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 5a
Rotterdam to Fuera Bush, NY

Dear Mr. Neff:

Brierley Associates Underground Engineers, PLLC (Brierley) is pleased to provide this HDD Design Summary Report for Segment 5a 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

6323 Fly Road Ste. 4, East Syracuse, NY 13057
www.BrierleyAssociates.com

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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 5a which extends from Rotterdam to Fuera Bush. Package 5a includes a total of 23 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
71	50005+00	50024+14	1,905	Railroads (2), culvert
72	50042+78	50048+32	554	Mariaville Road/Route 7 (elevated)
73	50065+00	50070+26	522	Route 159/Duansburg Rd.
73A,74	50100+15	50120+10	1,991	NYS Throughway (I-90)
75	50145+80	50153+85	798	Route 158/Guildalard Rd
75A.A	50168+45	50175+45	700	Stream, wetland
75A	50210+60	50233+02	2,241	Stream, wetland
75B	50290+65	50297+92	729	Stream, wetland
76,76A	50306+80	50327+60	2,075	Railroad, Route 20, Pond
77	50332+50	50346+30	1,380	Railroad
78	50382+60	50402+20	1,958	Route 146
79A	50409+75	50422+20	1,238	Railroad, Black Creek

80	50442+95	50461+75	1,877	Railroad, Black Creek
80A	50551+25	50571+85	2,060	Wetland
81	50578+50	50588+85	1,029	Norfolk Southern Railroad
82,83	5060-+05	50615+75	1,574	Vly Creek, Maple Ave.
83A	50673+90	50681+02	702	Stream, Culvert
84	50687+00	50697+95	1,086	New Scotland Rd/Route 85, Streams
84A	50728+75	50739+05	1,028	Route 308/New Scotland Road, Stream
84B	50777+55	50787+93	1,032	Game Farm Road, Stream
85	50808+00	50823+55	1,555	Route 443, Stream
87	50830+60	50842+60	1,215	Railroad
87A.A	50890+60	50897+02	650	Culvert

*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.

Available geotechnical data used to develop the HDD designs are contained in Appendix A. A calculation package for each HDD crossing is included in Appendix B.

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. Package 5a is approximately 17 miles in plan length. Project location maps showing the locations of the HDD crossings associated with Package 5a are presented in Figures 1 and 2.

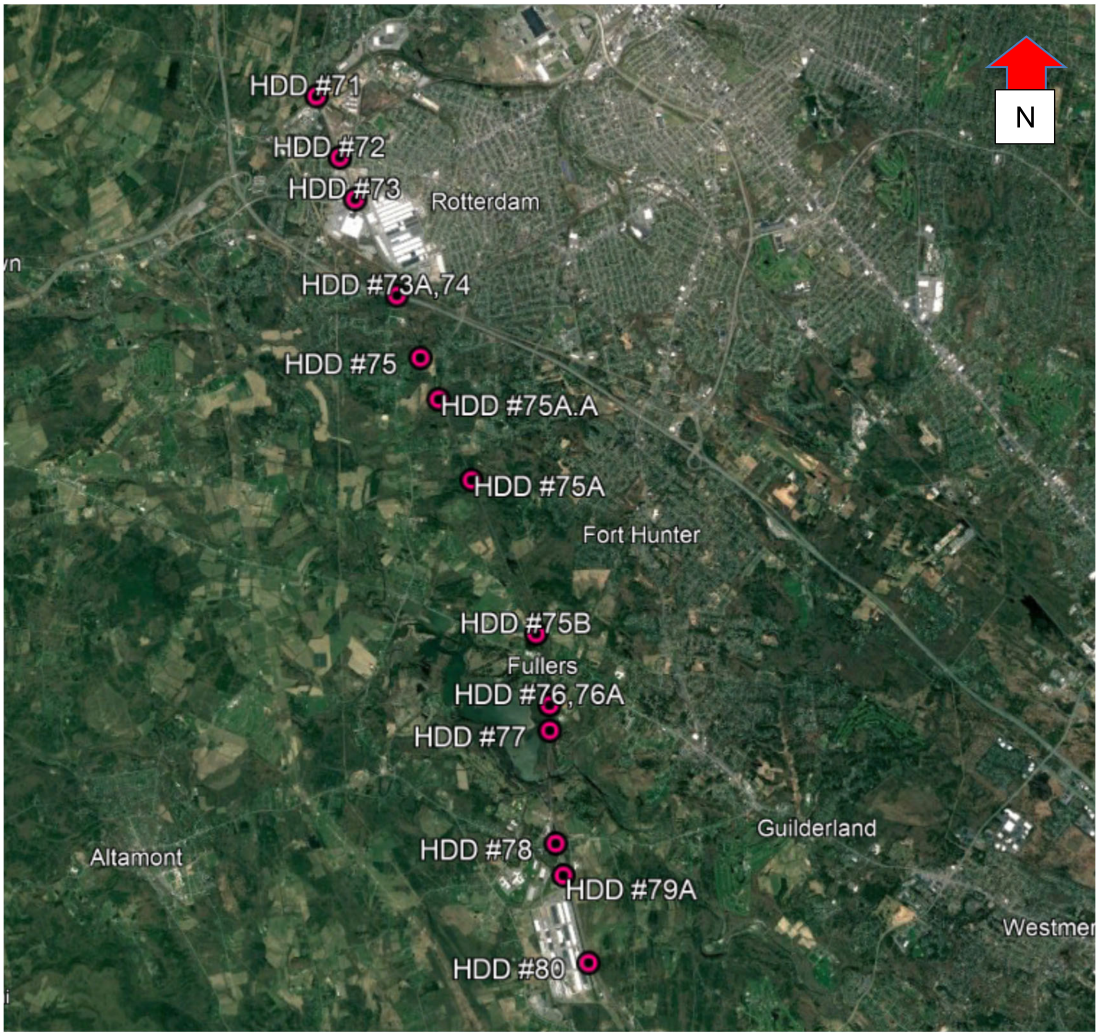

Figure 1 – Crossing Location Plan, HDD #71 through HDD #80. Photo from www.googleearth.com. Not to scale.

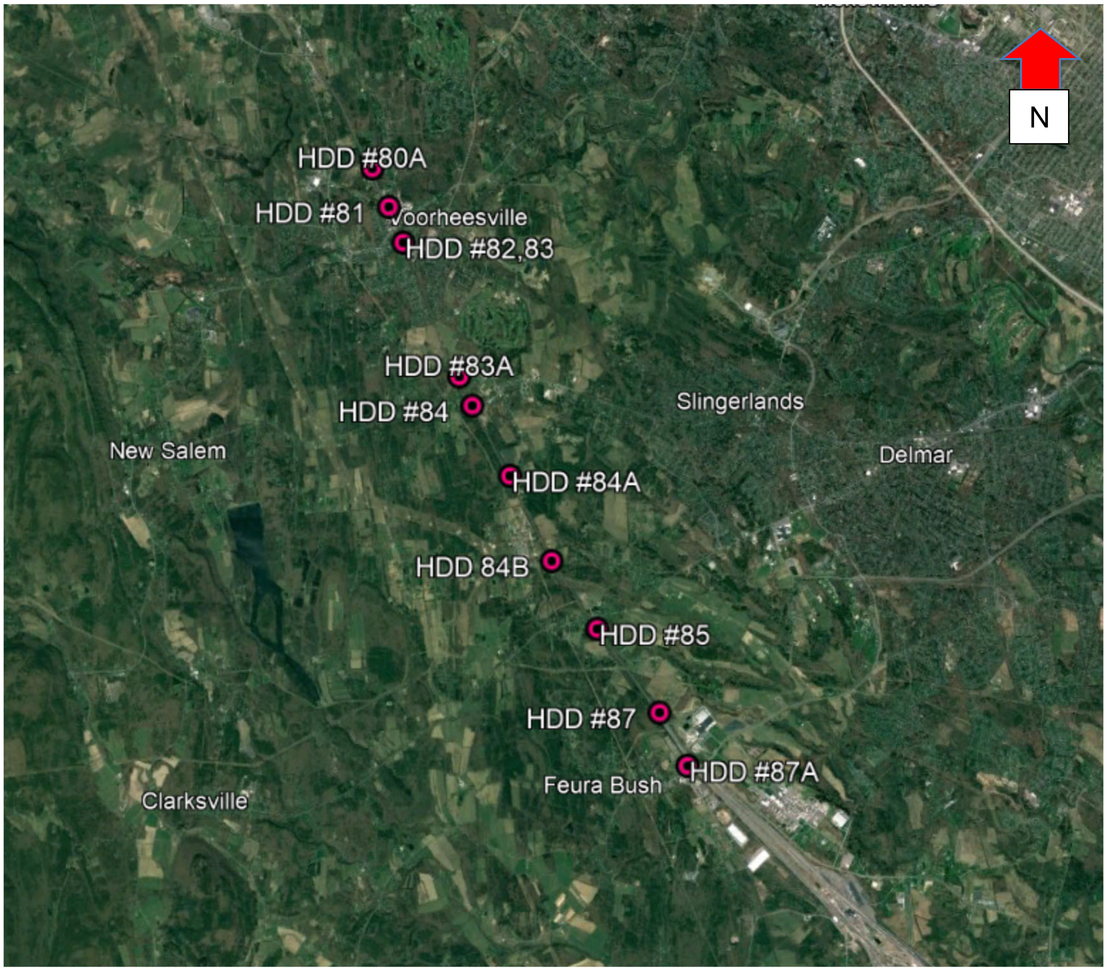

Figure 2 – Crossing Location Plan, HDD #80A through HDD #87A. Photo from www.googleearth.com*. Not to scale.*

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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 wetlands, 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 above and underground obstructions, and to the adjacent water bodies and wetlands to the extent possible.

