR-WR			
	45							
	50			24	WR-WR-WR-WR	39.6	42-23-19	96
	55							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4 1/4"HSA
Cased to 10'
Mud Rotary to 97

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

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Logged by AB
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-15-2022 | Boring Completed: 09-15-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

BORING LOG NO. KB-194.0-3.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546299° Longitude: -73.836627°

Surface Elev.: 172.9310 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		LEAN CLAY (CL), varved silt and clay, brown, very soft to very stiff *(continued)*								
	70.0	102.9	60			24	WR-WR-WR-WR			
		SILT (ML), varved silt and clay, gray, very soft	65							
			70			24	WR-WR-WR-WR	46.7	49-29-20	92
			75							
			80			24	WR-WR-WR-WR 3" Split Spoon With Ring Samplers			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4 1/4"HSA
Cased to 10'
Mud Rotary to 97

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by AB
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-15-2022 | Boring Completed: 09-15-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

BORING LOG NO. KB-194.0-3.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546299° Longitude: -73.836627°

Surface Elev.: 172.9310 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		SILT (ML), varved silt and clay, gray, very soft *(continued)*	85							
			90			24	WR-WR-WR-WR			
			95			24	WR-WR-WR-WR			
	97.0	75.9								
		Boring Terminated at 97 Feet								

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4 1/4"HSA
Cased to 10'
Mud Rotary to 97

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by AB
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-15-2022 | Boring Completed: 09-15-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

Summary of Laboratory Results

BORING ID	Depth (Ft.)	Water Content (%)	Organic Content (%)
KB-182.7B	20-22	31.1	
KB-182.7B	50-52	35.4	
KB-182.7B	80-82	26.5	
KB-184.2	4-6	17.3	
KB-184.2	20-21.5	10.0	
KB-184.9	10-12	35.4	
KB-184.9	25-26.5	8.6	
KB-184.9	40-42	9.2	
KB-184.9	55-56.5	12.2	
KB-185.4	6-8	34.3	
KB-185.4	20-21.5	13.7	
KB-185.4	35-39	9.1	
KB-185.4	45-47	14.7	
KB-192.4	15-17	36.9	
KB-192.4	25-27	42.6	
KB-192.4	45-47	46.0	
KB-192.4	65-67	8.0	
KB-192.8B	15-17	36.5	
KB-192.8B	40-40.2	14.1	
KB-192.8B	50-50.2	14.2	
KB-194.0-3.6B	5-7	31.0	
KB-194.0-3.6B	30-32	37.9	
KB-194.0-3.6B	50-52	39.6	
KB-194.0-3.6B	70-72	46.7	
KB-194.0-3.9B	4-6	31.5	
KB-194.0-3.9B	25-26.5	50.2	
KB-194.0-3.9B	45-46.5	43.4	
KB-194.0-3.9B	60-61.5	52.9	
KB-194.0-4.4	20-22	50.1	
KB-194.0-4.4	40-42	37.9	
KB-194.0-4.4	50-52	47.6	
KB-194.0-4.4	70-72	37.4	
KB-194.0-4.6B	4-6	24.1	
KB-194.0-4.6B	20-21.5	40.3	
KB-194.0-4.6B	40-41.5	42.9	
KB-194.0-4.6B	60-61.5	45.6	
KB-200.6	8-10	20.3	
KB-200.6	30-32	30.5	
KB-200.6	45-47	26.3	
KB-200.6	55-57	33.6	
KB-200.8A	15-17	39.6	
KB-200.8A	35-36.5	45.0	

PROJECT: CHPE - Additional HDD Borings - Phase 3

SITE: Fort Ann to Coxsackie, NY

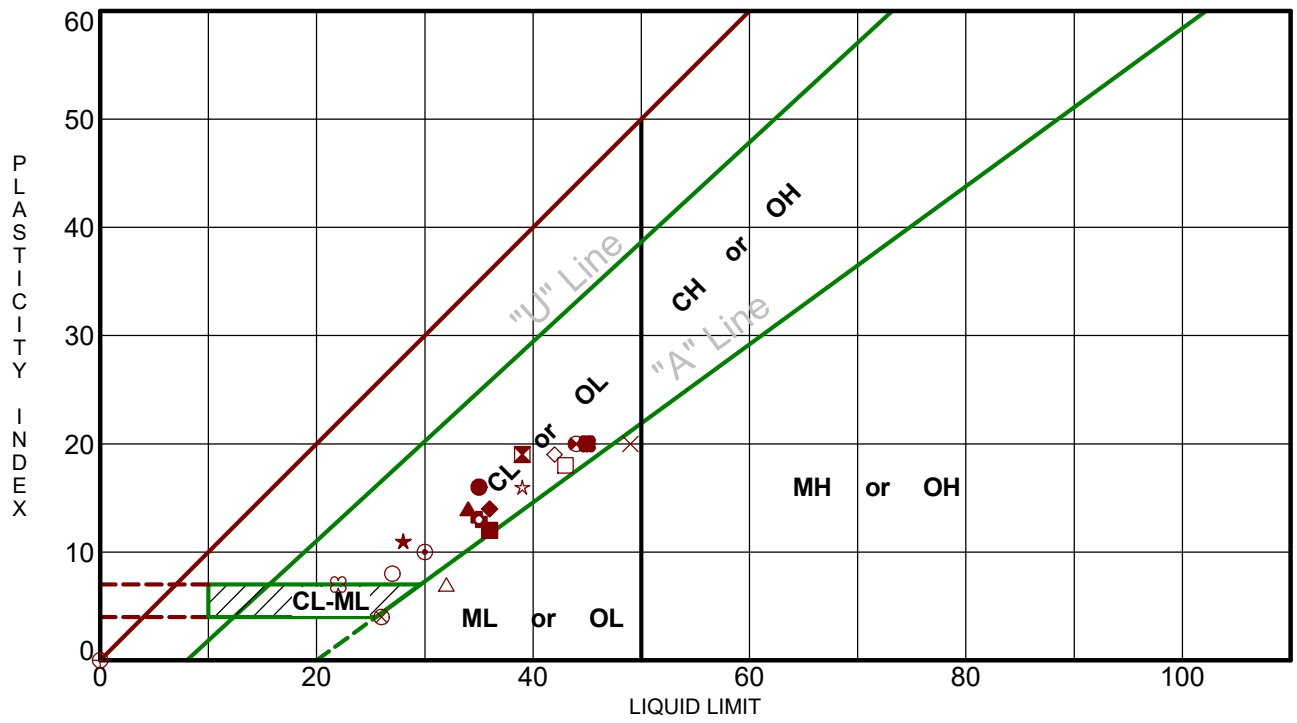
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256G

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	KB-135.7	30 - 32	35	19	16	96.6	CL	LEAN CLAY
⊠	KB-135.8	15 - 17	39	20	19	93.6	CL	LEAN CLAY
▲	KB-135.8	30 - 32	34	20	14	94.2	CL	LEAN CLAY
★	KB-135.8	40 - 42	28	17	11	99.5	CL	LEAN CLAY
⊙	KB-182.7B	20 - 22	30	20	10	98.6	CL	LEAN CLAY
✿	KB-182.7B	50 - 52	35	22	13	98.6	CL	LEAN CLAY
○	KB-182.7B	80 - 82	27	19	8	98.3	CL	LEAN CLAY
△	KB-184.9	10 - 12	32	25	7	86.1	ML	SILT
⊗	KB-185.4	6 - 8	26	22	4	87.4	ML	SILT
⊕	KB-185.4	20 - 21.5	NP	NP	NP	15.8	SM	SILTY SAND
□	KB-192.4	15 - 17	43	25	18	87.5	CL	LEAN CLAY
⊠	KB-192.4	25 - 27	44	24	20	97.7	CL	LEAN CLAY
◕	KB-192.4	45 - 47	45	25	20	92.4	CL	LEAN CLAY
☆	KB-192.8B	15 - 17	39	23	16	81.8	CL	LEAN CLAY with SAND
✿	KB-192.8B	50 - 50.2	22	15	7	26.0	SC-SM	SILTY, CLAYEY SAND
■	KB-194.0-3.6B	5 - 7	36	24	12	89.4	CL	LEAN CLAY
◆	KB-194.0-3.6B	30 - 32	36	22	14	95.7	CL	LEAN CLAY
◇	KB-194.0-3.6B	50 - 52	42	23	19	95.7	CL	LEAN CLAY
×	KB-194.0-3.6B	70 - 72	49	29	20	91.9	ML	SILT
✖	KB-194.0-3.9B	4 - 6	45	25	20	76.6	CL	LEAN CLAY with SAND

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

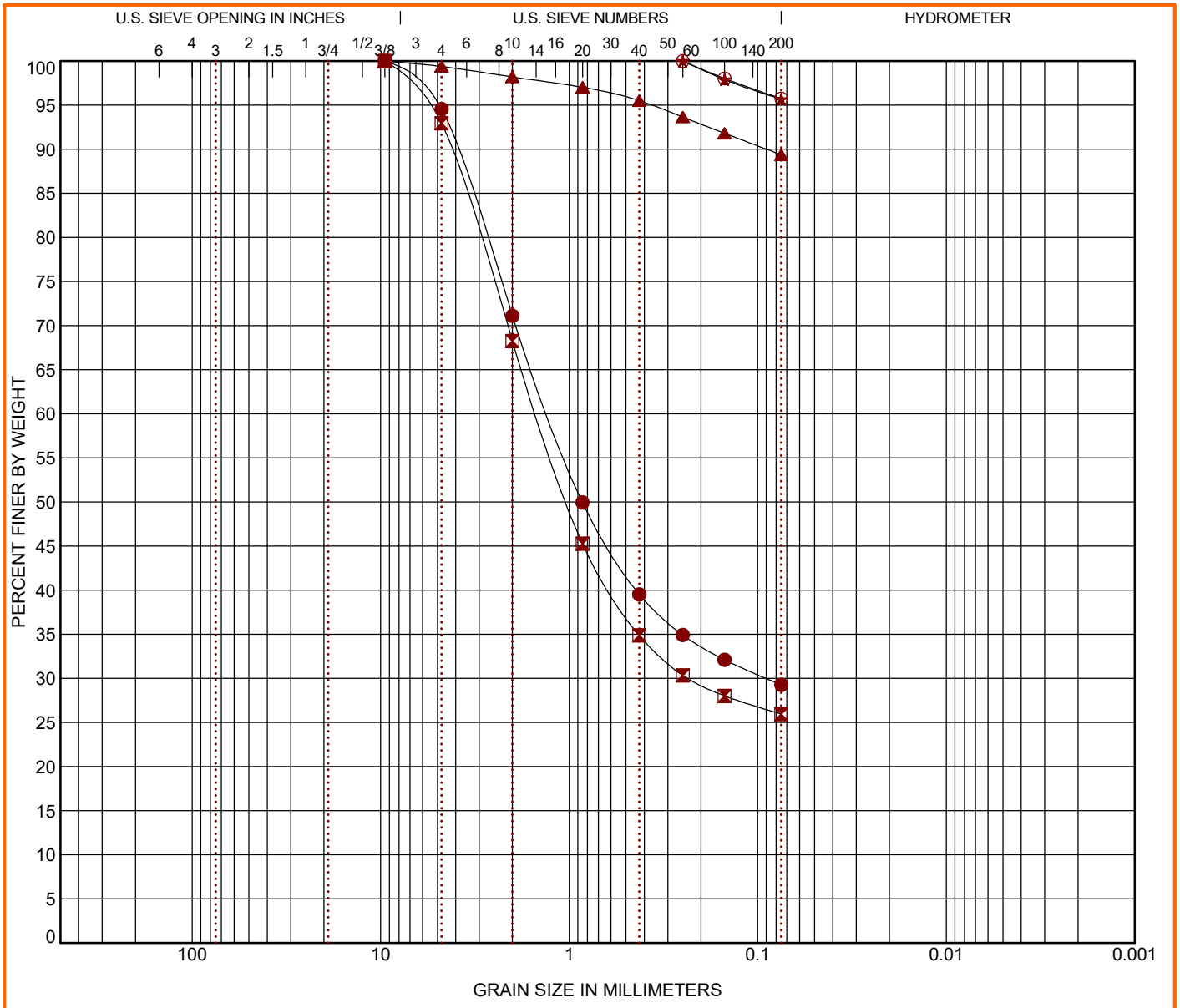
SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	KB-192.8B	40 - 40.2	SILTY SAND (SM)	14.1					
⊠	KB-192.8B	50 - 50.2	SILTY, CLAYEY SAND (SC-SM)	14.2	22	15	7		
▲	KB-194.0-3.6B	5 - 7	LEAN CLAY (CL)	31.0	36	24	12		
★	KB-194.0-3.6B	30 - 32	LEAN CLAY (CL)	37.9	36	22	14		
⊙	KB-194.0-3.6B	50 - 52	LEAN CLAY (CL)	39.6	42	23	19		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	KB-192.8B	40 - 40.2	9.5	1.277	0.09		0.0	5.4	65.3		29.3	
⊠	KB-192.8B	50 - 50.2	9.5	1.472	0.232		0.0	7.1	67.0		26.0	
▲	KB-194.0-3.6B	5 - 7	9.5				0.0	0.6	10.0		89.4	
★	KB-194.0-3.6B	30 - 32	0.25				0.0	0.0	4.3		95.7	
⊙	KB-194.0-3.6B	50 - 52	0.25				0.0	0.0	4.3		95.7	

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

SITE: Fort Ann to Coxsackie, NY

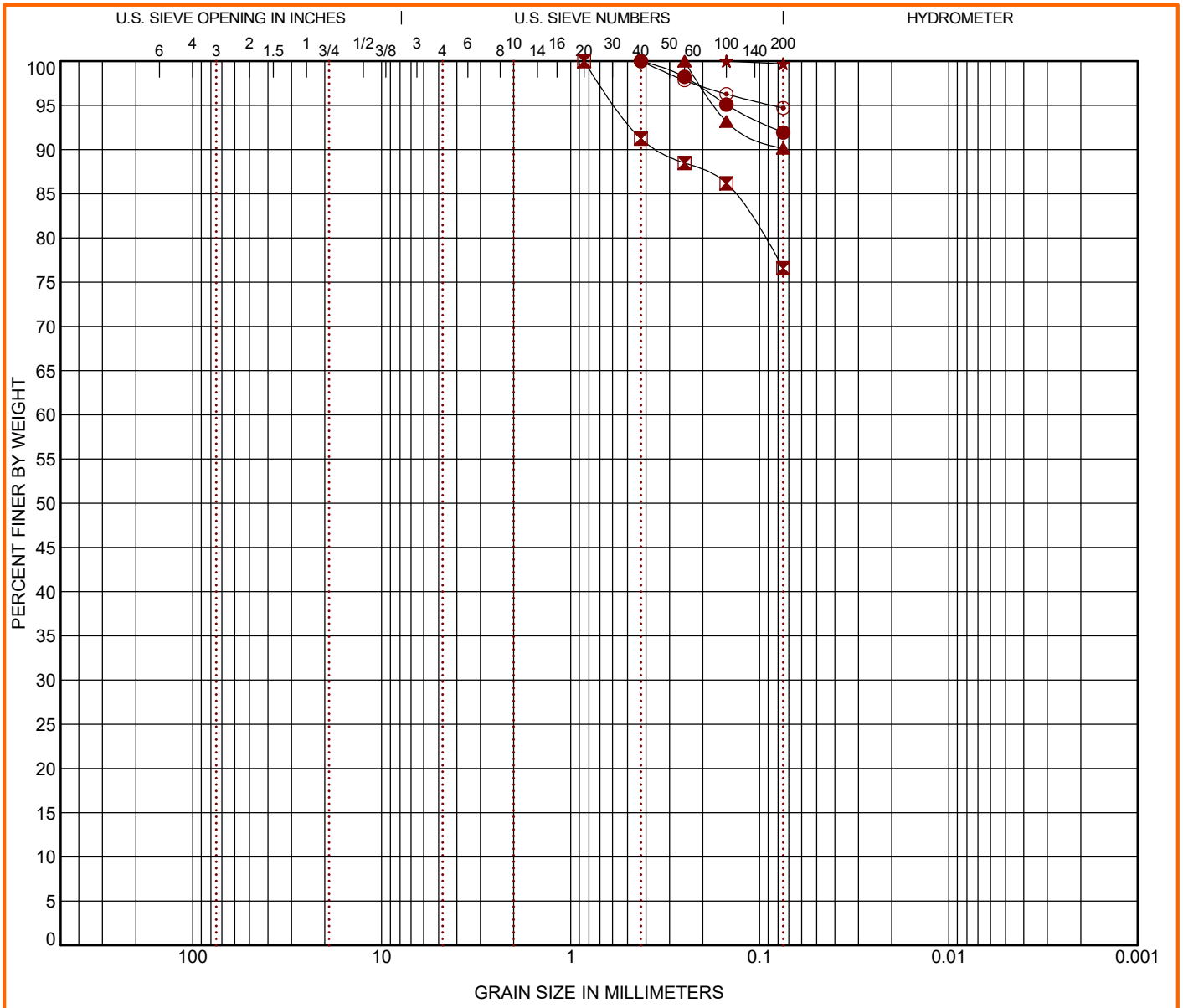
Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256G CHPE - ADDITIONAL.GPJ TERRACON_DATATEMPLATE.GDT 11/2/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
KB-194.0-3.6B	70 - 72	SILT (ML)	46.7	49	29	20		
KB-194.0-3.9B	4 - 6	LEAN CLAY with SAND (CL)	31.5	45	25	20		
KB-194.0-3.9B	25 - 26.5	LEAN CLAY (CL)	50.2	44	26	18		
KB-194.0-3.9B	45 - 46.5	LEAN CLAY (CL)	43.4	39	25	14		
KB-194.0-3.9B	60 - 61.5	FAT CLAY (CH)	52.9	50	26	24		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
KB-194.0-3.6B	70 - 72	0.425				0.0	0.0	8.1		91.9	
KB-194.0-3.9B	4 - 6	0.85				0.0	0.0	23.4		76.6	
KB-194.0-3.9B	25 - 26.5	0.25				0.0	0.0	9.8		90.2	
KB-194.0-3.9B	45 - 46.5	0.15				0.0	0.0	0.3		99.7	
KB-194.0-3.9B	60 - 61.5	0.425				0.0	0.0	5.3		94.7	

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256G CHPE - ADDITIONAL.GPJ TERRACON_DATATEMPLATE.GDT 11/2/22

Kiewit

MEMORANDUM

DATE: February 13, 2023

TO: Nick Strater; Brierley Associates Underground Engineers, PLLC

FROM: Matthew Hawley, P.E.; Kiewit Engineering (NY) Corp. MKH
Jaren Knighton; Kiewit Engineering (NY) Corp.

SUBJECT: Geotechnical Data: Segment 9 – Package 5 – HDD Crossing 89 – Revision 1
Champlain Hudson Power Express Project
Selkirk, New York

Kiewit Engineering is providing the attached geotechnical data for use in the horizontal direction drill (HDD) design for the Champlain Hudson Power Express project in Upstate New York. This HDD crossing is located northwest of Selkirk, New York. The approximate station for the start of HDD crossing Number 89 is STA 51202+00 (42.5469° N, 73.8325° W).

The geotechnical data at this HDD crossing is attached. The available data is from the previous investigation by AECOM and the recent investigation by Terracon, referenced below.

- AECOM, Geotechnical Data Report, Upland Segments, Champlain Hudson Power Express, dated May 28, 2021.
- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express-Package 5, Schenectady through Selkirk, dated April 4, 2022.
- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express – Additional HDD Borings – Phase 3, Fort Ann to Coxsackie, dated November 3, 2022.

Contact us if you have questions or require additional information.

HDD 89
Borings SY-8, SY-9, SY-9A,
K-194.0-3.8, K-194.0-3.9,
K-194.0-4.0, K-194.0-4.2,
K-194.0-4.3, KB-194.0-3.9B,
KB-194.0-4.4
Segment 9 - Package 5

CHPE Segment 8 & 9 - Package 5
HDD Soil Boring Coordinates and Elevations

Firm	Boring	Northing (feet)	Easting (feet)	Ground Surface Elevation (feet)
TRC*	A179.6-1	1433335.8	631009.7	332.5
	A182.4-1	1420048.2	636557.9	291.5
	A187.65-1	1394856.5	644775.4	327.7
	A191.05-1	1378814.5	652321.0	274.7
	A191.82-1	1375154.9	654314.3	257.1
	A192.9-1	1370644.3	657458.6	232.8
	B177.1-1	1445275.2	626125.8	347.3
	B177.6-1	1442944.0	627003.0	346.5
	B178.01-1	1440838.2	627828.3	368.5
	B178.9-1	1436461.4	629767.4	322.1
	B180.1-1	1431140.9	631965.3	310.4
	B180.9-1	1427158.5	633611.8	307.5
	B182.9-1	1417657.6	637123.9	291.5
	B183.2-1	1415871.4	637202.5	290.2
	B184.3-1	1410133.0	637597.6	324.0
	B184.8-1	1408223.8	638230.4	323.1
	B185.6-1	1403875.9	639489.9	328.2
	B188.0-1	1392812.4	645793.4	330.9
	B188.35-1	1391616.5	646333.6	333.4
	B188.51-1	1390815.1	646697.7	340.2
	B190.0-1	1383732.6	649743.4	296.3
	B190.1-1	1383134.9	649975.5	294.6
	B190.8-1	1379726.2	651827.2	282.3
	B192.4-1	1372732.4	655878.1	239.3
	B193.5-1	1367919.2	659547.5	218.6
AECOM**	RS-2	1436092.2	629800.7	315.6
	RS-3	1418336.4	636985.0	303.2
	RS-4	1414567.4	637285.8	302.2
	RS-5	1411399.1	637471.6	319.0
	RS-7A	1391599.9	646333.6	340.5
	RS-9	1372089.8	656230.9	238.7
	SY-7	1353089.8	670133.9	159.8
	SY-8	1353716.5	671626.7	175.0
	SY-9	1353046.4	673133.41	163.1
	SY-9A	1351940.0	674314.3	158.3
	SY-10	1350838.3	675488.6	166.0
	SCH-19	1446199.8	625927.0	333.8
	SCH-19A	1445712.1	626032.4	343.1

Notes:

- Northings and Eastings are provided in NAD83 New York State Plane East Zone.
- Elevations are referenced to the NAVD88 datum.

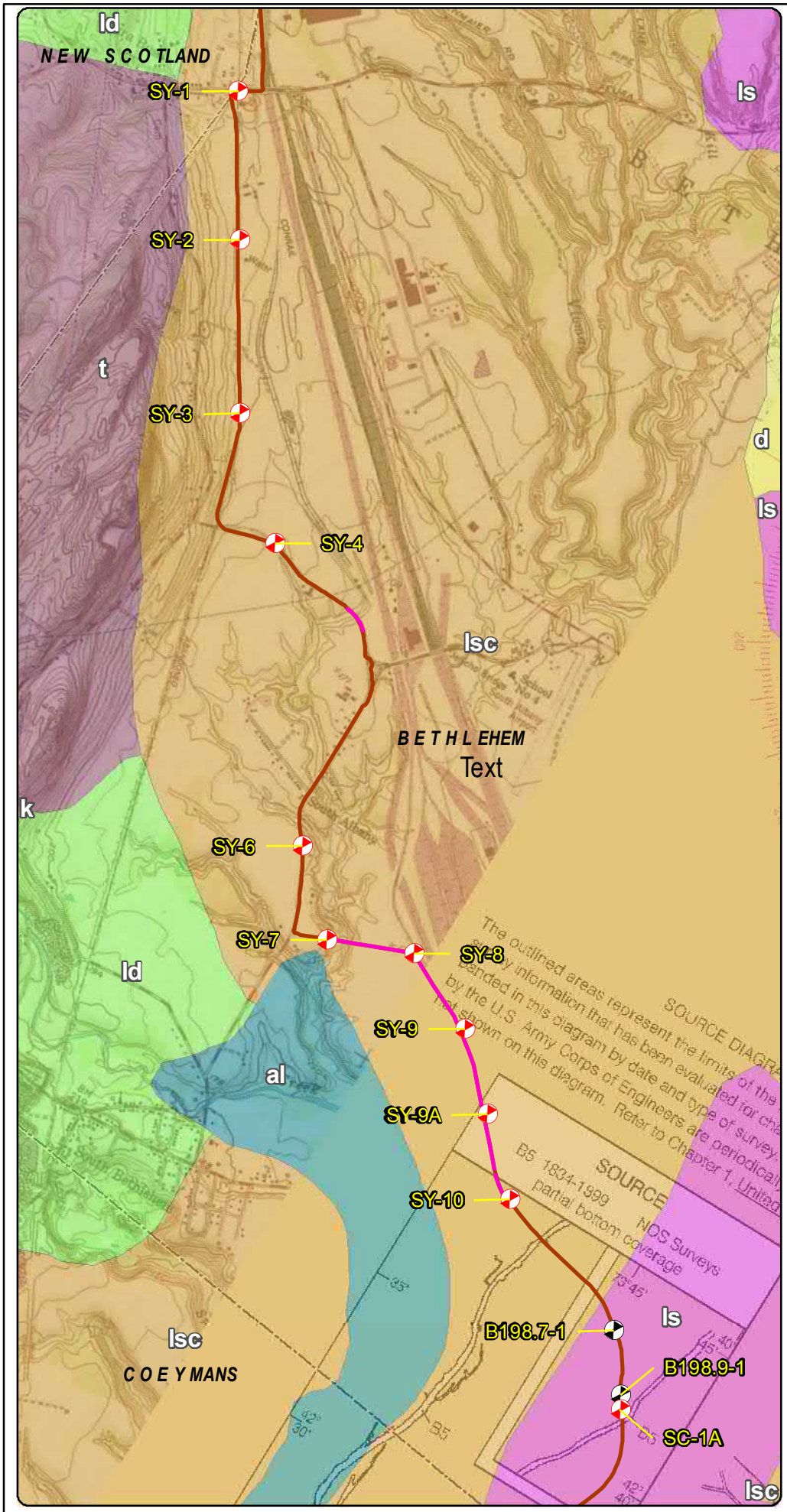
* TRC boring coordinates as shown in Table 1-6 in AECOM report (reference below). Boring elevations estimated from November 2021 topographic survey by Williams Aerial.

** AECOM boring coordinates and elevations as shown in Table 1-6 in AECOM report.

*** Kiewit boring coordinates and elevations are noted on the boring logs.

Reference:

AECOM, Geotechnical Data Report, Upland Segments: Putnam Station, Washington County, to Cementon, Green County, NY, Champlain Hudson Power Express, dated May 28, 2021.



LEGEND

- 2021 Boring Location
- Previous (2013) Boring Location
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- Town Boundary
- County Boundary

Surficial Geology

- al - Recent alluvium
- d - Dunes
- k - Kame deposits
- ld - Lacustrine delta
- ls - Lacustrine sand
- lsc - Lacustrine silt and clay
- t - Till

0.25 0.125 0 0.25 Miles

Transmission

Champlain Hudson Power Express Project

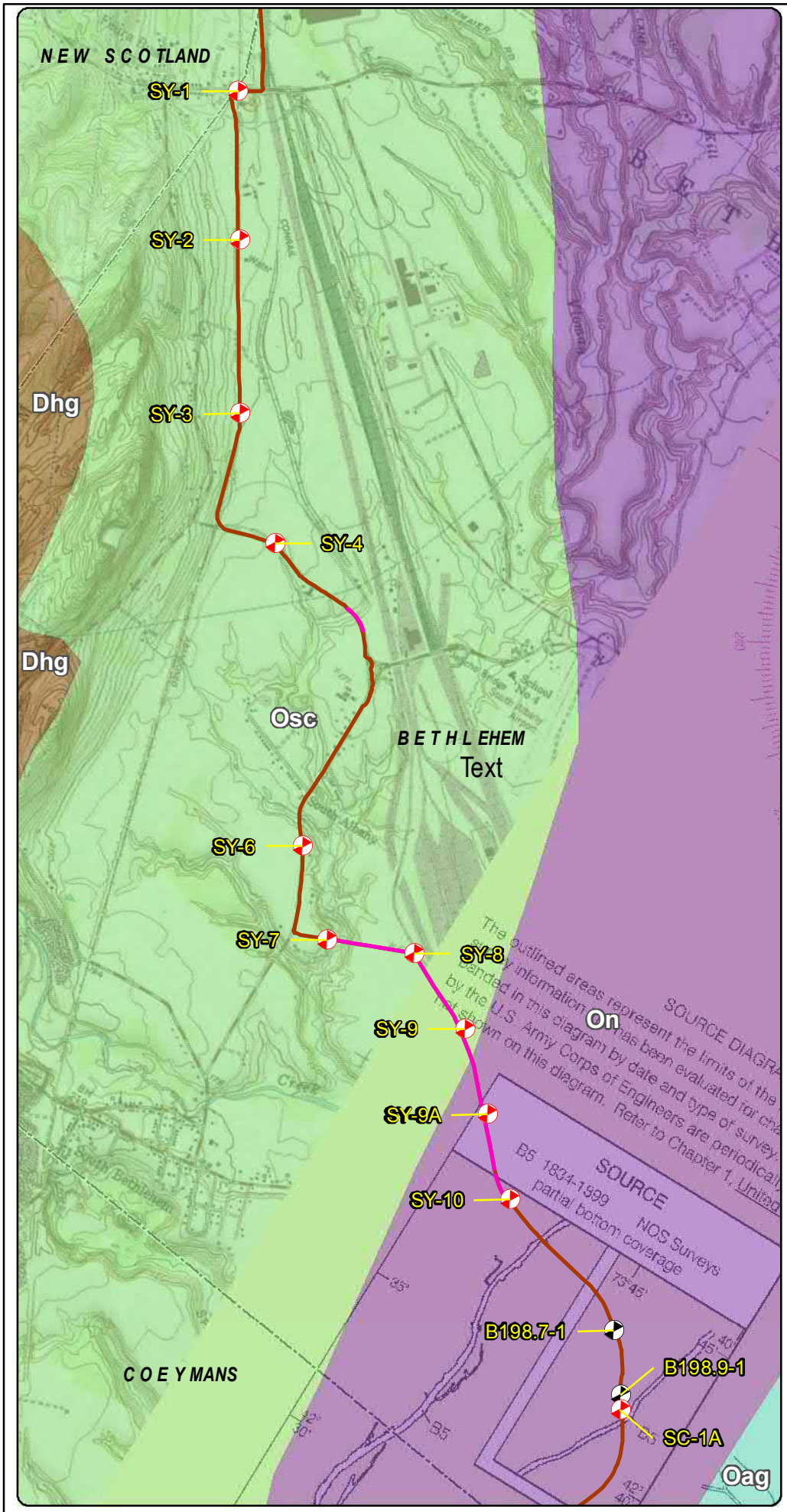
Champlain Hudson Power Express Inc.

Surficial Geology and Geotechnical Borings
Selkirk Rail Yard Bypass
Figure 3-9

Prepared on 4/30/2021
by: AECOM

DATA SOURCES: ESRI, NYSDOT, NOAA, USACE, NYDOS, TDI, TRC

Y:\Projects\CHPE\IRoute\Consensus_Alternative_Routes\MXD\Alt 5_Routes_DZ_20190\Boring_Locations\Maps_for_May_2021_Report\Selkirk_Rail_Yard_Bypass_Boring_Locations_Surficial_May_2021_Report.mxd



LEGEND

- 2021 Boring Location
- Previous (2013) Boring Location
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- Town Boundary
- County Boundary

Bedrock Geology

- Dhg - Port Ewen Formation
- Oag - Austin Glen Formation
- On - Normanskill Shale
- Osc - Schenectady Formation

* Schenectady Formation includes: graywacke, sandstone, siltstone, shale

0.25 0.125 0 0.25 Miles

Transmission

Champlain Hudson Power Express Project

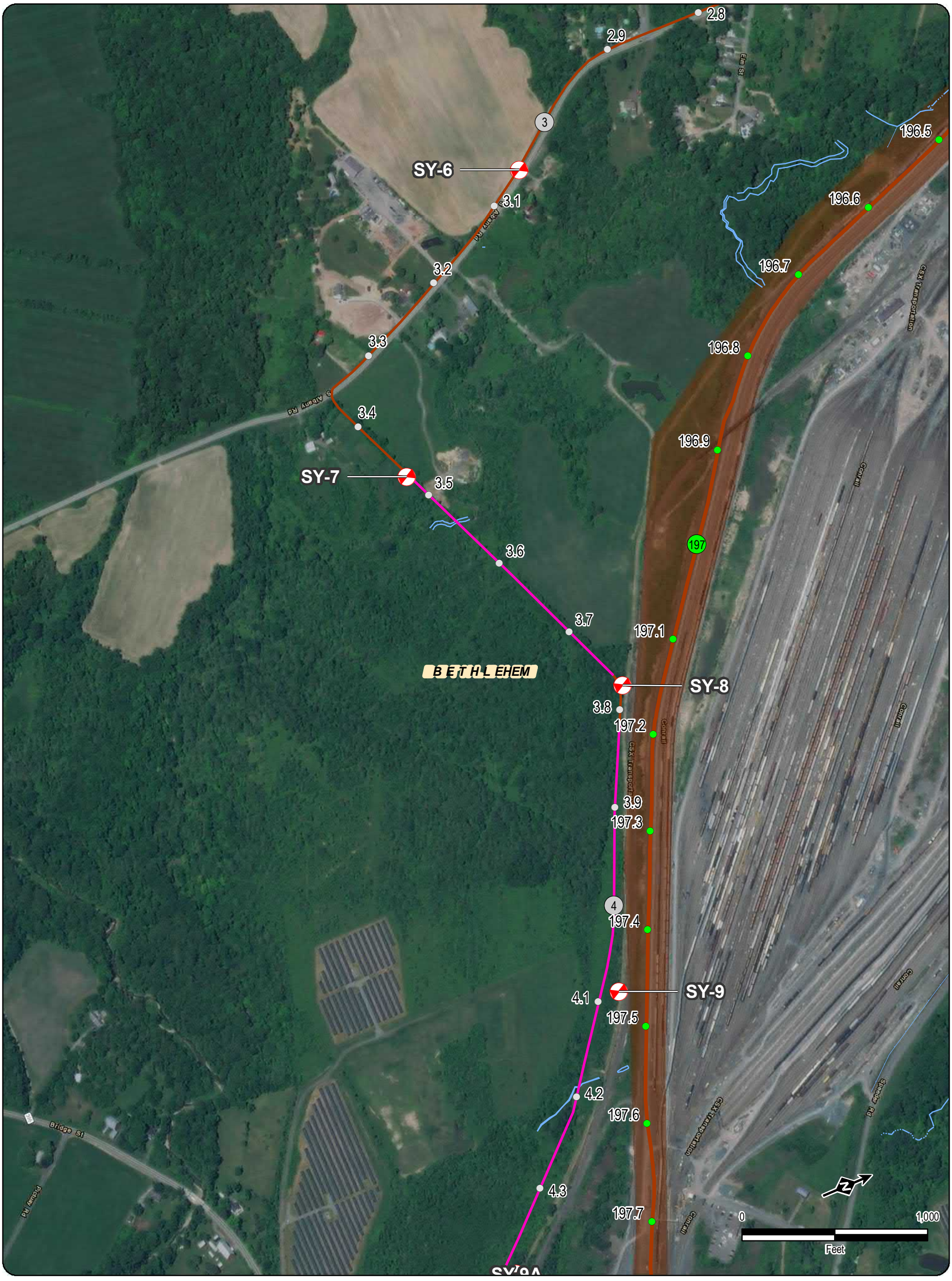
Champlain Hudson Power Express Inc.

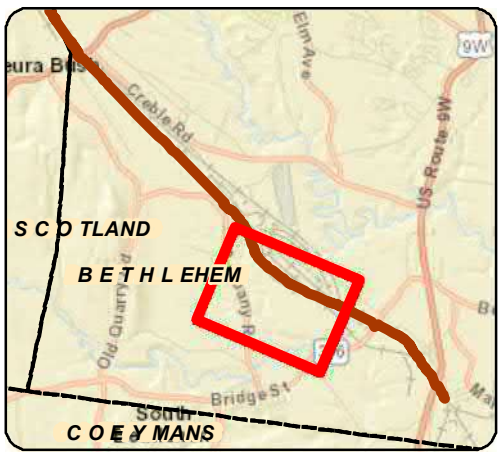
Bedrock Geology and Geotechnical Borings
Selkirk Rail Yard Bypass
Figure 4-9

Prepared on 4/30/2021
by: AECOM

DATA SOURCES: ESRI, NYSDOT, NOAA, USACE, NYDOS, TDI, TRC

Y:\Projects\CHPE\Route\Consensus_Alternative_Routes\MXD\Alt 5_Routes_DZ_20190\Boring_Locations\Maps_for_May_2021_Report\Selkirk_Rail_Yard_Bypass_Boring_Locations_Bedrock_May_2021_Report.mxd





LEGEND

- 111.8 Certified Milepost - Tenths
- 135 Certified Milepost
- 111.8 Preferred Alternative Milepost - Tenths
- 135 Preferred Alternative Milepost
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- 2021 Boring Location
- Previous (2013) Boring Location
- Streams/Ditches
- Railroad ROW
- Deviation Zone
- Deviation Zone Outside ROW
- Preferred Alternative Deviation Zone
- Preferred Alternative Deviation Zone Outside ROW
- Town Boundary
- Village Boundary
- State Park (OPRHP)
- Reported Buried Structure

Parcel Ownership: TOWN NAME

Road Name: Village Name

Transmission Developers Inc.

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

BORING LOCATION PLAN

Selkirk Rail Yard Bypass

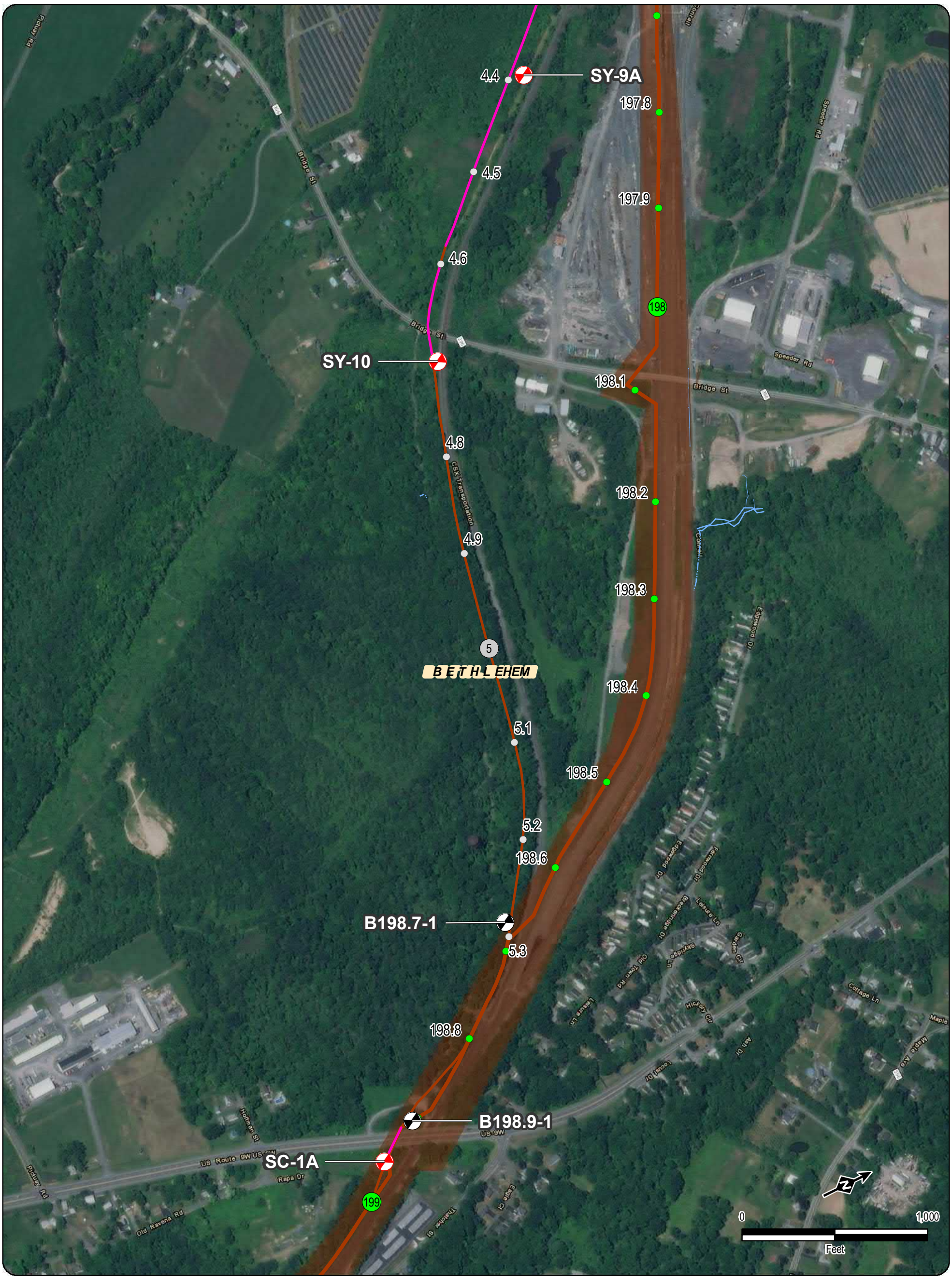
Figure A-9

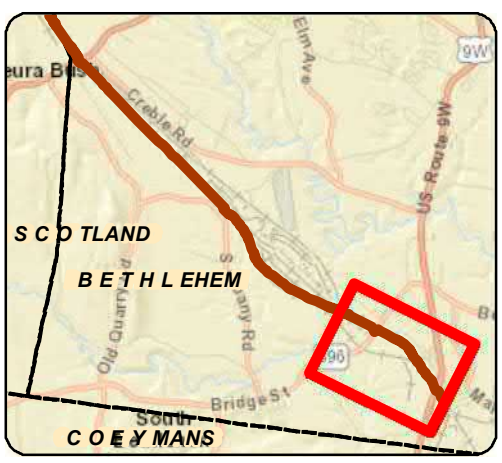
Sheet 3 of 4

Prepared by: AECOM 5/19/2021

DATA SOURCES: ESRI, NETWORK MAPPING 2010, NYSDOT, OPRHP, TDI, TRC

Y:\Projects\CHPEI\Route\Consensus_Alternative_Routes\MXD\Alt_5_Routes_DZ_201909\Boring_Locations\Maps_for_May_2021_Report\Selkirk_Rail_Yard_Bypass_Boring_Location_Consensus_Alternative_Routes_May_2021_Report.mxd





LEGEND

- 111.8 Certified Milepost - Tenths
- 135 Certified Milepost
- 111.8 Preferred Alternative Milepost - Tenths
- 135 Preferred Alternative Milepost
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- 2021 Boring Location
- Previous (2013) Boring Location
- Streams/Ditches
- Railroad ROW
- Deviation Zone
- Deviation Zone Outside ROW
- Preferred Alternative Deviation Zone
- Preferred Alternative Deviation Zone Outside ROW
- Town Boundary
- Village Boundary
- State Park (OPRHP)
- Reported Buried Structure

Parcel Ownership: TOWN NAME

Road Name: Village Name

DATA SOURCES: ESRI, NETWORK MAPPING 2010, NYSDOT, OPRHP, TDI, TRC

Transmission Developers Inc.

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

BORING LOCATION PLAN

Selkirk Rail Yard Bypass

Figure A-9

Sheet 4 of 4

Prepared by: AECOM 5/19/2021

Y:\Projects\CHPEI\Route\Consensus_Alternative_Routes\MXD\Alt_5_Routes_DZ_201909\Boring_Locations\Maps_for_May_2021_Report\Selkirk_Rail_Yard_Bypass_Boring_L...mxd

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER/GEOLOGIST: Chris French

LOCATION: Selkirk Yard MP - 3.78

AECOM

Boring Log

SHEET 1 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-8**

START DATE: 02/26/2021

FINISH DATE: 02/26/2021

OFFSET: N/A

DRILL RIG: CME LC-55

BORING TYPE: SPT

BORING O.D.: 4.5"

SURFACE ELEV.:

LONGITUDE:

LATITUDE:

GROUND WATER OBSERVATIONS		CASING	SAMPLER	DRILL BIT	CORE BARREL
	TYPE	Flush Joint Steel	California Modified	Tricone Roller Bit	
	SIZE I.D.	4"	2.5"	- -	
	SIZE O.D.	4.5"	3"	3 7/8"	
	HAMMER WT.	140 lbs	140 lbs		
	HAMMER FALL	30"	30"		

DEPTH	CORING RATE MIN/FT	SAMPLE DEPTHS FROM - TO (FEET)	SAMPLE TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.(2)	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		0'-5'				Hand Cleared					CL		Brown CLAY and SILT, trace fine sand, trace organics, medium stiff, moist
1.0													1.1': Brown CLAY and SILT, trace fine sand, medium stiff, moist
2.0													
											CL		
3.0													TR-1; (3.0'-5.0')
		3'-5'	S-1										
4.0													
5.0													
		5'-7'	S-2	24"	19"	5	12	8	18	13	ML	SILT AND CLAY	Brown SILT and CLAY, stiff, moist
6.0													
7.0													
		7'-9'	S-3	24"	24"	13	14	16	13		ML		Brown clayey SILT, stiff, moist
8.0													TR-2; (8.0'-8.5')
9.0													
		9'-11'	S-4	24"	24"	4	8	9	11		ML		SAA
10.0													
11.0													
		11'-'13'	S-5	24"	24"	6	8	10	11				Brown clayey SILT and gray silty CLAY, medium stiff, moist
12.0													TR-3;(12.0'-12.5')
13.0													
		13'-15'	S-6	24"	24"	1	2	3	4		CH		Gray silty CLAY, some gray silt and clay, soft, wet
14.0													
15.0													
		15'-17'	S-7	24"	24"	2	3	4	4		CH		SAA
16.0												Silty CLAY	
17.0													
18.0													
19.0													
20.0													

NOTES:

(1) Thick-wall ring lined drive sampler (California sampler) used for SPT samples. Rings dimensions = 2-1/2" O.D. by 2-7/16" I.D. by 6" length.

(2) Correction factor: $N_{corr}=N*(2.0^2-1.375^2)in./(3.0^2-2.4^2)in. = N*0.65$.

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER: Chris French

LOCATION: Selkirk Yard MP - 3.78

AECOM

Boring Log

SHEET 2 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-8**

START DATE: 02/26/2021

FINISH DATE: 02/26/2021

OFFSET: N/A

DEPTH	CORING RATE MIN/FT	DEPTHS FROM - TO (FEET)	TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		20'-22'	S-8	24"	24"	WOH	3	3	5	4	CH		Gray silty CLAY, soft, wet
21.0													
22.0													
23.0													
24.0													
25.0													
		25'-27'	S-9	24"	24"	WOH	2	4	4	4	CH		SAA
26.0													TR-4; (26.0'-26.5')
27.0													
28.0													
29.0													
30.0													
		30'-32'	S-10	24"	24"	WOH	1	4	4	3	CH	Silty CLAY	SAA
31.0													
32.0													
33.0													
34.0													
35.0													
		35'-37'	S-11	24"	24"	WOH	WOH	4	5	3	CH		SAA
36.0													TR-5; (36.0'-36.5')
37.0													
38.0													
		38'-40'	S-12	24"	24"	WHO/8"	2	4	6	4	CH		SAA
39.0													
40.0													
													SY-8 terminated at 40 fbg
41.0													
42.0													
43.0													
44.0													
45.0													

NOTES:

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER/GEOLOGIST: Chris French

LOCATION: Selkirk NY MP - 4.08

AECOM

Boring Log

SHEET 1 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-9**

START DATE: 02/26/2021

FINISH DATE: 02/26/2021

OFFSET: N/A

DRILL RIG: CME LC-55

BORING TYPE: SPT

BORING O.D.: 4.5"

SURFACE ELEV.:

LONGITUDE:

LATITUDE:

GROUND WATER OBSERVATIONS		CASING	SAMPLER	DRILL BIT	CORE BARREL
Water at surface	TYPE	Flush Joint Steel	California Modified	Tricone Roller Bit	
	SIZE I.D.	4"	2.5"	- -	
	SIZE O.D.	4.5"	3"	3 7/8"	
	HAMMER WT.	140 lbs	140 lbs		
	HAMMER FALL	30"	30"		

DEPTH	CORING RATE MIN/FT	SAMPLE DEPTHS FROM - TO (FEET)	SAMPLE TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)	N Corr.(2)	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		0'-5'				Hand Cleared		CL		Brown CLAY and SILT, trace fine sand, trace organics, medium stif, moist
1.0								CL		0.7': Brown CLAY and SILT, trace fine sand, medium stiff, moist
2.0										
3.0										
		3'-5'	S-1							TR-1; (3.0'-5.0')
4.0										
5.0										
		5'-7'	S-2	24"	24"	9 22 25 31	31	CL		Brown CLAY and SILT, very stiff, moist
6.0										
7.0										
		7'-9'	S-3	24"	24"	12 19 25 25	29			
8.0								CL		Brown silty CLAY, very stiff, moist
9.0										TR-2; (8.0'-8.5')
		9'-11'	S-4	24"	24"	11 36 37 18	47	CL		SAA
10.0								ML/SP	Silty CLAY	10.5': Brown SILT and fine SAND, stiff, saturated
11.0										
		11'-'13'	S-5	24"	24"	8 8 8 7	10	ML/SP		SAA
12.0								CH		12.2': Gray silty CLAY, soft, wet
13.0										TR-3; (12.0'-12.5')
		13'-15'	S-6	24"	24"	WOH/13" 3 2	2	CH		SAA
14.0										
15.0										
		15'-17'	S-7	24"	24"	WOH/4" 4 4 6	5	CH		SAA
16.0										
17.0										
18.0										
19.0										
20.0										

NOTES:

(1) Thick-wall ring lined drive sampler (California sampler) used for SPT samples. Rings dimensions = 2-1/2" O.D. by 2-7/16" I.D. by 6" length.

(2) Correction factor: $N_{corr}=N*(2.0^2-1.375^2)in./(3.0^2-2.4^2)in. = N*0.65$.

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER: Chris French

LOCATION: Selkirk NY MP - 4.08

AECOM

Boring Log

SHEET 2 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-9**

START DATE: 02/26/2021

FINISH DATE: 02/26/2021

OFFSET: N/A

DEPTH	CORING RATE MIN/FT	DEPTHS FROM - TO (FEET)	TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)	N Corr.	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		20'-22'	S-8	24"	24"	WOH/16" 1 3	1	CH		Brown silty CLAY, soft, wet
21.0										
22.0										
23.0										
24.0										
25.0										
		25'-27'	S-9	24"	24"	WOH/15" 1 4	1	CH		Gray silty CLAY, very soft, wet
26.0										
										TR-4; (26.0'-26.5')
27.0										
28.0										
29.0										
30.0										
		30'-32'	S-10	24"	24"	WOH/21" 2	0	CH	Silty CLAY	SAA
31.0										
32.0										
33.0										
34.0										
35.0										
		35'-37'	S-11	24"	24"	WOH/4" WOH/12' 1 4	1	CH		SAA
36.0										
										TR-5; (36.0' -36.5')
37.0										
38.0										
		38'-40'	S-12	24"	24"	WOH WOH/17" 1	0	CH		SAA
39.0										
40.0										
										SY-9 terminated at 40- fbg
41.0										
42.0										
43.0										
44.0										
45.0										

NOTES:

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT	AECOM		SHEET 1 OF 2
DRILLER: Chris Chaillou			PROJECT NAME: CHPE -
SOILS ENGINEER/GEOLOGIST: Chris French			PROJECT NO.: 60323056
			HOLE NO.: **SY-9A**
	BORING LOG		START DATE: 2/25/21
			FINISH DATE: 2/25/21
LOCATION: MP - 4.39 (CSX Rail)			OFFSET: N/A

GROUND WATER OBSERVATIONS		CASING	SAMPLER	DRILL BIT	CORE BARREL	DRILL RIG: CME LC-55
	TYPE	Flush Joint Steel	California Modified	Tricone Roller Bit		BORING TYPE: SPT
	SIZE I.D.	4"	2.5"	- -		BORING O.D.: 4.5"
	SIZE O.D.	4.5"	3"	3 7/8"		SURFACE ELEV.:
	HAMMER WT.	140 lbs	140 lbs			NORTHING
	HAMMER FALL	30"	30"			EASTING

DEPTH	CORING RATE MIN/FT	SAMPLE DEPTHS FROM - TO (FEET)	SAMPLE TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.(2)	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		0'-5'				Hand Cleared					OL		0'-0.5' Black SILT and fine Sand, trace, sub-rounded Gravel, organics, frozen
1.0													
											CL	CLAY AND SILT	0.5'-5' Brown CLAY and Silt, trace fine Sand, medium stiff, moist
2.0													
3.0													
		3'-5'	S-1										TR-1; (3.0'-5.0')
4.0													
5.0													
		5'-7'	S-2	24"	24"	13	22	23	27	29	CL		Brown CLAY and Silt, very stiff, moist
6.0													
7.0													
		7'-9'	S-3	24"	24"	17	17	16	16	21	CL		Brown CLAY and Silt, stiff, moist
8.0													
9.0													
		9'-11'	S-4	24"	24"	4	7	9	11	10	CL		Brown CLAY and Silt, sporadic lenses of fine Sand and
10.0													
11.0													
		11'-13'	S-5	24"	24"	9	12	38	16	33	MH	Sandy SILT	Brown SILT and fine Sand, very stiff, saturated
12.0													
													TR-2; (12.0'-12.5')
13.0													
		13'-15'	S-6	24"	24"	WOH	3	3	4	4	CH		Gray Silty CLAY, soft, wet
14.0													
15.0													
		15'-17'	S-7	24"	24"	WOH	4	4	4	5	CH		SAA
16.0													
													TR-3; (16.0'-16.5')
17.0													
18.0													
19.0													
20.0													

NOTES:

(1) Thick-wall ring lined drive sampler (California sampler) used for SPT samples. Rings dimensions = 2-1/2" O.D. by 2-7/16" I.D. by 6" length.

(2) Correction factor: $N_{corr}=N*(2.0^2-1.375^2)in./(3.0^2-2.4^2)in. = N*0.65$.

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER/GEOLOGIST: Chris French

LOCATION: MP - 4.39 (CSX Rail)

AECOM

BORING LOG

SHEET 2 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-9A**

START DATE: 2/25/21

FINISH DATE: 2/25/21

OFFSET: N/A

DEPTH	CORING RATE MIN/FT	DEPTHS FROM - TO (FEET)	TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		20'-22'	S-8	24"	24"	WOH	3	2	3	3	CH		SAA
21.0													
22.0													
23.0													
24.0													
25.0													
		25'-27'	S-9	24"	22"	WOH/5"	3	2	3	3	CH		SAA
26.0													
													TR-4; (26.0'-26.5')
27.0													
28.0													
29.0													
30.0													
		30'-32'	S-10	24"	24"	WOH	3	2	3	3	CH	Silty CLAY	SAA
31.0													
32.0													
33.0													
34.0													
35.0													
		35'-37'	S-11	24"	21"	WOH/7"	2	3	3	3	CH		Gray CLAY and Silt, soft, wet
36.0													
													TR-5; (36.0'-36.5')
37.0													
38.0													
		38'-40'	S-12	24"	24"	WOH	WOH	WOH	4	0	CH		SAA
39.0													
40.0													
													SY-9A terminated at 40' then grouted to surface
41.0													
42.0													
43.0													
44.0													
45.0													

NOTES:

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

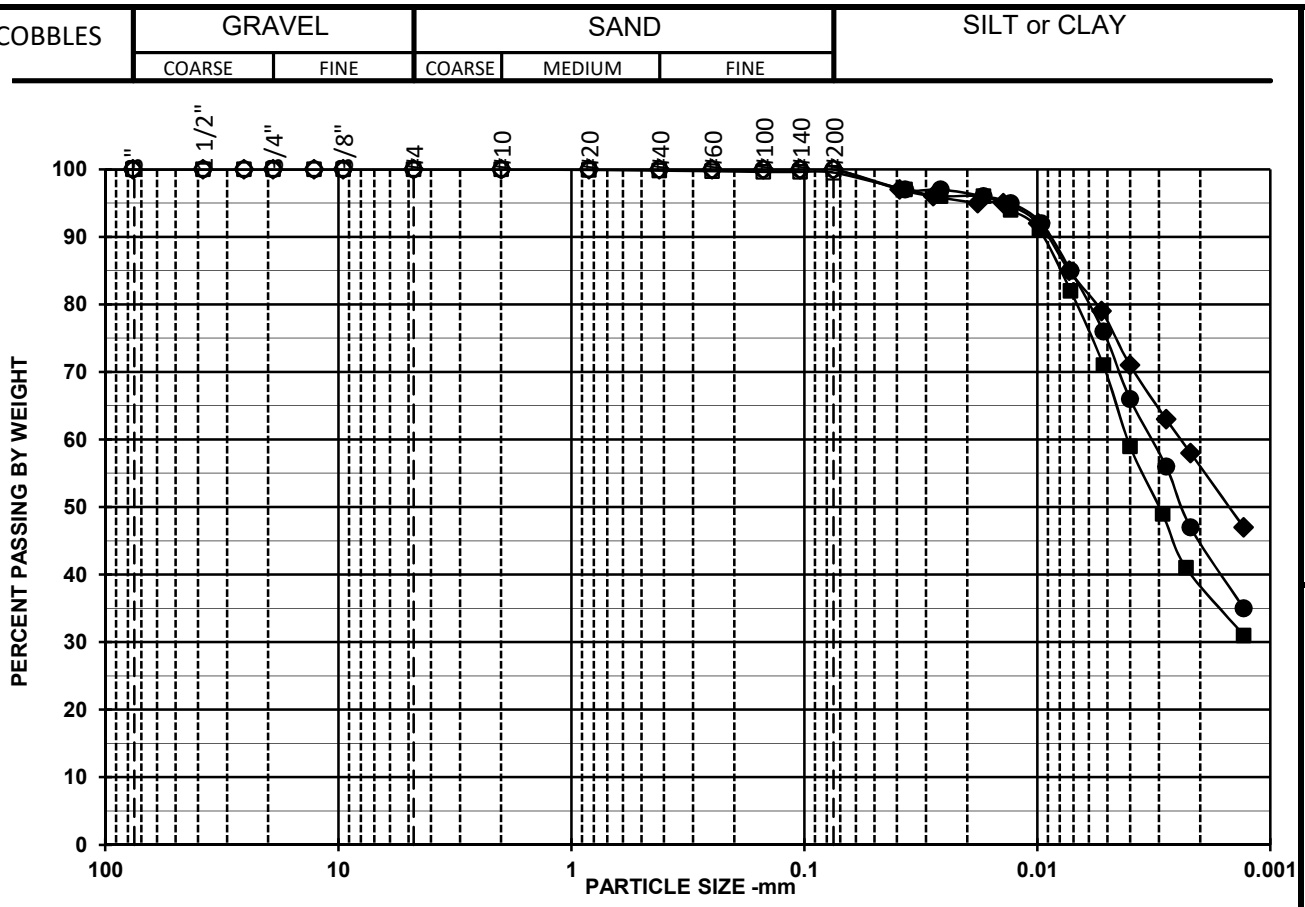
SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

Aquifer
CHPE- Selkirk Bypass Borings
LABORATORY SOIL TESTING DATA SUMMARY

BORING NO.	SAMPLE NO.	DEPTH (ft)	IDENTIFICATION TESTS							REMARKS
			WATER CONTENT (%)	LIQUID LIMIT (-)	PLASTIC LIMIT (-)	PLAS. INDEX (-)	USCS SYMB. (1)	SIEVE MINUS NO. 200 (%)	HYDROMETER % MINUS 2 μm (%)	
SY-1	S-2	5-7	25.6	34	20	14	CL	97	26	
SY-1	S-4	9-11	23.4	37	20	17	CL	88	33	
SY-3	S-2	5-7	33.3	60	25	35	CH	88	48	
SY-3	S-4	9-11	24.3	46	22	24	CL	65	30	
SY-6	S-3	7-9	20.5				SC	35	18	
SY-6	S-5	11-13	24.4				CL	91	35	
SY-7	S-2	5-7	26.1	41	21	20	CL	88	35	
SY-7	S-7	15-17	33.5	33	19	14	CL	99.8	33	
SY-7	S-10	30-32	39.4	43	20	23	CL	100	51	
SY-8	S-3	7-9	30.6	41	23	18	CL	99.5	39	
SY-8	S-8	20-22	42.7	46	20	26	CL	100	56	
SY-8	S-10	30-32	41.3	45	20	25	OL	100	45	
SY-9A	S-3	7-9	28.1	41	19	22	CL	99.7	44	
SY-9A	S-8	20-22	35.6	37	18	19	CL	100	47	
SY-9A	S-11	35-37	30.9	33	19	14	OL	100	27	
SY-10	S-3	7-9	31.6	40	19	21	CL	94.6	34	
SY-10	S-8	20-22	26.6	44	20	24	CL	99.9	49	
SY-10	S-10	30-32	33.8	30	19	11	CL	99.9	31	

Note: (1) USCS symbol based on visual observation and Sieve and Atterberg limits reported.



Open Symbols: Sieve analysis by ASTM D6913
Filled symbols: Hydrometer analysis by ASTM D7928 corrected for complete sample

SYMBOL	w (%)	LL	PL	PI	USCS	AASHTO	USCS DESCRIPTION AND REMARKS	DATE
□	30.6	41	23	18	CL		Brown, Lean clay	04/12/21
◇	42.7	46	20	26	CL		Gray, Lean clay	04/12/21
○	41.3	45	20	25	OL		Gray, Organic silt	04/12/21

Aquifer

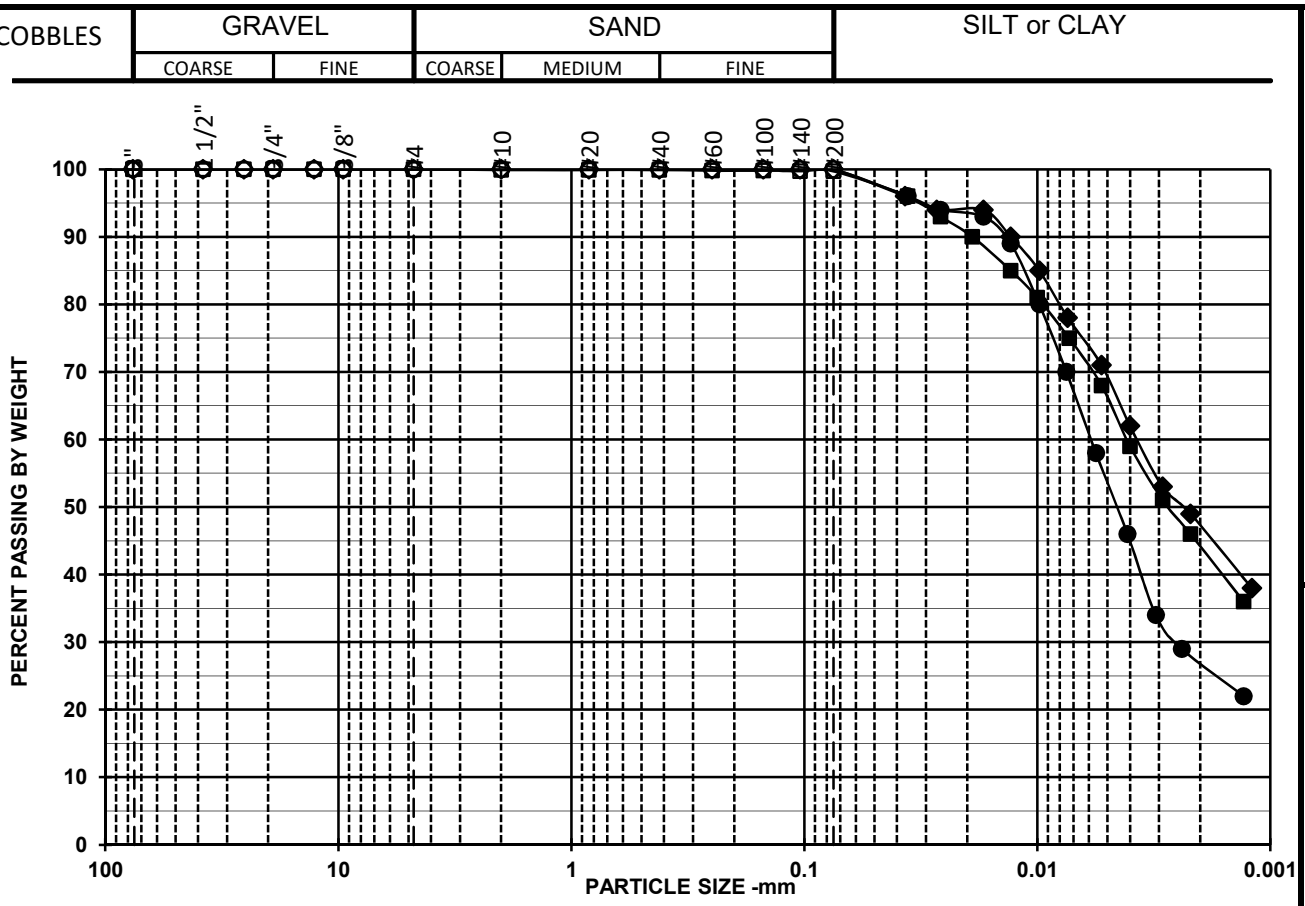
TerraSense, LLC #7853-21010

CHPE- Selkirk Bypass Borings

Symbol	□	◇	○
Boring	SY-8	SY-8	SY-8
Sample	S-3	S-8	S-10
Depth	7-9	20-22	30-32
% +3"	0	0	0
% Gravel	0	0	0
% SAND	0.5	0	0
%C SAND	0	0	0
%M SAND	0.2	0	0
%F SAND	0.3	0	0
% FINES	99.5	100	100
D_{100} (mm)	2	0.075	4.75
D_{60} (mm)	0.004	0.002	0.003
D_{30} (mm)			
D_{10} (mm)			
Cc			
Cu			

Sieve Size/ID #	Percent Finer Data		
6"	100.0	100.0	100
4"	100.0	100.0	100
3"	100.0	100.0	100
1 1/2"	100.0	100.0	100
1"	100.0	100.0	100
3/4"	100.0	100.0	100
1/2"	100.0	100.0	100
3/8"	100.0	100.0	100
#4	100.0	100.0	100
#10	100.0	100.0	100
#20	99.9	100.0	100
#40	99.8	100.0	100
#60	99.7	100.0	100
#100	99.6	100.0	100
#140	99.6	100.0	100
#200	99.5	100.0	100
5μ m	69	77	75
2μ m	39	56	45
1μ m	26	42	29

PARTICLE SIZE DISTRIBUTION
ASTM D6913 & ASTM D7928



Open Symbols: Sieve analysis by ASTM D6913
Filled symbols: Hydrometer analysis by ASTM D7928 corrected for complete sample

SYMBOL	w (%)	LL	PL	PI	USCS	AASHTO	USCS DESCRIPTION AND REMARKS	DATE
□	28.1	41	19	22	CL		Brown, Lean clay	04/12/21
◇	35.6	37	18	19	CL		Gray, Lean clay	04/12/21
○	30.9	33	19	14	OL		Gray, Organic silt	04/12/21

Aquifer

TerraSense, LLC #7853-21010

CHPE- Selkirk Bypass Borings

Symbol	□	◇	○
Boring	SY-9A	SY-9A	SY-9A
Sample	S-3	S-8	S-11
Depth	7-9	20-22	35-37
% +3"	0	0	0
% Gravel	0	0	0
% SAND	0.3	0	0
%C SAND	0.1	0	0
%M SAND	0	0	0
%F SAND	0.2	0	0
% FINES	99.7	100	100
D_{100} (mm)	4.75	0.075	0.075
D_{60} (mm)	0.004	0.004	0.006
D_{30} (mm)			0.003
D_{10} (mm)			
Cc			
Cu			

Sieve Size/ID #	Percent Finer Data		
6"	100.0	100.0	100.0
4"	100.0	100.0	100.0
3"	100.0	100.0	100.0
1 1/2"	100.0	100.0	100.0
1"	100.0	100.0	100.0
3/4"	100.0	100.0	100.0
1/2"	100.0	100.0	100.0
3/8"	100.0	100.0	100.0
#4	100.0	100.0	100.0
#10	99.9	100.0	100.0
#20	99.9	100.0	100.0
#40	99.9	100.0	100.0
#60	99.8	100.0	100.0
#100	99.8	100.0	100.0
#140	99.7	100.0	100.0
#200	99.7	100.0	100.0
5μ m	66	69	54
2μ m	44	47	27
1μ m	31	35	19

PARTICLE SIZE DISTRIBUTION
ASTM D6913 & ASTM D7928

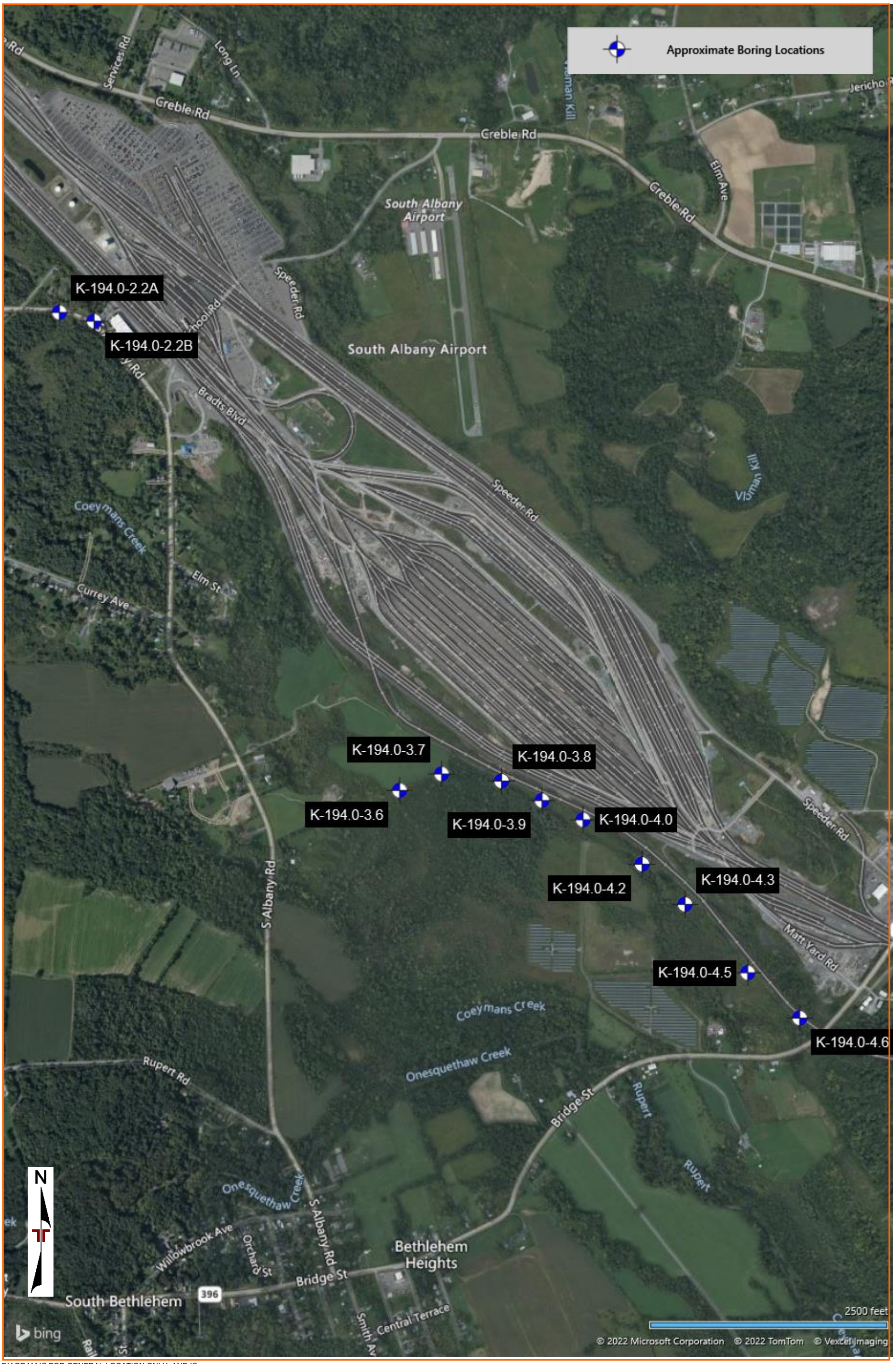


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. K-194.0-3.8

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.546900° Longitude: -73.832497°

Surface Elev.: 174.64 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.1	174.5								
TOPSOIL									
SILT AND CLAY (CL-ML), brown, soft to stiff									
				20	5-2-3-4 N=5	4.5 (HP)			
				16	6-6-6-8 N=12	3.0 (HP)			
		5		16	2-3-4-6 N=7	3.25 (HP)			
				20	3-5-5-6 N=10	2.5 (HP)	34.6		
				20	5-5-4-6 N=9	2.5 (HP)			
		10		24	2-2-2-3 N=4	1.0 (HP)	33.3	31-19-12	95
15.0	159.5								
SILT AND CLAY (CL-ML), gray, very soft		15		24	WOH/24"	.5 (HP)			
		20		24	WOH/24"	.25 (HP)			
		25		24	WOH/24"	.25 (HP)	47.5		

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-02-2022 | Boring Completed: 02-02-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-3.8

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.546900° Longitude: -73.832497°

Surface Elev.: 174.64 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		SILT AND CLAY (CL-ML), gray, very soft *(continued)*	30								
					X	24	WOH/24"	.25 (HP)			
			35								
					X	24	WOH/24"	.25 (HP)			
		grades with sand			X	24	WOH/24" 3" Split Spoon With Ring Samplers	.25 (HP)	43.9	40-23-17	82
	40.0	134.5	40								
		Boring Terminated at 40 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-02-2022 | Boring Completed: 02-02-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-3.9

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.546242° Longitude: -73.831012°

Surface Elev.: 172.23 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.2	172	**TOPSOIL**
1.0	171	**POORLY GRADED SAND WITH GRAVEL (SP)**, brown, loose
		SILT AND CLAY (CL-ML), brown, medium stiff to stiff
8.0	164	**SILT AND CLAY (CL-ML)**, gray, very soft to medium stiff
		grades with Sand

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		24	10-4-3-4 N=7	1.5 (HP)			
		20	5-6-7-20 N=13	2.5 (HP)			
5		20	3-3-5-5 N=8	2.0 (HP)			
		20	4-6-6-5 N=12	2.5 (HP)			
		22	5-4-4-4 N=8	2.25 (HP)	40.3		
10		23	1-2-2-3 N=4	1.0 (HP)			
15		24	WOH/24"	.25 (HP)	34.1	29-20-9	94
20		24	WOH/24"	.25 (HP)			
25		24	WOH/24"	.25 (HP)	46.8		

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-01-2022 | Boring Completed: 02-01-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-3.9

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.546242° Longitude: -73.831012°

Surface Elev.: 172.23 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
			30								
						24	WOH/24"	.25 (HP)			
						24	WOH/24" 3" Split Spoon With Ring Samplers	.25 (HP)	44.0	42-24-18	90
			35								
						24	WOH/24"	.25 (HP)			
						24	WOH/24"	.25 (HP)			
	40.0	132	40								

SILT AND CLAY (CL-ML), gray, very soft to medium stiff
(continued)

Boring Terminated at 40 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3 1/4"HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by: JK
Hammer Efficency Summary:
Energy Transfer Ratio: 89.2% +/- 2.4%
Hammer Efficiency Correction (CE):1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 02-01-2022 | Boring Completed: 02-01-2022

Drill Rig: Deidrich D-70 | Driller: J. Rauscher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.0

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.545720° Longitude: -73.829402°

Surface Elev.: 166.17 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.2	166	**TOPSOIL**
		SILT AND CLAY (CL-ML), orange and brown, medium stiff to very stiff
		grades trace gravel
9.0	157	**grades trace fine sand, no gravel**
		SILT AND CLAY (CL-ML), varved, gray, very soft to soft

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		14	3-2-4-5 N=6				
		14	7-7-10-12 N=17				
5		14	4-10-14-20 N=24	4 (HP)			
		24	9-9-9-10 N=18	2.5 (HP)			
		14	10-5-3-3 N=8		31.8	NP	80
10		24	WOH-2-1-1 N=3	0 (HP)			
15		24	WOH/24"	0 (HP)			
20		24	WOH/24"	0 (HP)	42.6		
25		24	WOH/24"	0 (HP)			

Stratification lines are approximate. In-situ, the transition may be gradual.

Advancement Method:
4 1/4" HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

At completion of drilling

After 48 Hours

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-27-2022 | Boring Completed: 01-28-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.0

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.545720° Longitude: -73.829402°

Surface Elev.: 166.17 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
					24	Pushed Shleby Tube	24 (HP)	39.4	33-22-11	94
		30			24	WOH/24"	0 (HP)			
			▽							
		35			24	WOH/24"	0 (HP)	33.7		
		40			24	WOH/24"	0 (HP)			
42.0	124									

SILT AND CLAY (CL-ML), varved, gray, very soft to soft *(continued)*

Boring Terminated at 42 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Advancement Method:
4 1/4" HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *At completion of drilling*

▽ *After 48 Hours*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-27-2022 | Boring Completed: 01-28-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.2

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.544578° Longitude: -73.827107°

Surface Elev.: 165.30 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.1	165	**TOPSOIL**
		FILL - SILT AND CLAY (CL-ML), rootlets noted, brown and gray, medium stiff **contains black cinders from 2' to 4'**
5.0	160.5	**SILT AND CLAY (CL-ML)**, with fine sand partings, brown, soft to very stiff
20.0	145.5	**SILT AND CLAY (CL-ML)**, varved, gray, very soft

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		6	4-4-6-6 N=10				
		4	4-3-4-5 N=7				
5		18	3-3-8-9 N=11	3.0 (HP)			
		18	9-12-13-12 N=25	3.5 (HP)			
		24	3-5-5-8 N=10	3.0 (HP)	28.9	43-25-18	76
10		24	7-9-9-11 N=18	3.5 (HP)			
15		24	2-2-2-3 N=4	1.5 (HP)			
20		24	1/24"	0 (HP)	41.1		
25		24	WOH/18"-1				

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4" HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

▽ *After 24 hours*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-27-2022 | Boring Completed: 01-27-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.2

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.544578° Longitude: -73.827107°

Surface Elev.: 165.30 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
						24	Pushed Shelby Tube		36.7	29-21-8	95
			30			24	WOH/24"				
			35			24	WOH/24"		32.3		
			40			24	WOH/24"				
	42.0	123.5									

SILT AND CLAY (CL-ML), varved, gray, very soft *(continued)*

Boring Terminated at 42 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4" HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

▽ *After 24 hours*

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-27-2022 | Boring Completed: 01-27-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.3

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.543533° Longitude: -73.825129°

Surface Elev.: 160.90 (Ft.)