4.0 Surface Conditions

A brief description of the surface conditions at each HDD crossing follows. As noted, two parallel to subparallel HDD installations are involved in each case.

HDD #71

The HDD #71 alignments pass below Phillips Rd, two active rails operated by CSX, which are oriented approximately northwest-southeast, and a third, depressed rail operated by the Delaware & Hudson Railway Company (DHRC), which is oriented northeast-southwest. The DHRC rail passes below the CSX rails by means of box tunnel. In addition, HDD #71 passes below the Poentic Kill (stream), which is contained within a 15-ft box culvert, and Burdeck Street. The surrounding area is characterized by farmland and mixed industrial/commercial use.

The HDD entry (north) is located in Princetown Road; the HDD exit (south) is located in a wooded area to the southwest of the CSX rails. Surface grades in the crossing vicinity are variable and generally range from about El. 327 to El. 349. The CSX rails are located on an elevated embankment to the north, and are at-grade to the south. The surface grade of the DHRC rails is at about El. 320.

HDD #72

The HDD #72 alignments pass below Mariaville Road which is oriented approximately east-west, 50-ft wide, and located on an elevated embankment. Mariaville Road passes over two (2) active CSX rails to the immediate east by means of a concrete deck bridge. The western bridge abutment and roadway retaining walls are located to the immediate east and above the HDD alignments.

The HDD entry (northwest) is located in a landscaped area adjacent to and existing residential structure. The HDD exit (southeast) is located in a paved parking area behind the Schenectady County Dept. of Engineering and Public Works (single-story building). The CSX rails are located approximately at-grade to the east-northeast, and are oriented northwest-southeast. Portions of the HDD #72 alignments are located within the CSX right-of-way.

The surface grades in the site vicinity are relatively flat and range from about El. 346 to El. 348. The surface of Mariaville Road is at about El. 374.

HDD #73:

The HDD #73 alignments pass below Route 159/Duanesburg Road which is oriented approximately northeast-southwest, 50-ft wide, and located on an elevated, sloped embankment. Utility poles are located within the southeast side of the embankment. Route 159/Duanesburg Road passes over two (2) active CSX rails to the immediate east by means of a concrete deck bridge. The western bridge abutment is located to the immediate east of the HDD alignments.

The HDD entry (northwest) is located in a paved parking area behind a single-story commercial building. The HDD exit (southeast) is located in a paved parking area behind the Golub Corporation Facility (single-story commercial building). The CSX rails are located approximately at-grade to the east-northeast, and are oriented northwest-southeast. Portions of the HDD #73 alignments are located within the CSX right-of-way.

The surface grades in the site vicinity are relatively flat fat and range from about El. 333 to El. 336. The surface of Route 159/Duanesburg Road is at about El. 370.

HDD #73A,74

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

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

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

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

HDD #75:

The HDD #75 alignments pass below Route 158/Guilderland Ave which is oriented approximately northeast-southwest, 35-ft wide, and located on an elevated, sloped embankment. Utility poles are located within the southeast side of the embankment. Route 158/Guilderland Road passes over two (2) active CSX rails to the immediate east by means of a concrete deck bridge. The western bridge abutment is located to the immediate east of the HDD alignments.

The HDD #75 entry (northwest) and exit (southeast) are located in wooded areas adjacent to Route 158/Guilderland Road. The CSX rails are located approximately at-grade to the east-northeast, and are oriented northwest-southeast. The HDD #75 alignments are located within the CSX right-of-way.

The surface grades in the site vicinity generally slope downward to the south, from about El. 317 to El. 313. The surface of Route 158/Guilderland Ave is at about El. 343.

HDD #75A.A

HDD #75A.A passes below a small stream and adjacent wetland located to the southwest of two (2) active CSX rails. The CSX rails are oriented northwest-southeast and rest on an elevated embankment, about 10 to 12 feet higher than adjacent grades. The surrounding area is covered by small trees and brush. The stream is oriented approximately northeast-southwest, and flows beneath the CSX rails by means of a 30-in RCP culvert. The HDD #75A.A alignments are located within the CSX right-of-way.

The HDD #75A.A entry is located to the southeast; the exit to the northwest. The surface grades along the HDD alignment slope downward gently to the southeast, from about El. 304 to El. 299.

HDD #75A

The HDD #75A alignments pass below two small streams to the southwest of two (2) active CSX rails, which are oriented northwest-southeast. The surrounding area is wooded. The streams are oriented approximately east-west, and flow beneath the CSX rails by means of a 42-in steel culvert (northwest) and twin 12-in RCP culverts (southeast). The HDD #75A alignments are located within the CSX right-of-way.

The HDD #75A entry is located to the northwest; the exit to the southwest. The surface grades along the HDD alignments are variable, ranging from about El. 301 to El. 316.

HDD #75B

The HDD #75B alignments pass below a small stream and adjacent wetlands to the southwest of two (2) active CSX rails, which are oriented northwest-southeast. The surrounding area is wooded, and farmland and a solar farm are located to the northwest. The stream is oriented approximately northeast-southwest, and flows beneath the CSX rails by means of a 24-in steel culvert. The HDD #75B alignments are located within the CSX right-of-way.

The HDD #75B entry is located to the southwest; the exit to the northwest. The surface grades along the HDD alignments are variable, ranging from about El. 276 to El. 294.

HDD #76,76A

The HDD #76,76A alignments begin behind an 84 Lumber facility (HDD entry, El. 290), to the southwest of a railroad operated by CSX (single rail), and passes below Route 20, which is depressed (sunken road, El. 275) at this location. An interlocking concrete block retaining wall is located on the northeast side of Route 20. The aforementioned CSX rail is oriented northwest-southeast and passes over Route 20 to the northeast of the crossing. A second CSX rail is oriented northeast-southwest and passes over the first rail by means of a separate girder bridge. The HDD #76,76A alignments curve around both bridge structures, then passes below the second CSX rail (below an elevated embankment, El. 317), below a small pond and exits in a wooded area to the south (between the first and second rails). Portions of HDD #76,76A are located within the CSX right-of-way.

HDD #77

HDD #77 is located to the immediate south of HDD #76,#76A, with an HDD exit (El. 287) located between two separate CSX rails (east and west), which are oriented approximately north-south. The HDD alignment passes below and then parallels the western CSX rail, which rests on an elevated embankment at about El. 312. Both the HDD entry (El 280) and exit (El. 290) are heavily wooded. The HDD #77 alignments are located within the CSX right-of-way.

HDD #78

The HDD #78 alignments are located to the west and parallel to twin CSX rails, which are oriented northwest-southeast and at-grade with the surrounding area. In this vicinity, HDD#77 crossed below a abutment for a concrete deck bridge carrying Route 146 over the CSX rails. At this location Route 146 also passes over a single paved offramp, which is oriented north-south.

To the north of Route 146, the HDD #78 also passes below a pond, which is surrounded by small trees. Facilities operated by the Guilderland Highway Department are located to the east of this area.

We understand that an existing natural gas line owned by Northeast Utilities has been installed by HDD across (perpendicular) the proposed HDD #78 alignments, to the south of the Route 146 deck bridge. The location and depth of this installation was not available at the time of this report. Overhead utility poles are also present in this area.

Existing surface grades in this area are relatively flat, and range from about El. 318 to El. 321. The surface of Route 146 at the overpass is at about El. 347. The HDD entry is located to the south; the exit to the north. The HDD #78 alignments are located within the CSX right-of-way.

HDD #79B

The HDD #79B alignments pass below a CSX siding, and Black Creek. The HDD entry is located to the north, in a paved parking area, to the west of the primary CSX rail alignment, which is oriented northwest-southeast and at grade with the surrounding area. A siding connects to the primary CSX alignment, and is oriented approximately northeast-southwest. At this location Black Creek parallels the primary CSX alignment and flows beneath the siding within a concrete culvert. A series of industrial park buildings are located to south-southwest of the siding, on the west side of Black Creek. The HDD #79A alignments terminate between these buildings.

Site grades adjacent to Black Creek are relatively flat, and range from about El. 319 to El. 321. The banks of the creek are relatively steep and covered by small trees and brush, and the channel is approximately 35-ft wide. The bottom elevation of the creek has not been established, but estimated to be at about El. 310 to El. 312. The HDD #79B entry area is located in a small depression, with a surface grade of about El. 317. A paved parking area is located to the west, and a small building to the south. Portions of the HDD#79B alignments are located within the CSX right-of-way.

HDD #80

HDD #80 is located to the immediate south of HDD #79B, and passes back below Black Creek. At this location Black Creek is oriented northwest-southeast, approximately 35-ft wide, and parallels the primary CSX alignment to the east-northeast (two rails and a siding). A paved parking area and industrial buildings are located to the west, accessed by Northeastern Industrial Park Road.

The HDD #80 exit is located in the paved parking area to the west of Black Creek. Site grades in this area are relatively flat, and range from about El. 319 to El. 320. The banks of the creek are steep and covered by small trees and brush, and the channel is approximately 35-ft wide. The bottom elevation of the creek has not been established, but estimated to be at about El. 312 to El. 313.

In the vicinity of the HDD #80 crossing the CSX rails are elevated relative to the adjacent area, at about El. 327 to El. 330. The HDD #80 entry located in a wooded area to the southeast, between the primary CSX rails and an adjacent siding. Surface grades in this area range from about El. 323 to El. 326. Portions of the HDD #80 alignments are located within the CSX right-of-way.

HDD #80A

The HDD #80A alignments are located immediately adjacent and parallel to the primary CSX rail alignment (2 rails) and passes below a large wetland, and a series of small ponds. The HDD exit area is located in an open field to the northwest; the entry in a wooded area between Foundry Street and the CSX rails.

Surface grades in this are slope downward to the wetland/ponds which have a surface elevation of about El. 315 to El. 325. The HDD entry area has a surface grade of about El. 326, whereas the exit has a surface grade of about El. 336. The adjacent CSX rails slope gently to the northwest adjacent to the HDD #80A alignment from about El. 329 to El. 334. The rails pass through the wetland by means of an elevated embankment. Water flows below the rails by means of a 10’x8’ box culvert.

HDD #81

The HDD #81 alignments pass below the CSX rails (2 rails) at the intersection of Foundry, Main and Grove Street. The rails are oriented northwest-southeast. Foundry and Grove are oriented roughly northwest-southwest; Main northeast-southwest.

The HDD #81 entry is located in a wooded area between the CSX rails (northeast) and Foundry Street (southwest). Small residential structures are located to the west. The surface grades in this area range from about El. 310 to El. 312 and are lower than the adjacent CSX rails, which are located in an elevated embankment, with a surface grade of about El. 330. The HDD #81 exit is located to the southeast in a grassy area between Grove Street and the CSX rails.

In the vicinity of the intersection, the railroad surface is generally at-grade with the surrounding area, ranging from about El. 331 to El. 332. The intersection is also occupied by a series of railroad signal devices and overhead utility poles. We understand that a portion of the railroad easement in the vicinity of the intersection is located within Norfolk Southern Railroad (NSRR) jurisdiction.

HDD #82,83

HDD #82,83 is located to the northeast of and parallels the CSX rails (2 rails, oriented northeast-southwest), and passes below Vly Creek. The rails pass over the creek by means of a small deck bridge. At this location the creek is approximately 30 to 40 feet wide, with banks covered by small trees.

The HDD #82,83 entry is located in a wooded area to the north, where surface grades are at about El. 320. The adjacent CSX rails are located on an elevated embankment, with a surface grade of about El. 334.

Surface grades rise steeply to the south of Vly Creek, where the surround area is predominantly residential. The HDD #82,83 alignment passes below Maple road, and to the immediate southwest of two existing single-story commercial buildings located in the Vorheesville Shopping Center and exits in a paved area to the southeast, where surface grades are at about El. 341 to El. 343. In this area the adjacent CSX rails are lower (depressed) with surface grades at about El. 335 to El. 336.

HDD #83A

HDD #83A is located to the northeast of and parallels the CSX rails (2 rails, oriented northeast-southwest), and passes beneath a 60” culvert, small stream (5 to 8 feet wide) and adjacent wetland. The HDD entry is located to the southwest; the exit to the northeast. The CSX rails in this vicinity are located on an elevated embankment, with surface grades ranging from about El. 301 to El. 305. The site grades along the HDD alignments increase from southeast to northwest from about El. 286 to El. 295.

The area around the stream is covered by brush and trees. The areas to the northwest and southeast are characterized by residential landscaped lawns. Portions of the HDD #83A alignments are located within the CSX right-of-way.

HDD #84

HDD #84 is located to the northeast of and parallels the CSX rails (2 rails, oriented northeast-southwest), and passes beneath two (2) separate, small streams, and Route 85/New Scotland Road, which is depressed at this location, and oriented east-west. The CSX rails pass over Route 85/New Scotland Road by means of a steel bridge with concrete wingwalls.

The HDD entry area is located on the northwest end of the alignment, in an open field with surface grades of about El. 287. The CSX rails in this vicinity are located on an elevated embankment, with surface grades ranging from about El. 299 to El. 301. Residential structures and trees are present along the HDD alignments to the northwest of Route 85/New Scotland Road.

To the southeast of Route 85/New Scotland Road the HDD #84 alignment passes between the CSX rails and timber framed storage structures associated with a lumber yard. The plan distance between the lumber yard structures and the closest CSX rail is about 40-ft.

The HDD exit is located within an unpaved portion of the lumber yard, to the southeast. Site grades in this area range from about El. 285 to El. 290. The adjacent CSX rails are located on an elevated embankment, with a surface grade of about El. 294 to El. 295. The HDD #84 alignments are located within the CSX right-of-way.

HDD #84A

HDD #84A is located to the northeast of and parallels the CSX rails (2 rails, oriented northeast-southwest), and passes beneath Route 308/New Scotland Road, which is at-grade with the railroad at this location and a small stream to the south-southeast. The stream passes below the CSX rails by means of a 12’x3.5’ box culvert.

The HDD entry is located in a wooded area to the northeast. The surface grades in this vicinity slope upward toward the southeast from about El. 270 to El 280. The surface grade of the adjacent CSX rails are at about El. 283. The area to the east-northeast consists of open fields.

The surface grade at the intersection of the CSX rails and Route 308/New Scotland Road is at about El. 280 to El. 282. The intersection is also occupied by a series of railroad signal devices and overhead utility poles.

Unpaved driveways, residential structures and an agricultural facility are located to the southeast of the intersection. The agricultural facility includes numerous timber-framed structures and unpaved clearings, with fill and timber stockpiles. The HDD exit is located in a partially cleared area with surface grades ranging from about El. 277 to El. 280. The adjacent CSX rails are slightly elevated, with a surface grade of about El. 281 to El. 282. Portions of the HDD #84A alignments are located within the CSX right-of-way.

HDD #84B

The HDD #84B alignments are located to the northeast of and parallels the CSX rails (2 rails, oriented northeast-southwest), and passes beneath Game Farm Road, which is at-grade and intersects with the railroad at this location and is oriented approximately east-west. HDD #84B also passes below a small stream to the southeast, which flows below the CSX rails by means of a 72” RCP culvert.

The HDD entry is located in a wooded area to the northeast. The surface grades in this vicinity are relatively flat and range from about El. 254 to El 255. The adjacent CSX rails rest on an elevated earthen embankment with a surface grade of about El. 260 to El. 262. The area to the east-northeast consists of farmland and fields.

The surface grade at the intersection of the CSX rails and Game Farm Road is at about El. 258 to El. 261. The intersection is also occupied by a series of railroad signal devices and overhead utility poles.

The area to the southeast of the Game Farm Road is wooded, and slopes downward at moderate grades (to the southeast and east-northeast) toward the stream, where the surface grade is at about El. 225.

The HDD exit area is currently located within a National Grid utility easement to the southeast, which is occupied by numerous utility poles and overhead power lines, and is oriented northwest-southeast. The utility easement is approximately 415-ft wide (as cleared) and characterized by small brush. Surface grades in this area slope downward gently toward the east, from about El. 251 to El. 249. The adjacent CSX rails rest on an elevated earthen embankment, with a surface grade of about El. 256. The HDD #84B alignments are located within the CSX right-of-way.

HDD #85

The HDD #85 alignments are located to the northeast of and generally parallels the CSX rails (2 rails, oriented northeast-southwest, with a parallel siding to the southeast), and passes beneath Route 443, which is depressed at this location. The CSX rails pass over Route 443 by means of a steel bridge with concrete wingwalls. Overhead utility poles are located on both sides of Route 443. The area to the north and south of Route 443 is wooded. The HDD #85 alignments are located within the CSX right-of-way.

HDD #85 also passes below two small streams to the southeast of Route 443, which flow below the CSX rails through an 18” CMP culvert (north, invert elevation of El. 216.5) and a 72” RCP culvert (south, invert elevation of El. 211.4). Moderate to steep wooded slopes border both streams.

The HDD entry is located in a wooded area on the southeast end of the alignment. Surface grades in this area range from about El. 245 to El. 250. The adjacent CSX rails are topographically lower, at about El. 238.