DEPTH	ELEVATION (Ft.)	Description
0.2	160.5	**TOPSOIL**
		SILT AND CLAY (CL-ML), rootlets noted, mottled brown and gray, medium stiff to stiff
4.0	157	
		SILT AND CLAY (CL-ML), varved, brown, very stiff
8.0	153	
		SILT AND CLAY (CL-ML), varved, gray, very soft to medium stiff

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		10	10-4-3-5 N=7				
		16	4-4-6-5 N=10				
5		10	3-4-5-9 N=9	4.0 (HP)			
		24	5-9-8-10 N=17	3.0 (HP)			
		12	3-4-2-2 N=6	0.5 (HP)	34.7	41-17-24	85
10		24	2-3-3-3 N=6	1.0 (HP)			
15		24	1-1-2-1 N=3	0 (HP)			
20		24	Pushed Shelby Tube		41.7	36-22-14	96
		24	WOH/24"	0 (HP)			
25		24	WOH/24"	0 (HP)	39.9		

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4 HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

No measurable groundwater noted

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-26-2022 | Boring Completed: 01-26-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.3

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.543533° Longitude: -73.825129°

Surface Elev.: 160.90 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
			30		X	24	WOH/24"	0 (HP)			
			35		X	24	WOH/24"	0 (HP)	34.8	36-21-15	95
			40		X	24	WOH/24"	0 (HP)			
	42.0	119									

SILT AND CLAY (CL-ML), varved, gray, very soft to medium stiff *(continued)*

Boring Terminated at 42 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4 HSA

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49
WOH = Weight of Hammer

WATER LEVEL OBSERVATIONS

No measurable groundwater noted

Terracon
30 Corporate Cir Ste 201
Albany, NY

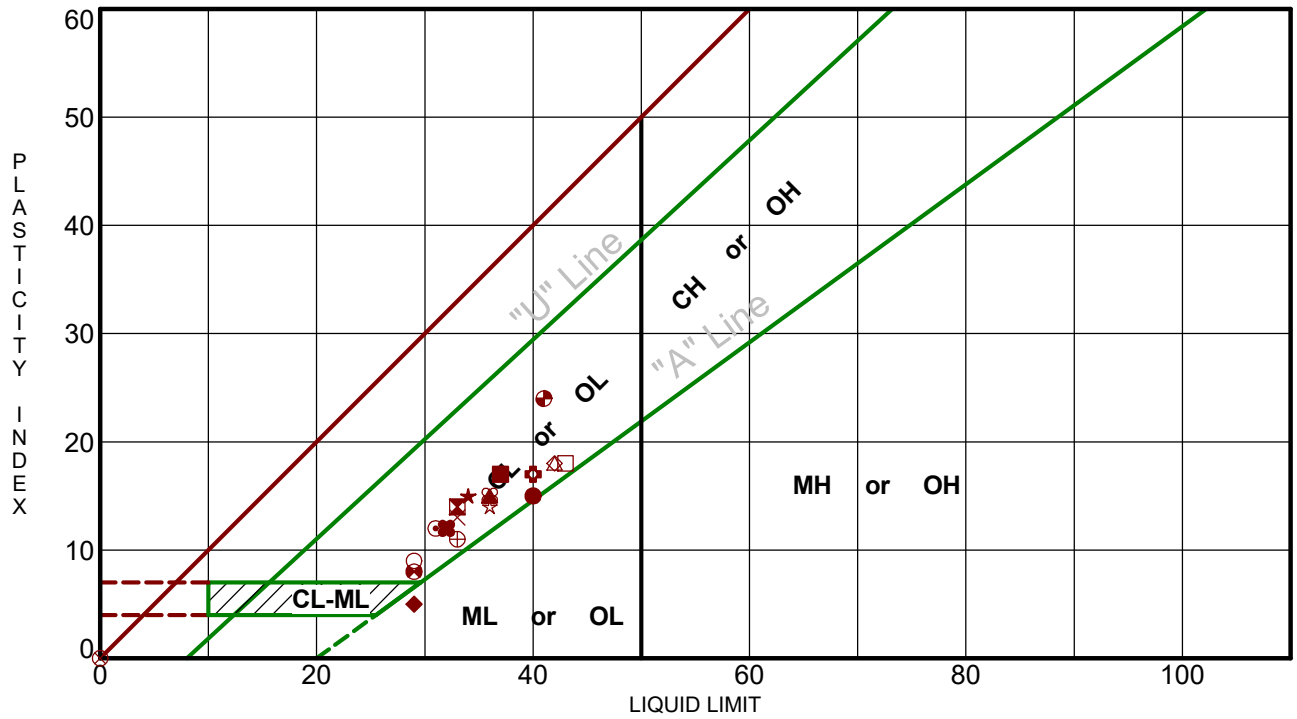
Boring Started: 01-26-2022 | Boring Completed: 01-26-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	K-194.0-2.2A	8 - 10	40	25	15	82.2	CL	LEAN CLAY with SAND
⊠	K-194.0-2.2A	30 - 32	33	19	14	92.9	CL	LEAN CLAY
▲	K-194.0-2.2B	8 - 10	36	21	15	92.5	CL	LEAN CLAY
★	K-194.0-2.2B	29 - 31	34	19	15	86.5	CL	LEAN CLAY
⊙	K-194.0-3.8	10 - 12	31	19	12	94.8	CL	LEAN CLAY
✿	K-194.0-3.8	38 - 40	40	23	17	81.8	CL	LEAN CLAY with SAND
○	K-194.0-3.9	15 - 17	29	20	9	94.3	CL	LEAN CLAY
△	K-194.0-3.9	33 - 35	42	24	18	89.9	CL	LEAN CLAY
⊗	K-194.0-4.0	8 - 10	NP	NP	NP	79.8	ML	SILT with SAND
⊕	K-194.0-4.0	28 - 30	33	22	11	94.4	CL	LEAN CLAY
□	K-194.0-4.2	8 - 10	43	25	18	75.7	CL	LEAN CLAY with SAND
⊠	K-194.0-4.2	28 - 30	29	21	8	94.5	CL	LEAN CLAY
◕	K-194.0-4.3	8 - 10	41	17	24	85.3	CL	LEAN CLAY
☆	K-194.0-4.3	19 - 21	36	22	14	95.8	CL	LEAN CLAY
⊠	K-194.0-4.3	35 - 37	36	21	15	94.7	CL	LEAN CLAY
■	K-194.0-4.5	15 - 17	37	20	17		CL	LEAN CLAY
◆	K-194.0-4.5	29 - 31	29	24	5	98.7	ML	SILT
◇	K-194.0-4.6	15 - 17	42	24	18	67.4	CL	SANDY LEAN CLAY
✕	K-194.0-4.6	30 - 32	33	20	13	95.1	CL	LEAN CLAY
■	K-194.0-4.6	43 - 45	32	20	12	98.0	CL	LEAN CLAY

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

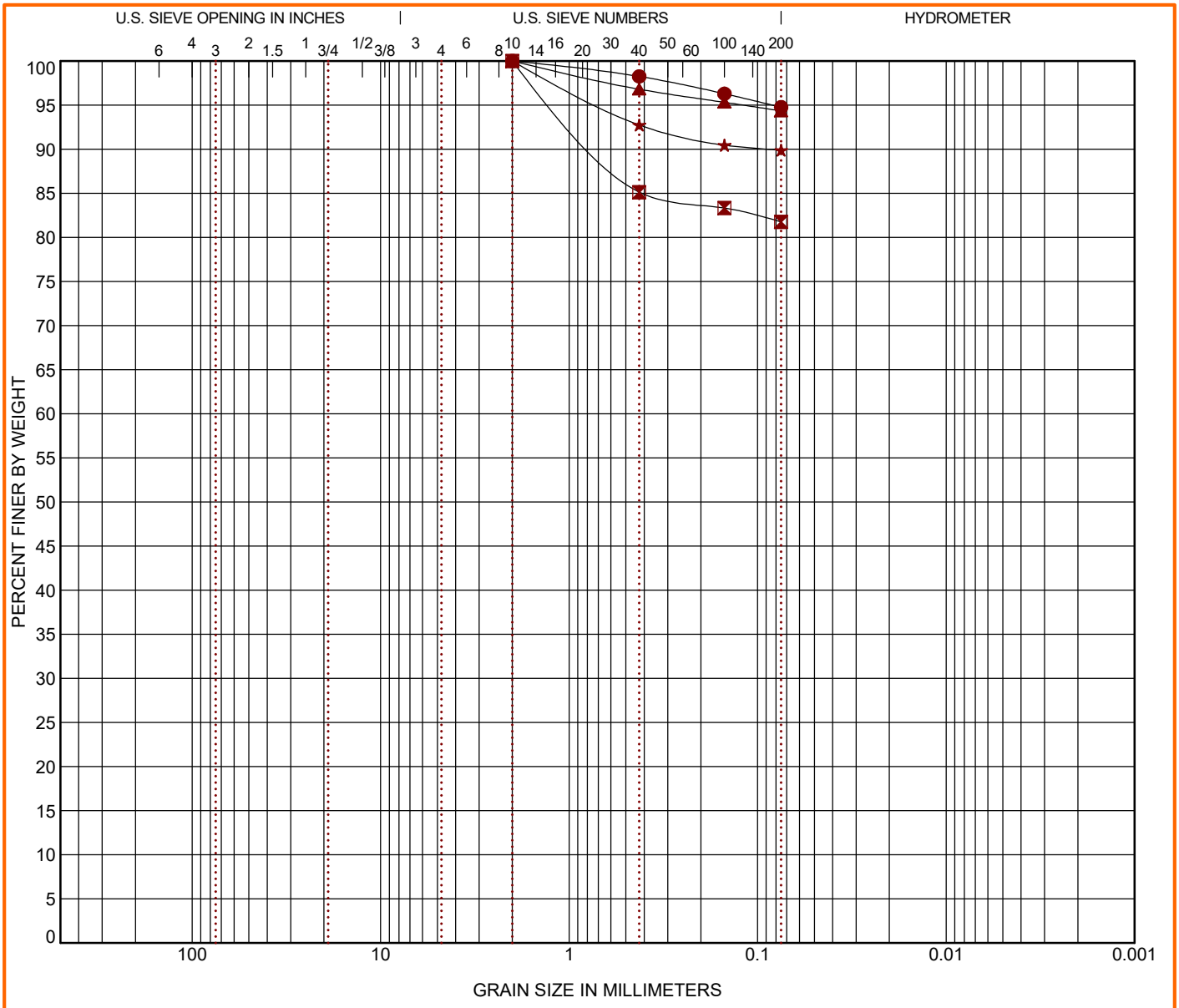
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-3.8	10 - 12	LEAN CLAY (CL)	33.3	31	19	12		
⊠	K-194.0-3.8	38 - 40	LEAN CLAY with SAND (CL)	43.9	40	23	17		
▲	K-194.0-3.9	15 - 17	LEAN CLAY (CL)	34.1	29	20	9		
★	K-194.0-3.9	33 - 35	LEAN CLAY (CL)	44.0	42	24	18		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-3.8	10 - 12	2				0.0	0.0	5.2		94.8	
⊠	K-194.0-3.8	38 - 40	2				0.0	0.0	18.2		81.8	
▲	K-194.0-3.9	15 - 17	2				0.0	0.0	5.7		94.3	
★	K-194.0-3.9	33 - 35	2				0.0	0.0	10.1		89.9	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

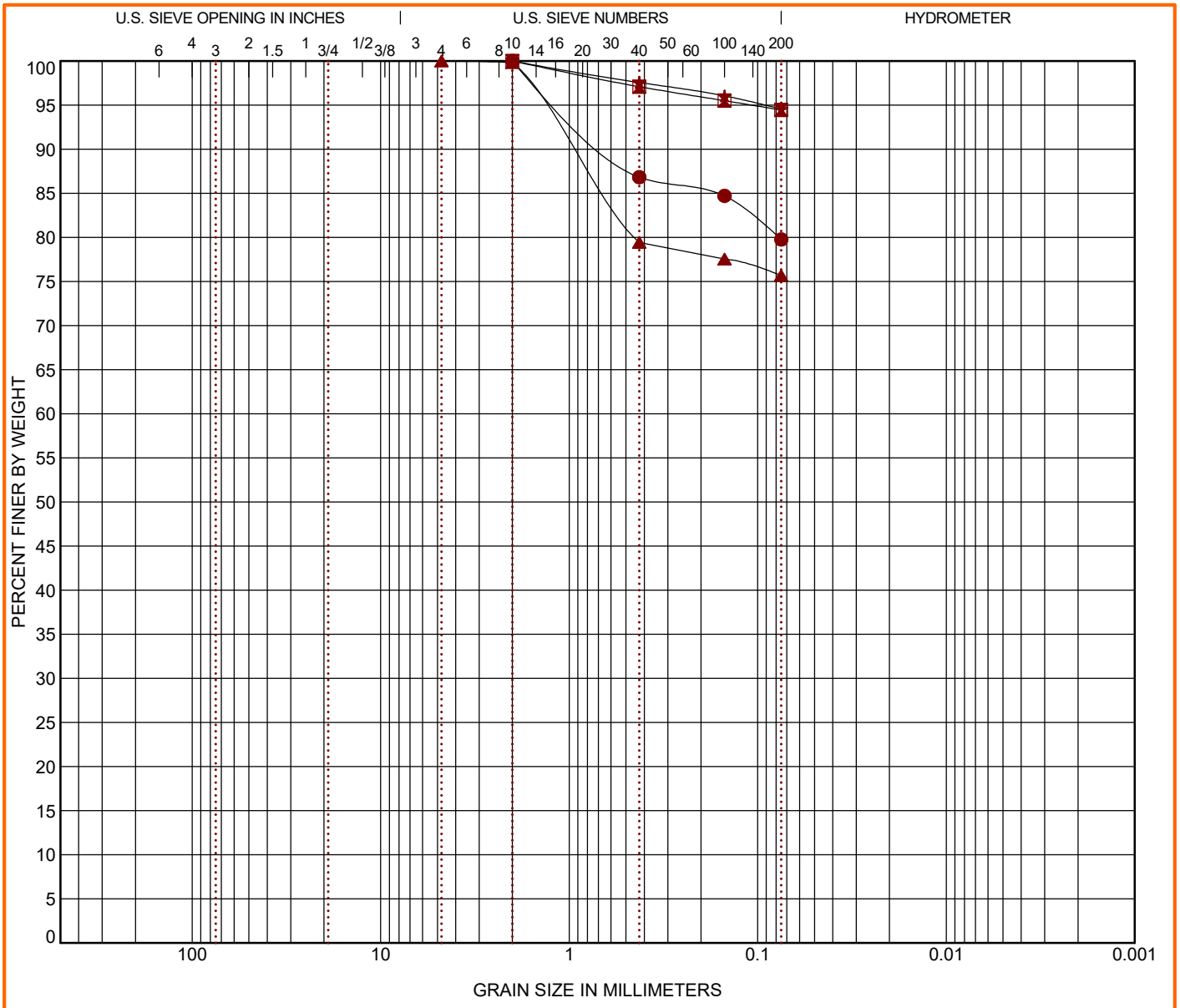
PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 3/30/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-4.0	8 - 10	SILT with SAND (ML)	31.8	NP	NP	NP		
⊠	K-194.0-4.0	28 - 30	LEAN CLAY (CL)	39.4	33	22	11		
▲	K-194.0-4.2	8 - 10	LEAN CLAY with SAND (CL)	28.9	43	25	18		
★	K-194.0-4.2	28 - 30	LEAN CLAY (CL)	36.7	29	21	8		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-4.0	8 - 10	2				0.0	0.0	20.2		79.8	
⊠	K-194.0-4.0	28 - 30	2				0.0	0.0	5.6		94.4	
▲	K-194.0-4.2	8 - 10	4.75				0.0	0.0	24.3		75.7	
★	K-194.0-4.2	28 - 30	2				0.0	0.0	5.5		94.5	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

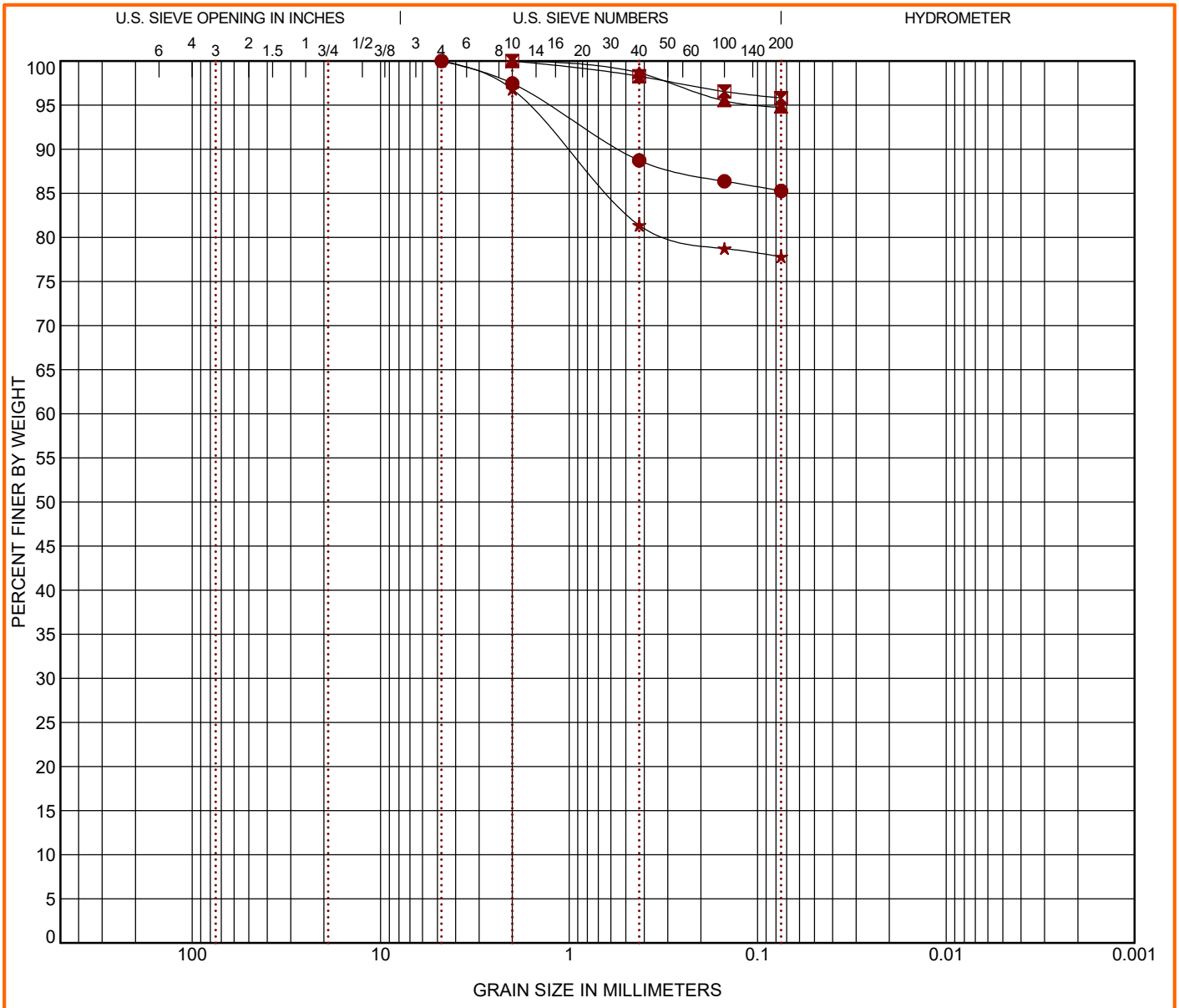
PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 3/30/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-4.3	8 - 10	LEAN CLAY (CL)	34.7	41	17	24		
⊠	K-194.0-4.3	19 - 21	LEAN CLAY (CL)	41.7	36	22	14		
▲	K-194.0-4.3	35 - 37	LEAN CLAY (CL)	34.8	36	21	15		
★	K-194.0-4.5	6 - 8	SILT with SAND (ML)	28.1					

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-4.3	8 - 10	4.75				0.0	0.0	14.7		85.3	
⊠	K-194.0-4.3	19 - 21	2				0.0	0.0	4.2		95.8	
▲	K-194.0-4.3	35 - 37	2				0.0	0.0	5.3		94.7	
★	K-194.0-4.5	6 - 8	4.75				0.0	0.0	22.2		77.8	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 3/30/22

Approximate Boring Locations

KB-192.4

KB-192.8B

KB-194.0-3.9B

KB-194.0-3.6B

KB-194.0-4.4

KB-194.0-4.6B

N

1 mile

bing

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DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. KB-194.0-3.9B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546522° Longitude: -73.831165°

Surface Elev.: 171.5230 (Ft.)

DEPTH	ELEVATION (Ft.)	DESCRIPTION
0.3	171.3	**TOPSOIL**
		LEAN CLAY WITH SAND (CL), varved silt and clay, brown, soft to very stiff
8.0	163.5	**LEAN CLAY (CL)**, varved silt and clay, occasional fine sand partings, gray, very soft to medium stiff

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		14	1-1-2-3 N=3			
		18	3-6-7-8 N=13			
5		24	1-10-11-11 N=21	31.5	45-25-20	77
		19	8-8-8-8 N=16			
		24	3-2-3-3 N=5			
10		24	4-3-4-4 N=7			
15		24	WH-WH-WH-WH			
20		24	WH-WH-WH-WH			
25		18	WH-WH-WH	50.2	44-26-18	90

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4"HSA
Cased to 10'
Mud Rotary with 3 7/8" Drag bit to 76.5

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-12-2022 | Boring Completed: 09-14-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

BORING LOG NO. KB-194.0-3.9B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546522° Longitude: -73.831165°

Surface Elev.: 171.5230 (Ft.)

DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
30				X	18	WH-WH-WH			
35				X	18	WH-WH-WH			
40				X	18	WH-WH-WH			
45				X	18	WR-WR-WR	43.4	39-25-14	100
50				X	18	WR-WR-WR			
55				X	18	WR-WR-WR			

LEAN CLAY (CL), varved silt and clay, occasional fine sand partings, gray, very soft to medium stiff *(continued)*

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4"HSA
Cased to 10'
Mud Rotary with 3 7/8" Drag bit to 76.5

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-12-2022 | Boring Completed: 09-14-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

BORING LOG NO. KB-194.0-3.9B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.546522° Longitude: -73.831165°

Surface Elev.: 171.5230 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		LEAN CLAY (CL), varved silt and clay, occasional fine sand partings, gray, very soft to medium stiff *(continued)*								
	60.0	111.5	60							
		FAT CLAY (CH), varved silt and clay, occasional fine sand partings, gray, very soft				24	WR-WR-WR-WR 3" Splt Spoon With Ring Samplers	52.9	50-26-24	95
			65			18	WR-WR-WR			
			70			18	WR-WR-WR			
			75			18	WR-WR-WR			
	76.5	95								
		Boring Terminated at 76.5 Feet								

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 4"HSA
Cased to 10'
Mud Rotary with 3 7/8" Drag bit to 76.5

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
Hammer Efficiency Summary:
Energy Transfer Ratio: 84.7% +/-5.0%
Hammer Efficiency Correction (CE): 1.41
WH = Weight of Hammer
WR = Weight of Rods

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-12-2022 | Boring Completed: 09-14-2022

Drill Rig: Diedrich D-50 | Driller: S. Morey

Project No.: JB215256G

BORING LOG NO. KB-194.0-4.4

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.542480° Longitude: -73.823906°

Surface Elev.: 158.9240 (Ft.)

DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
			5							
10.0	148.9		10		X	19	2-3-7-19 N=10			
			15		X	24	WH-WH-WH-WH			
			20		X	24	WH-WH-WH-WH	50.1	46-26-20	96
			25		X	24	WH-WH-WH-WH			

"Soft Dig" (by others) to 10 feet. Set casing at 10'

LEAN CLAY (CL), varved silt and clay, brown, very soft to stiff

grades to gray below 12 feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud Rotary

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
WH = Weight of hammer
Hammer Efficiency Summary:
Energy Transfer Ratio: 78.6% +/-2.9%
Hammer Efficiency Correction (CE): 1.31

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-09-2022 | Boring Completed: 09-12-2022

Drill Rig: Diedrich D-50 | Driller: C. Johnston

Project No.: JB215256G

BORING LOG NO. KB-194.0-4.4

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.542480° Longitude: -73.823906°

Surface Elev.: 158.9240 (Ft.)

DEPTH ELEVATION (Ft.)

GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
LEAN CLAY (CL), varved silt and clay, brown, very soft to stiff *(continued)*	30							
				24	WH-WH-WH-WH			
	35							
				24	WH-WH-WH-WH			
	40							
				24	WH-WH-WH-WH	37.9	35-21-14	99
	45							
				24	WH-WH-WH-WH			
	50							
				24	WH-WH-WH-WH	47.6	48-27-21	90
	55							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud Rotary

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
WH = Weight of hammer
Hammer Efficiency Summary:
Energy Transfer Ratio: 78.6% +/-2.9%
Hammer Efficiency Correction (CE): 1.31

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-09-2022 | Boring Completed: 09-12-2022

Drill Rig: Diedrich D-50 | Driller: C. Johnston

Project No.: JB215256G

BORING LOG NO. KB-194.0-4.4

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.542480° Longitude: -73.823906°

Surface Elev.: 158.9240 (Ft.)

DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
					24	WH-WH-WH-WH			
60					24	WH-WH-WH-WH			
65					24	WH-WH-WH-WH			
70					24	WH-WH-WH-WH	37.4	37-23-14	99
75					24	WH-WH-WH-WH			
77.0	81.9								

LEAN CLAY (CL), varved silt and clay, brown, very soft to stiff *(continued)*

Boring Terminated at 77 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud Rotary

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
WH = Weight of hammer
Hammer Efficiency Summary:
Energy Transfer Ratio: 78.6% +/-2.9%
Hammer Efficiency Correction (CE): 1.31

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-09-2022 | Boring Completed: 09-12-2022

Drill Rig: Diedrich D-50 | Driller: C. Johnston

Project No.: JB215256G

Summary of Laboratory Results

BORING ID	Depth (Ft.)	Water Content (%)	Organic Content (%)
KB-182.7B	20-22	31.1	
KB-182.7B	50-52	35.4	
KB-182.7B	80-82	26.5	
KB-184.2	4-6	17.3	
KB-184.2	20-21.5	10.0	
KB-184.9	10-12	35.4	
KB-184.9	25-26.5	8.6	
KB-184.9	40-42	9.2	
KB-184.9	55-56.5	12.2	
KB-185.4	6-8	34.3	
KB-185.4	20-21.5	13.7	
KB-185.4	35-39	9.1	
KB-185.4	45-47	14.7	
KB-192.4	15-17	36.9	
KB-192.4	25-27	42.6	
KB-192.4	45-47	46.0	
KB-192.4	65-67	8.0	
KB-192.8B	15-17	36.5	
KB-192.8B	40-40.2	14.1	
KB-192.8B	50-50.2	14.2	
KB-194.0-3.6B	5-7	31.0	
KB-194.0-3.6B	30-32	37.9	
KB-194.0-3.6B	50-52	39.6	
KB-194.0-3.6B	70-72	46.7	
KB-194.0-3.9B	4-6	31.5	
KB-194.0-3.9B	25-26.5	50.2	
KB-194.0-3.9B	45-46.5	43.4	
KB-194.0-3.9B	60-61.5	52.9	
KB-194.0-4.4	20-22	50.1	
KB-194.0-4.4	40-42	37.9	
KB-194.0-4.4	50-52	47.6	
KB-194.0-4.4	70-72	37.4	
KB-194.0-4.6B	4-6	24.1	
KB-194.0-4.6B	20-21.5	40.3	
KB-194.0-4.6B	40-41.5	42.9	
KB-194.0-4.6B	60-61.5	45.6	
KB-200.6	8-10	20.3	
KB-200.6	30-32	30.5	
KB-200.6	45-47	26.3	
KB-200.6	55-57	33.6	
KB-200.8A	15-17	39.6	
KB-200.8A	35-36.5	45.0	

PROJECT: CHPE - Additional HDD Borings - Phase 3

SITE: Fort Ann to Coxsackie, NY

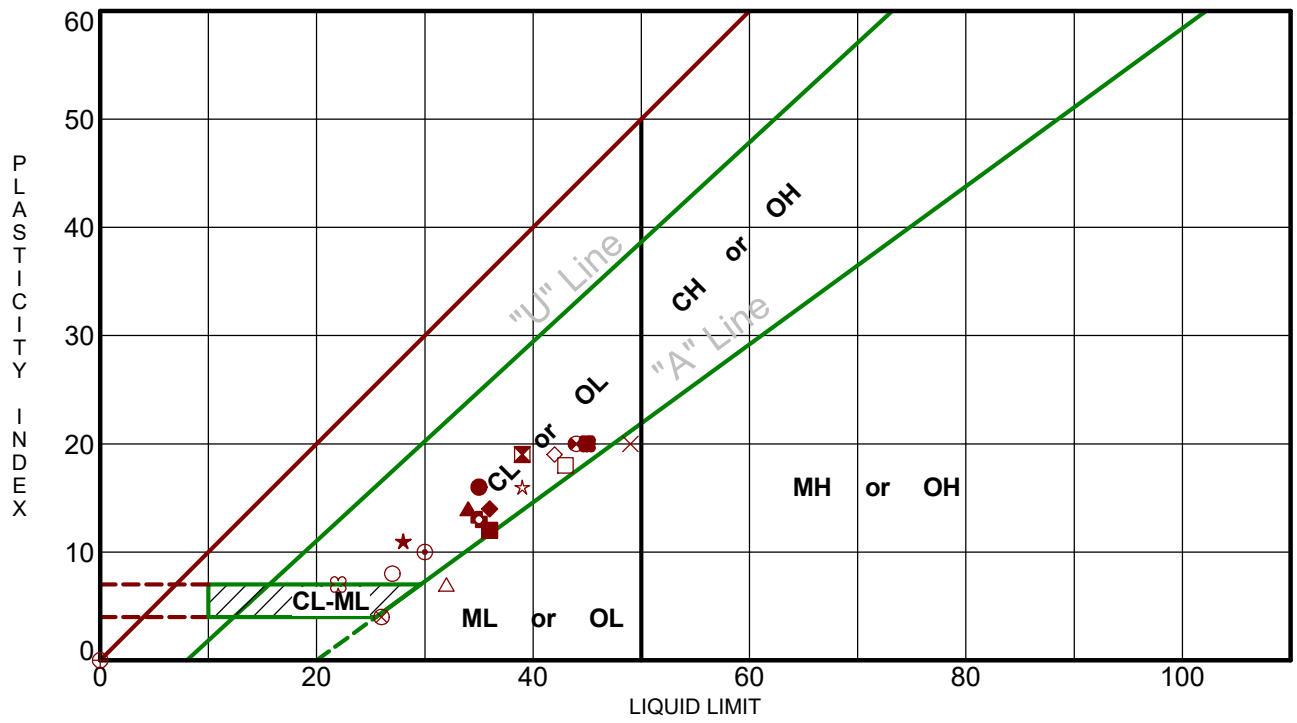
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256G

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	KB-135.7	30 - 32	35	19	16	96.6	CL	LEAN CLAY
⊠	KB-135.8	15 - 17	39	20	19	93.6	CL	LEAN CLAY
▲	KB-135.8	30 - 32	34	20	14	94.2	CL	LEAN CLAY
★	KB-135.8	40 - 42	28	17	11	99.5	CL	LEAN CLAY
⊙	KB-182.7B	20 - 22	30	20	10	98.6	CL	LEAN CLAY
✿	KB-182.7B	50 - 52	35	22	13	98.6	CL	LEAN CLAY
○	KB-182.7B	80 - 82	27	19	8	98.3	CL	LEAN CLAY
△	KB-184.9	10 - 12	32	25	7	86.1	ML	SILT
⊗	KB-185.4	6 - 8	26	22	4	87.4	ML	SILT
⊕	KB-185.4	20 - 21.5	NP	NP	NP	15.8	SM	SILTY SAND
□	KB-192.4	15 - 17	43	25	18	87.5	CL	LEAN CLAY
⊠	KB-192.4	25 - 27	44	24	20	97.7	CL	LEAN CLAY
◕	KB-192.4	45 - 47	45	25	20	92.4	CL	LEAN CLAY
☆	KB-192.8B	15 - 17	39	23	16	81.8	CL	LEAN CLAY with SAND
✿	KB-192.8B	50 - 50.2	22	15	7	26.0	SC-SM	SILTY, CLAYEY SAND
■	KB-194.0-3.6B	5 - 7	36	24	12	89.4	CL	LEAN CLAY
◆	KB-194.0-3.6B	30 - 32	36	22	14	95.7	CL	LEAN CLAY
◇	KB-194.0-3.6B	50 - 52	42	23	19	95.7	CL	LEAN CLAY
×	KB-194.0-3.6B	70 - 72	49	29	20	91.9	ML	SILT
✖	KB-194.0-3.9B	4 - 6	45	25	20	76.6	CL	LEAN CLAY with SAND

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

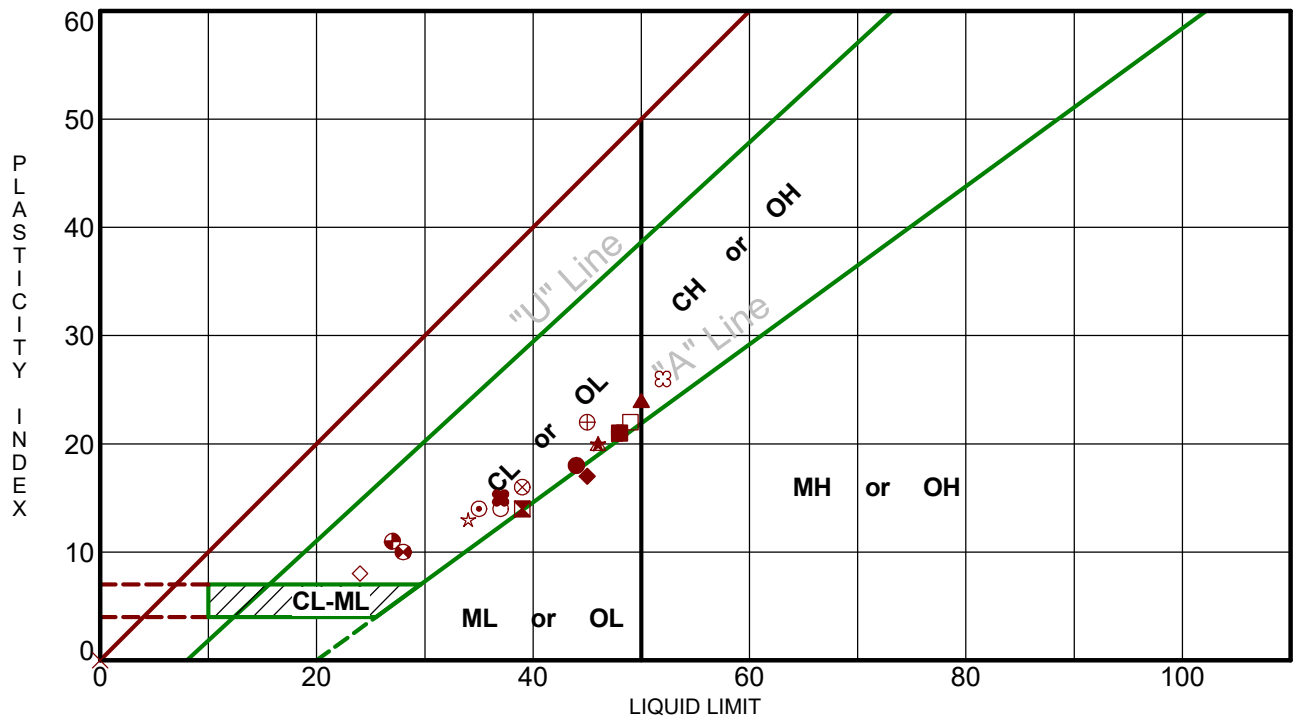
SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	KB-194.0-3.9B	25 - 26.5	44	26	18	90.2	CL	LEAN CLAY
⊠	KB-194.0-3.9B	45 - 46.5	39	25	14	99.7	CL	LEAN CLAY
▲	KB-194.0-3.9B	60 - 61.5	50	26	24	94.7	CH	FAT CLAY
★	KB-194.0-4.4	20 - 22	46	26	20	96.1	CL	LEAN CLAY
⊙	KB-194.0-4.4	40 - 42	35	21	14	99.0	CL	LEAN CLAY
✿	KB-194.0-4.4	50 - 52	48	27	21	90.3	CL	LEAN CLAY
○	KB-194.0-4.4	70 - 72	37	23	14	99.2	CL	LEAN CLAY
△	KB-194.0-4.6B	4 - 6	46	26	20	78.4	CL	LEAN CLAY with SAND
⊗	KB-194.0-4.6B	20 - 21.5	39	23	16	93.3	CL	LEAN CLAY
⊕	KB-194.0-4.6B	40 - 41.5	45	23	22	84.8	CL	LEAN CLAY with SAND
□	KB-194.0-4.6B	60 - 61.5	49	27	22	92.6	CL	LEAN CLAY
⊛	KB-200.6	8 - 10	28	18	10	60.1	CL	SANDY LEAN CLAY
◕	KB-200.6	30 - 32	27	16	11	100.0	CL	LEAN CLAY
☆	KB-200.6	55 - 57	34	21	13	100.0	CL	LEAN CLAY
❀	KB-200.8A	15 - 17	52	26	26	90.5	CH	FAT CLAY
■	KB-200.8A	35 - 36.5	48	27	21	100.0	CL	LEAN CLAY
◆	KB-200.8A	60 - 61.5	45	28	17	100.0	ML	SILT
◇	KB-200.8A	85 - 86.5	24	16	8	95.2	CL	LEAN CLAY
×	KB-200.8A	100 - 102	NP	NP	NP	85.6	ML	SILT
✖	KB-200.8A	120 - 122	37	22	15	100.0	CL	LEAN CLAY

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

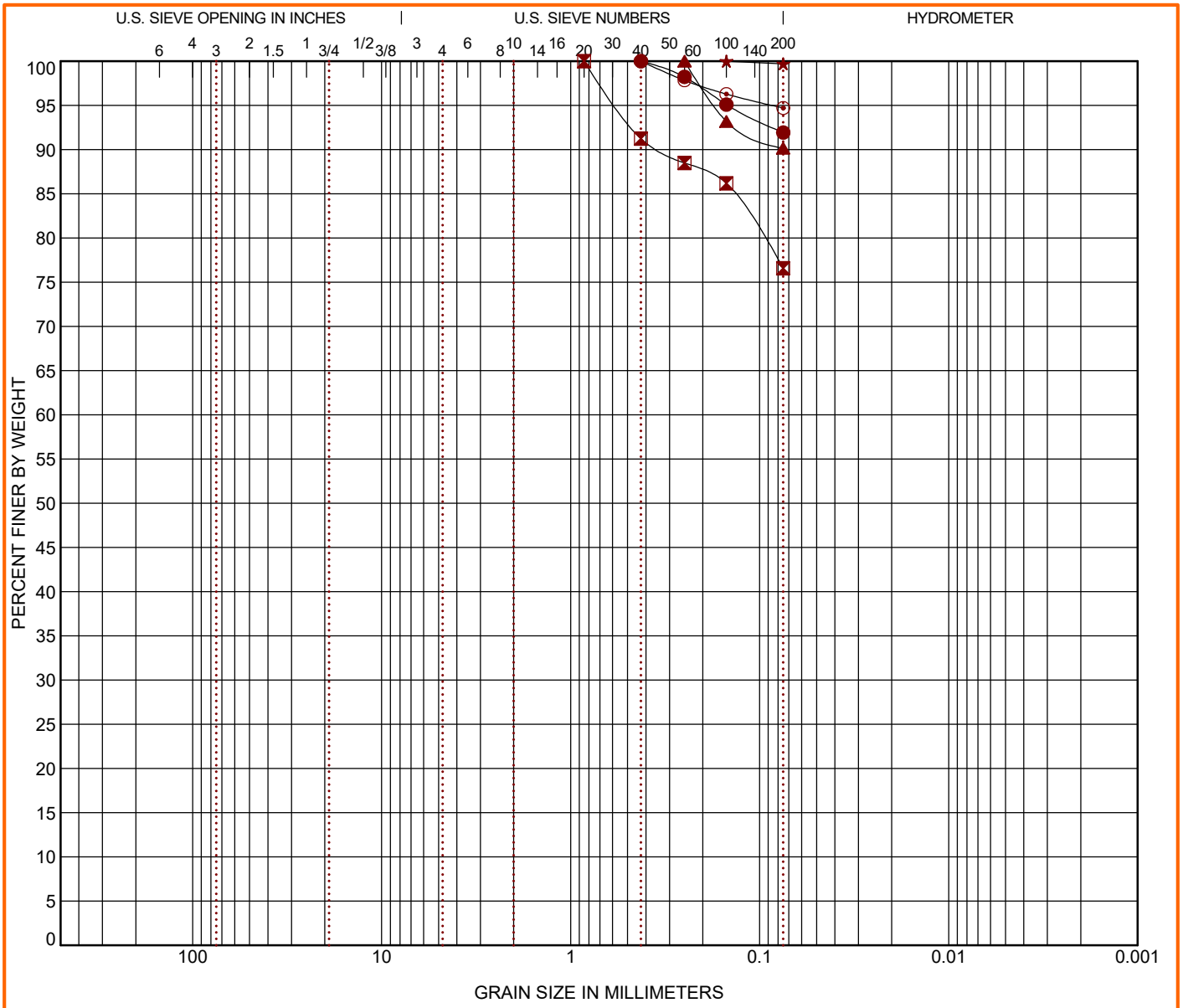
SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID	Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
KB-194.0-3.6B	70 - 72	SILT (ML)	46.7	49	29	20		
KB-194.0-3.9B	4 - 6	LEAN CLAY with SAND (CL)	31.5	45	25	20		
KB-194.0-3.9B	25 - 26.5	LEAN CLAY (CL)	50.2	44	26	18		
KB-194.0-3.9B	45 - 46.5	LEAN CLAY (CL)	43.4	39	25	14		
KB-194.0-3.9B	60 - 61.5	FAT CLAY (CH)	52.9	50	26	24		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
KB-194.0-3.6B	70 - 72	0.425				0.0	0.0	8.1		91.9	
KB-194.0-3.9B	4 - 6	0.85				0.0	0.0	23.4		76.6	
KB-194.0-3.9B	25 - 26.5	0.25				0.0	0.0	9.8		90.2	
KB-194.0-3.9B	45 - 46.5	0.15				0.0	0.0	0.3		99.7	
KB-194.0-3.9B	60 - 61.5	0.425				0.0	0.0	5.3		94.7	

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

SITE: Fort Ann to Coxsackie, NY

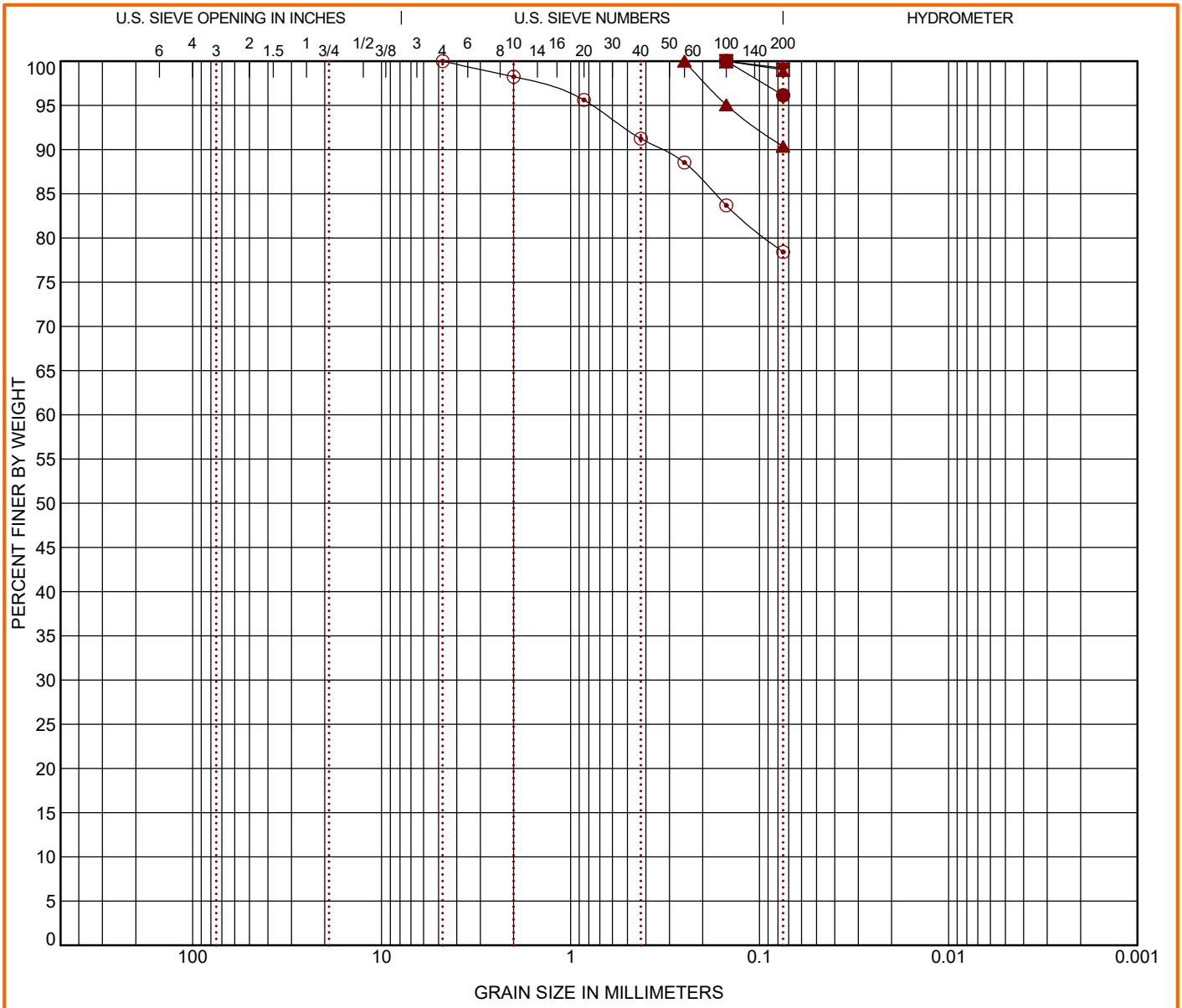
Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256G CHPE - ADDITIONAL.GPJ TERRACON_DATATEMPLATE.GDT 11/2/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	KB-194.0-4.4	20 - 22	LEAN CLAY (CL)	50.1	46	26	20		
⊠	KB-194.0-4.4	40 - 42	LEAN CLAY (CL)	37.9	35	21	14		
▲	KB-194.0-4.4	50 - 52	LEAN CLAY (CL)	47.6	48	27	21		
★	KB-194.0-4.4	70 - 72	LEAN CLAY (CL)	37.4	37	23	14		
⊙	KB-194.0-4.6B	4 - 6	LEAN CLAY with SAND (CL)	24.1	46	26	20		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	KB-194.0-4.4	20 - 22	0.15				0.0	0.0	3.9		96.1	
⊠	KB-194.0-4.4	40 - 42	0.15				0.0	0.0	1.0		99.0	
▲	KB-194.0-4.4	50 - 52	0.25				0.0	0.0	9.7		90.3	
★	KB-194.0-4.4	70 - 72	0.15				0.0	0.0	0.8		99.2	
⊙	KB-194.0-4.6B	4 - 6	4.75				0.0	0.0	21.6		78.4	

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256G CHPE - ADDITIONAL.GPJ TERRACON_DATATEMPLATE.GDT 11/2/22

Kiewit

MEMORANDUM

DATE: February 13, 2023

TO: Nick Strater; Brierley Associates Underground Engineers, PLLC

FROM: Matthew Hawley, P.E.; Kiewit Engineering (NY) Corp. MKH
Jaren Knighton; Kiewit Engineering (NY) Corp.

SUBJECT: Geotechnical Data: Segment 9 – Package 5 – HDD Crossing 90 – Revision 1
Champlain Hudson Power Express Project
Selkirk, New York

Kiewit Engineering is providing the attached geotechnical data for use in the horizontal direction drill (HDD) design for the Champlain Hudson Power Express project in Upstate New York. This HDD crossing is located northwest of Selkirk, New York. The approximate station for the start of HDD crossing Number 90 is STA 51235+00 (42.5413° N, 73.8228° W).

The geotechnical data at this HDD crossing is attached. The available data is from the previous investigation by AECOM and the recent investigations by Terracon, referenced below.

- AECOM, Geotechnical Data Report, Upland Segments, Champlain Hudson Power Express, dated May 28, 2021.
- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express-Package 5, Schenectady through Selkirk, dated April 4, 2022.
- Terracon, Geotechnical Data Report, Champlain-Hudson Power Express – Additional HDD Borings – Phase 3, Fort Ann to Coxsackie, dated November 3, 2022.

Contact us if you have questions or require additional information.

HDD 90
Borings SY-10, K-194.0-4.5,
K-194.0-4.6, KB-194.0-4.6B
Segment 9 - Package 5

CHPE Segment 8 & 9 - Package 5
HDD Soil Boring Coordinates and Elevations

Firm	Boring	Northing (feet)	Easting (feet)	Ground Surface Elevation (feet)
TRC*	A179.6-1	1433335.8	631009.7	332.5
	A182.4-1	1420048.2	636557.9	291.5
	A187.65-1	1394856.5	644775.4	327.7
	A191.05-1	1378814.5	652321.0	274.7
	A191.82-1	1375154.9	654314.3	257.1
	A192.9-1	1370644.3	657458.6	232.8
	B177.1-1	1445275.2	626125.8	347.3
	B177.6-1	1442944.0	627003.0	346.5
	B178.01-1	1440838.2	627828.3	368.5
	B178.9-1	1436461.4	629767.4	322.1
	B180.1-1	1431140.9	631965.3	310.4
	B180.9-1	1427158.5	633611.8	307.5
	B182.9-1	1417657.6	637123.9	291.5
	B183.2-1	1415871.4	637202.5	290.2
	B184.3-1	1410133.0	637597.6	324.0
	B184.8-1	1408223.8	638230.4	323.1
	B185.6-1	1403875.9	639489.9	328.2
	B188.0-1	1392812.4	645793.4	330.9
	B188.35-1	1391616.5	646333.6	333.4
	B188.51-1	1390815.1	646697.7	340.2
	B190.0-1	1383732.6	649743.4	296.3
	B190.1-1	1383134.9	649975.5	294.6
	B190.8-1	1379726.2	651827.2	282.3
	B192.4-1	1372732.4	655878.1	239.3
	B193.5-1	1367919.2	659547.5	218.6
AECOM**	RS-2	1436092.2	629800.7	315.6
	RS-3	1418336.4	636985.0	303.2
	RS-4	1414567.4	637285.8	302.2
	RS-5	1411399.1	637471.6	319.0
	RS-7A	1391599.9	646333.6	340.5
	RS-9	1372089.8	656230.9	238.7
	SY-7	1353089.8	670133.9	159.8
	SY-8	1353716.5	671626.7	175.0
	SY-9	1353046.4	673133.41	163.1
	SY-9A	1351940.0	674314.3	158.3
	SY-10	1350838.3	675488.6	166.0
	SCH-19	1446199.8	625927.0	333.8
	SCH-19A	1445712.1	626032.4	343.1

Notes:

- Northings and Eastings are provided in NAD83 New York State Plane East Zone.
- Elevations are referenced to the NAVD88 datum.

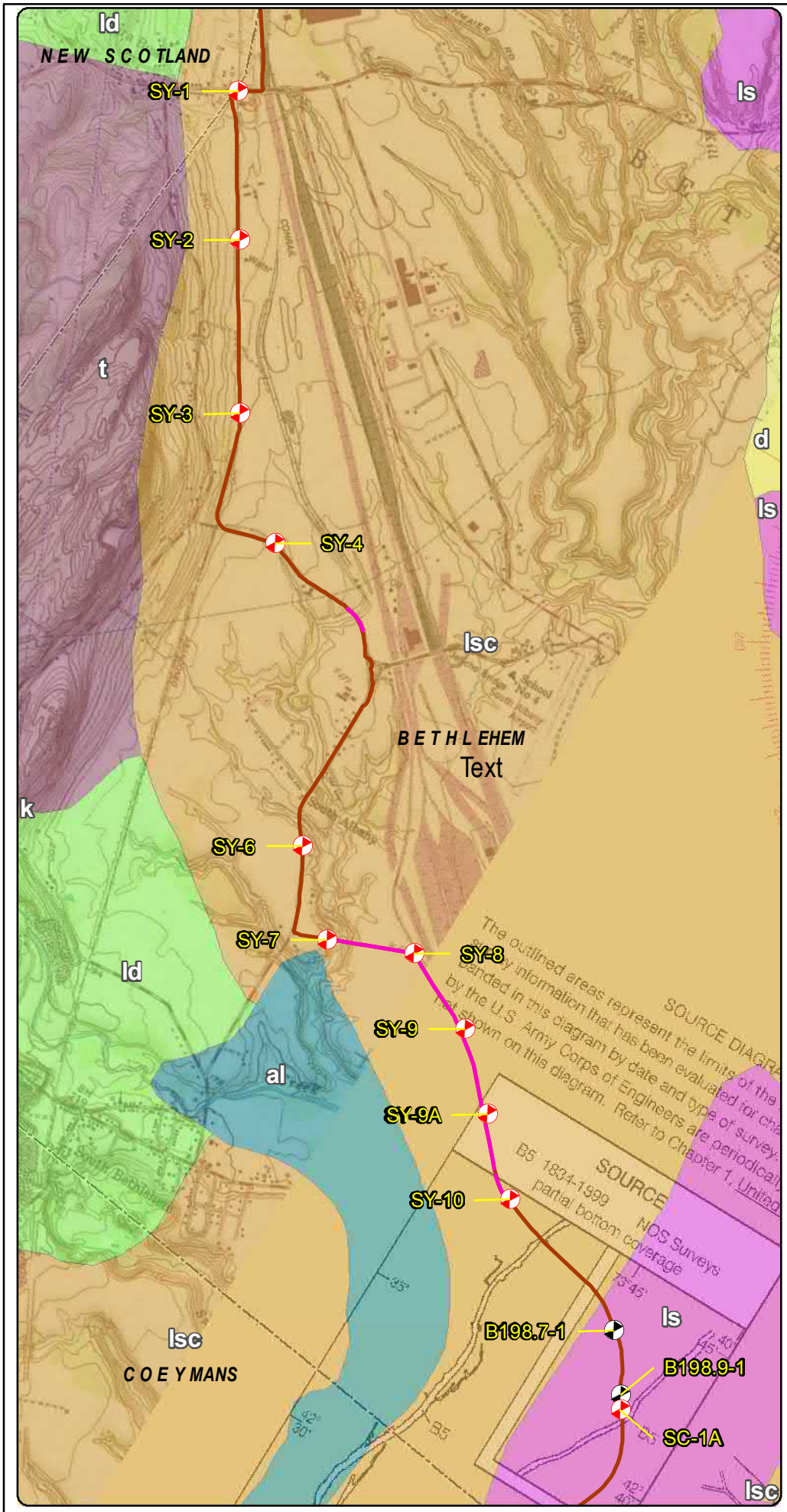
* TRC boring coordinates as shown in Table 1-6 in AECOM report (reference below). Boring elevations estimated from November 2021 topographic survey by Williams Aerial.

** AECOM boring coordinates and elevations as shown in Table 1-6 in AECOM report.

*** Kiewit boring coordinates and elevations are noted on the boring logs.

Reference:

AECOM, Geotechnical Data Report, Upland Segments: Putnam Station, Washington County, to Cementon, Green County, NY, Champlain Hudson Power Express, dated May 28, 2021.



LEGEND

- 2021 Boring Location
- Previous (2013) Boring Location
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- Town Boundary
- County Boundary

Surficial Geology

- al - Recent alluvium
- d - Dunes
- k - Kame deposits
- ld - Lacustrine delta
- ls - Lacustrine sand
- lsc - Lacustrine silt and clay
- t - Till

0.25 0.125 0 0.25 Miles

Transmission

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

Surficial Geology and Geotechnical Borings
Selkirk Rail Yard Bypass
Figure 3-9

Prepared on 4/30/2021
by: AECOM

DATA SOURCES: ESRI, NYSDOT, NOAA, USACE, NYDOS, TDI, TRC

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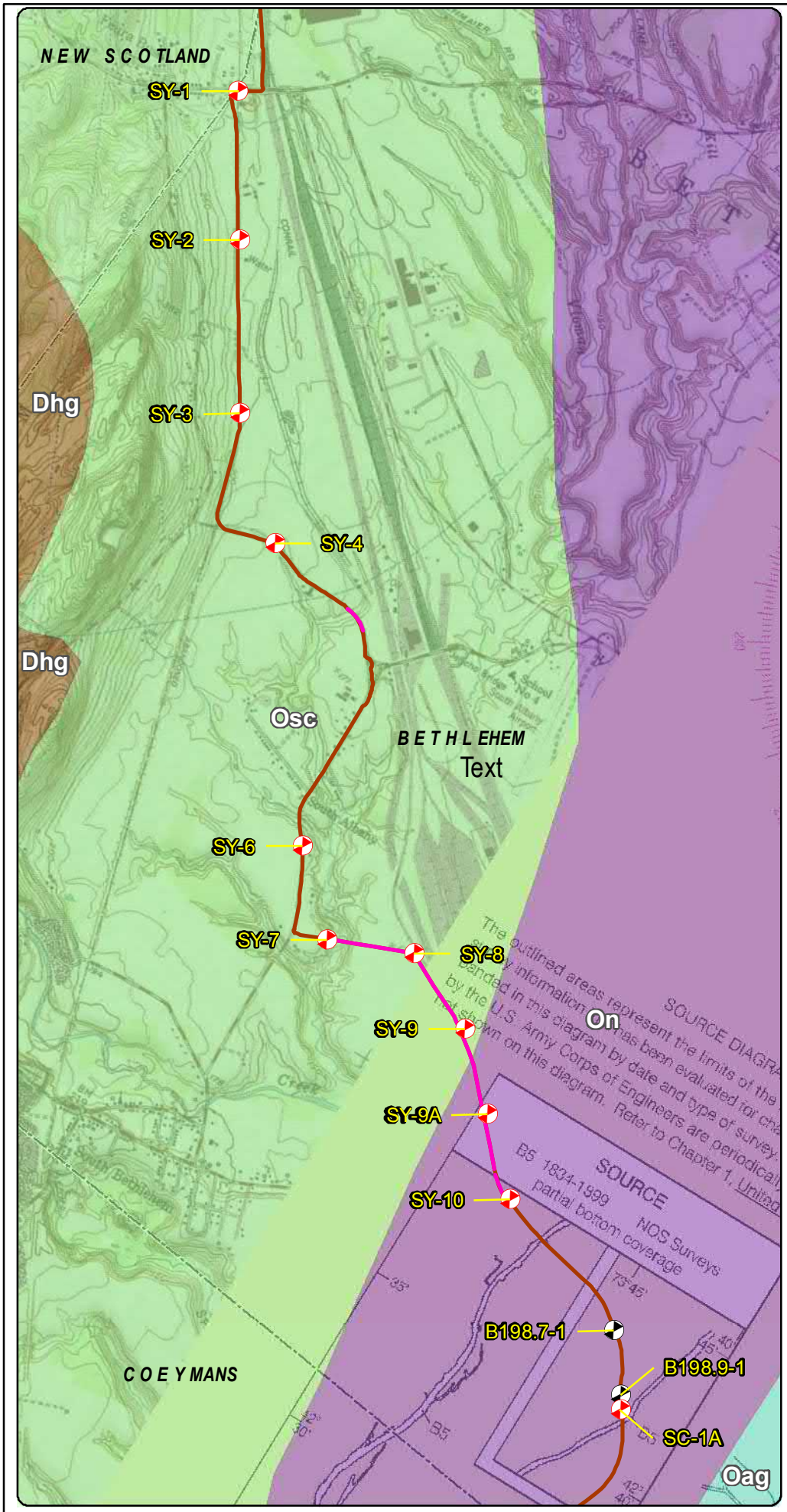

LEGEND

- 2021 Boring Location
- Previous (2013) Boring Location
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- Town Boundary
- County Boundary

Bedrock Geology

- Dhg - Port Ewen Formation
- Oag - Austin Glen Formation
- On - Normanskill Shale
- Osc - Schenectady Formation

* Schenectady Formation includes: graywacke, sandstone, siltstone, shale

0.25 0.125 0 0.25 Miles

Transmission

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

Bedrock Geology and Geotechnical Borings
Selkirk Rail Yard Bypass
Figure 4-9

Prepared on 4/30/2021
by: AECOM

DATA SOURCES: ESRI, NYSDOT, NOAA, USACE, NYDOS, TDI, TRC

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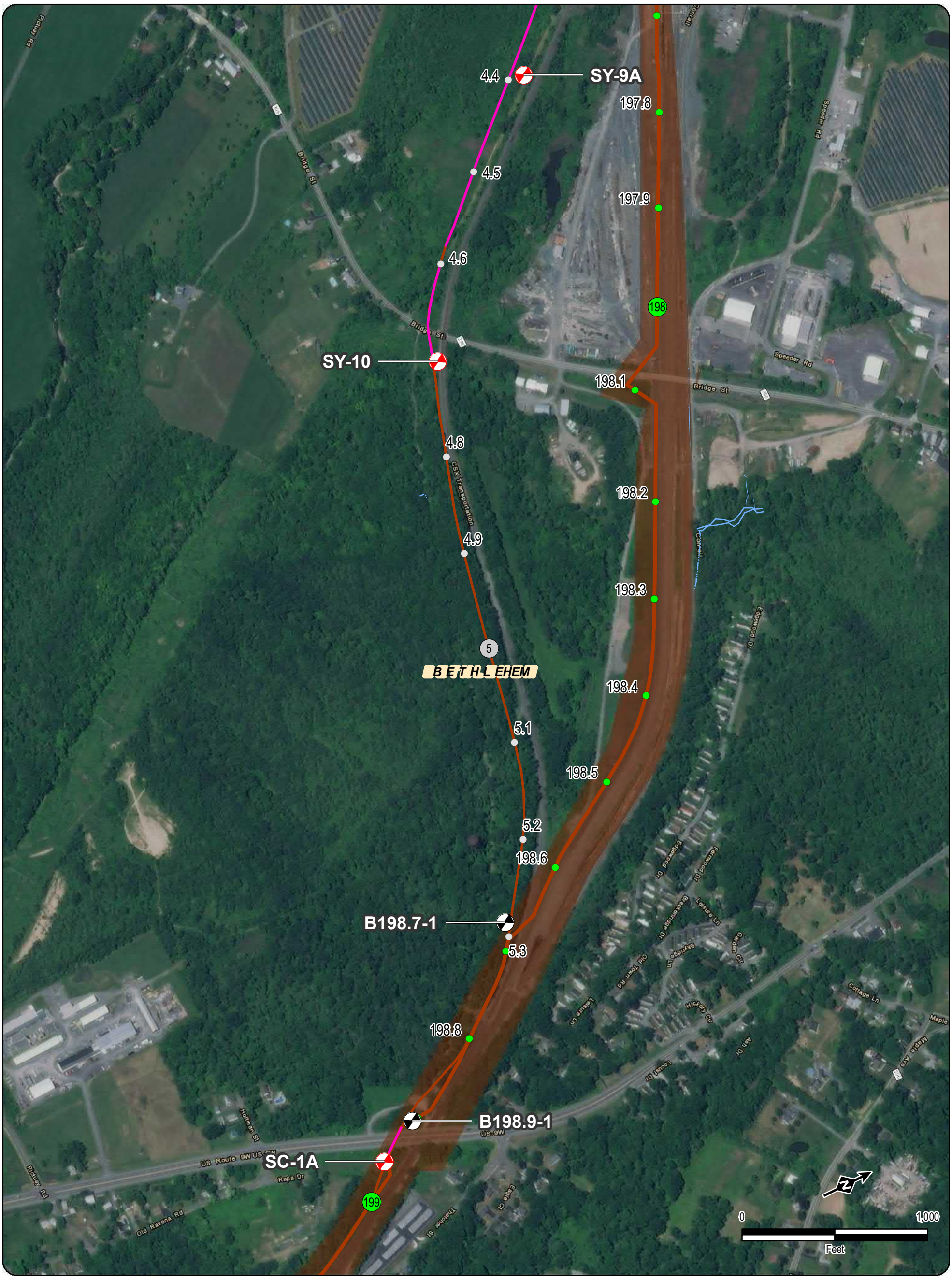
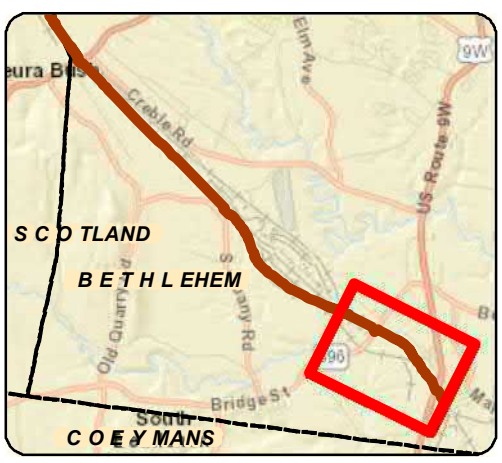




LEGEND

- 111.8 Certified Milepost - Tenths
- 135 Certified Milepost
- 111.8 Preferred Alternative Milepost - Tenths
- 135 Preferred Alternative Milepost
- Terrestrial Route HVDC
- Submarine Route HVDC
- Terrestrial Route HVAC
- Preliminary HDD Locations
- Preliminary Pipe Bridge Location
- 2021 Boring Location
- Previous (2013) Boring Location
- Streams/Ditches
- Railroad ROW
- Deviation Zone
- Deviation Zone Outside ROW
- Preferred Alternative Deviation Zone
- Preferred Alternative Deviation Zone Outside ROW
- Town Boundary
- Village Boundary
- State Park (OPRHP)
- Reported Buried Structure

Parcel Ownership: TOWN NAME

Road Name: Village Name

DATA SOURCES: ESRI, NETWORK MAPPING 2010, NYSDOT, OPRHP, TDI, TRC

Transmission Developers Inc.

Champlain Hudson Power Express Project

Champlain Hudson Power Express Inc.

BORING LOCATION PLAN

Selkirk Rail Yard Bypass

Figure A-9

Sheet 4 of 4

Prepared by: AECOM 5/19/2021

Y:\Projects\CHPEI\Route\Consensus_Alternative_Routes\MXD\Alt_5_Routes_DZ_201909\Boring_Locations\Maps_for_May_2021_Report\Selkirk_Rail_Yard_Bypass_Boring_L...mxd

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER/GEOLOGIST: Chris French

AECOM

BORING LOG

SHEET 1 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-10**

START DATE: 2/25/21

FINISH DATE: 2/25/21

LOCATION: MP - 4.70 (CSX Rail)

OFFSET: N/A

GROUND WATER OBSERVATIONS		CASING	SAMPLER	DRILL BIT	CORE BARREL	DRILL RIG: CME LC-55
WT at ~25' (inferred)	TYPE	Flush Joint Steel	California Modified	Tricone Roller Bit		BORING TYPE: SPT
	SIZE I.D.	4"	2.5"	- -		BORING O.D.: 4.5"
	SIZE O.D.	4.5"	3"	3 7/8"		SURFACE ELEV.:
	HAMMER WT.	140 lbs	140 lbs			NORTHING
	HAMMER FALL	30"	30"			EASTING

DEPTH	CORING RATE MIN/FT	SAMPLE DEPTHS FROM - TO (FEET)	SAMPLE TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.(2)	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		0'-5'				Hand Cleared					SP/GP	Fill	0'-1.4' Black fine to coarse SAND and Gravel, trace Silt, frozen
1.0													1.4'-1.9' Black fine to coarse SAND and Gravel, trace Silt, dense, moist
2.0													1.9'-3.1' Black fine to coarse SAND, trace Silt, trace angular Gravel, medium dense, moist
3.0													
		3'-5'	S-1								ML	Clayey SILT	3.1'-5' Brown Clayey SILT, trace fine Sand, medium stiff, moist
4.0													TR-1; (3.0'-5.0')
5.0													
		5'-7'	S-2	24"	17"	5	7	9	9	10	ML		Brown SILT, some fine Sand, medium stiff, moist
6.0													
7.0													
		7'-9'	S-3	24"	22"	9	13	11	10	16	ML		Gray Clayey SILT, trace fine Sand, medium stiff, moist
8.0													TR-2; (8.0'-8.5')
9.0													
		9'-11'	S-4	24"	18"	3	5	9	9	9	ML		Gray Clayey SILT, trace fine Sand, stiff, moist
10.0													
11.0													
		11'-13'	S-5	24"	24"	18	23	22	19	29	ML		Brown and Gray Clayey SILT, very stiff, moist
12.0													
13.0													
		13'-15'	S-6	24"	24"	6	9	12	15	14	ML		Brown SILT and Clay, stiff, moist
14.0													
15.0													
		15'-17'	S-7	24"	24"	16	16	21	17	24	CL	CLAY AND SILT	Brown CLAY and Silt, very stiff, moist
16.0													TR-3; (16.0'-16.5')
17.0													
18.0													
19.0													
20.0													

NOTES:

(1) Thick-wall ring lined drive sampler (California sampler) used for SPT samples. Rings dimensions = 2-1/2" O.D. by 2-7/16" I.D. by 6" length.

(2) Correction factor: $N_{corr}=N*(2.0^2-1.375^2)in./(3.0^2-2.4^2)in. = N*0.65$.

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

BORING CONTRACTOR: ADT

DRILLER: Chris Chaillou

SOILS ENGINEER/GEOLOGIST: Chris French

AECOM

BORING LOG

SHEET 2 OF 2

PROJECT NAME: CHPE -

PROJECT NO.: 60323056

HOLE NO.: **SY-10**

START DATE: 2/25/21

FINISH DATE: 2/25/21

LOCATION: MP - 4.70 (CSX Rail)

OFFSET: N/A

DEPTH	CORING RATE MIN/FT	DEPTHS FROM - TO (FEET)	TYPE AND NO.	PEN. in	REC. in	BLOWS PER 6 in ON SAMPLER (ROCK QUALITY DESIGNATION)				N Corr.	USCS CLASS.	STRAT. CHNG. DEPTH	FIELD IDENTIFICATION OF SOILS
		20'-22'	S-8	24"	24"	10	12	15	19	18	CL		SAA
21.0													
22.0													
23.0													
24.0													
25.0													
		25'-27'	S-9	24"	24"	3	6	5	6	7	CH		Gray Silty CLAY, soft, wet
26.0													TR-4; (26.0'-26.5')
27.0													
28.0													
29.0													
30.0												CLAY AND SILT	
		30'-32'	S-10	24"	24"	2	4	6	6	7	CH		Gray Silty CLAY, occasional Silt lenses, soft, wet
31.0													
32.0													
33.0													
34.0													
35.0													
		35'-37'	S-11	24"	24"	3	6	6	7	8	CH		Gray CLAY and Silt, soft, wet
36.0													TR-5; (36.0'-36.5')
37.0													
38.0													
		38'-40'	S-12	24"	24"	2	5	7	6	8	CH		Gray Silty CLAY, soft, wet
39.0													
40.0													
													SY-10 terminated at 40' then grouted to surface
41.0													
42.0													
43.0													
44.0													
45.0													

NOTES:

Soil description represents a field identification after D.M. Burmister unless otherwise noted.

The information contained on this log is not warranted to show the actual subsurface condition. The contractor agrees that he will make no claims against AECOM if he finds that the actual conditions do not conform to those indicated by this log.

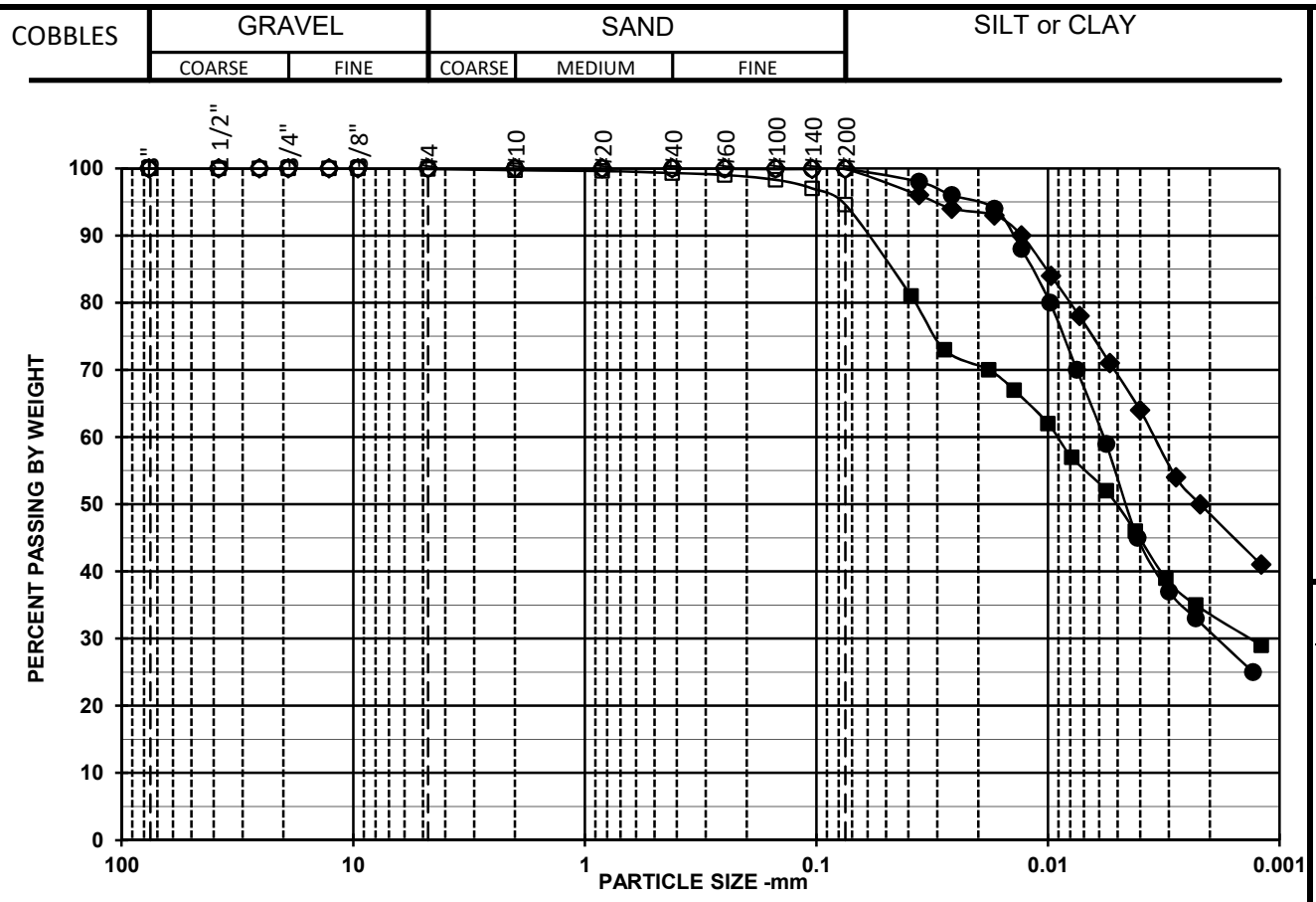
SAMPLE TYPE: S= SPLIT SPOON U=SHELBY TUBE R=ROCK CORE

PROPORTIONS: TRACE=1-10% LITTLE=10-20% SOME=20-35% AND=35-50%

Aquifer
CHPE- Selkirk Bypass Borings
LABORATORY SOIL TESTING DATA SUMMARY

BORING NO.	SAMPLE NO.	DEPTH (ft)	IDENTIFICATION TESTS							REMARKS
			WATER CONTENT (%)	LIQUID LIMIT (-)	PLASTIC LIMIT (-)	PLAS. INDEX (-)	USCS SYMB. (1)	SIEVE MINUS NO. 200 (%)	HYDROMETER % MINUS 2 μm (%)	
SY-1	S-2	5-7	25.6	34	20	14	CL	97	26	
SY-1	S-4	9-11	23.4	37	20	17	CL	88	33	
SY-3	S-2	5-7	33.3	60	25	35	CH	88	48	
SY-3	S-4	9-11	24.3	46	22	24	CL	65	30	
SY-6	S-3	7-9	20.5				SC	35	18	
SY-6	S-5	11-13	24.4				CL	91	35	
SY-7	S-2	5-7	26.1	41	21	20	CL	88	35	
SY-7	S-7	15-17	33.5	33	19	14	CL	99.8	33	
SY-7	S-10	30-32	39.4	43	20	23	CL	100	51	
SY-8	S-3	7-9	30.6	41	23	18	CL	99.5	39	
SY-8	S-8	20-22	42.7	46	20	26	CL	100	56	
SY-8	S-10	30-32	41.3	45	20	25	OL	100	45	
SY-9A	S-3	7-9	28.1	41	19	22	CL	99.7	44	
SY-9A	S-8	20-22	35.6	37	18	19	CL	100	47	
SY-9A	S-11	35-37	30.9	33	19	14	OL	100	27	
SY-10	S-3	7-9	31.6	40	19	21	CL	94.6	34	
SY-10	S-8	20-22	26.6	44	20	24	CL	99.9	49	
SY-10	S-10	30-32	33.8	30	19	11	CL	99.9	31	

Note: (1) USCS symbol based on visual observation and Sieve and Atterberg limits reported.