The HDD exit is located in an open field to the north of Route 443, to the east of the CSX rails. The surface grades in the vicinity of the HDD entry range from about El. 238 to El. 240. The adjacent rails rest on an elevated earthen embankment, with a surface elevation of about El. 246 to El. 247.

HDD #87

HDD #87 is oriented approximately northwest-southeast, and passes below active CSX rails (2 rails, also oriented northeast-southwest, and a parallel siding to the southeast). The railroad is slightly elevated at this location, at about El 235 to El. 237. The HDD alignment also passes below a culvert, having an invert of about El. 214.5, which allows a stream to flow below the rails.

The HDD #87 entry area is located to the northeast of the rails. This area is heavily wooded, and slopes upward to the north, from about El. 235 to El. 250. Waldermater Road is located to the east-northeast.

The HDD #87 exit area is located to the southwest of the rails. This area is heavily wooded. Site survey was not available for this area at the time of this report.

HDD #87A

HDD #87A is oriented approximately northwest-southeast, and passes below an existing 3’x4’ culvert, which allows water to flow beneath the adjacent, parallel CSX rails to the east. The culvert invert is at about El. 203.4. The railroad is approximately at-grade with the surrounding area, with a surface elevation of about El. 209 to El. 211. Small commercial facilities and laydown are located to the west.

The HDD #87A entry area is located to the southeast at about El. 207, and the HDD exit to the northwest at about El. 212.

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. It should be noted that some below (and above) grade utilities may result in electronic inference that could adversely impact HDD steering tool accuracy.

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. A brief summary of the geologic units anticipated at each crossing location is provided below.

HDD #71:

Fill soils overlying Deltaic Deposits (glacial lake deposits) consisting of interbedded sand and silt with gravel (loose to medium dense). The deltaic deposits overlie Glacial Till consisting of a heterogenous mixture of very dense silty sand with gravel, sandy silt, sand and gravel and clayey silt. Although not encountered on the test borings, cobbles and boulders are expected within the Glacial Till.

HDD #72:

In the vicinity of HDD #72, Fill soils are expected to overlie glacial lake deposits consisting of poorly graded sand with lesser amounts of silt (very loose to medium dense).

HDD #73:

In the vicinity of HDD #73, Fill soils are expected to overlie deltaic deposits (glacial lake deposits) consisting of poorly graded sand and silty sand (very loose to medium dense).

HDD #73A,74:

In the vicinity of HDD #73A,74, Fill soils are expected to overlie deltaic deposits (glacial lake deposits) consisting of interbedded silt with trace to some clay, poorly graded sand and silty sand (very loose to dense) and clay (medium stiff to stiff).

HDD #75:

In the vicinity of HDD #75, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (medium stiff to stiff).

HDD #75A.A:

In the vicinity of HDD #75A.A, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (very soft), with lesser amounts of loose silty sand and sand.

HDD #75A:

In the vicinity of HDD #75A, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (very soft), with lesser amounts of loose silty sand and sand.

HDD #75B:

In the vicinity of HDD #75B, Fill soils are expected to overlie glacial lake deposits consisting of very soft varved silt and clay (very soft to medium stiff), with lesser amounts of loose silty sand and sand. The density/consistency of the silt and clay appears to decrease with depth.

HDD #76,76A:

In the vicinity of HDD #76,76A, Fill soils are expected to overlie 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.

HDD #77:

In the vicinity of HDD #77, Fill soils are expected to overlie 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.

HDD #78:

In the vicinity of HDD #78, fill soils are expected to overlie Glacial Till consisting of dense to very dense silty sand, sandy stilt and sandy clay with cobbles and boulders. The glacial till overlies bedrock (shale of the Schenectady Formation) at a depth of about 30-ft below grade on the north end of the HDD alignment. Although not encountered by the test borings, the Schenectady Formation may also contain sandstone and siltstone.

HDD #79A:

In the vicinity of HDD #79A, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (very soft to medium stiff), with lesser amounts of fine sand. The lake deposits overlie Glacial Till consisting of very dense silty sand with gravel, with occasional cobbles and boulders

HDD #80:

In the vicinity of HDD #80, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (very soft to medium stiff), with lesser amounts of fine sand. The glacial lake deposits overlie Glacial Till consisting of medium dense to very dense silty sand with gravel, with occasional cobbles and boulders.

HDD #80A:

On the north side of the HDD alignment, Fill soils are expected to overlie medium dense to very dense sand and gravel with some silt and clay (possible glacial till).

On the south end of the HDD alignment, Fill soils overlie a layer of medium dense sand (outwash), which overlies a layer of medium stiff to stiff silt with clay (possible lacustrine deposits), which appear to overlie Glacial Till consisting of very denes silt with gravel, with occasional cobbles and boulders.

HDD #81:

In the vicinity of HDD #81, Fill soils are expected to overlie loose to medium dense sand and gravel with varying amounts of silt and cobbles (probable glacial outwash).

HDD #82,83:

In the vicinity of HDD #82,83, Fill soils are expected to overlie loose to dense sand and gravel with varying amounts of silt and cobbles (probable glacial outwash). Layers of loose to medium dense fine sandy silt are also present (possible lacustrine deposits).

HDD #83A:

In the vicinity of HDD #83A, Fill soils are expected to overlie loose to medium dense sand and gravel (probable glacial outwash), which overlies Glacial Till consisting of very dense silty sand with occasional cobbles and boulders. Bedrock (shale of the Schenectady Formation) was encountered at depths of about 50 feet by the test borings taken along the HDD alignment. Although not encountered by the test borings, the Schenectady Formation may also contain sandstone and siltstone.

HDD #84:

In the vicinity of HDD #84, Fill soils are expected to overlie loose to medium dense to dense sand with varying amounts of silt (probable glacial outwash). The lower portion of these materials (very dense) may represent glacial till. Bedrock (shale of the Schenectady Formation) was encountered at depths of about 20 to 23 feet by the test borings taken along the HDD alignment. Although not encountered by the test borings, the Schenectady Formation may also contain sandstone and siltstone.

HDD #84A:

In the vicinity of HDD #84A, Fill soils are expected to overlie dense to very dense silty sand with gravel with occasional cobbles and boulders (glacial till). Bedrock (shale of the Schenectady Formation) was encountered at depths of about 20 to 23 feet by the test borings taken along the HDD alignment. Although not encountered by the test borings, the Schenectady Formation may also contain sandstone and siltstone.

HDD #84B:

In the vicinity of HDD #84B, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (soft to hard), with lesser amounts of fine sand. The lake deposits overlie probable Glacial Till of very dense silty sand, which may contain occasional cobbles and boulders. Bedrock (shale of the Schenectady Formation) was encountered at depths of about 20 to 23 feet by the test borings taken along the HDD alignment. Although not encountered by the test borings, the Schenectady Formation may also contain sandstone and siltstone.

HDD #85:

In the vicinity of HDD #85, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (very soft to stiff), with lesser amounts of fine sand. The lake deposits decrease in consistency, becoming very soft with depth, and overlie Glacial Till consisting of medium dense to very dense silty sand with gravel, with occasional cobbles and boulders.

HDD #87

In the vicinity of HDD #87, Fill soils are expected to overlie glacial lake deposits consisting of silt and clay (very soft to medium stiff), with lesser amounts of fine sand. The lake deposits decrease in consistency with depth, becoming very soft. On the northern end of the HDD alignment the glacial lake deposits overlie Bedrock (shale of the Schenectady Formation). On the southern end of the alignment the glacial lake deposits overlie Glacial Till consisting of very dense silty sand with gravel, with occasional cobbles and boulders, which in turn overlies bedrock. Bedrock was encountered at depths of about 51 to 54 feet by the test borings taken along the HDD alignment.

HDD #87A

In the vicinity of HDD #87A, Fill soils are expected to overlie glacial lake deposits consisting of clay (very soft to medium stiff), with lesser amounts of fine sand. The lake deposits decrease in consistency with depth, becoming very soft. On the northern end of the HDD alignment the glacial lake deposits overlie Bedrock (shale of the Schenectady Formation) at a depth of 36 feet, which was sampled with split spoons.

7.0 HDD Process

HDD involves drilling a small diameter (6 to 9in) "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 330507.13 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 5A 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 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.

The anticipated range of downhole drill fluid pressures (combined static and dynamic) for each HDD crossing in Package 5a 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.

- **Kirsch Model**: This method was developed by the Shell Oil Company for oil field drilling and is based in rock mechanics and Hooks Law. This method is generally considered appropriate for bedrock, including fractured bedrock.

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 200 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 the following:

- The 5a package alignment can be broken into 4 main groupings to describe the performance of the soil in profile, as the geology changes moving north to south:
    - Sand and silt with some gravel and good strength characteristics (HDDs #71-73)
    - Fine grained lacustrine soils, primarily silt and clays (HDDs #73-77), with weaker strength characteristics
    - Glacial till and bedrock (HDD #78-84)
    - Fine grained lacustrine soils, primarily silt and clays very weak, soft clays and silt, including Weight of Hammer (W.O.H.) material (HDD #85-87)
- For HDDs #72 #73, #75, there is an apparent risk of IR is near the HDD entry and exit. This is common, and related to limited confining capabilities of the surround geologic formations due to limited depth. At these locations it may be prudent to control the drill fluid through use of temporary steel conductor casings.
- HDDs #73A-74, #75A and #75A.A have critical areas with Factors of Safety below 2.0.
- For HDD #77 there is an apparent risk of IR is near the HDD entry and exit due to high groundwater and loose fill materials. This is common, and related to limited confining capabilities of the surround geologic formations due to limited depth. At these locations it may be prudent to control the drill fluid through use of temporary steel conductor casings.
- For HDD #84 there is an apparent risk of IR is near the HDD exit as the pilot passes out of the groundwater and into soft silt, sand and fill. This is common, and related to limited confining capabilities of the surround geologic formations. At these locations it may be prudent to control the drill fluid through use of temporary steel conductor casings.
- For HDD #85 there is an apparent risk of IR for the entire length of the crossing. This is due to the poor strength characteristics (W.O.H. material) of the formation and equates to limited confining capabilities of the surround geologic formations. At this location careful consideration during drilling operations needs to be given to maintain borehole stability.

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 5a HDD installations is 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 unit encountered along the package 5a 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.
- Glaciofluvial Deposits: Coarse outwash deposits (sand and gravel) may present hole stability issues, particularly where poorly graded clean gravel is present. Drill fluid additives may be require to improve gel strength, filter cake development, minimize groundwater inflow, and to maintain carrying capacity.
- Glacial Till Deposits: Dense to very dense Glacial Till deposits were encountered at numerous HDD crossing locations. Where present, these materials will likely require a mud motor for pilot hole advance, involving increased pump rates and annular pressures. In addition, the Glacial Till should be expected to contain cobbles and boulders which could become obstructions and adversely impact HDD steering and alignment control.
- Bedrock: Sedimentary bedrock may be encountered at some of the HDD locations. This will require a mud motor and rock reaming tools. While the majority of the bedrock encountered by the test borings consisted of shale, sandstone may also be present, which may result in decreased penetration rates and tool wear through abrasion.

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.

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

APPENDIX B

HDD Calculations Per Crossing

BRIERLEY
ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 71 Circuit #1**
CSX RR and Burdeck St.

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: 7-Mar-2023

Revision	REV	DESCRIPTION	BY
10/23/2023	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT
Exit Station	**19+05.63**	FT

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

	East	North	Elevation
Entry	626294.8113	1444782.3789	347.50 ft
Horizontal Curve PI	625897.5674	1446019.0700	
Exit	625889.2815	1446630.1298	339.50 ft
Depth to Mudline	8.00 ft	Clearance Depth =	49.50 ft
Measured Plan Length at ties =	1905.6253 ft		
Coordinate Length =	1905.6253 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	312.00 ft
Mudline Elev.*	339.50 ft
Lowest centerline Elev.	290.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	626294.8113	1444782.3789	9+99.47	625989.1479	1445733.9636	E 342.19220 N	999.47		
Curve	9+99.47	625989.1479	1445733.9636	15+93.96	625893.5072	1446318.4963	E 359.22312 N	594.49	2000.00	17.031 deg.
Tangent	15+93.96	625893.5072	1446318.4963	19+05.63	625889.2815	1446630.1298	E 359.22312 N	311.66		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	999.47	Input Radius, ft.	2000.00	Plan Length, ft.	311.66	
Entry Azimuth, deg.^{5}	N 342.19220 E	Curve, deg	17.031 deg.	Exit Azimuth, deg.^{5}	N 359.22312 E	
Entry Azimuth, rad.^{5}	5.97238	Curve, rad	0.29725	Exit Azimuth, rad.^{5}	6.26963	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	592.31	Easting	625889.2815	**Check**
PCH Easting	625989.1479	Arc Length, ft.	594.49	Northing	1446630.1298	**Delta**
PCH Northing	1445733.9636	Chord Azimuth, deg	350.7077			**0.0000**
		PI Easting =	625897.5674			**0.0000**
		PI Northing =	1446019.0700			**OK CALC**
		PTH Easting =	625893.5072			
		PTH Northing =	1446318.4963			**Exit Station** **19+05.63**
Cum Plan Length	999.47	Cum Plan Length	1593.96	Cum Plan Length	1905.625311	**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	339.50 ft	306.71 ft	-10.00 deg	-10.00 deg	0.00 deg	188.82 ft	0.00 ft
Entry Curve	306.71 ft	290.00 ft	-10.00 deg	0.00 deg	10.00 deg	191.99 ft	1100.00 ft
Bottom Tangent	290.00 ft	290.00 ft	0.00 deg	0.00 deg	0.00 deg	1150.70 ft	0.00 ft
Exit Curve	290.00 ft	325.65 ft	0.00 deg	14.00 deg	14.00 deg	293.22 ft	1200.00 ft
Exit Tangent	325.65 ft	347.50 ft	14.00 deg	14.00 deg	0.00 deg	90.34 ft	0.00 ft
					Total Check =	**1915.06 ft**	**OK**

Compound Curve Assessment

Start	**Vert. Plan**	**Horiz. Plan**	
Entry	377.96	999.47	No, Horiz > Entry V(Tan+Curve)
Exit	376.97	311.66	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	1200.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	339.50	
		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	87.655 ft	Plan Length	290.306 ft	Plan Length	1,150.69795 ft	Plan Length	191.013 ft	Plan Length	185.953 ft	1,905.625 ft
Rod Length	90.339 ft	Arc Rod Length	293.215 ft	Rod Length	1,150.69795 ft	Arc Rod Length	191.986 ft	Rod Length	188.822 ft	1,915.060 ft
Vertical Depth	-21.855 ft	Curve Δ Vert Depth	-35.645 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	16.711 ft	Vertical Depth	32.789 ft	-8.000 ft
		Lowest Elevation	290.000 ft			Lowest Elevation	290.000 ft	CK Total Cum Depth	-8.000 ft	
Start Elevation	347.500 ft	Start Elevation	325.645 ft	Start Elevation	290.000 ft	Start Elevation	290.000 ft	Start Elevation	306.711 ft	
End Elevation	325.645 ft	End Elevation	290.000 ft	End Elevation	290.000 ft	End Elevation	306.711 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*	1905.625311	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+87.66	Start Station	3+77.96	Start Station	15+28.66	Start Station	17+19.67	**Stationing Check**
PVC Station	0+87.66	PTV Station	3+77.96	PCV Station	15+28.66	PTV Station	17+19.67	Exit Station	19+05.625	**OK STATIONING**
Cum Plan Length	87.66	Cum Plan Length	377.96	Cum Plan Length	1528.66 ft	Cum Plan Length	1719.67	Cum Plan Length	1905.63	**Plan Length Check**
Cum Rod Length	90.34	Cum Rod Length	383.55	Cum Rod Length	1534.25 ft	Cum Rod Length	1726.24	Cum Rod Length	1915.06	**OK CALCULATION** / **Elevation Change Check**
Cum Depth	-21.85	Cum Depth	-57.50	Cum Depth	-57.50 ft	Cum Depth	-40.7885	Cum Depth	-8.00	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-8.00 ft**
Minimum Design Elevation =	**290.00 ft**
Invert Depth below exit =	**49.50 ft**
Invert Depth below entry =	**57.50 ft**
Path Length =	**1,915.06 ft**
Plan Length =	**1,905.63 ft**
Minimum Plan Length (No Tangent) =	**754.93 ft**
Entry Angle =	**-14.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**964 ft**

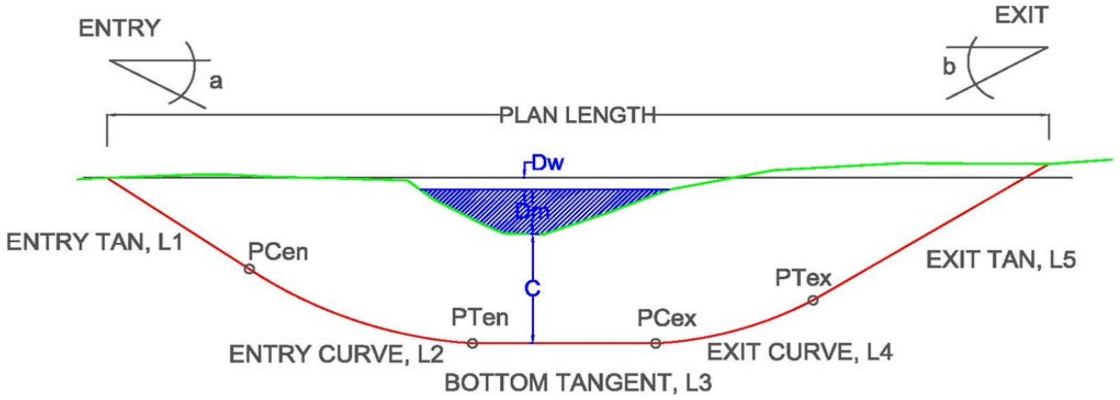
NOTES:

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:	**Issued for Construction (IFC)**

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"
Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 71 Circuit #1
CSX RR and Burdeck St.