Open Symbols: Sieve analysis by ASTM D6913
Filled symbols: Hydrometer analysis by ASTM D7928 corrected for complete sample

SYMBOL	w (%)	LL	PL	PI	USCS	AASHTO	USCS DESCRIPTION AND REMARKS	DATE
□	31.6	40	19	21	CL		Brown, Lean clay organic mat'l noted	04/12/21
◇	26.6	44	20	24	CL		Brown, Lean clay	04/12/21
○	33.8	30	19	11	CL		Gray, Lean clay	04/12/21

Aquifer

TerraSense, LLC #7853-21010

CHPE- Selkirk Bypass Borings

Symbol	□	◇	○
Boring	SY-10	SY-10	SY-10
Sample	S-3	S-8	S-10
Depth	7-9	20-22	30-32
% +3"	0	0	0
% Gravel	0.1	0	0
% SAND	5.3	0.1	0.1
%C SAND	0.2	0	0
%M SAND	0.4	0	0
%F SAND	4.7	0.1	0.1
% FINES	94.6	99.9	99.9
D_{100} (mm)	9.53	2	0.841
D_{60} (mm)	0.009	0.003	0.006
D_{30} (mm)	0.001		0.002
D_{10} (mm)			
Cc			
Cu			

Sieve Size/ID #	Percent Finer Data		
6"	100.0	100.0	100.0
4"	100.0	100.0	100.0
3"	100.0	100.0	100.0
1 1/2"	100.0	100.0	100.0
1"	100.0	100.0	100.0
3/4"	100.0	100.0	100.0
1/2"	100.0	100.0	100.0
3/8"	100.0	100.0	100.0
#4	99.9	100.0	100.0
#10	99.7	100.0	100.0
#20	99.6	100.0	100.0
#40	99.3	100.0	100.0
#60	99.0	100.0	99.9
#100	98.3	100.0	99.9
#140	97.0	99.9	99.9
#200	94.6	99.9	99.9
5μ m	50	69	54
2μ m	34	49	31
1μ m	27	38	21

PARTICLE SIZE DISTRIBUTION
ASTM D6913 & ASTM D7928

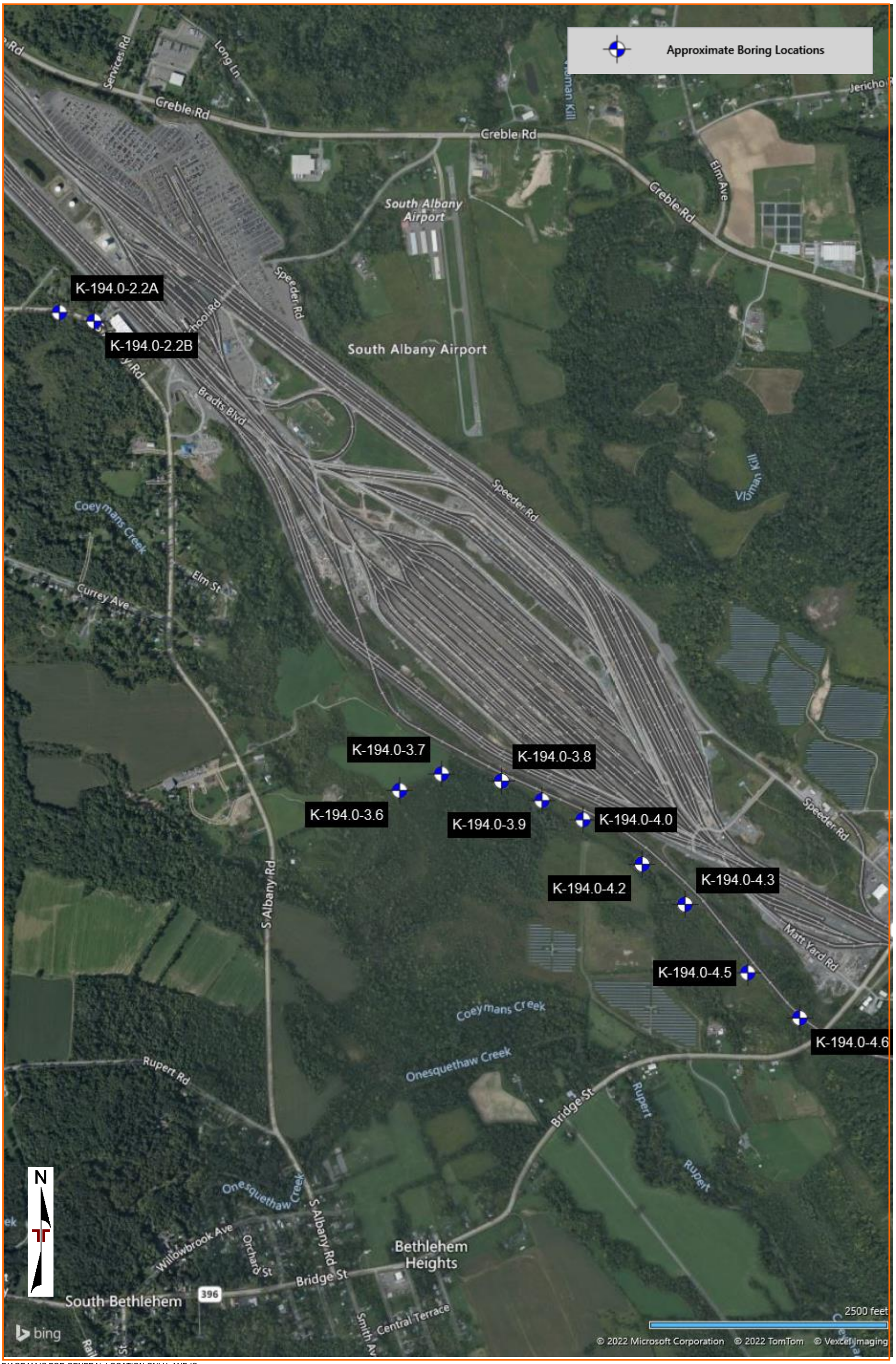


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. K-194.0-4.5

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.541435° Longitude: -73.822739°

Surface Elev.: 157.90 (Ft.)

DEPTH	ELEVATION (Ft.)	DESCRIPTION
0.1	158	**TOPSOIL**
		SILT AND CLAY (CL-ML), brown, very soft to very stiff
		occasional fine sand partings
		6" fine sand lense at 8 feet
11.0	147	**SILT AND CLAY (CL-ML)**, varved, gray, very soft

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		6	3-1-2-2 N=3				
		19	3-5-6-9 N=11	3.0 (HP)			
5		16	5-5-7-9 N=12	4.5 (HP)			
		24	9-10-12-10 N=22	4.25 (HP)	28.1		78
		14	4-4-6-4 N=10	3.5 (HP)			
10		20	1-1-1-1 N=2				
15		24	WOH/24"	0 (HP)	36.1	37-20-17	
20		24	WOH/24"	0 (HP)			
25		24	WOH/24"	0 (HP)			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4" Casing and 3 7/8" Tricone Bit, Shelby tube from 29-31'

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

No measurable groundwater noted

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-24-2022 | Boring Completed: 01-25-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.5

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.541435° Longitude: -73.822739°

Surface Elev.: 157.90 (Ft.)

DEPTH ELEVATION (Ft.)

GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
SILT AND CLAY (CL-ML), varved, gray, very soft *(continued)*									
	30			24	Pushed Shelby Tube		34.9	29-24-5	99
				24	WOH/24"	0 (HP)			
	35			24	WOH/24"	0 (HP)	39.5		
	40			24	WOH/24"	0 (HP)			
42.0 116									
Boring Terminated at 42 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4" Casing and 3 7/8" Tricone Bit, Shelby tube from 29-31'

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by JCH
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

No measurable groundwater noted

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-24-2022 | Boring Completed: 01-25-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.6

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.540147° Longitude: -73.821016°

Surface Elev.: 165.85 (Ft.)

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		FILL - POORLY GRADED GRAVEL, trace sand and wood fragments, black, dense, ballast			15	21-31-15-8 N=46			
2.0	164								
		FILL - CINDERS, black, loose			2	5-4-3-3 N=7			
4.0	162								
		FILL - SILT AND CLAY, brown and black, medium stiff to very stiff	5		3	1-2-3-16 N=5			
		organics noted at 6'			21	3-2-3-4 N=5			
					7	2-1-22-3 N=23			
			10		23	2-2-3-4 N=5			
15.0	151								
		FILL - SANDY LEAN CLAY, brown and black, medium stiff	15		24	2-3-5-7 N=8	26.8	42-24-18	67
20.0	146								
		SILT AND CLAY (CL-ML), brown, medium stiff	20		24	5-3-4-5 N=7			
			25		5	2-2-3-4 N=5			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4" HSA to 50', Mud rotary below 50'

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by AEB
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-31-2022 | Boring Completed: 02-01-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.6

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.540147° Longitude: -73.821016°

Surface Elev.: 165.85 (Ft.)

DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
SILT AND CLAY (CL-ML), brown, medium stiff *(continued)*											
30.0	136										
SILT AND CLAY (CL-ML), gray, very soft			30			24	WOH-WOH-WOH-2		35.9	33-20-13	95
			35			24	WOH-WOH-WOH-2				
			40			24	WOH-WOH-WOH-1				
						24	WOH-WOH -WOH-3 3" Split Spoon With Ring Samplers		31.9	32-20-12	98
			45			24	WOH-WOH -WOH-WOH				
			50			24	WOH-WOH -WOH-WOH				
			55				WOH-WOH				

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4" HSA to 50', Mud rotary below 50'

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

Logged by AEB
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49
Logged by AEB
WOH = Weight of Hammer
Hammer Efficency Summary:
Energy Transfer Ratio: 89.1% +/- 4.4%
Hammer Efficiency Correction (CE): 1.49

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 01-31-2022 Boring Completed: 02-01-2022

Drill Rig: Mobile B-57 Driller: L. Spicher

Project No.: JB215256B

BORING LOG NO. K-194.0-4.6

PROJECT: Champlain-Hudson Power Express Package 5

CLIENT: Kiewit Engineering (NY) Corp.

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

LOCATION See Exploration Plan

Latitude: 42.540147° Longitude: -73.821016°

Surface Elev.: 165.85 (Ft.)

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
57.0	109				24	-WOH-3				

SILT AND CLAY (CL-ML), gray, very soft *(continued)*

Boring Terminated at 57 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4 1/4" HSA to 50', Mud rotary below 50'

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by Kiewit.

Notes:

WATER LEVEL OBSERVATIONS

No measurable groundwater prior to grouting

Terracon
30 Corporate Cir Ste 201
Albany, NY

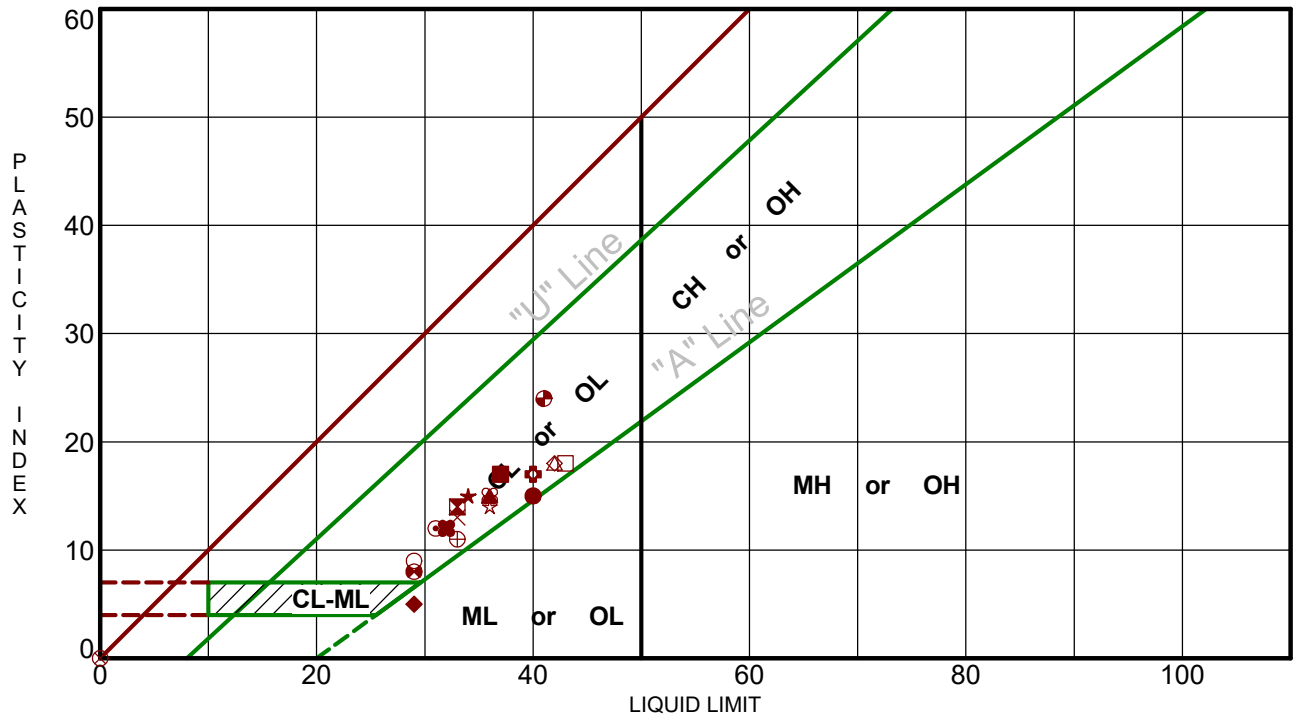
Boring Started: 01-31-2022 | Boring Completed: 02-01-2022

Drill Rig: Mobile B-57 | Driller: L. Spicher

Project No.: JB215256B

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	K-194.0-2.2A	8 - 10	40	25	15	82.2	CL	LEAN CLAY with SAND
⊠	K-194.0-2.2A	30 - 32	33	19	14	92.9	CL	LEAN CLAY
▲	K-194.0-2.2B	8 - 10	36	21	15	92.5	CL	LEAN CLAY
★	K-194.0-2.2B	29 - 31	34	19	15	86.5	CL	LEAN CLAY
⊙	K-194.0-3.8	10 - 12	31	19	12	94.8	CL	LEAN CLAY
✿	K-194.0-3.8	38 - 40	40	23	17	81.8	CL	LEAN CLAY with SAND
○	K-194.0-3.9	15 - 17	29	20	9	94.3	CL	LEAN CLAY
△	K-194.0-3.9	33 - 35	42	24	18	89.9	CL	LEAN CLAY
⊗	K-194.0-4.0	8 - 10	NP	NP	NP	79.8	ML	SILT with SAND
⊕	K-194.0-4.0	28 - 30	33	22	11	94.4	CL	LEAN CLAY
□	K-194.0-4.2	8 - 10	43	25	18	75.7	CL	LEAN CLAY with SAND
⊠	K-194.0-4.2	28 - 30	29	21	8	94.5	CL	LEAN CLAY
◕	K-194.0-4.3	8 - 10	41	17	24	85.3	CL	LEAN CLAY
☆	K-194.0-4.3	19 - 21	36	22	14	95.8	CL	LEAN CLAY
⊠	K-194.0-4.3	35 - 37	36	21	15	94.7	CL	LEAN CLAY
■	K-194.0-4.5	15 - 17	37	20	17		CL	LEAN CLAY
◆	K-194.0-4.5	29 - 31	29	24	5	98.7	ML	SILT
◇	K-194.0-4.6	15 - 17	42	24	18	67.4	CL	SANDY LEAN CLAY
✕	K-194.0-4.6	30 - 32	33	20	13	95.1	CL	LEAN CLAY
■	K-194.0-4.6	43 - 45	32	20	12	98.0	CL	LEAN CLAY

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

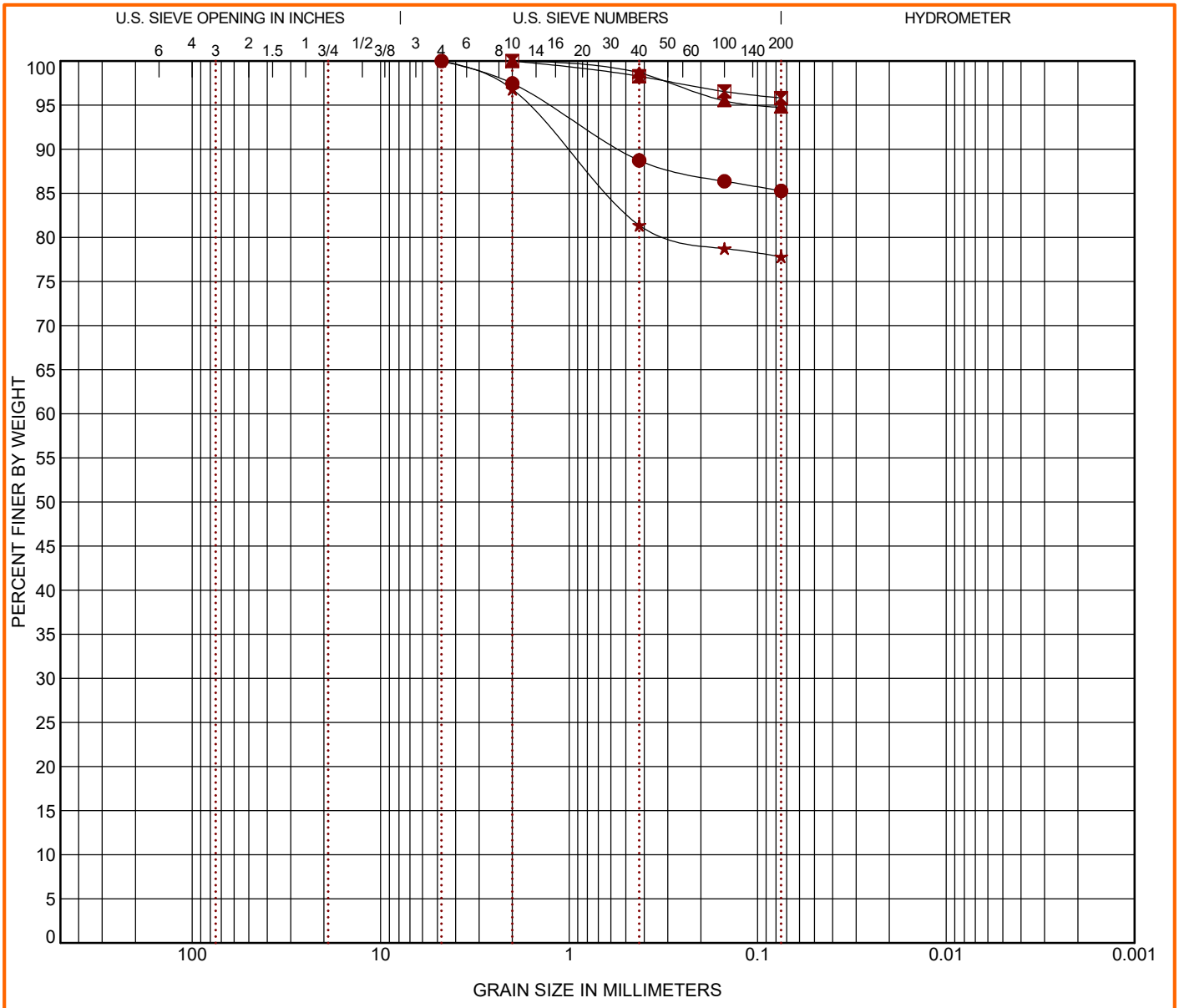
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-4.3	8 - 10	LEAN CLAY (CL)	34.7	41	17	24		
⊠	K-194.0-4.3	19 - 21	LEAN CLAY (CL)	41.7	36	22	14		
▲	K-194.0-4.3	35 - 37	LEAN CLAY (CL)	34.8	36	21	15		
★	K-194.0-4.5	6 - 8	SILT with SAND (ML)	28.1					

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-4.3	8 - 10	4.75				0.0	0.0	14.7		85.3	
⊠	K-194.0-4.3	19 - 21	2				0.0	0.0	4.2		95.8	
▲	K-194.0-4.3	35 - 37	2				0.0	0.0	5.3		94.7	
★	K-194.0-4.5	6 - 8	4.75				0.0	0.0	22.2		77.8	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

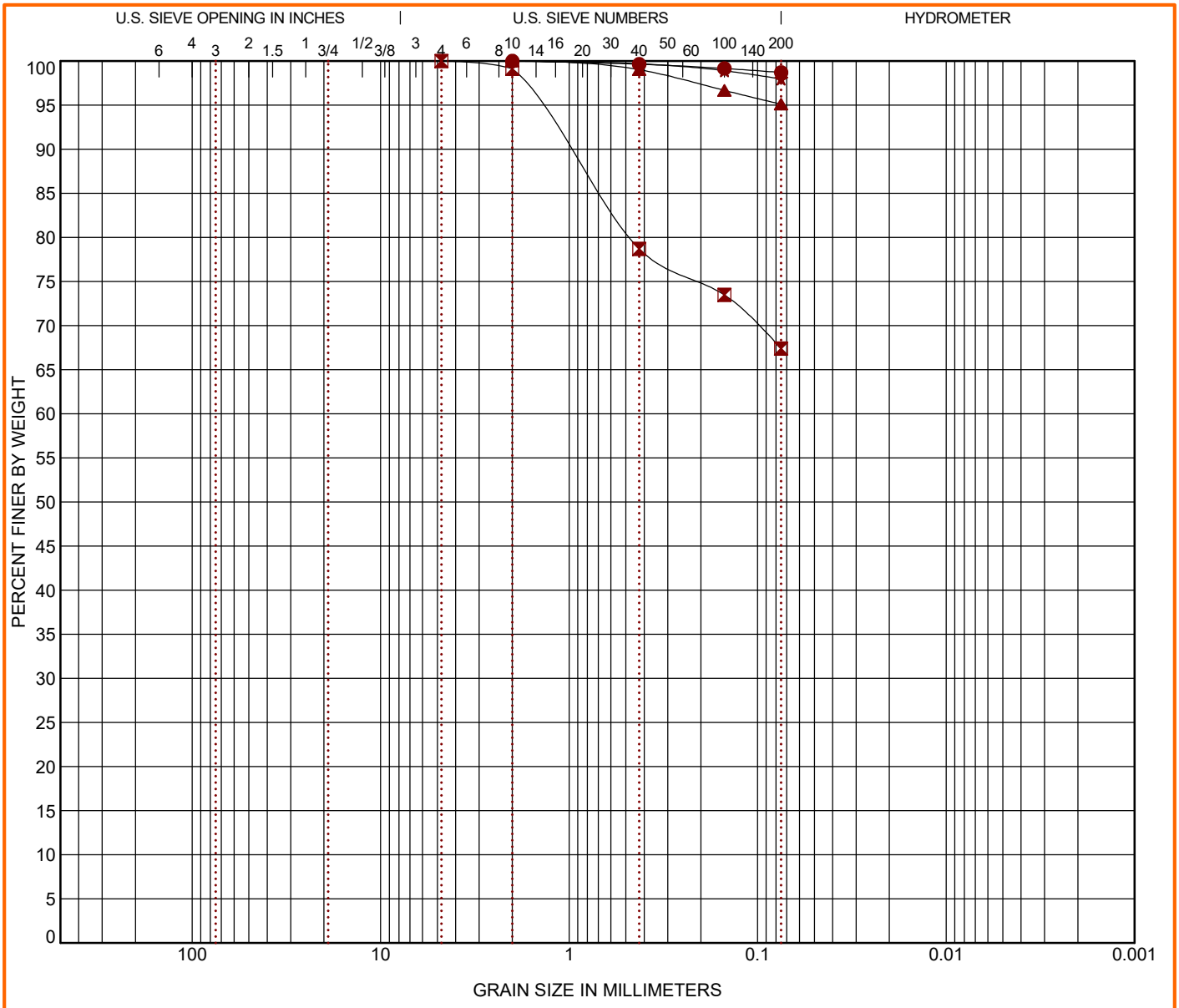
PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 3/30/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	K-194.0-4.5	29 - 31	SILT (ML)	34.9	29	24	5		
⊠	K-194.0-4.6	15 - 17	SANDY LEAN CLAY (CL)	26.8	42	24	18		
▲	K-194.0-4.6	30 - 32	LEAN CLAY (CL)	35.9	33	20	13		
★	K-194.0-4.6	43 - 45	LEAN CLAY (CL)	31.9	32	20	12		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	K-194.0-4.5	29 - 31	2				0.0	0.0	1.3		98.7	
⊠	K-194.0-4.6	15 - 17	4.75				0.0	0.0	32.6		67.4	
▲	K-194.0-4.6	30 - 32	2				0.0	0.0	4.9		95.1	
★	K-194.0-4.6	43 - 45	2				0.0	0.0	2.0		98.0	

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256B CHAMPLAIN-HUDSON.GPJ TERRACON_DATATEMPLATE.GDT 3/30/22

Summary of Laboratory Results

BORING ID	Depth (Ft.)	Organic Content (%)
K-178.0	4-6	2
K-178.96	6-8	2.1
K-184.4	10-12	0.4
K-184.7	8-10	0.3
K-185.6	6-8	11.6
K-188.4B	8-10	1.2
K-194.0-4.6	6-8	4.3

PROJECT: Champlain-Hudson Power Express Package 5

SITE: Champlain to Hudson HDD Crossings Schenectady, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256B

CLIENT: Kiewit Engineering (NY) Corp.

Approximate Boring Locations

KB-192.4

KB-192.8B

KB-194.0-3.9B

KB-194.0-3.6B

KB-194.0-4.4

KB-194.0-4.6B

N

1 mile

bing

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DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

BORING LOG NO. KB-194.0-4.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.540504° Longitude: -73.821649°

Surface Elev.: 156.8450 (Ft.)

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.2	156.6	**TOPSOIL**							
		LEAN CLAY WITH SAND (CL), varved silt and clay, brown, soft to very stiff			12	1-1-2-3 N=3			
					18	2-5-6-7 N=11			
			5		24	7-8-10-14 N=18	24.1	46-26-20	78
					24	10-13-13-13 N=26			
					24	6-5-4-6 N=9			
			10		24	4-4-6-4 N=10			
			15		18	WH/18"			
20.0	136.8	**LEAN CLAY (CL)**, varved silt and clay, occasional silt bands, gray, very soft	20		18	WH/18"	40.3	39-23-16	93
			25		18	WH/18"			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 2 1/4"HSA
Cased to 10'
Mud Rotary with 3 7/8" Drag bit to 81.5

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
WH = Weight of hammer
WR = Weight of rods
Hammer Efficiency Summary:
Energy Transfer Ratio: 91.3% +/- 2.7%
Hammer Efficiency Correction (CE): 1.52

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-08-2022 | Boring Completed: 09-09-2022

Drill Rig: CME 750-X | Driller: C. Schindler

Project No.: JB215256G

BORING LOG NO. KB-194.0-4.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.540504° Longitude: -73.821649°

Surface Elev.: 156.8450 (Ft.)

DEPTH	ELEVATION (Ft.)	GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	LEAN CLAY (CL), varved silt and clay, occasional silt bands, gray, very soft *(continued)*		30							
						18	WR/18"			
			35							
						18	WR/18"			
40.0	116.8		40							
	LEAN CLAY WITH SAND (CL), varved silt and clay, occasional silt bands, gray, very soft					18	WR/18"	42.9	45-23-22	85
			45							
						18	WR/18"			
			50							
						18	WR/18"			
			55							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 2 1/4"HSA
Cased to 10'
Mud Rotary with 3 7/8" Drag bit to 81.5

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
WH = Weight of hammer
WR = Weight of rods
Hammer Efficiency Summary:
Energy Transfer Ratio: 91.3% +/- 2.7%
Hammer Efficiency Correction (CE): 1.52

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-08-2022 | Boring Completed: 09-09-2022

Drill Rig: CME 750-X | Driller: C. Schindler

Project No.: JB215256G

BORING LOG NO. KB-194.0-4.6B

PROJECT: CHPE - Additional HDD Borings - Phase 3

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

SITE: Fort Ann to Coxsackie, NY

LOCATION See Exploration Plan

Latitude: 42.540504° Longitude: -73.821649°

Surface Elev.: 156.8450 (Ft.)

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		LEAN CLAY WITH SAND (CL), varved silt and clay, occasional silt bands, gray, very soft *(continued)*								
	60.0	96.8	60							
		LEAN CLAY (CL), varved silt and clay, occasional silt bands, gray, very soft				18	WR/18"	45.6	49-27-22	93
			65			18	WR/24" 3" Split Spoon With Ring Samplers			
			70			18	WR/18"			
			75							
			80			18	WR/18"			
	81.5	75.3								
		Boring Terminated at 81.5 Feet								

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
0-10' 2 1/4"HSA
Cased to 10'
Mud Rotary with 3 7/8" Drag bit to 81.5

Abandonment Method:
Boring backfilled with bentonite grout upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

Logged by JCH
WH = Weight of hammer
WR = Weight of rods
Hammer Efficiency Summary:
Energy Transfer Ratio: 91.3% +/- 2.7%
Hammer Efficiency Correction (CE): 1.52

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
30 Corporate Cir Ste 201
Albany, NY

Boring Started: 09-08-2022 | Boring Completed: 09-09-2022

Drill Rig: CME 750-X | Driller: C. Schindler

Project No.: JB215256G

Summary of Laboratory Results

BORING ID	Depth (Ft.)	Water Content (%)	Organic Content (%)
KB-182.7B	20-22	31.1	
KB-182.7B	50-52	35.4	
KB-182.7B	80-82	26.5	
KB-184.2	4-6	17.3	
KB-184.2	20-21.5	10.0	
KB-184.9	10-12	35.4	
KB-184.9	25-26.5	8.6	
KB-184.9	40-42	9.2	
KB-184.9	55-56.5	12.2	
KB-185.4	6-8	34.3	
KB-185.4	20-21.5	13.7	
KB-185.4	35-39	9.1	
KB-185.4	45-47	14.7	
KB-192.4	15-17	36.9	
KB-192.4	25-27	42.6	
KB-192.4	45-47	46.0	
KB-192.4	65-67	8.0	
KB-192.8B	15-17	36.5	
KB-192.8B	40-40.2	14.1	
KB-192.8B	50-50.2	14.2	
KB-194.0-3.6B	5-7	31.0	
KB-194.0-3.6B	30-32	37.9	
KB-194.0-3.6B	50-52	39.6	
KB-194.0-3.6B	70-72	46.7	
KB-194.0-3.9B	4-6	31.5	
KB-194.0-3.9B	25-26.5	50.2	
KB-194.0-3.9B	45-46.5	43.4	
KB-194.0-3.9B	60-61.5	52.9	
KB-194.0-4.4	20-22	50.1	
KB-194.0-4.4	40-42	37.9	
KB-194.0-4.4	50-52	47.6	
KB-194.0-4.4	70-72	37.4	
KB-194.0-4.6B	4-6	24.1	
KB-194.0-4.6B	20-21.5	40.3	
KB-194.0-4.6B	40-41.5	42.9	
KB-194.0-4.6B	60-61.5	45.6	
KB-200.6	8-10	20.3	
KB-200.6	30-32	30.5	
KB-200.6	45-47	26.3	
KB-200.6	55-57	33.6	
KB-200.8A	15-17	39.6	
KB-200.8A	35-36.5	45.0	

PROJECT: CHPE - Additional HDD Borings - Phase 3

SITE: Fort Ann to Coxsackie, NY

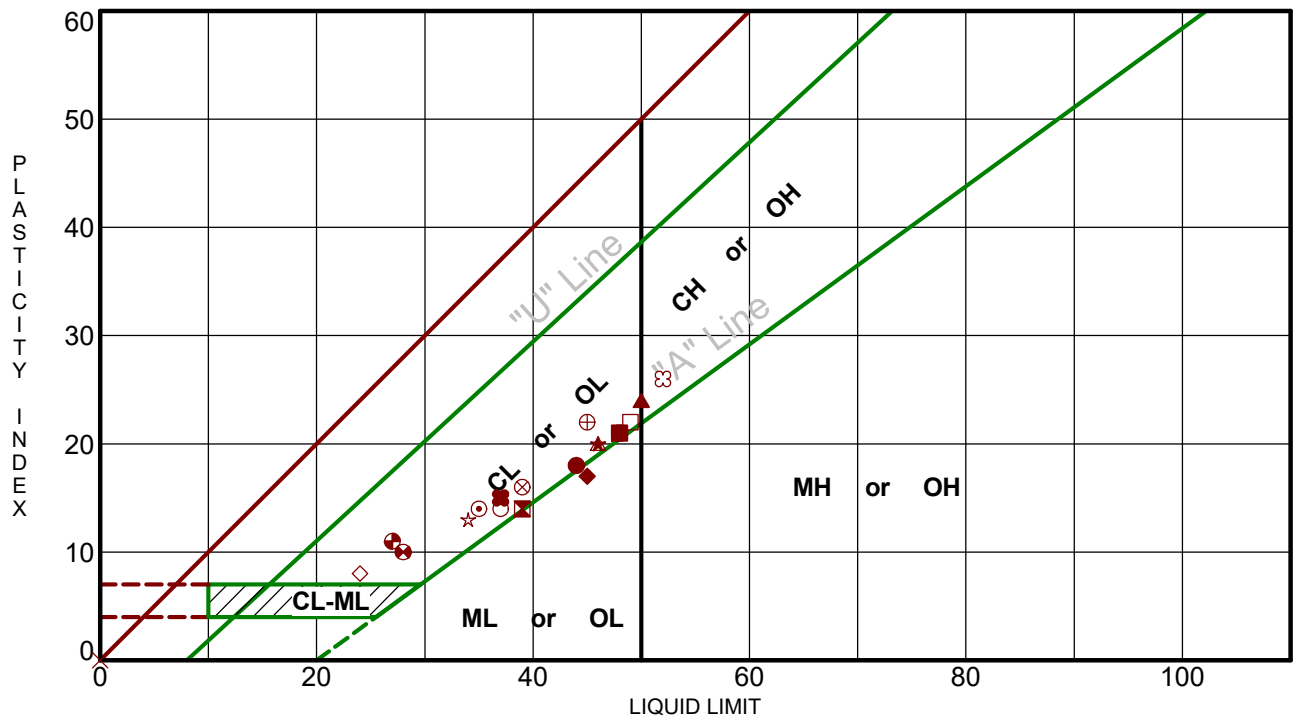
Terracon
30 Corporate Cir Ste 201
Albany, NY

PROJECT NUMBER: JB215256G

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	KB-194.0-3.9B	25 - 26.5	44	26	18	90.2	CL	LEAN CLAY
⊠	KB-194.0-3.9B	45 - 46.5	39	25	14	99.7	CL	LEAN CLAY
▲	KB-194.0-3.9B	60 - 61.5	50	26	24	94.7	CH	FAT CLAY
★	KB-194.0-4.4	20 - 22	46	26	20	96.1	CL	LEAN CLAY
⊙	KB-194.0-4.4	40 - 42	35	21	14	99.0	CL	LEAN CLAY
✿	KB-194.0-4.4	50 - 52	48	27	21	90.3	CL	LEAN CLAY
○	KB-194.0-4.4	70 - 72	37	23	14	99.2	CL	LEAN CLAY
△	KB-194.0-4.6B	4 - 6	46	26	20	78.4	CL	LEAN CLAY with SAND
⊗	KB-194.0-4.6B	20 - 21.5	39	23	16	93.3	CL	LEAN CLAY
⊕	KB-194.0-4.6B	40 - 41.5	45	23	22	84.8	CL	LEAN CLAY with SAND
□	KB-194.0-4.6B	60 - 61.5	49	27	22	92.6	CL	LEAN CLAY
⊛	KB-200.6	8 - 10	28	18	10	60.1	CL	SANDY LEAN CLAY
◕	KB-200.6	30 - 32	27	16	11	100.0	CL	LEAN CLAY
☆	KB-200.6	55 - 57	34	21	13	100.0	CL	LEAN CLAY
❀	KB-200.8A	15 - 17	52	26	26	90.5	CH	FAT CLAY
■	KB-200.8A	35 - 36.5	48	27	21	100.0	CL	LEAN CLAY
◆	KB-200.8A	60 - 61.5	45	28	17	100.0	ML	SILT
◇	KB-200.8A	85 - 86.5	24	16	8	95.2	CL	LEAN CLAY
×	KB-200.8A	100 - 102	NP	NP	NP	85.6	ML	SILT
✖	KB-200.8A	120 - 122	37	22	15	100.0	CL	LEAN CLAY

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

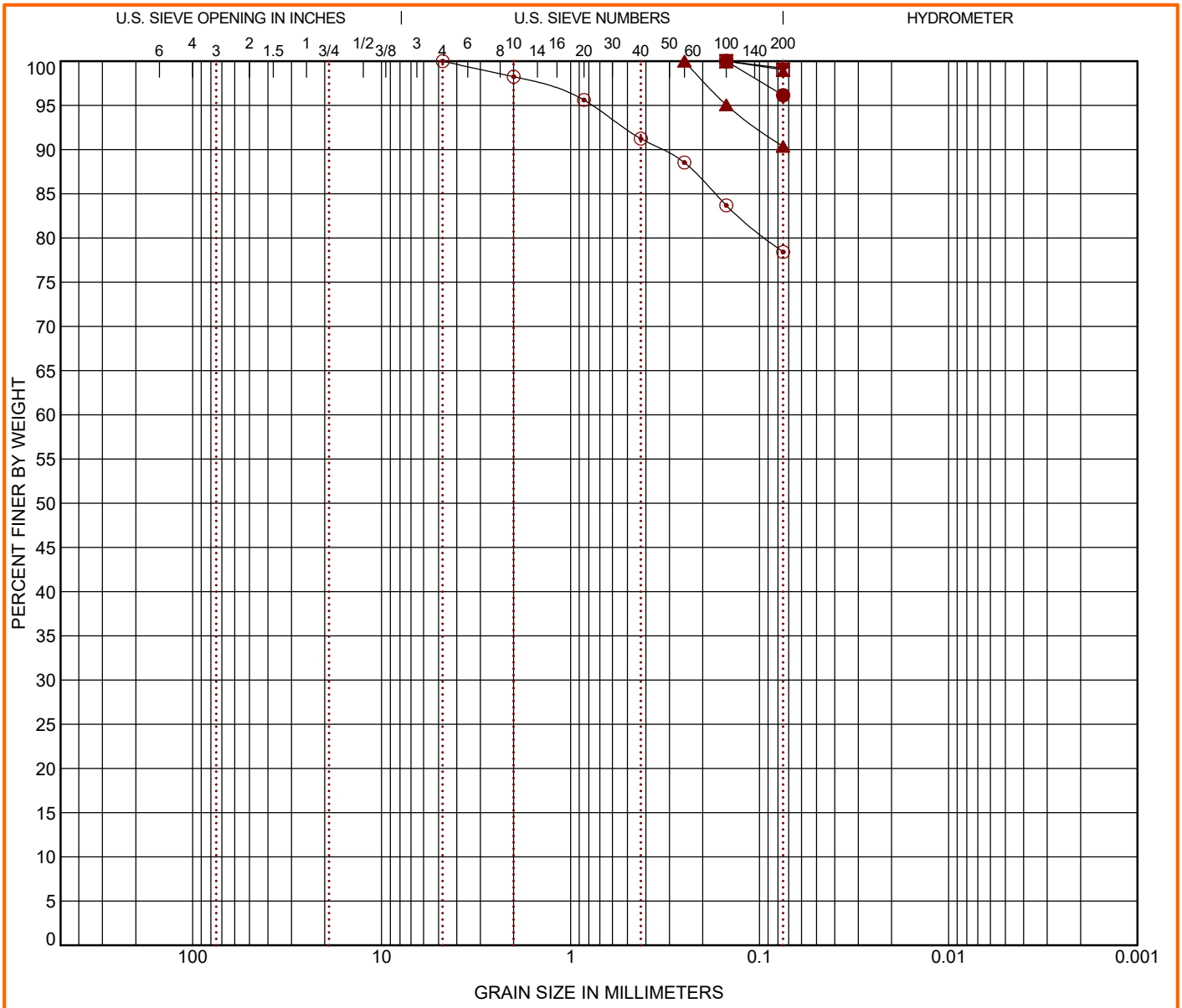
SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	KB-194.0-4.4	20 - 22	LEAN CLAY (CL)	50.1	46	26	20		
⊠	KB-194.0-4.4	40 - 42	LEAN CLAY (CL)	37.9	35	21	14		
▲	KB-194.0-4.4	50 - 52	LEAN CLAY (CL)	47.6	48	27	21		
★	KB-194.0-4.4	70 - 72	LEAN CLAY (CL)	37.4	37	23	14		
⊙	KB-194.0-4.6B	4 - 6	LEAN CLAY with SAND (CL)	24.1	46	26	20		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	KB-194.0-4.4	20 - 22	0.15				0.0	0.0	3.9		96.1	
⊠	KB-194.0-4.4	40 - 42	0.15				0.0	0.0	1.0		99.0	
▲	KB-194.0-4.4	50 - 52	0.25				0.0	0.0	9.7		90.3	
★	KB-194.0-4.4	70 - 72	0.15				0.0	0.0	0.8		99.2	
⊙	KB-194.0-4.6B	4 - 6	4.75				0.0	0.0	21.6		78.4	

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

SITE: Fort Ann to Coxsackie, NY

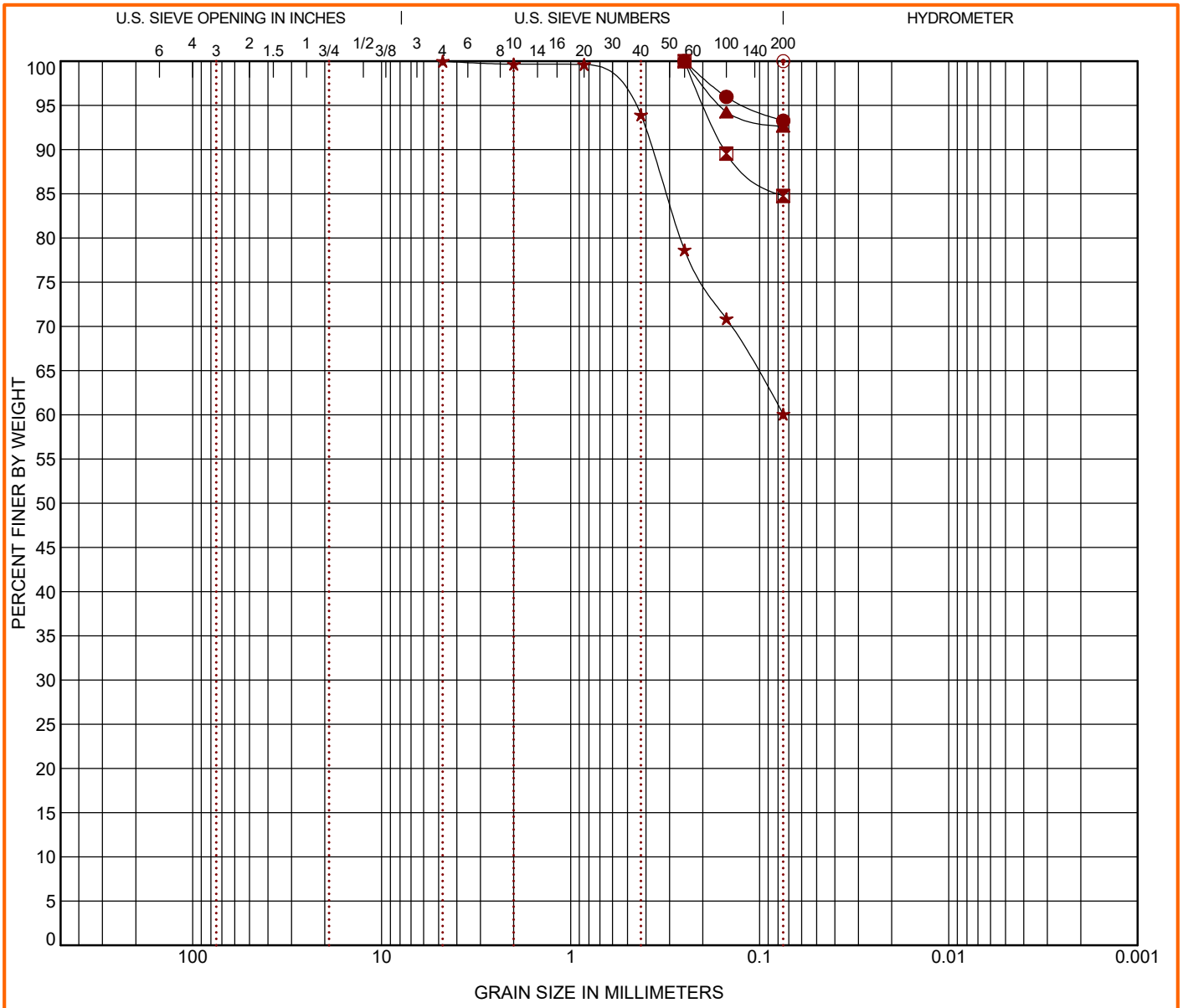
Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256G CHPE - ADDITIONAL.GPJ TERRACON_DATATEMPLATE.GDT 11/2/22

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID		Depth (Ft)	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	KB-194.0-4.6B	20 - 21.5	LEAN CLAY (CL)	40.3	39	23	16		
⊠	KB-194.0-4.6B	40 - 41.5	LEAN CLAY with SAND (CL)	42.9	45	23	22		
▲	KB-194.0-4.6B	60 - 61.5	LEAN CLAY (CL)	45.6	49	27	22		
★	KB-200.6	8 - 10	SANDY LEAN CLAY (CL)	20.3	28	18	10		
⊙	KB-200.6	30 - 32	LEAN CLAY (CL)	30.5	27	16	11		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Silt	%Fines	%Clay
●	KB-194.0-4.6B	20 - 21.5	0.25				0.0	0.0	6.7		93.3	
⊠	KB-194.0-4.6B	40 - 41.5	0.25				0.0	0.0	15.2		84.8	
▲	KB-194.0-4.6B	60 - 61.5	0.25				0.0	0.0	7.4		92.6	
★	KB-200.6	8 - 10	4.75				0.0	0.0	39.9		60.1	
⊙	KB-200.6	30 - 32	0.075				0.0	0.0	0.0		100.0	

PROJECT: CHPE - Additional HDD Borings - Phase 3

PROJECT NUMBER: JB215256G

SITE: Fort Ann to Coxsackie, NY

Terracon
30 Corporate Cir Ste 201
Albany, NY

CLIENT: Kiewit Engineering (NY) Corp
Lone Tree, CO

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 JB215256G CHPE - ADDITIONAL.GPJ TERRACON_DATATEMPLATE.GDT 11/2/22

APPENDIX B
HDD CALCULATIONS PER CROSSING

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 87B Circuit #1**
South Albany Street

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)

Project No: 322004-000
Print Date: 23-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/23/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	14+50.37	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)	East	North	Elevation
Entry	666606.9202	1358439.9206	176.70 ft
Horizontal Curve PI	667412.5591	1358416.1179	
Exit	667939.8081	1358009.5464	174.90 ft
Depth to Mudline	2.70 ft	Clearance Depth =	43.10 ft
Measured Plan Length at ties =	1450.3740 ft		
Coordinate Length =	1450.3740 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	149.00 ft
Mudline Elev.*	174.00 ft
Lowest centerline Elev.	130.90 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	666606.9202	1358439.9206	4+81.61	667088.3195	1358425.6976	E 091.69232 N	481.61		
Curve	4+81.61	667088.3195	1358425.6976	11+08.95	667669.4368	1358218.0347	E 127.63648 N	627.34	1000.00	35.944 deg.
Tangent	11+08.95	667669.4368	1358218.0347	14+50.37	667939.8081	1358009.5464	E 127.63648 N	341.42		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	481.61	Input Radius, ft.	1000.00	Plan Length, ft.	341.42	
Entry Azimuth, deg.[5]	N 091.69232 E	Curve, deg	35.944 deg.	Exit Azimuth, deg.[5]	N 127.63648 E	
Entry Azimuth, rad.[5]	1.60033	Curve, rad	0.62734	Exit Azimuth, rad.[5]	2.22768	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	617.11	Easting	667939.8081	***Check***
PCH Easting	667088.3195	Arc Length, ft.	627.34	Northing	1358009.5464	***Delta***
PCH Northing	1358425.6976	Chord Azimuth, deg	109.6644			**0.0000**
		PI Easting =	667412.5591			**0.0000**
		PI Northing =	1358416.1179			**OK CALC**
		PTH Easting =	667669.4368			
		PTH Northing =	1358218.0347			**Exit Station 14+50.37**
Cum Plan Length	481.61	Cum Plan Length	1108.95	Cum Plan Length	1450.37399	**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	174.90 ft	154.94 ft	-12.00 deg	-12.00 deg	0.00 deg		96.01 ft	0.00 ft
Entry Curve	154.94 ft	130.90 ft	-12.00 deg	0.00 deg	12.00 deg		230.38 ft	1100.00 ft
Bottom Tangent	130.90 ft	130.90 ft	0.00 deg	0.00 deg	0.00 deg		796.67 ft	0.00 ft
Exit Curve	130.90 ft	154.94 ft	0.00 deg	12.00 deg	12.00 deg		230.38 ft	1100.00 ft
Exit Tangent	154.94 ft	176.70 ft	12.00 deg	12.00 deg	0.00 deg		104.67 ft	0.00 ft
						Total Check =	1458.12 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	331.09	481.61	No, Horiz > Entry V(Tan+Curve)
Exit	322.62	341.42	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	1100.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	174.90	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	12.000 deg.	Design Exit Angle	12.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	102.384 ft	Plan Length	228.703 ft	Plan Length	796.66889 ft	Plan Length	228.703 ft	Plan Length	93.916 ft	1,450.374 ft
Rod Length	104.671 ft	Arc Rod Length	230.383 ft	Rod Length	796.66889 ft	Arc Rod Length	230.383 ft	Rod Length	96.014 ft	1,458.121 ft
Vertical Depth	-21.762 ft	Curve Δ Vert Depth	-24.038 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	24.038 ft	Vertical Depth	19.962 ft	-1.800 ft
		Lowest Elevation	130.900 ft			Lowest Elevation	130.900 ft	CK Total Cum Depth	-1.800 ft	
Start Elevation	176.700 ft	Start Elevation	154.938 ft	Start Elevation	130.900 ft	Start Elevation	130.900 ft	Start Elevation	154.938 ft	
End Elevation	154.938 ft	End Elevation	130.900 ft	End Elevation	130.900 ft	End Elevation	154.938 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	12.000 deg	***Prop. Plan Length***	***1450.37399***	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	1+02.38	Start Station	3+31.09	Start Station	11+27.76	Start Station	13+56.46	**Stationing Check**
PVC Station	1+02.38	PTV Station	3+31.09	PCV Station	11+27.76	PTV Station	13+56.46	Exit Station	14+50.374	**OK STATIONING**
Cum Plan Length	102.38	Cum Plan Length	331.09	Cum Plan Length	1127.76 ft	Cum Plan Length	1356.46	Cum Plan Length	1450.37	**Plan Length Check**
Cum Rod Length	104.67	Cum Rod Length	335.05	Cum Rod Length	1131.72 ft	Cum Rod Length	1362.11	Cum Rod Length	1458.12	**OK CALCULATION**
Cum Depth	-21.76	Cum Depth	-45.80	Cum Depth	-45.80 ft	Cum Depth	-21.7624	Cum Depth	-1.80	**Elevation Change Check**
										OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-1.80 ft**
Minimum Design Elevation =	**130.90 ft**
Invert Depth below exit =	**44.00 ft**
Invert Depth below entry =	**45.80 ft**
Path Length =	**1,458.12 ft**
Plan Length =	**1,450.37 ft**
Minimum Plan Length (No Tangent) =	**653.71 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**12.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

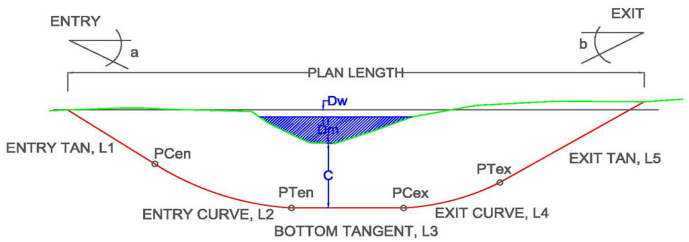
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DRILL PATH DESIGN CALCULATION
HDD 87B Circuit #1
South Albany Street

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

Revision 1 TBD

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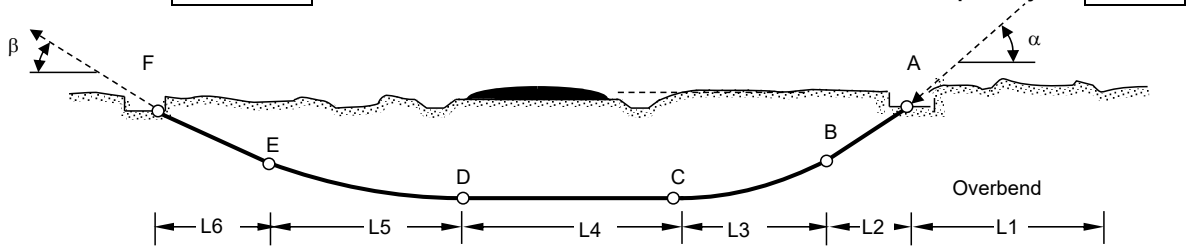
Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	96.0 ft	α =	-12.0 °	-0.2094	
L3 =	230.4 ft				1,100.0 ft
L4 =	796.7 ft	χ =	0.0 °	0.0000	
L5 =	230.4 ft				1,100.0 ft
L6 =	104.7 ft	β =	12.0 °	0.2094	
LT =	1558.1 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 176.70 ft **Pipe Entry El =** 174.90 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 =	174.00 ft	
Ballast Water El., H_W =	174.00 ft	
Lowest Invert El., El_m =	130.90 ft	

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 =	0.61 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

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	2,762 lb	198 psi	OK	2,762 lb	198 psi	OK	OK	OK
B	3,749 lb	95 psi	OK	3,834 lb	97 psi	OK	OK	OK
C	5,484 lb	173 psi	OK	4,685 lb	153 psi	OK	OK	OK
D	8,915 lb	225 psi	OK	8,115 lb	205 psi	OK	OK	OK
E	13,673 lb	380 psi	OK	10,650 lb	304 psi	OK	OK	OK
F	15,681 lb	396 psi	OK	11,602 lb	293 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 96.74 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.90435145	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.171967628	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	396 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	4.67	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	23.35	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 $D_H=D_O+12$"

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87B Circuit #1
South Albany Street

Revision 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #1

South Albany Street

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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	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 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 =	0.63	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 =	1.66	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%	2%	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} =			-3.55 lb/ft
Buoyant Unballasted Fluid 2, B_{B2} =			-3.69 lb/ft
Ballasted on ground, B_G =			4.10 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-1.11 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-1.24 lb/ft

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

W_P-W_{D1}

W_P-W_{D2}

W_P+W_B

BG-W_{D1}

BG-W_{D2}

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HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 87B Circuit #1
South Albany Street

BRIERLEY ASSOCIATES
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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: 45.80 ft | Ballast depth to invert, H_B: 44.00 ft | Drill Fluid depth to invert, H_{DF}: 44.00 ft

Pipe Invert Internal Pressure, P_I		Pipe Invert External Pressure, P_E	
Air Ballast, P_A	0.00 psi	Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	23.91 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	19.13 psi	Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	24.53 psi
		Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	19.13 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 = $(P_A+P_a)-P_{DF1}$	83.06 psi	9.00 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	82.45 psi	8.39 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.19 psi	28.13 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.58 psi	27.52 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 = $(P_A+P_a)-P_W$	87.85 psi	13.79 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. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #1

South Albany Street

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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	**AFE PULL STRENTH, SPS =**	**5,321 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	13,303 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 =	5,321 lb	**Useing SSAS =**	**4,371 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 =	0.90435		
r = σ_i/2*(SSAS) =	0.17197	Example from Table T5, σ_i =	396 psi
P_{CRR} =	241.9 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	120.9 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	116.15 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	115.53 psi	Pull Back Condition - C	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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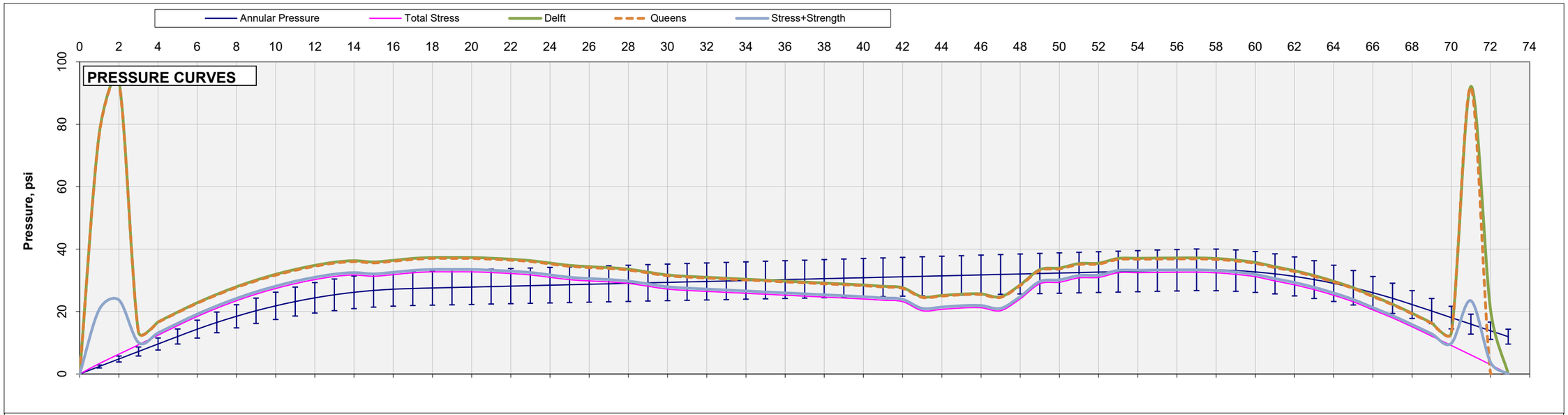
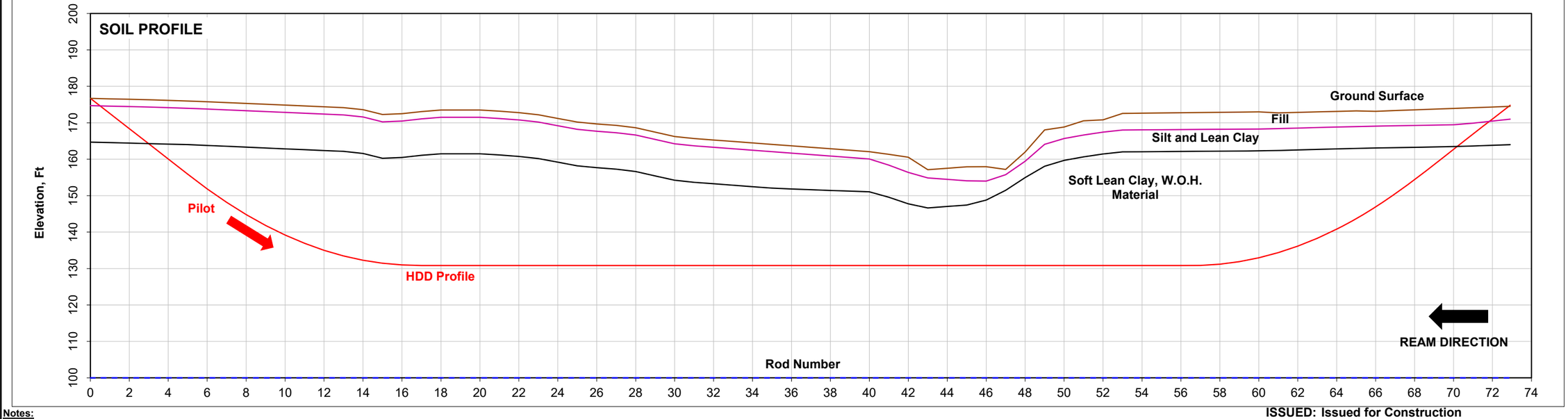


Entry - West



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

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

Bore Logs
K194.0-2.2A
K194.0-2.2B

Print Date ; 3/23/2023 20:54

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87B Circuit #1
South Albany Street

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 87B Circuit #2**
South Albany Street

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

Contents:

Prepared For: Kiewit

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

Project No: 322004-000
Print Date: 23-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/23/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	13+99.00	FT

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

	East	North	Elevation
Entry	666607.6454	1358461.3878	177.70 ft
Horizontal Curve PI	667426.8983	1358447.4981	
Exit	667896.3268	1358065.1066	175.00 ft

Depth to Mudline	3.70 ft	Clearance Depth =	34.00 ft
Measured Plan Length at ties =		1398.9994 ft	
Coordinate Length =		1398.9994 ft	
		OK-HORIZONTAL CURVE	

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

Water Surface Elev.*	149.00 ft
Mudline Elev.*	174.00 ft
Lowest centerline Elev.	140.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	666607.6454	1358461.3878	4+73.14	667080.7199	1358453.3672	E 090.97131 N	473.14		
Curve	4+73.14	667080.7199	1358453.3672	11+39.76	667695.3361	1358228.8315	E 129.16590 N	666.62	1000.00	38.195 deg.
Tangent	11+39.76	667695.3361	1358228.8315	13+99.00	667896.3268	1358065.1066	E 129.16590 N	259.24		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	473.14	Input Radius, ft.	1000.00	Plan Length, ft.	259.24	
Entry Azimuth, deg.[5]	N 090.97131 E	Curve, deg	38.195 deg.	Exit Azimuth, deg.[5]	N 129.16590 E	
Entry Azimuth, rad.[5]	1.58775	Curve, rad	0.66662	Exit Azimuth, rad.[5]	2.25437	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	654.35	Easting	667896.3268	***Check***
PCH Easting	667080.7199	Arc Length, ft.	666.62	Northing	1358065.1066	***Delta***
PCH Northing	1358453.3672	Chord Azimuth, deg	110.0686			**0.0000**
		PI Easting =	667426.8983			**0.0000**
		PI Northing =	1358447.4981			**OK CALC**
		PTH Easting =	667695.3361			
		PTH Northing =	1358228.8315			**Exit Station 13+99.00**
Cum Plan Length	473.14	Cum Plan Length	1139.76	Cum Plan Length	1398.999403	**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	175.00 ft	164.04 ft	-12.00 deg	-12.00 deg	0.00 deg		52.73 ft	0.00 ft
Entry Curve	164.04 ft	140.00 ft	-12.00 deg	0.00 deg	12.00 deg		230.38 ft	1100.00 ft
Bottom Tangent	140.00 ft	140.00 ft	0.00 deg	0.00 deg	0.00 deg		825.74 ft	0.00 ft
Exit Curve	140.00 ft	164.04 ft	0.00 deg	12.00 deg	12.00 deg		230.38 ft	1100.00 ft
Exit Tangent	164.04 ft	177.70 ft	12.00 deg	12.00 deg	0.00 deg		65.71 ft	0.00 ft
						Total Check =	1404.95 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	292.98	473.14	No, Horiz > Entry V(Tan+Curve)
Exit	280.28	259.24	Yes, Horiz < Exit 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	1100.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	175.00	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	12.000 deg.	Design Exit Angle	12.00 deg	
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**		**SUMS**
Plan Length	64.276 ft	Plan Length	228.703 ft	Plan Length	825.74348 ft	Plan Length	228.703 ft	Plan Length	51.574 ft	1,398.999 ft
Rod Length	65.712 ft	Arc Rod Length	230.383 ft	Rod Length	825.74348 ft	Arc Rod Length	230.383 ft	Rod Length	52.726 ft	1,404.949 ft
Vertical Depth	-13.662 ft	Curve Δ Vert Depth	-24.038 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	24.038 ft	Vertical Depth	10.962 ft	-2.700 ft
		Lowest Elevation	140.000 ft			Lowest Elevation	140.000 ft	CK Total Cum Depth	-2.700 ft	
Start Elevation	177.700 ft	Start Elevation	164.038 ft	Start Elevation	140.000 ft	Start Elevation	140.000 ft	Start Elevation	164.038 ft	
End Elevation	164.038 ft	End Elevation	140.000 ft	End Elevation	140.000 ft	End Elevation	164.038 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	12.000 deg	***Prop. Plan Length***	***1398.999403***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+64.28	Start Station	2+92.98	Start Station	11+18.72	Start Station	13+47.43	**Stationing Check**
PVC Station	0+64.28	PTV Station	2+92.98	PCV Station	11+18.72	PTV Station	13+47.43	Exit Station	13+98.999	**OK STATIONING**
Cum Plan Length	64.28	Cum Plan Length	292.98	Cum Plan Length	1118.72 ft	Cum Plan Length	1347.43	Cum Plan Length	1399.00	**Plan Length Check**
Cum Rod Length	65.71	Cum Rod Length	296.10	Cum Rod Length	1121.84 ft	Cum Rod Length	1352.22	Cum Rod Length	1404.95	**OK CALCULATION**
Cum Depth	-13.66	Cum Depth	-37.70	Cum Depth	-37.70 ft	Cum Depth	-13.6624	Cum Depth	-2.70	**Elevation Change Check**
										OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	-2.70 ft
Minimum Design Elevation =	140.00 ft
Invert Depth below exit =	35.00 ft
Invert Depth below entry =	37.70 ft
Path Length =	1,404.95 ft
Plan Length =	1,399.00 ft
Minimum Plan Length (No Tangent) =	573.26 ft
Entry Angle =	-12.00 deg
Exit Angle =	12.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	740 ft

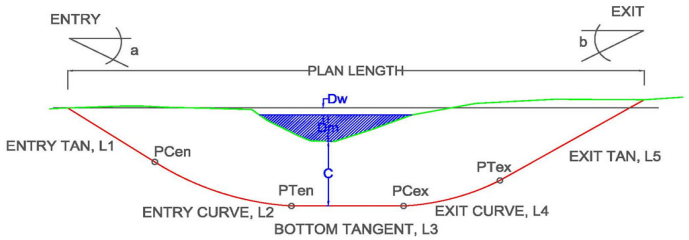
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 87B Circuit #2
South Albany Street

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

Revision 1 TBD

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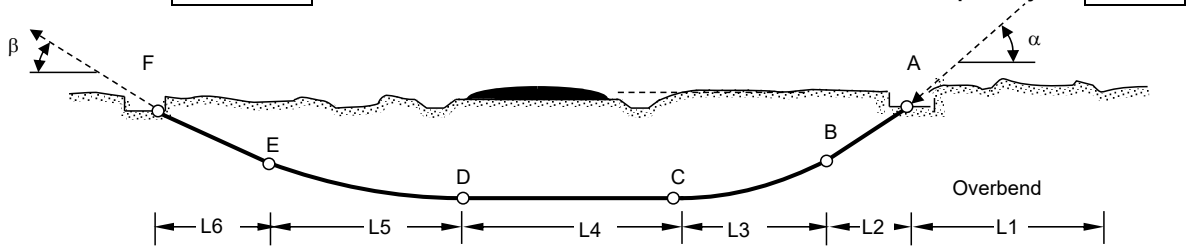
Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	52.7 ft	α =	-12.0 °	-0.2094	
L3 =	230.4 ft				1,100.0 ft
L4 =	825.7 ft	χ =	0.0 °	0.0000	
L5 =	230.4 ft				1,100.0 ft
L6 =	65.7 ft	β =	12.0 °	0.2094	
LT =	1504.9 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 177.70 ft **Pipe Entry El =** 175.00 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	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}	PIPE	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 =	174.00 ft	
Ballast Water El., H_W =	174.00 ft	
Lowest Invert El., El_m =	140.00 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 =	0.47 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

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	2,413 lb	164 psi	OK	2,413 lb	164 psi	OK	OK	OK
B	2,869 lb	80 psi	OK	2,909 lb	81 psi	OK	OK	OK
C	4,313 lb	147 psi	OK	3,551 lb	126 psi	OK	OK	OK
D	7,617 lb	213 psi	OK	6,856 lb	191 psi	OK	OK	OK
E	11,798 lb	356 psi	OK	9,024 lb	278 psi	OK	OK	OK
F	12,761 lb	356 psi	OK	9,489 lb	265 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 97.89 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.915118738	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.154788675	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	356 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	3.68	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	18.42	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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Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87B Circuit #2
South Albany Street

Revision 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #2

South Albany Street

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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 =	0.63	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 =	15.70	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%	2%	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} =			-33.46 lb/ft
Buoyant Unballasted Fluid 2, B_{B2} =			-34.72 lb/ft
Ballasted on ground, B_G =			38.69 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-10.47 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-11.73 lb/ft

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.70 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

W_P-W_{D1}

W_P-W_{D2}

W_P+W_B

BG-W_{D1}

BG-W_{D2}

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HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 87B Circuit #2
South Albany Street

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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: 37.70 ft | Ballast depth to invert, H_B: 35.00 ft | Drill Fluid depth to invert, H_{DF}: 35.00 ft

Pipe Invert Internal Pressure, P_I		Pipe Invert External Pressure, P_E	
Air Ballast, P_A	0.00 psi	Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	19.20 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	15.36 psi	Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	19.69 psi
		Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	15.36 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 = $(P_A+P_a)-P_{DF1}$	87.77 psi	13.71 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	87.28 psi	13.22 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.13 psi	29.08 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.64 psi	28.58 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 = $(P_A+P_a)-P_W$	91.61 psi	17.55 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.

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 87B Circuit #2

South Albany Street

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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	**AFE 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 =	0.91512		
r = σ_i/2*(SSAS) =	0.15479	Example from Table T5, σ_i =	356 psi
P_{CRR} =	244.7 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	122.4 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	118.53 psi	Pull Back Condition - Optior	**OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	118.04 psi	Pull Back Condition - Optior	**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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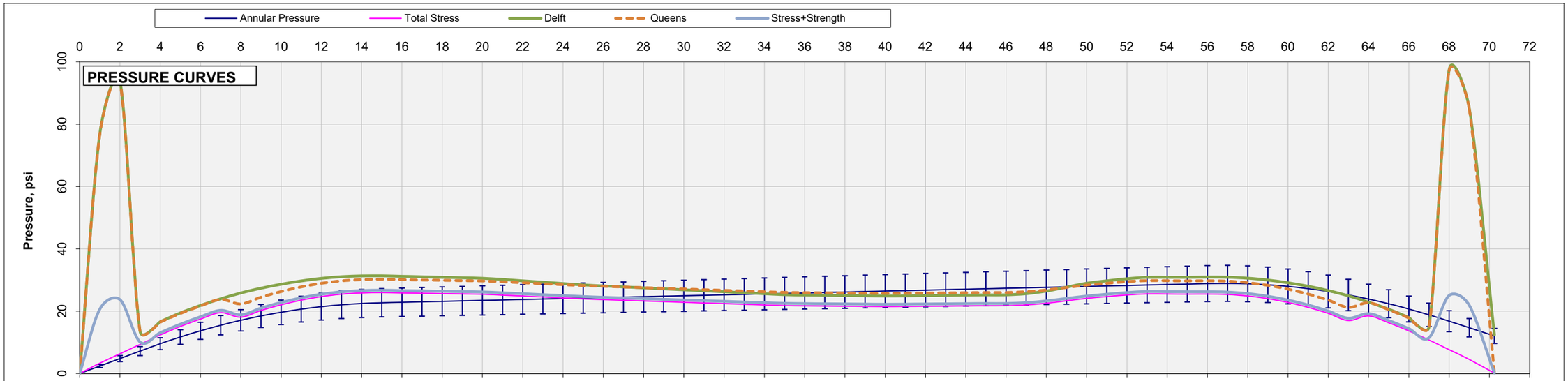

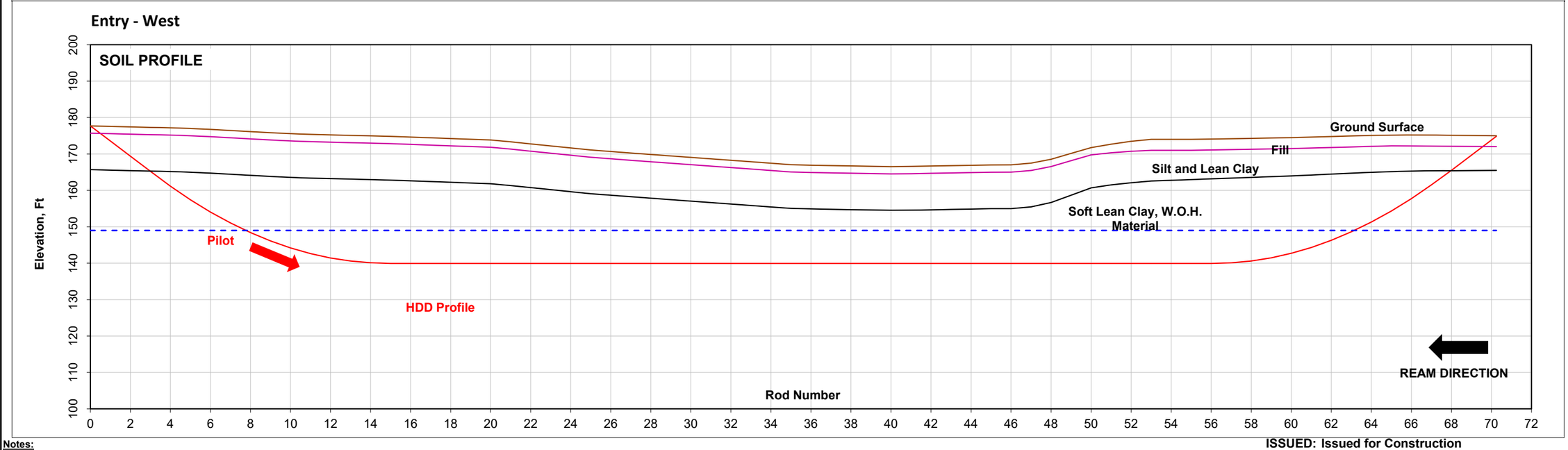

Notes:

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

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

Bore Logs
K194.0-2.2A
K194.0-2.2B

Print Date ; 3/23/2023 20:57

ISSUED: Issued for Construction

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87B Circuit #2
South Albany Street

Revision 1

FIGURE 1

BRIERLEY ASSOCIATES
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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 88 Circuit #1**
Coeyman's Creek

ISSUE: **IFC**

Contents:

Prepared For: Kiewit

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Project No: 322004-000
Print Date: 23-Mar-2023

Date	ID	DESCRIPTION	BY
11/22/2022	0	Design Submittal	ABL
3/23/2023	1	IFC	NS

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	14+67.06	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	669916.8713	1352961.8801	163.90 ft
Horizontal Curve PI	670592.6414	1353245.8376	
Exit	671269.3799	1353530.2020	175.30 ft
Depth to Mudline	0.90 ft	Clearance Depth =	68.60 ft
Measured Plan Length at ties =	1467.0614 ft		
Coordinate Length =	1467.0614 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	153.00 ft
Mudline Elev.*	163.00 ft
Lowest centerline Elev.	94.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	669916.8713	1352961.8801	7+33.01	670592.6414	1353245.8376	E 067.20793 N	733.01		
Curve	7+33.01	670592.6414	1353245.8376	7+33.01	670592.6414	1353245.8376	E 067.20793 N	0.00	0.00	0.000 deg.
Tangent	7+33.01	670592.6414	1353245.8376	14+67.06	671269.3799	1353530.2020	E 067.20793 N	734.06		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	733.01	Input Radius, ft.	0.00	Plan Length, ft.	734.06	
Entry Azimuth, deg.[5]	N 067.20793 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 067.20793 E	
Entry Azimuth, rad.[5]	1.17300	Curve, rad	0.00000	Exit Azimuth, rad.[5]	1.17300	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	0.00	Easting	671269.3799	***Check***
PCH Easting	670592.6414	Arc Length, ft.	0.00	Northing	1353530.2020	***Delta***
PCH Northing	1353245.8376	Chord Azimuth, deg	67.2079			**0.0000**
		PI Easting =	670592.6414			**0.0000**
		PI Northing =	1353245.8376			**OK CALC**
		PTH Easting =	670592.6414			
		PTH Northing =	1353245.8376			**Exit Station 14+67.06**
Cum Plan Length	733.01	Cum Plan Length	733.01	Cum Plan Length	1467.061449	**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	175.30 ft	112.63 ft	-10.00 deg	-10.00 deg	0.00 deg	360.90 ft	0.00 ft	
Entry Curve	112.63 ft	94.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft	
Bottom Tangent	94.40 ft	94.40 ft	0.00 deg	0.00 deg	0.00 deg	450.17 ft	0.00 ft	
Exit Curve	94.40 ft	120.62 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft	
Exit Tangent	120.62 ft	163.90 ft	12.00 deg	12.00 deg	0.00 deg	208.15 ft	0.00 ft	
					Total Check =	1479.99 ft	OK	

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry			No, Horiz > Entry V(Tan+Curve)
Exit			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	175.30	
		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**		**SUMS**
Plan Length	203.603 ft	Plan Length	249.494 ft	Plan Length	450.17148 ft	Plan Length	208.378 ft	Plan Length	355.415 ft	1,467.061 ft
Rod Length	208.151 ft	Arc Rod Length	251.327 ft	Rod Length	450.17148 ft	Arc Rod Length	209.440 ft	Rod Length	360.898 ft	1,479.988 ft
Vertical Depth	-43.277 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	62.669 ft	11.400 ft
		Lowest Elevation	94.400 ft			Lowest Elevation	94.400 ft	CK Total Cum Depth	11.400 ft	
Start Elevation	163.900 ft	Start Elevation	120.623 ft	Start Elevation	94.400 ft	Start Elevation	94.400 ft	Start Elevation	112.631 ft	
End Elevation	120.623 ft	End Elevation	94.400 ft	End Elevation	94.400 ft	End Elevation	112.631 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***	***1467.061449***	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	2+03.60	Start Station	4+53.10	Start Station	9+03.27	Start Station	11+11.65	
PVC Station	2+03.60	PTV Station	4+53.10	PCV Station	9+03.27	PTV Station	11+11.65	Exit Station	14+67.061	
Cum Plan Length	203.60	Cum Plan Length	453.10	Cum Plan Length	903.27 ft	Cum Plan Length	1111.65	Cum Plan Length	1467.06	
Cum Rod Length	208.15	Cum Rod Length	459.48	Cum Rod Length	909.65 ft	Cum Rod Length	1119.09	Cum Rod Length	1479.99	
Cum Depth	-43.28	Cum Depth	-69.50	Cum Depth	-69.50 ft	Cum Depth	-51.2693	Cum Depth	11.40	

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**11.40 ft**
Minimum Design Elevation =	**94.40 ft**
Invert Depth below exit =	**80.90 ft**
Invert Depth below entry =	**69.50 ft**
Path Length =	**1,479.99 ft**
Plan Length =	**1,467.06 ft**
Minimum Plan Length (No Tangent) =	**1,016.89 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

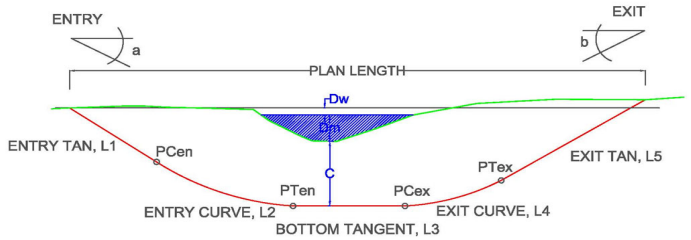
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 88 Circuit #1
Coeyman's Creek

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#88 CIR #1_APC_20221025.xlsb]T2 Path 1

Pull Geometry

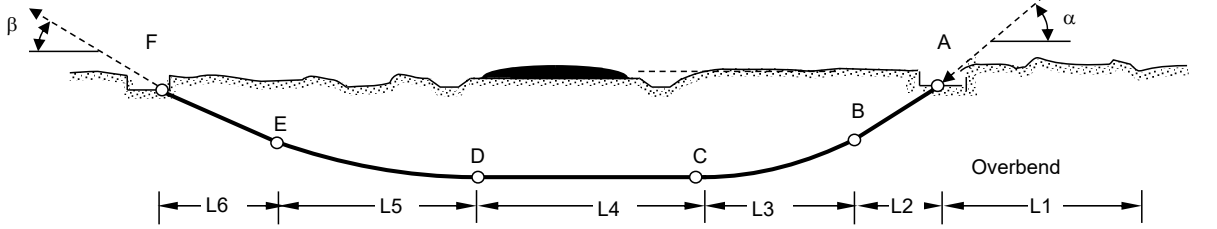
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	360.9 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	450.2 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	208.2 ft	β =	12.0 °	0.2094	
LT =	1580.0 ft				

Pipe Entry Location - Drill | **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 163.90 ft

Pipe Entry El = 175.30 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 =	1,008 psi	HDB/2		
Pressure Rating, $PR_{(80F)}$ =	252 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 =	163.00 ft	
Ballast Water El., H_W =	163.00 ft	
Lowest Invert El., El_m =	94.40 ft	

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 =	0.60 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

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	2,791 lb	148 psi	OK	2,791 lb	148 psi	OK	OK	OK
B	5,823 lb	147 psi	OK	6,358 lb	160 psi	OK	OK	OK
C	7,608 lb	224 psi	OK	7,266 lb	215 psi	OK	OK	OK
D	8,984 lb	227 psi	OK	8,642 lb	218 psi	OK	OK	OK
E	14,129 lb	389 psi	OK	11,390 lb	319 psi	OK	OK	OK
F	18,501 lb	467 psi	OK	13,416 lb	338 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 94.61 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.884440513	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.202897777	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	467 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	7.43	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	37.16	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 $D_H=D_O+12$"

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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"Creating Space Underground"

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 88 Circuit #1
Coeyman's Creek

Revision 1

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TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 88 Circuit #1

Coeyman's Creek

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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	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 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 =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 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 =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 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%	2%	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} =			-3.55 lb/ft
Buoyant Unballasted Fluid 2, B_{B2} =			-3.69 lb/ft
Ballasted on ground, B_G =			4.10 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-1.11 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-1.24 lb/ft

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$
		W_P-W_{D1}
		W_P-W_{D2}
		W_P+W_B
		$BG-W_{D1}$
		$BG-W_{D2}$

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HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 88 Circuit #1
Coeyman's Creek

BRIERLEY ASSOCIATES
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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 =	280 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 =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 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: 80.90 ft
Ballast depth to invert, H_B: 69.50 ft
Drill Fluid depth to invert, H_{DF}: 69.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	30.18 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	37.72 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	38.69 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	30.18 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 = $(P_A+P_a)-P_{DF1}$	69.25 psi	-4.81 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	68.28 psi	-5.78 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	99.43 psi	25.37 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	98.46 psi	24.40 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 = $(P_A+P_a)-P_W$	76.80 psi	2.74 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.