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#71 CIR #1_APC_20220729.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	188.8 ft	α =	-10.0 °	-0.1745	
L3 =	192.0 ft				1,100.0 ft
L4 =	1150.7 ft	χ =	0.0 °	0.0000	
L5 =	293.2 ft				1,200.0 ft
L6 =	90.3 ft	β =	14.0 °	0.2443	
LT =	2015.1 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 =	339.50 ft		
Ballast Water El., H_W =	339.50 ft		
Lowest Invert El., El_m =	290.00 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 =	0.46 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

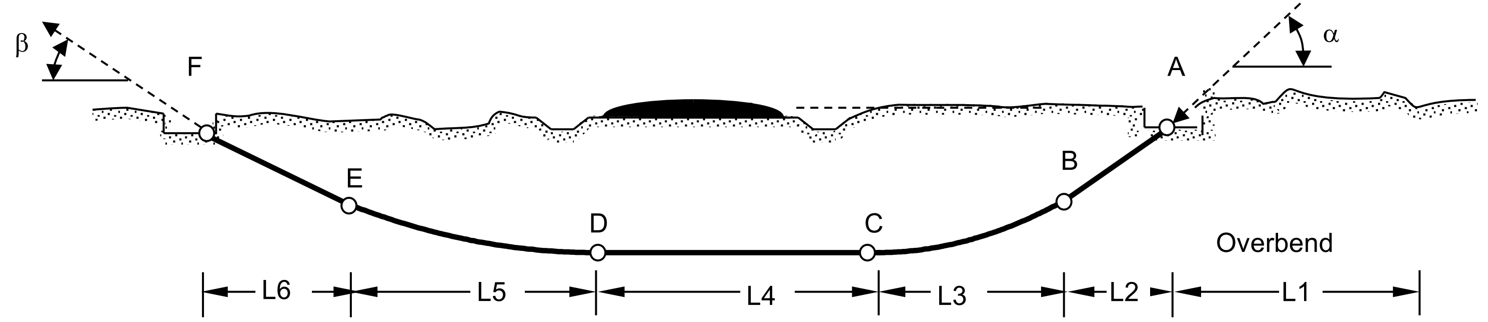
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 347.50 ft

Pipe Entry El = 339.50 ft



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	Ballast
	Calculated Pull Force							
A	3,560 lb	167 psi	OK	3,560 lb	167 psi	OK	OK	OK
B	5,177 lb	131 psi	OK	5,525 lb	139 psi	OK	OK	OK
C	6,806 lb	207 psi	OK	6,344 lb	195 psi	OK	OK	OK
D	12,010 lb	303 psi	OK	11,548 lb	291 psi	OK	OK	OK
E	18,447 lb	497 psi	OK	15,023 lb	411 psi	OK	OK	OK
F	19,834 lb	500 psi	OK	15,704 lb	396 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 93.58 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.874792164	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.217513577	r = $\sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	500 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	5.36	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	26.81	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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Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 71 Circuit #1
CSX RR and Burdeck St.

Revision 1

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TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 71 Circuit #1

CSX RR and Burdeck St.

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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 =	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 =	15.70	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

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

TABLE 4
HDPE PROPERTIES

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

HDD 71 Circuit #1

CSX RR and Burdeck St.

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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 =	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	57.50 ft	Ballast depth to invert, H_B	49.50 ft	Drill Fluid depth to invert, H_{DF}	49.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	21.64 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	27.06 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	27.75 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	21.64 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 = $(P_A+P_a)-P_{DF1}$	79.92 psi	5.86 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	79.23 psi	5.17 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.56 psi	27.50 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.87 psi	26.81 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 = $(P_A+P_a)-P_W$	85.33 psi	11.27 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.

HDPE PROPERTIES

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

HDD 71 Circuit #1

CSX RR and Burdeck St.

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

Source PPI PE Handbook Ch 12 Formula 17 SPS = π*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	**FE PULL STRENTH, SPS =**	**50,200 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	########	
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 =	0.87479		
r = σ_i/2*(SSAS) =	0.21751	Example from Table T5, σ_i =	500 psi
P_{CRR} =	234.0 psi		
FS =	2.0		
P_{ACRR} = P_{CRR}/FS =	117.0 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1}	111.57 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2}	110.87 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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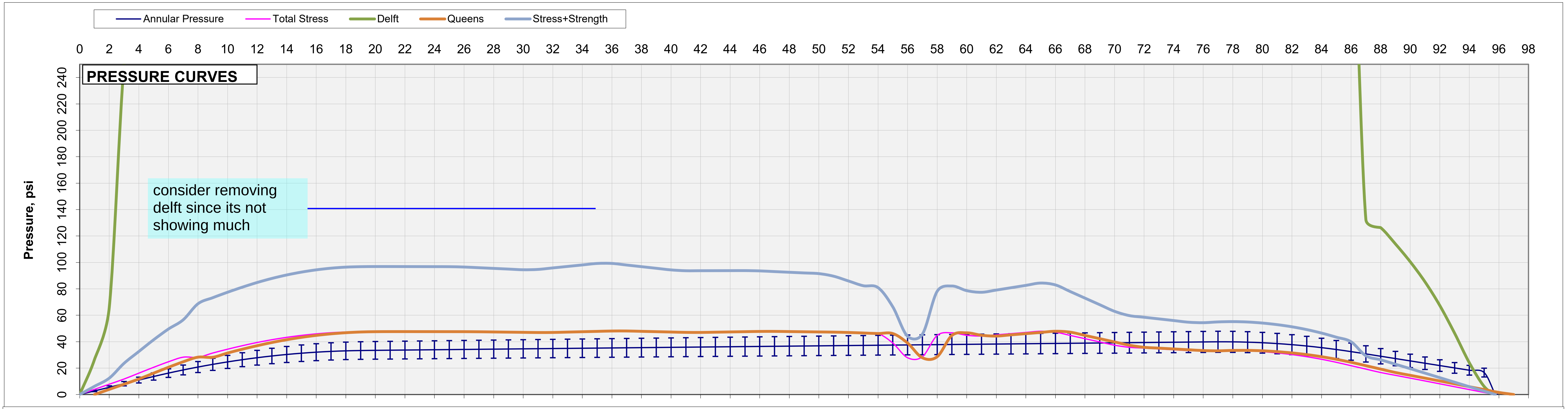

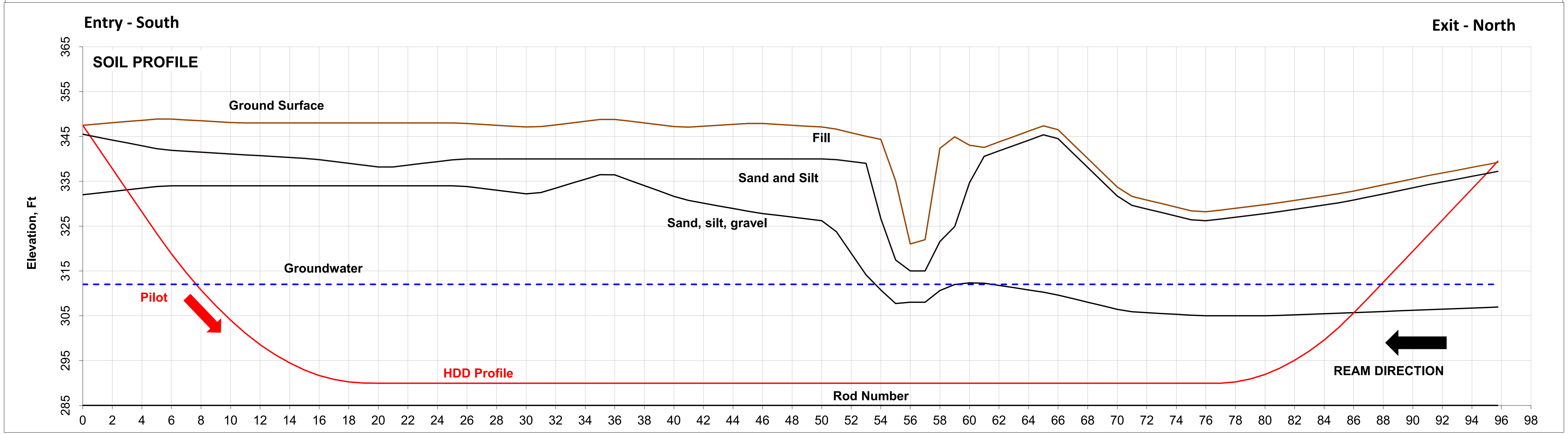

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Notes:
1. Geology is interpreted from project data
2. Rod length: 20 feet
3. The error bars are at 20% and represent Drill Fluid low and high density range.
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical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

Basis of annulur pressure calculations

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

Print Date ; 3/7/2023 14:05

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 71 Circuit #1
CSX RR and Burdeck St.

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

HDD 71 Circuit #2
CROSSING: **CSX RR and Burdeck St.**

Issued for Construction (IFC)
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Table 3	ANTICIPATED PULLING FORCE - SINGLE CONDUIT
Table 4	LONG TERM PLASTIC STRESS - 10-inch CONDUIT
Figure 1	APC AND FPC CURVES AND ASSUMED GEOLOGIC SECTION

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: 7-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2023	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	19+00.82	FT

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

	East	North	Elevation
Entry	626309.1078	1444786.9190	347.30 ft
Horizontal Curve PI	625919.6146	1446020.6673	
Exit	625904.2550	1446631.2335	339.10 ft
Depth to Mudline	8.20 ft	Clearance Depth =	49.50 ft
Measured Plan Length at ties =	1900.8157 ft		
Coordinate Length =	1900.8157 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	312.00 ft
Mudline Elev.*	339.10 ft
Lowest centerline Elev.	289.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	626309.1078	1444786.9190	10+11.27	626004.6628	1445751.2710	E 342.47914 N	1011.27		
Curve	10+11.27	626004.6628	1445751.2710	15+72.56	625912.5101	1446303.0802	E 358.55895 N	561.29	2000.00	16.080 deg.
Tangent	15+72.56	625912.5101	1446303.0802	19+00.82	625904.2550	1446631.2335	E 358.55895 N	328.26		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1011.27	Input Radius, ft.	2000.00	Plan Length, ft.	328.26	
Entry Azimuth, deg.^{5}	N 342.47914 E	Curve, deg	16.080 deg.	Exit Azimuth, deg.^{5}	N 358.55895 E	
Entry Azimuth, rad.^{5}	5.97739	Curve, rad	0.28065	Exit Azimuth, rad.^{5}	6.25803	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	559.45	Easting	625904.2550	**Check**
PCH Easting	626004.6628	Arc Length, ft.	561.29	Northing	1446631.2335	**Delta**
PCH Northing	1445751.2710	Chord Azimuth, deg	350.5190			**0.0000**
		PI Easting =	625919.6146			**0.0000**
		PI Northing =	1446020.6673			**OK CALC**
		PTH Easting =	625912.5101			
		PTH Northing =	1446303.0802			**Exit Station** **19+00.82**
Cum Plan Length	1011.27	Cum Plan Length	1572.56	Cum Plan Length	1900.815698	**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	339.10 ft	306.31 ft	-10.00 deg	-10.00 deg	0.00 deg	188.82 ft	0.00 ft
Entry Curve	306.31 ft	289.60 ft	-10.00 deg	0.00 deg	10.00 deg	191.99 ft	1100.00 ft
Bottom Tangent	289.60 ft	289.60 ft	0.00 deg	0.00 deg	0.00 deg	1145.09 ft	0.00 ft
Exit Curve	289.60 ft	325.25 ft	0.00 deg	14.00 deg	14.00 deg	293.22 ft	1200.00 ft
Exit Tangent	325.25 ft	347.30 ft	14.00 deg	14.00 deg	0.00 deg	91.17 ft	0.00 ft
					Total Check =	1910.27 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	378.76	1011.27	No, Horiz > Entry V(Tan+Curve)
Exit	376.97	328.26	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	1200.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	339.10	
		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	88.457 ft	Plan Length	290.306 ft	Plan Length	1,145.08618 ft	Plan Length	191.013 ft	Plan Length	185.953 ft	1,900.816 ft
Rod Length	91.165 ft	Arc Rod Length	293.215 ft	Rod Length	1,145.08618 ft	Arc Rod Length	191.986 ft	Rod Length	188.822 ft	1,910.275 ft
Vertical Depth	-22.055 ft	Curve Δ Vert Depth	-35.645 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	16.711 ft	Vertical Depth	32.789 ft	-8.200 ft
		Lowest Elevation	289.600 ft			Lowest Elevation	289.600 ft	CK Total Cum Depth	-8.200 ft	
Start Elevation	347.300 ft	Start Elevation	325.245 ft	Start Elevation	289.600 ft	Start Elevation	289.600 ft	Start Elevation	306.311 ft	
End Elevation	325.245 ft	End Elevation	289.600 ft	End Elevation	289.600 ft	End Elevation	306.311 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*	1900.815698	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+88.46	Start Station	3+78.76	Start Station	15+23.85	Start Station	17+14.86	**OK STATIONING**
PVC Station	0+88.46	PTV Station	3+78.76	PCV Station	15+23.85	PTV Station	17+14.86	Exit Station	19+00.816	**Plan Length Check**
Cum Plan Length	88.46	Cum Plan Length	378.76	Cum Plan Length	1523.85 ft	Cum Plan Length	1714.86	Cum Plan Length	1900.82	**OK CALCULATION**
Cum Rod Length	91.17	Cum Rod Length	384.38	Cum Rod Length	1529.47 ft	Cum Rod Length	1721.45	Cum Rod Length	1910.27	**Elevation Change Check**
Cum Depth	-22.05	Cum Depth	-57.70	Cum Depth	-57.70 ft	Cum Depth	-40.9885	Cum Depth	-8.20	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-8.20 ft**
Minimum Design Elevation =	**289.60 ft**
Invert Depth below exit =	**49.50 ft**
Invert Depth below entry =	**57.70 ft**
Path Length =	**1,910.27 ft**
Plan Length =	**1,900.82 ft**
Minimum Plan Length (No Tangent) =	**755.73 ft**
Entry Angle =	**-14.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**964 ft**

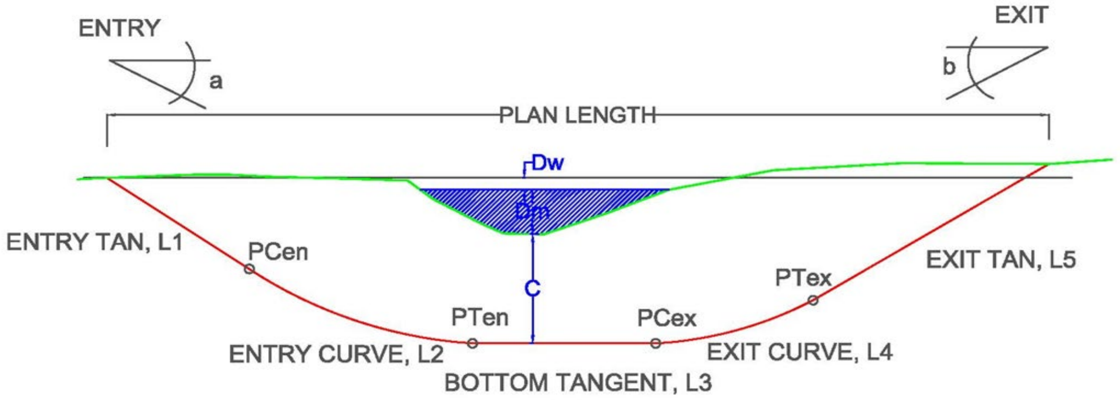
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 71 Circuit #2
CSX RR and Burdeck St.

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#71 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	188.8 ft	α =	-10.0 ˚	-0.1745	
L3 =	192.0 ft				1,100.0 ft
L4 =	1145.1 ft	χ =	0.0 ˚	0.0000	
L5 =	293.2 ft				1,200.0 ft
L6 =	91.2 ft	β =	14.0 ˚	0.2443	
LT =	2010.3 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} 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 = 339.10 ft

Ballast Water El., H_W = 339.10 ft

Lowest Invert El., El_m = 289.60 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 = 0.34 lb/ft Comparison Only @ 8psi

Calculated Buoyant Forces

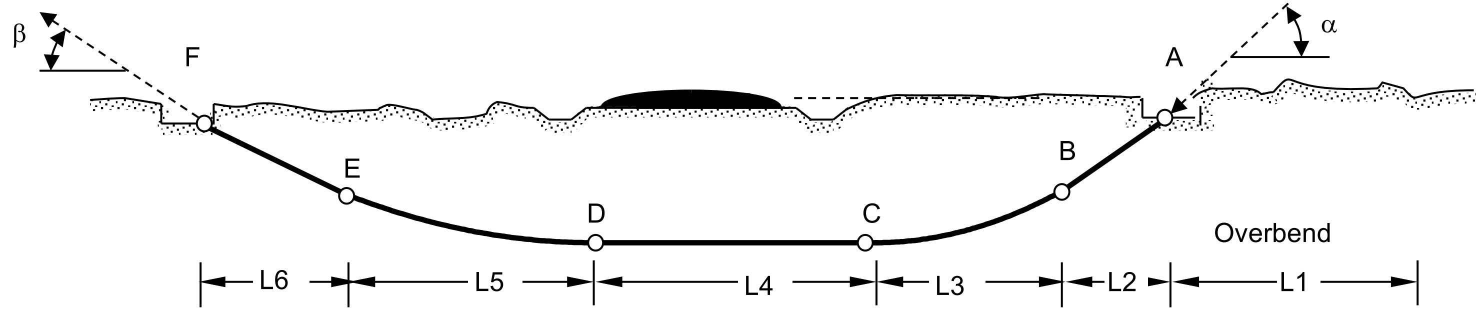
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 347.30 ft

Pipe Entry El = 339.10 ft



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
	Calculated Pull Force							
A	3,212 lb	148 psi	OK	3,212 lb	148 psi	OK	OK	OK
B	4,750 lb	133 psi	OK	5,065 lb	141 psi	OK	OK	OK
C	6,146 lb	198 psi	OK	5,728 lb	186 psi	OK	OK	OK
D	10,824 lb	302 psi	OK	10,407 lb	290 psi	OK	OK	OK
E	16,517 lb	485 psi	OK	13,422 lb	399 psi	OK	OK	OK
F	17,749 lb	495 psi	OK	14,016 lb	391 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 93.74 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.876272119 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.215286924 r = $\sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 495 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** = 5.36 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** = 26.81 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 71 Circuit #2
CSX RR and Burdeck St.