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\HDD#88 CIR #1_APC_20221025.xlsb]T2 Path 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 88 Circuit #1

Coeyman's Creek

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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	**AFE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 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 =	448 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 =	0.88444		
r = σ_i/2*(SSAS) =	0.20290	Example from Table T5, σ_i =	467 psi
P_{CRR} =	236.5 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	118.3 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	110.72 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	109.75 psi	Pull Back Condition - C	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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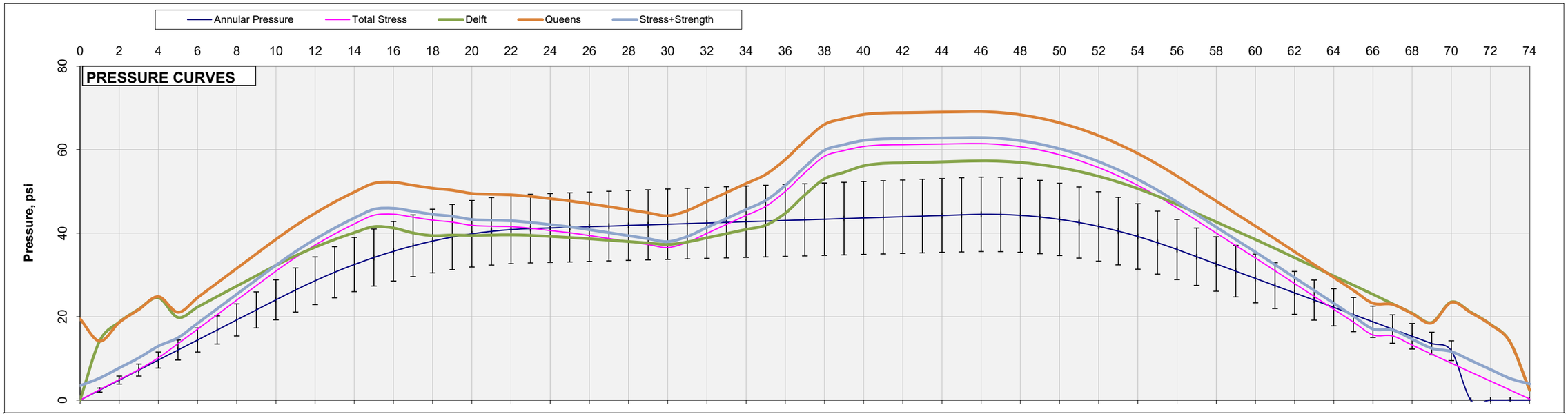

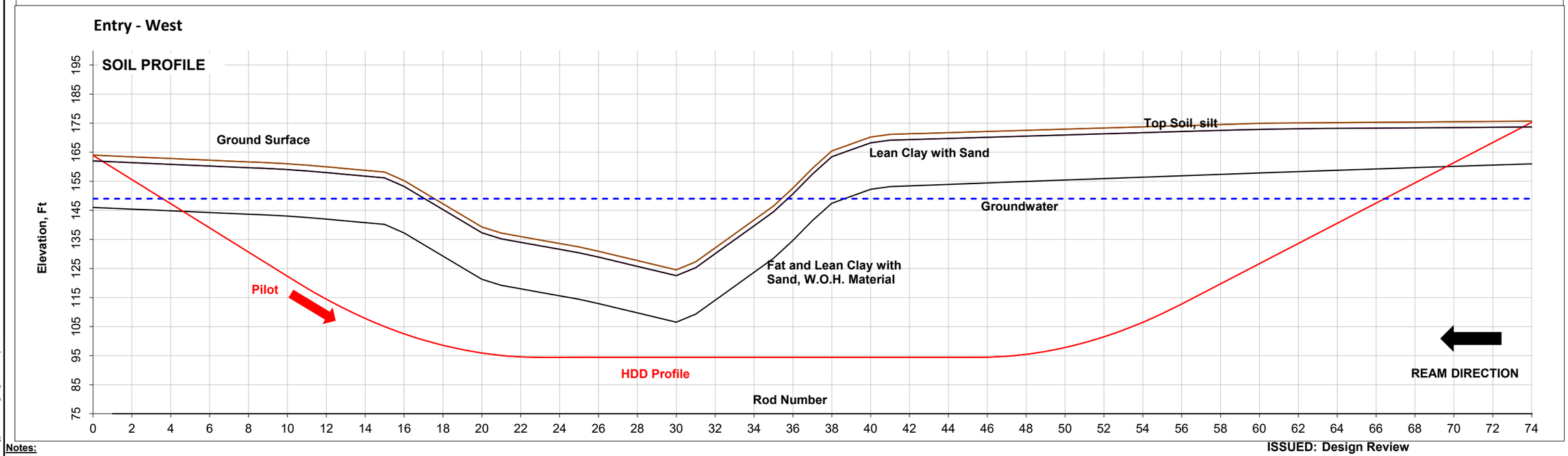

Notes:

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

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

Print Date ; 3/23/2023 20:38

ISSUED: Design Review

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 88 Circuit #1
Coeyman's Creek

Revision 1

FIGURE 1

BRIERLEY ASSOCIATES
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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 88 Circuit #2**
Coeyman's Creek

ISSUE: **IFC**

Contents:

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Project No: 322004-000
Print Date: 23-Mar-2023

Date	ID	DESCRIPTION	BY
11/22/2022	0	Design Submittal	ABL
3/23/2023	1	IFC	NS

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	14+67.06	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	669907.2728	1352984.9642	163.60 ft
Horizontal Curve PI	670583.0427	1353268.9217	
Exit	671259.7811	1353553.2862	175.70 ft
Depth to Mudline	0.60 ft	Clearance Depth =	68.60 ft
Measured Plan Length at ties =	1467.0612 ft		
Coordinate Length =	1467.0612 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	153.00 ft
Mudline Elev.*	163.00 ft
Lowest centerline Elev.	94.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	669907.2728	1352984.9642	7+33.01	670583.0427	1353268.9217	E 067.20793 N	733.01		
Curve	7+33.01	670583.0427	1353268.9217	7+33.01	670583.0427	1353268.9217	E 067.20792 N	0.00	0.00	0.000 deg.
Tangent	7+33.01	670583.0427	1353268.9217	14+67.06	671259.7811	1353553.2862	E 067.20792 N	734.06		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	733.01	Input Radius, ft.	0.00	Plan Length, ft.	734.06	
Entry Azimuth, deg.[b]	N 067.20793 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[b]	N 067.20792 E	
Entry Azimuth, rad.[b]	1.17300	Curve, rad	0.00000	Exit Azimuth, rad.[b]	1.17300	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	0.00	Easting	671259.7811	***Check***
PCH Easting	670583.0427	Arc Length, ft.	0.00	Northing	1353553.2862	***Delta***
PCH Northing	1353268.9217	Chord Azimuth, deg	67.2079			**0.0000**
		PI Easting =	670583.0427			**0.0000**
		PI Northing =	1353268.9217			**OK CALC**
		PTH Easting =	670583.0427			
		PTH Northing =	1353268.9217			**Exit Station 14+67.06**
Cum Plan Length	733.01	Cum Plan Length	733.01	Cum Plan Length	1467.061211	**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	175.70 ft	112.63 ft	-10.00 deg	-10.00 deg	0.00 deg	363.20 ft	0.00 ft	
Entry Curve	112.63 ft	94.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft	
Bottom Tangent	94.40 ft	94.40 ft	0.00 deg	0.00 deg	0.00 deg	449.31 ft	0.00 ft	
Exit Curve	94.40 ft	120.62 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft	
Exit Tangent	120.62 ft	163.60 ft	12.00 deg	12.00 deg	0.00 deg	206.71 ft	0.00 ft	
					Total Check =	1479.99 ft	OK	

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry			No, Horiz > Entry V(Tan+Curve)
Exit			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	175.70	
		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**		**SUMS**
Plan Length	202.191 ft	Plan Length	249.494 ft	Plan Length	449.31412 ft	Plan Length	208.378 ft	Plan Length	357.684 ft	1,467.061 ft
Rod Length	206.709 ft	Arc Rod Length	251.327 ft	Rod Length	449.31412 ft	Arc Rod Length	209.440 ft	Rod Length	363.202 ft	1,479.991 ft
Vertical Depth	-42.977 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	63.069 ft	12.100 ft
		Lowest Elevation	94.400 ft			Lowest Elevation	94.400 ft	CK Total Cum Depth	12.100 ft	
Start Elevation	163.600 ft	Start Elevation	120.623 ft	Start Elevation	94.400 ft	Start Elevation	94.400 ft	Start Elevation	112.631 ft	
End Elevation	120.623 ft	End Elevation	94.400 ft	End Elevation	94.400 ft	End Elevation	112.631 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***	***1467.061211***	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	2+02.19	Start Station	4+51.69	Start Station	9+01.00	Start Station	11+09.38	
PVC Station	2+02.19	PTV Station	4+51.69	PCV Station	9+01.00	PTV Station	11+09.38	Exit Station	14+67.061	
Cum Plan Length	202.19	Cum Plan Length	451.69	Cum Plan Length	901.00 ft	Cum Plan Length	1109.38	Cum Plan Length	1467.06	
Cum Rod Length	206.71	Cum Rod Length	458.04	Cum Rod Length	907.35 ft	Cum Rod Length	1116.79	Cum Rod Length	1479.99	
Cum Depth	-42.98	Cum Depth	-69.20	Cum Depth	-69.20 ft	Cum Depth	-50.9693	Cum Depth	12.10	

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**12.10 ft**
Minimum Design Elevation =	**94.40 ft**
Invert Depth below exit =	**81.30 ft**
Invert Depth below entry =	**69.20 ft**
Path Length =	**1,479.99 ft**
Plan Length =	**1,467.06 ft**
Minimum Plan Length (No Tangent) =	**1,017.75 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

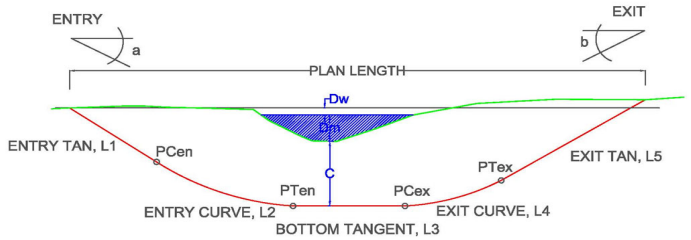
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 88 Circuit #2
Coeyman's Creek

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#88 CIR #2_APC_20221102.xlsb]T2 Path 1

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	363.2 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	449.3 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	206.7 ft	β =	12.0 °	0.2094	
LT =	1580.0 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.	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 =	15.68 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	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 =	1,008 psi	HDB/2		
Pressure Rating, $PR_{(80F)}$ =	252 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 =	163.00 ft	
Ballast Water El., H_W =	163.00 ft	
Lowest Invert El., El_m =	94.40 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 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 =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.60 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

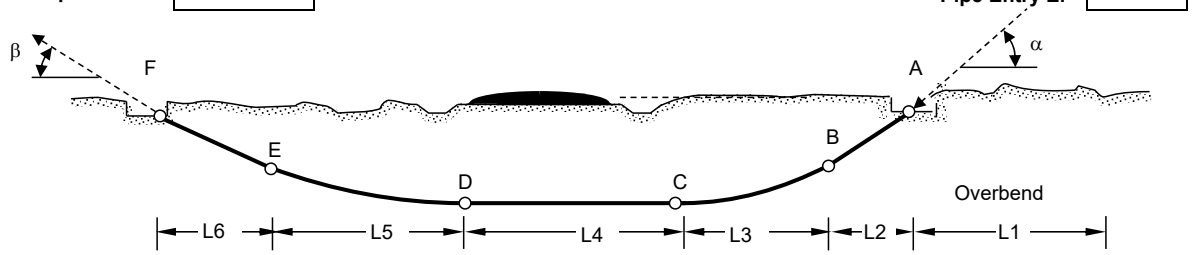
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.68 Lb/LF	38.67 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.48 Lb/LF	-10.49 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 163.60 ft

Pipe Entry El = 175.70 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	2,521 lb	148 psi	OK	2,521 lb	148 psi	OK	OK	OK
B	5,196 lb	145 psi	OK	5,680 lb	158 psi	OK	OK	OK
C	6,864 lb	224 psi	OK	6,555 lb	215 psi	OK	OK	OK
D	8,105 lb	226 psi	OK	7,797 lb	218 psi	OK	OK	OK
E	12,826 lb	390 psi	OK	10,350 lb	321 psi	OK	OK	OK
F	16,828 lb	469 psi	OK	12,232 lb	341 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 94.53 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.883645104	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.204111666	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	469 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	7.43	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	37.16	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 $D_H=D_O+12$"

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.

ISSUE: Design Review

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 88 Circuit #2
Coeyman's Creek

Revision 1

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TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 88 Circuit #2

Coeyman's Creek

BRIERLEY ASSOCIATES
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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	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		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^/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 =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 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 =	1,120 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%	2%	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
Buoyant Unballasted Fluid 2, B_{B2} =			-34.74 lb/ft
Ballasted on ground, B_G =			38.67 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-10.49 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-11.75 lb/ft

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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

W_P-W_{D1}

W_P-W_{D2}

W_P+W_B

BG-W_{D1}

BG-W_{D2}

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HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 88 Circuit #2
Coeyman's Creek

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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 =	280 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 =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 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: 81.30 ft
Ballast depth to invert, H_B: 69.20 ft
Drill Fluid depth to invert, H_{DF}: 69.20 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	30.18 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	37.73 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	38.69 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	30.18 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 = $(P_A+P_a)-P_{DF1}$	69.25 psi	-4.81 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	68.28 psi	-5.78 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	99.43 psi	25.37 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	98.46 psi	24.40 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 = $(P_A+P_a)-P_W$	76.79 psi	2.73 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.

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#88 CIR #2_APC_20221102.xlsb]T2 Path 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 88 Circuit #2

Coeyman's Creek

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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	**AFE PULL STRENTH, SPS =**	**16,064 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	40,160 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	16,064 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 =	448 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 =	0.88365		
r = σ_i/2*(SSAS) =	0.20411	Example from Table T5, σ_i =	469 psi
P_{CRR} =	236.3 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	118.2 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	110.61 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	109.65 psi	Pull Back Condition - C	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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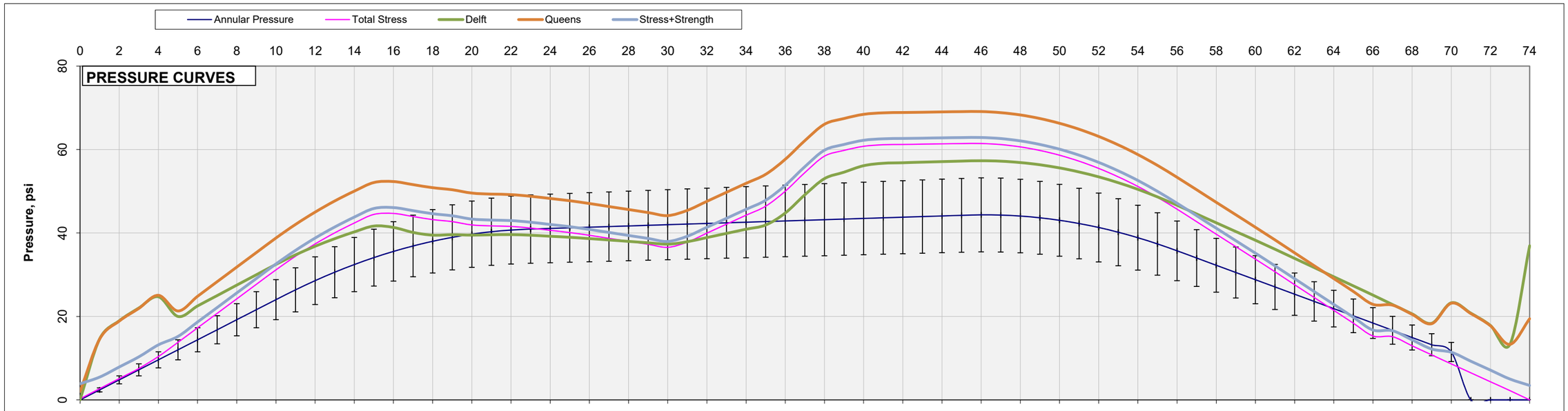

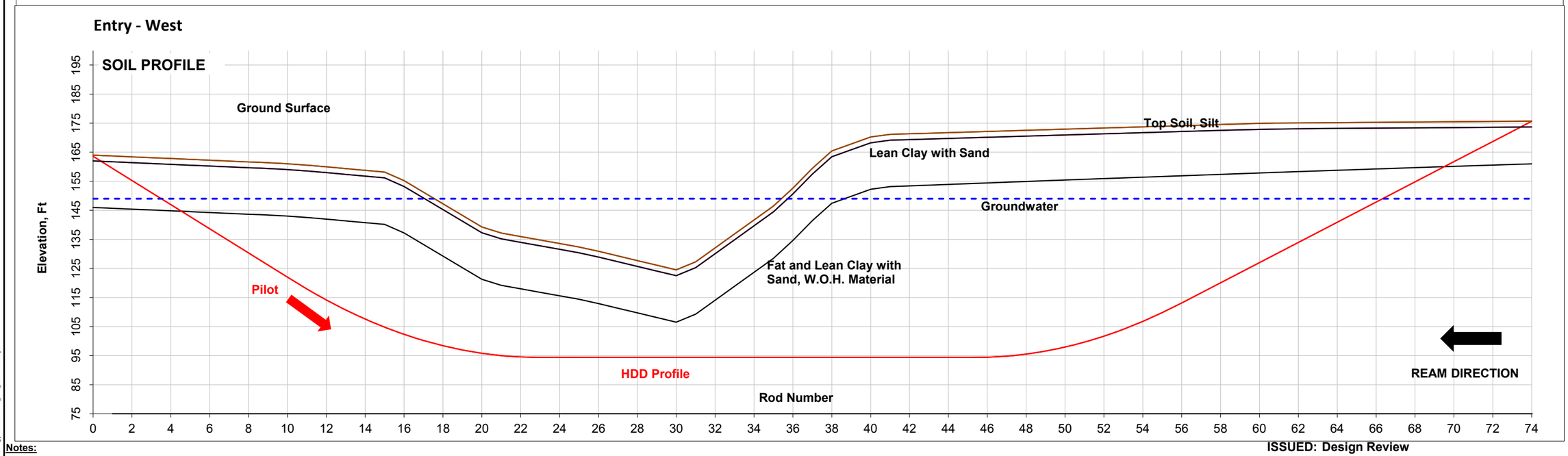

Notes:

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

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

Print Date ; 3/23/2023 20:48

ISSUED: Design Review

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 88 Circuit #2
Coeyman's Creek

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 89 Circuit #1**
Wetlands Crossing

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
167 S. River Road, Suite 8
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Project No: 322004-000
Print Date: 23-Mar-2023

Date	ID	DESCRIPTION	BY
10/27/2022	0	Design Submittal	ABL
3/23/2023	1	IFC	NHS

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	23+69.34	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	673933.703000	1352199.936500	159.90 ft
Horizontal Curve PI	673243.792700	1352891.563200	
Exit	671979.134200	1353490.536900	174.70 ft
Depth to Mudline	1.90 ft	Clearance Depth =	44.40 ft
Measured Plan Length at ties =	2369.3423 ft		
Coordinate Length =	2369.3423 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	152.00 ft
Mudline Elev.*	158.00 ft
Lowest centerline Elev.	113.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	673933.7030	1352199.9365	6+29.14	673489.3885	1352645.3564	E 315.07118 N	629.14		
Curve	6+29.14	673489.3885	1352645.3564	13+17.77	672929.5041	1353040.4181	E 295.34340 N	688.63	2000.00	-19.728 deg.
Tangent	13+17.77	672929.5041	1353040.4181	23+69.34	671979.1342	1353490.5369	E 295.34340 N	1051.57		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	629.14	Input Radius, ft.	2000.00	Plan Length, ft.	1051.57	
Entry Azimuth, deg.[5]	N 315.07118 E	Curve, deg	-19.728 deg.	Exit Azimuth, deg.[5]	N 295.34340 E	
Entry Azimuth, rad.[5]	5.49903	Curve, rad	-0.34431	Exit Azimuth, rad.[5]	5.15471	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	685.23	Easting	671979.1342	***Check***
PCH Easting	673489.3885	Arc Length, ft.	688.63	Northing	1353490.5369	***Delta***
PCH Northing	1352645.3564	Chord Azimuth, deg	305.2073			**0.0000**
		PI Easting =	673243.7927			**0.0000**
		PI Northing =	1352891.5632			**OK CALC**
		PTH Easting =	672929.5041			
		PTH Northing =	1353040.4181			**Exit Station 23+69.34**
Cum Plan Length	629.14	Cum Plan Length	1317.77	Cum Plan Length	2369.342264	**OK STA**

Pull Geometry

Pipe Entry	ENTRY	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	159.90 ft	139.82 ft	-12.00 deg	-12.00 deg	0.00 deg	96.57 ft	0.00 ft	
Entry Curve	139.82 ft	113.60 ft	-12.00 deg	0.00 deg	12.00 deg	251.33 ft	1200.00 ft	
Bottom Tangent	113.60 ft	113.60 ft	0.00 deg	0.00 deg	0.00 deg	1573.89 ft	0.00 ft	
Exit Curve	113.60 ft	131.83 ft	0.00 deg	10.00 deg	10.00 deg	209.44 ft	1200.00 ft	
Exit Tangent	131.83 ft	174.70 ft	10.00 deg	10.00 deg	0.00 deg	246.87 ft	0.00 ft	
					Total Check =	2378.10 ft	OK	

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	343.95	629.14	No, Horiz > Entry V(Tan+Curve)
Exit	451.50	1051.57	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

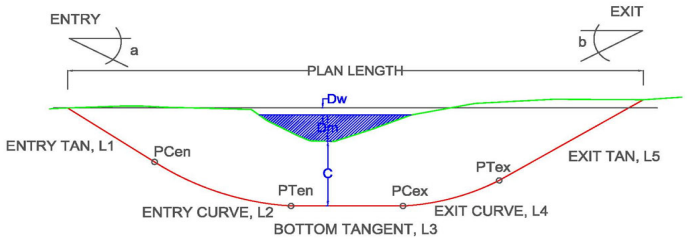
Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*		
Entry Angle	-12.000 deg.	Vertical Radius	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	174.70	
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom 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**		**SUMS**
Plan Length	94.455 ft	Plan Length	249.494 ft	Plan Length	1,573.89109 ft	Plan Length	208.378 ft	Plan Length	243.124 ft	2,369.342 ft
Rod Length	96.566 ft	Arc Rod Length	251.327 ft	Rod Length	1,573.89109 ft	Arc Rod Length	209.440 ft	Rod Length	246.874 ft	2,378.098 ft
Vertical Depth	-20.077 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	42.869 ft	14.800 ft
		Lowest Elevation	113.600 ft			Lowest Elevation	113.600 ft	CK Total Cum Depth	14.800 ft	
Start Elevation	159.900 ft	Start Elevation	139.823 ft	Start Elevation	113.600 ft	Start Elevation	113.600 ft	Start Elevation	131.831 ft	
End Elevation	139.823 ft	End Elevation	113.600 ft	End Elevation	113.600 ft	End Elevation	131.831 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***	***2369.342264***	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	0+94.46	Start Station	3+43.95	Start Station	19+17.84	Start Station	21+26.22	
PVC Station	0+94.46	PTV Station	3+43.95	PCV Station	19+17.84	PTV Station	21+26.22	Exit Station	23+69.342	
Cum Plan Length	94.46	Cum Plan Length	343.95	Cum Plan Length	1917.84 ft	Cum Plan Length	2126.22	Cum Plan Length	2369.34	
Cum Rod Length	96.57	Cum Rod Length	347.89	Cum Rod Length	1921.78 ft	Cum Rod Length	2131.22	Cum Rod Length	2378.10	
Cum Depth	-20.08	Cum Depth	-46.30	Cum Depth	-46.30 ft	Cum Depth	-28.0693	Cum Depth	14.80	

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	14.80 ft
Minimum Design Elevation =	113.60 ft
Invert Depth below exit =	61.10 ft
Invert Depth below entry =	46.30 ft
Path Length =	2,378.10 ft
Plan Length =	2,369.34 ft
Minimum Plan Length (No Tangent) =	795.45 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.
0
0
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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 89 Circuit #1
Wetlands Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#89 CIR #1_APC_20221025.xlsb]T2 Path 1

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	96.6 ft	α =	-12.0 °	-0.2094	
L3 =	251.3 ft				1,200.0 ft
L4 =	1573.9 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,200.0 ft
L6 =	246.9 ft	β =	10.0 °	0.1745	
LT =	2478.1 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 =	1,008 psi	HDB/2		
Pressure Rating, $PR_{(80F)}$ =	252 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 =	158.00 ft	
Ballast Water El., H_W =	158.00 ft	
Lowest Invert El., El_m =	113.60 ft	

Calculated Pipe and Fluid Properties

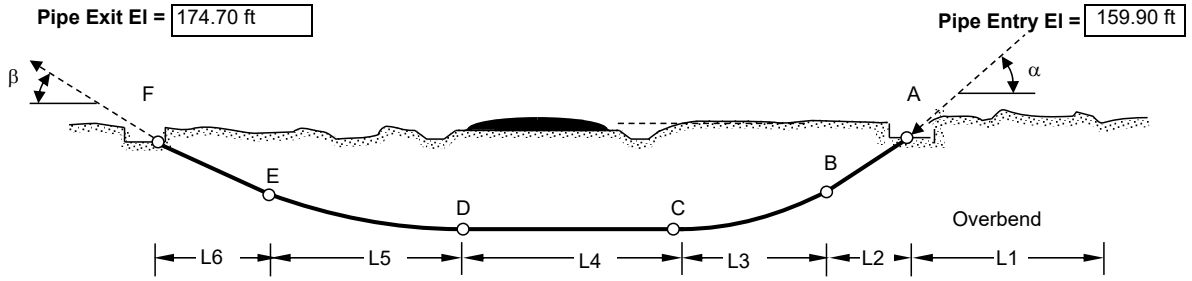
Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.37 lb/ft	Comparison Only @ 8psi

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

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)



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	4,393 lb	188 psi	OK	4,393 lb	188 psi	OK	OK	OK
B	5,297 lb	134 psi	OK	5,378 lb	136 psi	OK	OK	OK
C	7,255 lb	215 psi	OK	6,370 lb	193 psi	OK	OK	OK
D	14,576 lb	368 psi	OK	13,691 lb	345 psi	OK	OK	OK
E	18,945 lb	510 psi	OK	16,150 lb	440 psi	OK	OK	OK
F	22,377 lb	564 psi	OK	17,972 lb	453 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 91.56 psi — Ballasted: OK; No Ballast: OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.855941986	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.245406226	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	564 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	4.81	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	24.05	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 $D_H=D_O+12$"

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 89 Circuit #1
Wetlands Crossing

Revision 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 89 Circuit #1
Wetlands Crossing

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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	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 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 =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 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 =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 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%	2%	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} =			-3.55 lb/ft
Buoyant Unballasted Fluid 2, B_{B2} =			-3.69 lb/ft
Ballasted on ground, B_G =			4.10 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-1.11 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-1.24 lb/ft

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

W_P-W_{D1}
W_P-W_{D2}
W_P+W_B
BG-W_{D1}
BG-W_{D2}

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#89 CIR #1_APC_20221025.xlsb]T2 Path 1

HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 89 Circuit #1
Wetlands Crossing

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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 =	280 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 =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 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: 61.10 ft — Ballast depth to invert, H_B: 46.30 ft — Drill Fluid depth to invert, H_{DF}: 46.30 ft

Pipe Invert Internal Pressure, P_I		Pipe Invert External Pressure, P_E	
Air Ballast, P_A	0.00 psi	Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	25.16 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	20.13 psi	Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.80 psi
		Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	20.13 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 = $(P_A+P_a)-P_{DF1}$	81.82 psi	7.76 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.17 psi	7.11 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.94 psi	27.88 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.30 psi	27.24 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 = $(P_A+P_a)-P_W$	86.85 psi	12.79 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.

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#89 CIR #1_APC_20221025.xlsb]T2 Path 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 89 Circuit #1

Wetlands Crossing

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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	**AFE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 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 =	448 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 =	0.85594		
r = σ_i/2*(SSAS) =	0.24541	Example from Table T5, σ_i =	564 psi
P_{CRR} =	228.9 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	114.5 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	109.42 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	108.78 psi	Pull Back Condition - C	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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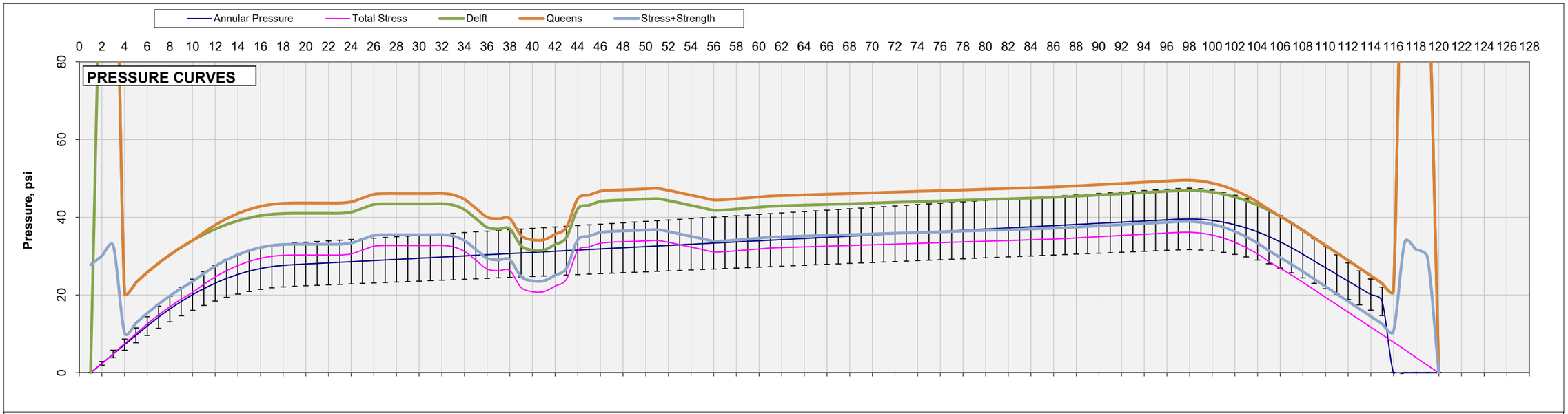

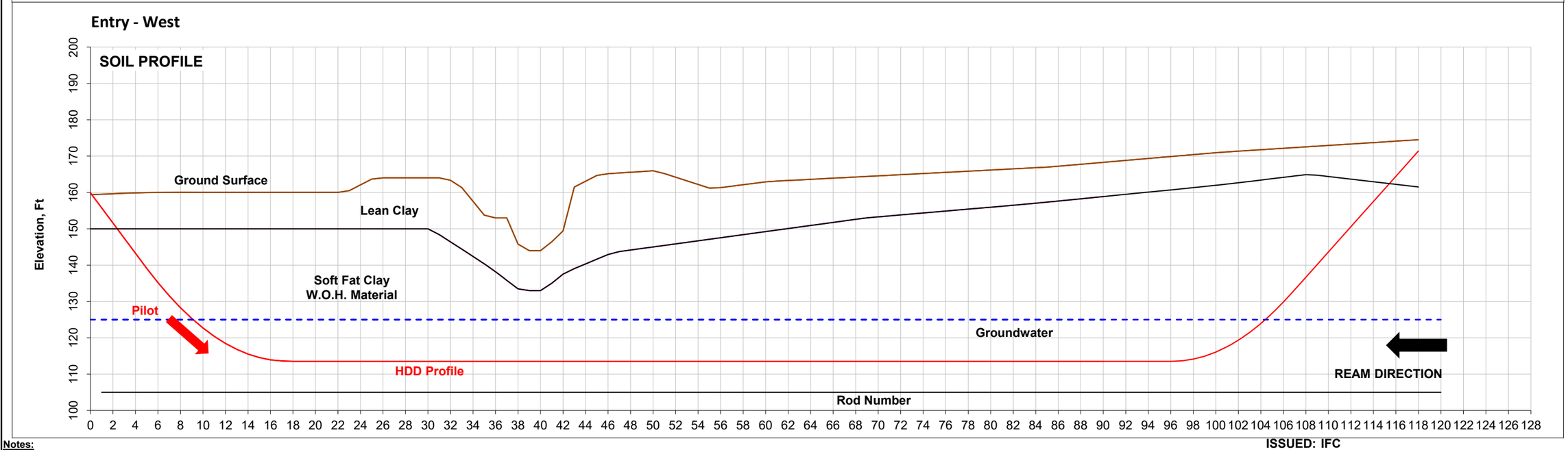

Notes:

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

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

Print Date ; 3/23/2023 20:12

ISSUED: IFC

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 89 Circuit #1
Wetlands Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\Hdd\89 GR.#1_APC_20221025.xlsx]T3 Path 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 89 Circuit #2**
Wetlands Crossing

ISSUE: **IFC**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
167 S. River Road, Suite 8
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Project No: 322004-000
Print Date: 23-Mar-2023

Date	ID	DESCRIPTION	BY
10/31/2022	0	Design Submittal	ABL
3/23/2023	1	IFC	NS

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	23+77.82	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)	East	North	Elevation
Entry	673948.118400	1352214.274200	159.90 ft
Horizontal Curve PI	673242.167000	1352924.022000	
Exit	671987.582000	1353508.665100	174.70 ft
Depth to Mudline	1.90 ft	Clearance Depth =	44.40 ft
Measured Plan Length at ties =	2377.8152 ft		
Coordinate Length =	2377.8152 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	125.00 ft
Mudline Elev.*	158.00 ft
Lowest centerline Elev.	113.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	673948.1184	1352214.2742	6+45.38	673492.9926	1352671.8476	E 315.15365 N	645.38		
Curve	6+45.38	673492.9926	1352671.8476	13+49.37	672919.7778	1353074.2571	E 294.98576 N	703.99	2000.00	-20.168 deg.
Tangent	13+49.37	672919.7778	1353074.2571	23+77.82	671987.5820	1353508.6651	E 294.98576 N	1028.45		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	645.38	Input Radius, ft.	2000.00	Plan Length, ft.	1028.45	
Entry Azimuth, deg.[5]	N 315.15365 E	Curve, deg	-20.168 deg.	Exit Azimuth, deg.[5]	N 294.98576 E	
Entry Azimuth, rad.[5]	5.50047	Curve, rad	-0.35200	Exit Azimuth, rad.[5]	5.14847	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	700.36	Easting	671987.5820	***Check***
PCH Easting	673492.9926	Arc Length, ft.	703.99	Northing	1353508.6651	***Delta***
PCH Northing	1352671.8476	Chord Azimuth, deg	305.0697			**0.0000**
		PI Easting =	673242.1670			**0.0000**
		PI Northing =	1352924.0220			**OK CALC**
		PTH Easting =	672919.7778			
		PTH Northing =	1353074.2571			**Exit Station 23+77.82**
Cum Plan Length	645.38	Cum Plan Length	1349.37	Cum Plan Length	2377.815162	**OK STA**

Pull Geometry

Pipe Entry	ENTRY	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	159.90 ft	139.82 ft	-12.00 deg	-12.00 deg	0.00 deg	96.57 ft	0.00 ft	
Entry Curve	139.82 ft	113.60 ft	-12.00 deg	0.00 deg	12.00 deg	251.33 ft	1200.00 ft	
Bottom Tangent	113.60 ft	113.60 ft	0.00 deg	0.00 deg	0.00 deg	1582.36 ft	0.00 ft	
Exit Curve	113.60 ft	131.83 ft	0.00 deg	10.00 deg	10.00 deg	209.44 ft	1200.00 ft	
Exit Tangent	131.83 ft	174.70 ft	10.00 deg	10.00 deg	0.00 deg	246.87 ft	0.00 ft	
					Total Check =	2386.57 ft	OK	

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	343.95	645.38	No, Horiz > Entry V(Tan+Curve)
Exit	451.50	1028.45	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	174.70	
		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**		**SUMS**
Plan Length	94.455 ft	Plan Length	249.494 ft	Plan Length	1,582.36399 ft	Plan Length	208.378 ft	Plan Length	243.124 ft	2,377.815 ft
Rod Length	96.566 ft	Arc Rod Length	251.327 ft	Rod Length	1,582.36399 ft	Arc Rod Length	209.440 ft	Rod Length	246.874 ft	2,386.571 ft
Vertical Depth	-20.077 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	42.869 ft	14.800 ft
		Lowest Elevation	113.600 ft			Lowest Elevation	113.600 ft	CK Total Cum Depth	14.800 ft	
Start Elevation	159.900 ft	Start Elevation	139.823 ft	Start Elevation	113.600 ft	Start Elevation	113.600 ft	Start Elevation	131.831 ft	
End Elevation	139.823 ft	End Elevation	113.600 ft	End Elevation	113.600 ft	End Elevation	131.831 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***	***2377.815162***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+94.46	Start Station	3+43.95	Start Station	19+26.31	Start Station	21+34.69	**Stationing Check**
PVC Station	0+94.46	PTV Station	3+43.95	PCV Station	19+26.31	PTV Station	21+34.69	Exit Station	23+77.815	**OK STATIONING**
Cum Plan Length	94.46	Cum Plan Length	343.95	Cum Plan Length	1926.31 ft	Cum Plan Length	2134.69	Cum Plan Length	2377.82	**Plan Length Check**
Cum Rod Length	96.57	Cum Rod Length	347.89	Cum Rod Length	1930.26 ft	Cum Rod Length	2139.70	Cum Rod Length	2386.57	**OK CALCULATION**
Cum Depth	-20.08	Cum Depth	-46.30	Cum Depth	-46.30 ft	Cum Depth	-28.0693	Cum Depth	14.80	**Elevation Change Check**
										OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**14.80 ft**
Minimum Design Elevation =	**113.60 ft**
Invert Depth below exit =	**61.10 ft**
Invert Depth below entry =	**46.30 ft**
Path Length =	**2,386.57 ft**
Plan Length =	**2,377.82 ft**
Minimum Plan Length (No Tangent) =	**795.45 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

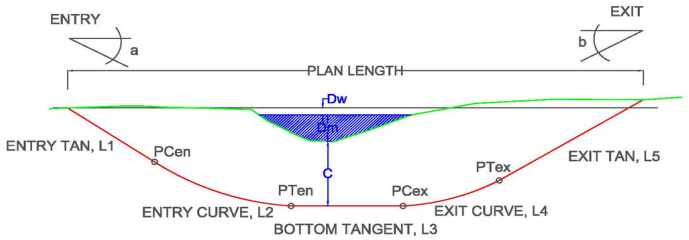
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 89 Circuit #2
Wetlands Crossing

Revision 1 TBD

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Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	96.6 ft	α =	-12.0 °	-0.2094	
L3 =	251.3 ft				1,200.0 ft
L4 =	1582.4 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,200.0 ft
L6 =	246.9 ft	β =	10.0 °	0.1745	
LT =	2486.6 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 =	1,008 psi	HDB/2		
Pressure Rating, $PR_{(80F)}$ =	252 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 =	158.00 ft	
Ballast Water El., H_W =	158.00 ft	
Lowest Invert El., El_m =	113.60 ft	

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 =	0.37 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

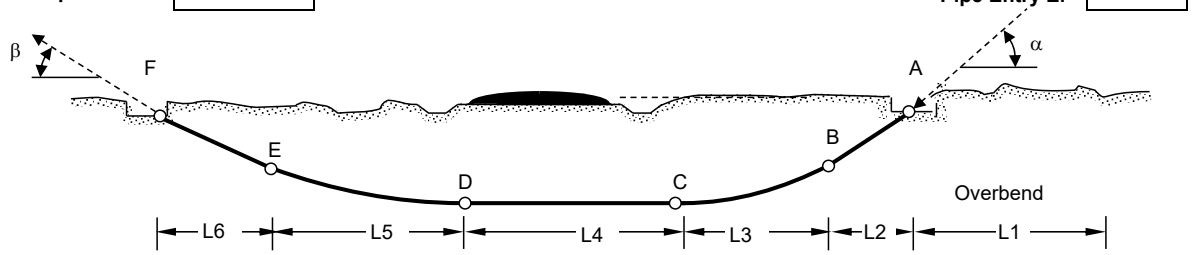
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 174.70 ft

Pipe Entry El = 159.90 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	4,408 lb	188 psi	OK	4,408 lb	188 psi	OK	OK	OK
B	5,311 lb	134 psi	OK	5,393 lb	136 psi	OK	OK	OK
C	7,270 lb	216 psi	OK	6,385 lb	193 psi	OK	OK	OK
D	14,636 lb	369 psi	OK	13,751 lb	347 psi	OK	OK	OK
E	19,008 lb	512 psi	OK	16,212 lb	441 psi	OK	OK	OK
F	22,440 lb	566 psi	OK	18,035 lb	455 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 91.51 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.85547046	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.246093068	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	566 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	4.81	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	24.05	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 $D_H=D_O+12$"

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 89 Circuit #2
Wetlands Crossing

Revision 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#89 CIR #2_APC_20221101.xlsb]T2 Path 1

TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 89 Circuit #2
Wetlands Crossing

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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	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 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 =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 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 =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 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%	2%	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} =			-3.55 lb/ft
Buoyant Unballasted Fluid 2, B_{B2} =			-3.69 lb/ft
Ballasted on ground, B_G =			4.10 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-1.11 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-1.24 lb/ft

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

W_P-W_{D1}
W_P-W_{D2}
W_P+W_B
BG-W_{D1}
BG-W_{D2}

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HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 89 Circuit #2
Wetlands Crossing

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"Creating Space Underground"

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 =	280 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 =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 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: 61.10 ft — Ballast depth to invert, H_B: 46.30 ft — Drill Fluid depth to invert, H_{DF}: 46.30 ft

Pipe Invert Internal Pressure, P_I		Pipe Invert External Pressure, P_E	
Air Ballast, P_A	0.00 psi	Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	25.16 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	20.13 psi	Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.80 psi
		Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	20.13 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 = $(P_A+P_a)-P_{DF1}$	81.82 psi	7.76 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.17 psi	7.11 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.94 psi	27.88 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.30 psi	27.24 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 = $(P_A+P_a)-P_W$	86.85 psi	12.79 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. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 89 Circuit #2

Wetlands Crossing

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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	**AFE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 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 =	448 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 =	0.85547		
r = σ_i/2*(SSAS) =	0.24609	Example from Table T5, σ_i =	566 psi
P_{CRR} =	228.8 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	114.4 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	109.36 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	108.72 psi	Pull Back Condition - C	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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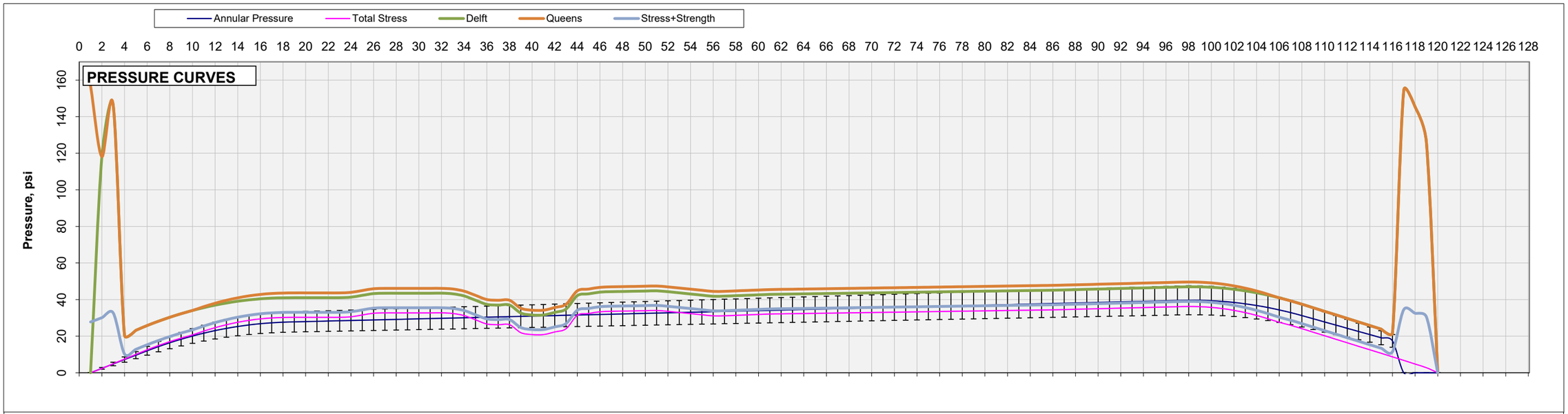

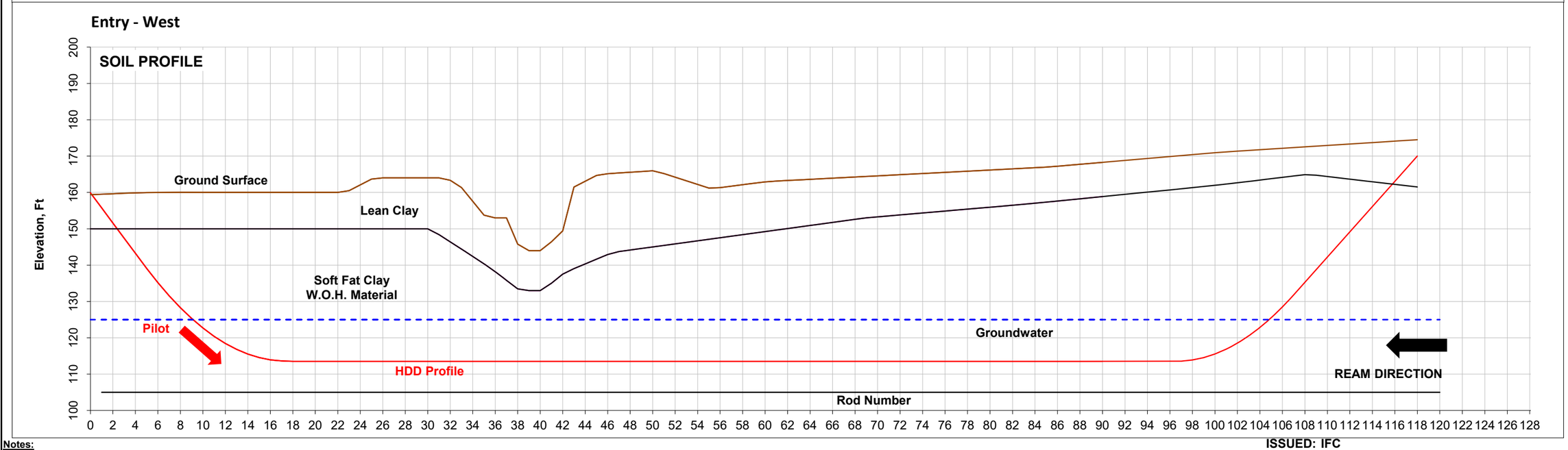

Notes:

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

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

Print Date ; 3/23/2023 20:26

ISSUED: IFC

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 89 Circuit #2
Wetlands Crossing

Revision 1

FIGURE 1

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 90 Circuit #1**
Route 396 & Stream Bank

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
167 S. River Road, Suite 8
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Project No: 322004-000
Print Date: 23-Mar-2023

Date	ID	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/23/2023	1	IFC	NS

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	12+37.41	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	675529.3478	1350699.6671	156.70 ft
Horizontal Curve PI	675004.6581	1351031.8525	
Exit	674615.2083	1351514.1974	158.20 ft
Depth to Mudline	0.70 ft	Clearance Depth =	57.70 ft
Measured Plan Length at ties =	1237.4070 ft		
Coordinate Length =	1237.4070 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	152.00 ft
Mudline Elev.*	156.00 ft
Lowest centerline Elev.	98.30 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	675529.3478	1350699.6671	4+22.95	675171.9971	1350925.9088	E 302.33824 N	422.95		
Curve	4+22.95	675171.9971	1350925.9088	8+15.52	674880.2382	1351185.9502	E 321.08227 N	392.57	1200.00	18.744 deg.
Tangent	8+15.52	674880.2382	1351185.9502	12+37.41	674615.2083	1351514.1974	E 321.08227 N	421.89		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	422.95	Input Radius, ft.	1200.00	Plan Length, ft.	421.89	
Entry Azimuth, deg.[b]	N 302.33824 E	Curve, deg	18.744 deg.	Exit Azimuth, deg.[b]	N 321.08227 E	
Entry Azimuth, rad.[b]	5.27680	Curve, rad	0.32715	Exit Azimuth, rad.[b]	5.60394	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	390.83	Easting	674615.2083	***Check***
PCH Easting	675171.9971	Arc Length, ft.	392.57	Northing	1351514.1974	***Delta***
PCH Northing	1350925.9088	Chord Azimuth, deg	311.7103			**0.0000**
		PI Easting =	675004.6581			**0.0000**
		PI Northing =	1351031.8525			**OK CALC**
		PTH Easting =	674880.2382			
		PTH Northing =	1351185.9502			**Exit Station 12+37.41**
Cum Plan Length	422.95	Cum Plan Length	815.52	Cum Plan Length	1237.406982	**OK STA**

Pull Geometry

Pipe Entry	ENTRY	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	156.70 ft	128.00 ft	-14.00 deg	-14.00 deg	0.00 deg	118.62 ft	0.00 ft	
Entry Curve	128.00 ft	98.30 ft	-14.00 deg	0.00 deg	14.00 deg	244.35 ft	1000.00 ft	
Bottom Tangent	98.30 ft	98.30 ft	0.00 deg	0.00 deg	0.00 deg	453.19 ft	0.00 ft	
Exit Curve	98.30 ft	113.49 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft	
Exit Tangent	113.49 ft	158.20 ft	10.00 deg	10.00 deg	0.00 deg	257.46 ft	0.00 ft	
					Total Check =	1248.15 ft	OK	

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	357.01	422.95	No, Horiz > Entry V(Tan+Curve)
Exit	427.20	421.89	Yes, Horiz < Exit 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	-14.000 deg.	Vertical Radius	1000.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	158.20	
		Vert. Curve, deg.	14.000 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**		**SUMS**
Plan Length	115.092 ft	Plan Length	241.922 ft	Plan Length	453.19437 ft	Plan Length	173.648 ft	Plan Length	253.550 ft	1,237.407 ft
Rod Length	118.616 ft	Arc Rod Length	244.346 ft	Rod Length	453.19437 ft	Arc Rod Length	174.533 ft	Rod Length	257.462 ft	1,248.151 ft
Vertical Depth	-28.696 ft	Curve Δ Vert Depth	-29.704 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	44.708 ft	1.500 ft
		Lowest Elevation	98.300 ft			Lowest Elevation	98.300 ft	CK Total Cum Depth	1.500 ft	
Start Elevation	156.700 ft	Start Elevation	128.004 ft	Start Elevation	98.300 ft	Start Elevation	98.300 ft	Start Elevation	113.492 ft	
End Elevation	128.004 ft	End Elevation	98.300 ft	End Elevation	98.300 ft	End Elevation	113.492 ft	Ck Exit Elevation		
End Vert Angle	-14.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***1237.406982***	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	1+15.09	Start Station	3+57.01	Start Station	8+10.21	Start Station	9+83.86	
PVC Station	1+15.09	PTV Station	3+57.01	PCV Station	8+10.21	PTV Station	9+83.86	Exit Station	12+37.407	
Cum Plan Length	115.09	Cum Plan Length	357.01	Cum Plan Length	810.21 ft	Cum Plan Length	983.86	Cum Plan Length	1237.41	
Cum Rod Length	118.62	Cum Rod Length	362.96	Cum Rod Length	816.16 ft	Cum Rod Length	990.69	Cum Rod Length	1248.15	
Cum Depth	-28.70	Cum Depth	-58.40	Cum Depth	-58.40 ft	Cum Depth	-43.2078	Cum Depth	1.50	

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**1.50 ft**
Minimum Design Elevation =	**98.30 ft**
Invert Depth below exit =	**59.90 ft**
Invert Depth below entry =	**58.40 ft**
Path Length =	**1,248.15 ft**
Plan Length =	**1,237.41 ft**
Minimum Plan Length (No Tangent) =	**784.21 ft**
Entry Angle =	**-14.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**768 ft**

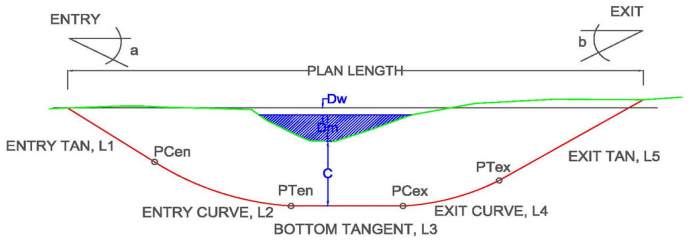
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

ISSUE: **IFC**

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 90 Circuit #1
Route 396 & Stream Bank

Revision 0 TBD

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Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	118.6 ft	α =	-14.0 °	-0.2443	
L3 =	244.3 ft				1,000.0 ft
L4 =	453.2 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	257.5 ft	β =	10.0 °	0.1745	
LT =	1348.2 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 =	17.34 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 =	1,008 psi	HDB/2		
Pressure Rating, $PR_{(80F)}$ =	252 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 =	156.00 ft	
Ballast Water El., H_W =	156.00 ft	
Lowest Invert El., El_m =	98.30 ft	

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 =	0.71 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

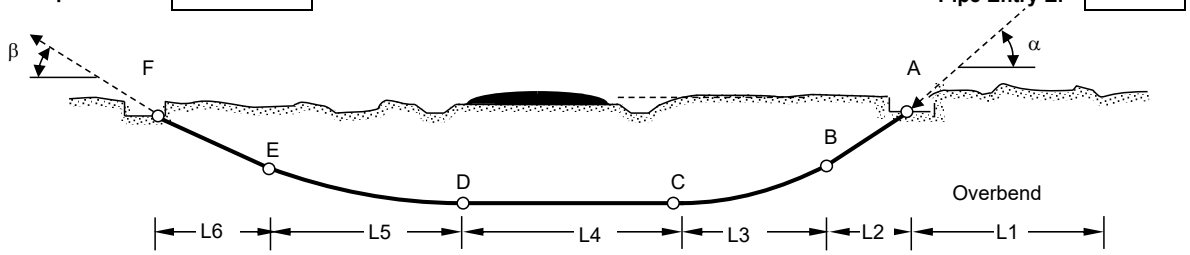
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.34 Lb/LF	42.78 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.03 Lb/LF	-11.60 Lb/LF

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 158.20 ft

Pipe Entry El = 156.70 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	2,396 lb	138 psi	OK	2,396 lb	138 psi	OK	OK	OK
B	3,933 lb	99 psi	OK	3,935 lb	99 psi	OK	OK	OK
C	5,653 lb	181 psi	OK	4,821 lb	160 psi	OK	OK	OK
D	7,095 lb	179 psi	OK	6,263 lb	158 psi	OK	OK	OK
E	10,515 lb	304 psi	OK	8,087 lb	243 psi	OK	OK	OK
F	15,514 lb	391 psi	OK	10,471 lb	264 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 96.87 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.90550772	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.170138461	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	391 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	6.25	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	31.25	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 $D_H=D_O+12$"

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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 90 Circuit #1
Route 396 & Stream Bank

Revision 0

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #1

Route 396 & Stream Bank

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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	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.500 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.680 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.80093926	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	131.95 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.067 cf/LF	$V_{Do} = \pi*(D_o/2)^2/144$	
Unit Inside Volume, V_{Di} =	0.039 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 =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 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 =	1.66	Lb/LF	
Tensile Yield, Ty psi =	1,120 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%	2%	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} =			-3.55 lb/ft
Buoyant Unballasted Fluid 2, B_{B2} =			-3.69 lb/ft
Ballasted on ground, B_G =			4.10 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-1.11 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-1.24 lb/ft

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.44 lb/ft	$W_B = V_{Di}*\gamma_{INT}$
Expected Displaced Fluid Weight, W_{D1} =	5.21 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	5.35 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$
		W_P-W_{D1}
		W_P-W_{D2}
		W_P+W_B
		$BG-W_{D1}$
		$BG-W_{D2}$

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#90 CIR #1_APC_20221025.xlsb]T3 Plastic Pull

HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 90 Circuit #1
Route 396 & Stream Bank

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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 =	280 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 =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 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: 59.90 ft | Ballast depth to invert, H_B: 58.40 ft | Drill Fluid depth to invert, H_{DF}: 58.40 ft

Pipe Invert Internal Pressure, P_I		Pipe Invert External Pressure, P_E	
Air Ballast, P_A	0.00 psi	Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	31.71 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	25.37 psi	Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	32.53 psi
		Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	25.37 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 = $(P_A+P_a)-P_{DF1}$	75.26 psi	1.20 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	74.45 psi	0.39 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	100.63 psi	26.57 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	99.82 psi	25.76 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 = $(P_A+P_a)-P_W$	81.61 psi	7.55 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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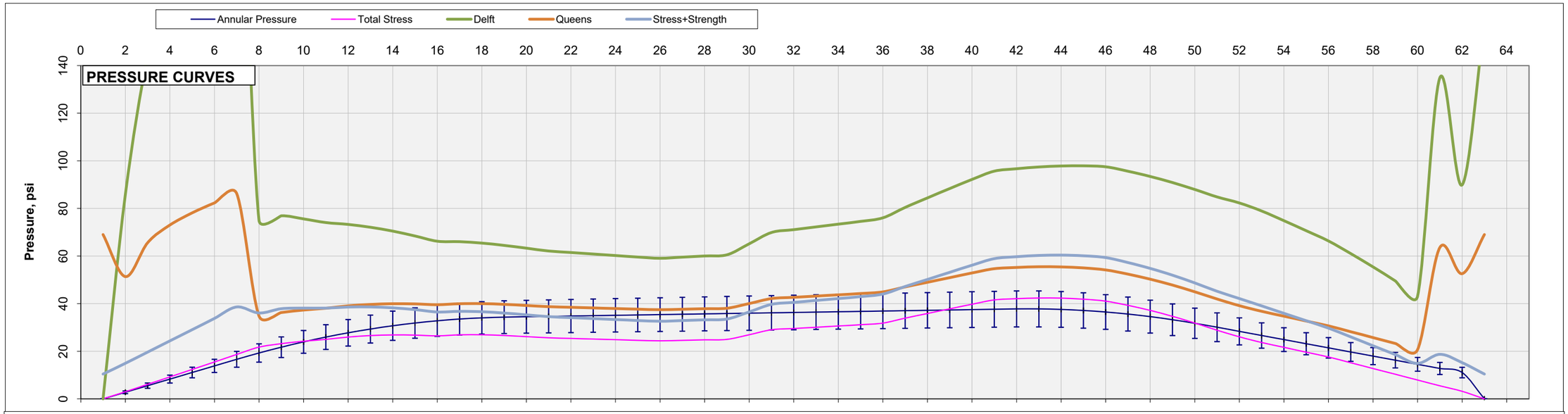

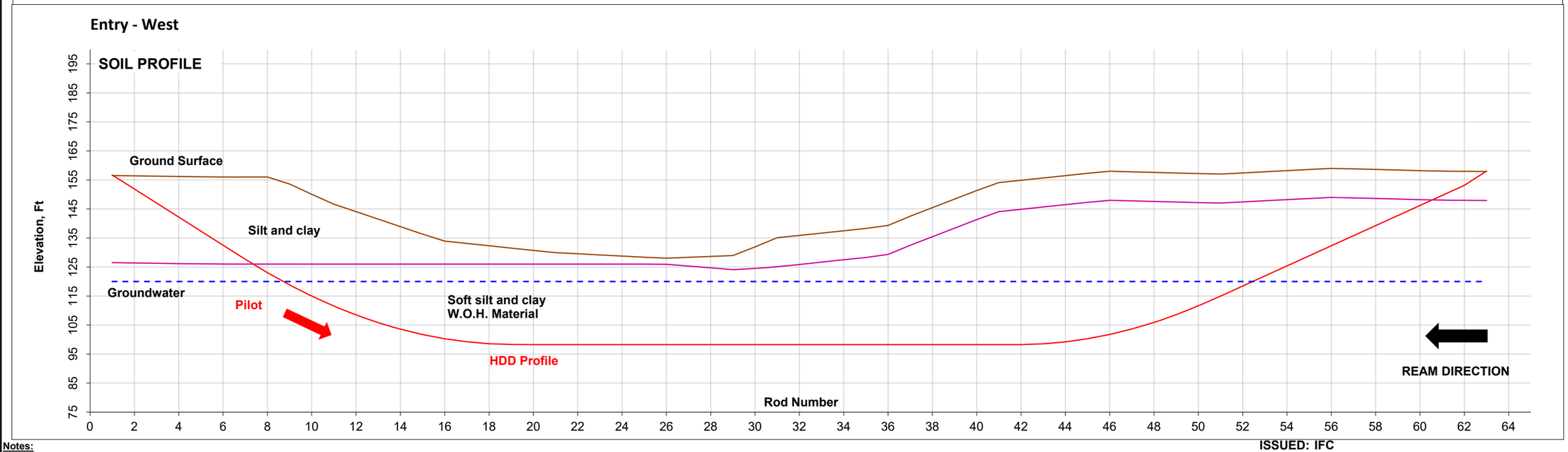

Notes:

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

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

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ISSUED: IFC

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 90 Circuit #1
Route 396 & Stream Bank

Revision 1

FIGURE 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #1

Route 396 & Stream Bank

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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	**AFE PULL STRENTH, SPS =**	**1,703 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	4,257 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	1,703 lb	**Useing SSAS =**	**4,371 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 =	448 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 =	0.90551		
r = σ_i/2*(SSAS) =	0.17014	Example from Table T5, σ_i =	391 psi
P_{CRR} =	242.2 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	121.1 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	114.74 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	113.93 psi	Pull Back Condition - C	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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HORIZONTAL DIRECTIONAL DRILL DESIGN

PROJECT: Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

CROSSING: **HDD 90 Circuit #2**
Route 396 & Stream Bank

ISSUE: **Design Submittal**

Contents:

Prepared For: Kiewit

Prepared By: Brierley Associates
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Project No: 322004-000
Print Date: 23-Mar-2023

Date	ID	DESCRIPTION	BY
10/30/2022	0	Design Submittal	ABL
3/23/2023	1	IFC	NS

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	12+31.23	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	675539.6563	1350715.3960	157.30 ft
Horizontal Curve PI	675025.8272	1351048.1647	
Exit	674615.2083	1351514.1974	158.50 ft
Depth to Mudline	-0.70 ft	Clearance Depth =	52.60 ft
Measured Plan Length at ties =	1231.2276 ft		
Coordinate Length =	1231.2276 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	152.00 ft
Mudline Elev.*	158.00 ft
Lowest centerline Elev.	105.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	675539.6563	1350715.3960	4+46.85	675164.5948	1350958.2953	E 302.92811 N	446.85		
Curve	4+46.85	675164.5948	1350958.2953	7+75.43	674916.5312	1351172.2104	E 318.61690 N	328.59	1200.00	15.689 deg.
Tangent	7+75.43	674916.5312	1351172.2104	12+31.23	674615.2083	1351514.1974	E 318.61690 N	455.80		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	446.85	Input Radius, ft.	1200.00	Plan Length, ft.	455.80	
Entry Azimuth, deg.[b]	N 302.92811 E	Curve, deg	15.689 deg.	Exit Azimuth, deg.[b]	N 318.61690 E	
Entry Azimuth, rad.[b]	5.28709	Curve, rad	0.27382	Exit Azimuth, rad.[b]	5.56091	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	327.56	Easting	674615.2083	***Check***
PCH Easting	675164.5948	Arc Length, ft.	328.59	Northing	1351514.1974	***Delta***
PCH Northing	1350958.2953	Chord Azimuth, deg	310.7725			**0.0000**
		PI Easting =	675025.8272			**0.0000**
		PI Northing =	1351048.1647			**OK CALC**
		PTH Easting =	674916.5312			
		PTH Northing =	1351172.2104			**Exit Station 12+31.23**
Cum Plan Length	446.85	Cum Plan Length	775.43	Cum Plan Length	1231.22755	**OK STA**

Pull Geometry

Pipe Entry	ENTRY	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	157.30 ft	135.10 ft	-14.00 deg	-14.00 deg	0.00 deg	91.75 ft	0.00 ft	
Entry Curve	135.10 ft	105.40 ft	-14.00 deg	0.00 deg	14.00 deg	244.35 ft	1000.00 ft	
Bottom Tangent	105.40 ft	105.40 ft	0.00 deg	0.00 deg	0.00 deg	511.65 ft	0.00 ft	
Exit Curve	105.40 ft	120.59 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft	
Exit Tangent	120.59 ft	158.50 ft	10.00 deg	10.00 deg	0.00 deg	218.30 ft	0.00 ft	
					Total Check =	1240.58 ft	OK	

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	330.94	446.85	No, Horiz > Entry V(Tan+Curve)
Exit	388.63	455.80	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	-14.000 deg.	Vertical Radius	1000.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	158.50	
		Vert. Curve, deg.	14.000 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**		**SUMS**
Plan Length	89.022 ft	Plan Length	241.922 ft	Plan Length	511.64973 ft	Plan Length	173.648 ft	Plan Length	214.986 ft	1,231.228 ft
Rod Length	91.747 ft	Arc Rod Length	244.346 ft	Rod Length	511.64973 ft	Arc Rod Length	174.533 ft	Rod Length	218.302 ft	1,240.578 ft
Vertical Depth	-22.196 ft	Curve Δ Vert Depth	-29.704 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	37.908 ft	1.200 ft
		Lowest Elevation	105.400 ft			Lowest Elevation	105.400 ft	CK Total Cum Depth	1.200 ft	
Start Elevation	157.300 ft	Start Elevation	135.104 ft	Start Elevation	105.400 ft	Start Elevation	105.400 ft	Start Elevation	120.592 ft	
End Elevation	135.104 ft	End Elevation	105.400 ft	End Elevation	105.400 ft	End Elevation	120.592 ft	Ck Exit Elevation		
End Vert Angle	-14.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***1231.22755***	
SUMMARY VERTICLE CURVE CALCULATIONS										**Stationing Check OK STATIONING**
Start Station	0+00.00	Start Station	0+89.02	Start Station	3+30.94	Start Station	8+42.59	Start Station	10+16.24	
PVC Station	0+89.02	PTV Station	3+30.94	PCV Station	8+42.59	PTV Station	10+16.24	Exit Station	12+31.228	**Plan Length Check OK CALCULATION**
Cum Plan Length	89.02	Cum Plan Length	330.94	Cum Plan Length	842.59 ft	Cum Plan Length	1016.24	Cum Plan Length	1231.23	
Cum Rod Length	91.75	Cum Rod Length	336.09	Cum Rod Length	847.74 ft	Cum Rod Length	1022.28	Cum Rod Length	1240.58	**Elevation Change Check OK CALCULATION**
Cum Depth	-22.20	Cum Depth	-51.90	Cum Depth	-51.90 ft	Cum Depth	-36.7078	Cum Depth	1.20	

Summary of Drill Calculations

Entry to Exit Elevation Change =	1.20 ft
Minimum Design Elevation =	105.40 ft
Invert Depth below exit =	53.10 ft
Invert Depth below entry =	51.90 ft
Path Length =	1,240.58 ft
Plan Length =	1,231.23 ft
Minimum Plan Length (No Tangent) =	719.58 ft
Entry Angle =	-14.00 deg
Exit Angle =	10.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	NO

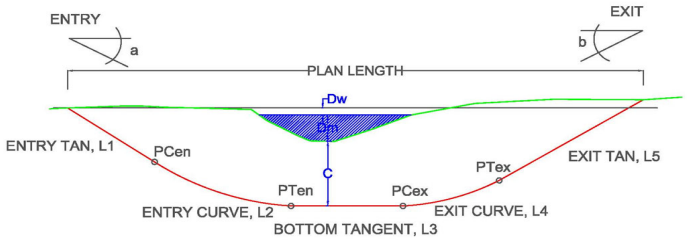
NOTES:

1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.

0

0

4. All calculation locations represent the center of the drill hole.



Indicates inputs

Indicates status on internal design checks

ISSUE: **IFC**

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Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 90 Circuit #2
Route 396 & Stream Bank

Revision 1 TBD

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Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	91.7 ft	α =	-14.0 °	-0.2443	
L3 =	244.3 ft				1,000.0 ft
L4 =	511.6 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	218.3 ft	β =	10.0 °	0.1745	
LT =	1340.6 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	Pipe	PIPE/BUNDLE	
Material Density, γ	59.28 pcf			
Outside Diameter, D_{OD}	10.75	Pipe or Bundle		
Pipe Dry Weight, W_P =	15.68 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 =	1,008 psi	HDB/2		
Pressure Rating, $PR_{(80F)}$ =	252 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 =	152.00 ft	
Ballast Water El., H_W =	152.00 ft	
Lowest Invert El., El_m =	105.40 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 =	0.53 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

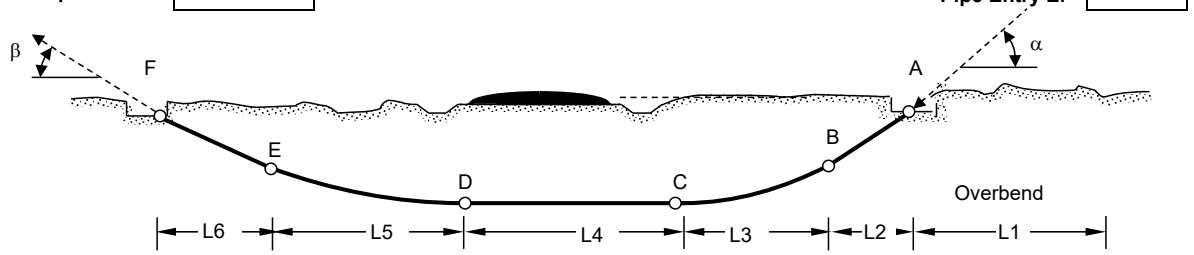
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.68 Lb/LF	38.67 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.48 Lb/LF	-10.49 Lb/LF

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 158.50 ft

Pipe Entry El = 157.30 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	2,154 lb	118 psi	OK	2,154 lb	118 psi	OK	OK	OK
B	3,118 lb	87 psi	OK	3,119 lb	87 psi	OK	OK	OK
C	4,542 lb	156 psi	OK	3,789 lb	135 psi	OK	OK	OK
D	6,189 lb	173 psi	OK	5,436 lb	152 psi	OK	OK	OK
E	9,198 lb	286 psi	OK	7,002 lb	224 psi	OK	OK	OK
F	12,568 lb	351 psi	OK	8,626 lb	241 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert $P_{PA} = P_A F_R$ = 98.05 psi

Ballasted	OK
No Ballast	OK

Maximum tensile stress during pullback = $\sigma_t = (F_T/\pi t_m(D_{OD}-t_m))+E_T D_{OD}/2R$ 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 =	0.916573236	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.152442694	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	351 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B invert =	5.05	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U invert =	25.24	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. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 90 Circuit #2
Route 396 & Stream Bank

Revision 1

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #2

Route 396 & Stream Bank

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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	HDPE	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification		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^/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 =	0.63	Based on PPI PE Handbook 2nd ED Chapter 5	
Hydrostatic Design Stress, HDS =	1008 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 =	1,120 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%	2%	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
Buoyant Unballasted Fluid 2, B_{B2} =			-34.74 lb/ft
Ballasted on ground, B_G =			38.67 lb/ft
Buoyant Ballasted in Fluid 1, BB_{B1} =			-10.49 lb/ft
Buoyant Ballasted in Fluid 2, B_{BB2} =			-11.75 lb/ft

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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

W_P-W_{D1}

W_P-W_{D2}

W_P+W_B

BG-W_{D1}

BG-W_{D2}

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HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5B) - CSX: Selkirk Railyard Bypass
Schenectady County, NY
HDD 90 Circuit #2
Route 396 & Stream Bank

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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 =	280 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 =	252 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	504 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	378 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: 53.10 ft
Ballast depth to invert, H_B: 51.90 ft
Drill Fluid depth to invert, H_{DF}: 51.90 ft

Pipe Invert Internal Pressure, P_I		Pipe Invert External Pressure, P_E	
Air Ballast, P_A	0.00 psi	Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	28.36 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	22.68 psi	Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	29.08 psi
		Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	22.68 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 = $(P_A+P_a)-P_{DF1}$	78.62 psi	4.56 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	77.89 psi	3.83 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.30 psi	27.24 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.58 psi	26.52 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 = $(P_A+P_a)-P_W$	84.29 psi	10.23 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. 5B) - CSX: Selkirk Railyard Bypass

Schenectady County, NY

HDD 90 Circuit #2

Route 396 & Stream Bank

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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	**AFE PULL STRENTH, SPS =**	**16,064 lb**	
Temperature factor, f_{temp} =	1	Ultimate Pull Strength, UPS =	40,160 lb	
Temp Corr Tensile Yield, $Ty*f_{temp}$ =	1,120 psi			
Safe Allowable Stress, SAS =	448 psi	SAS = $Ty*f_{temp}*DF$	Suggested SSAS =	1,150 psi
Safe Pull Strength, SPS Pipe =	16,064 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 =	448 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 =	0.91657		
r = σ_i/2*(SSAS) =	0.15244	Example from Table T5, σ_i =	351 psi
P_{CRR} =	245.1 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	122.6 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	116.89 psi	Pull Back Condition - C	OK as >0
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	116.16 psi	Pull Back Condition - C	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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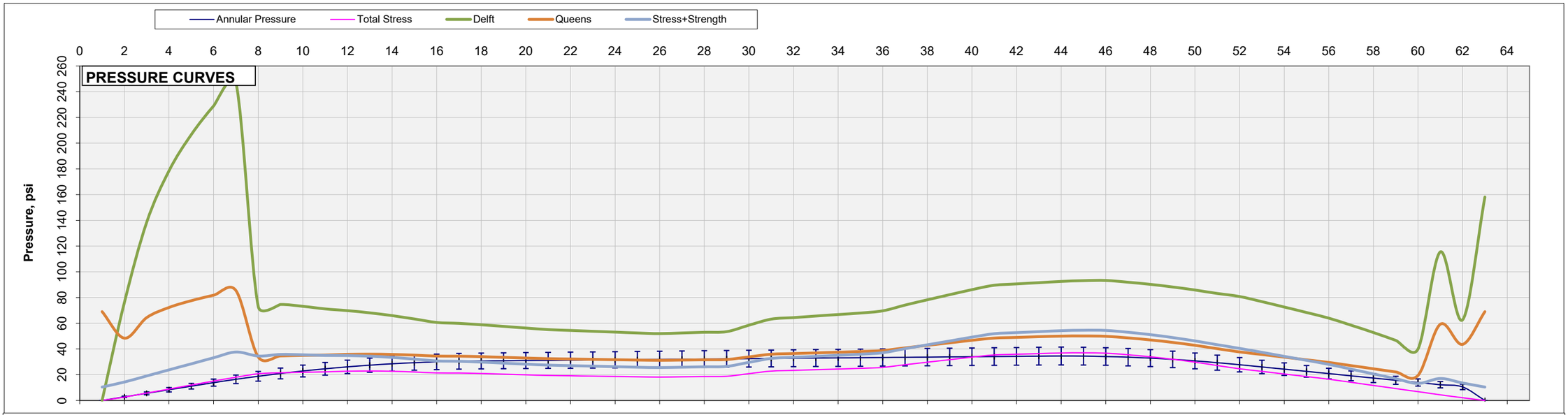
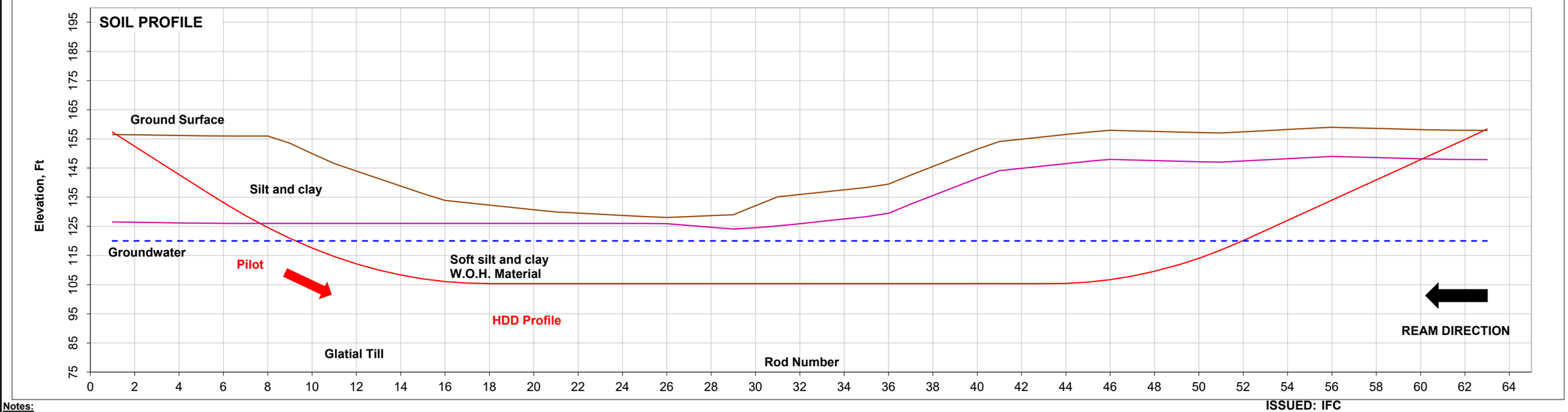


Entry - West



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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

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

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Schenectady County, NY

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 90 Circuit #2
Route 396 & Stream Bank

Revision 1

FIGURE 1