Revision 1

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 71 Circuit #2

CSX RR and Burdeck St.

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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 =	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 =	15.70	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

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

TABLE 4

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HDPE PROPERTIES

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

HDD 71 Circuit #2

CSX RR and Burdeck St.

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 =	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	57.70 ft	Ballast depth to invert, H_B	49.50 ft	Drill Fluid depth to invert, H_{DF}	49.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	21.64 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	27.06 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	27.75 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	21.64 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 = $(P_A+P_a)-P_{DF1}$	79.92 psi	5.86 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	79.23 psi	5.17 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.56 psi	27.50 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.87 psi	26.81 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 = $(P_A+P_a)-P_W$	85.33 psi	11.27 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 71 Circuit #2

CSX RR and Burdeck St.

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
FE PULL STRENTH, SPS = 50,200 lb
Temperature factor, f_{temp} = 1
ltimate Pull Strength, UPS = ########
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 = 0.87627
r = σ_i/2*(SSAS) = 0.21529
Example from Table T5, σ_i = 495 psi
P_{CRR} = 234.3 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 117.2 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 111.76 psi Pull Back Condition - C **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 111.07 psi Pull Back Condition - C **OK as >0**

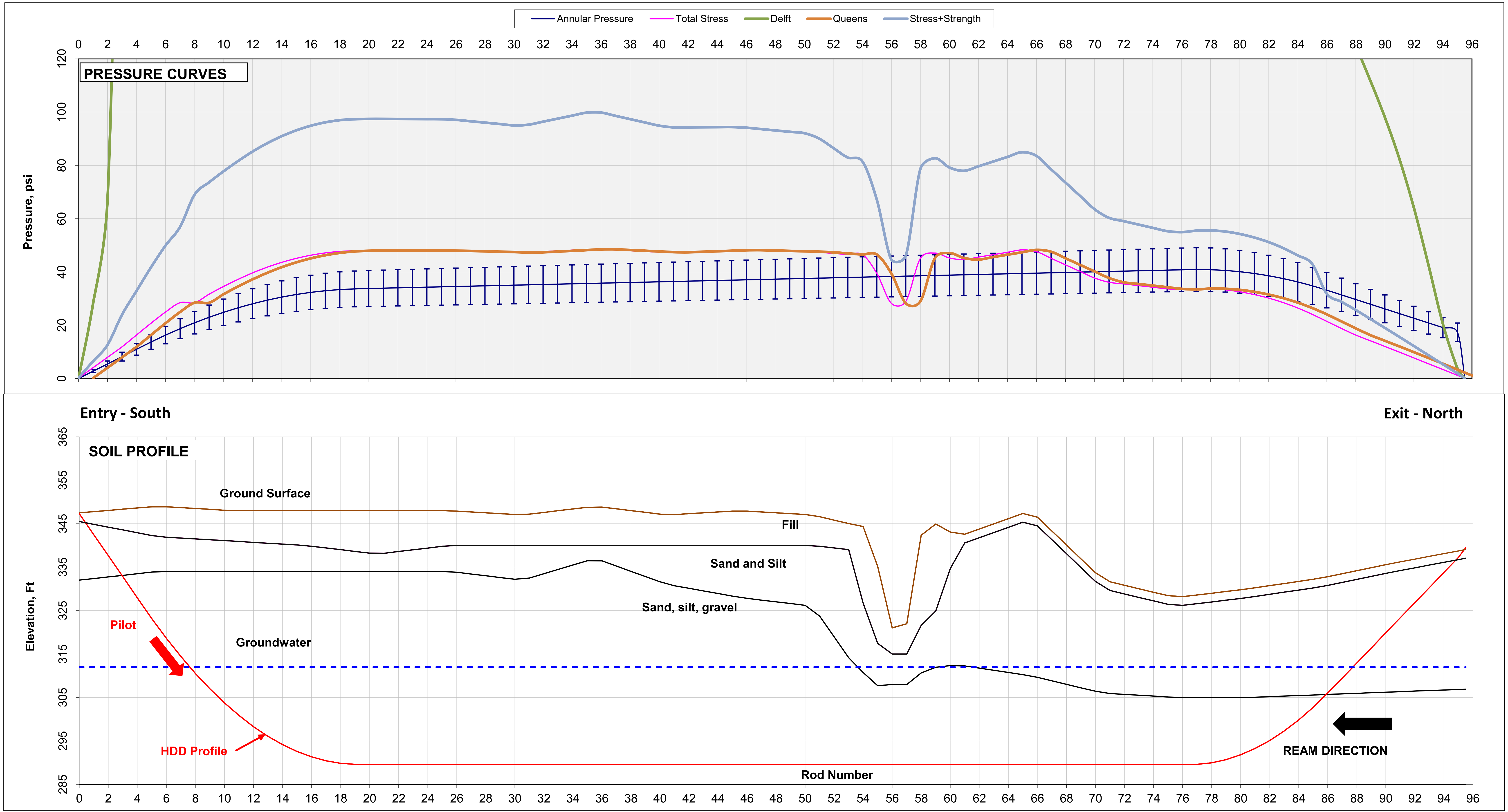
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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 annular pressure calculations

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

Print Date ; 3/7/2023 14:11

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 71 Circuit #2
CSX RR and Burdeck St.

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#71 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

HDD 72 Circuit #1
CROSSING: **Mariaville Rd**

Issued for Construction (IFC)
ISSUE:

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: 7-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	5+54.62	FT

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

	East	North	Elevation
Entry	626981.8714	1443056.6337	346.40 ft
Horizontal Curve PI	627089.1977	1442806.3041	
Exit	627200.4187	1442546.8903	346.30 ft
Depth to Mudline	0.10 ft	Clearance Depth =	27.80 ft

Measured Plan Length at ties = 554.6181 ft

Coordinate Length = 554.6181 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	330.70 ft
Mudline Elev.*	346.30 ft
Lowest centerline Elev.	318.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	626981.8714	1443056.6337	2+72.37	627089.1977	1442806.3041	E 156.79325 N	272.37		
Curve	2+72.37	627089.1977	1442806.3041	2+72.37	627089.1977	1442806.3041	E 156.79326 N	0.00	0.00	0.000 deg.
Tangent	2+72.37	627089.1977	1442806.3041	5+54.62	627200.4187	1442546.8903	E 156.79326 N	282.25		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	272.37	Input Radius, ft.	0.00	Plan Length, ft.	282.25	
Entry Azimuth, deg.^{5}	N 156.79325 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 156.79326 E	
Entry Azimuth, rad.^{5}	2.73656	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.73656	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	627200.4187	***Check***
PCH Easting	627089.1977	Arc Length, ft.	0.00	Northing	1442546.8903	***Delta***
PCH Northing	1442806.3041	Chord Azimuth, deg	156.7933			**0.0000**
		PI Easting =	627089.1977			**0.0000**
		PI Northing =	1442806.3041			**OK CALC**
		PTH Easting =	627089.1977			
		PTH Northing =	1442806.3041			**Exit Station**
						5+54.62
Cum Plan Length	272.37	Cum Plan Length	272.37	Cum Plan Length	554.6181174	**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**	**∆ Angle**	**Length**	**Radius**
Entry Tangent	346.30 ft	336.73 ft	-10.00 deg	-10.00 deg	0.00 deg	55.11 ft	0.00 ft
Entry Curve	336.73 ft	318.50 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	318.50 ft	318.50 ft	0.00 deg	0.00 deg	0.00 deg	55.61 ft	0.00 ft
Exit Curve	318.50 ft	340.35 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	340.35 ft	346.40 ft	12.00 deg	12.00 deg	0.00 deg	29.09 ft	0.00 ft
					Total Check =	**558.68 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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	346.30	
		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	28.452 ft	Plan Length	207.912 ft	Plan Length	55.60667 ft	Plan Length	208.378 ft	Plan Length	54.270 ft	554.618 ft
Rod Length	29.087 ft	Arc Rod Length	209.440 ft	Rod Length	55.60667 ft	Arc Rod Length	209.440 ft	Rod Length	55.107 ft	558.680 ft
Vertical Depth	-6.048 ft	Curve ∆ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	18.231 ft	Vertical Depth	9.569 ft	-0.100 ft
		Lowest Elevation	318.500 ft			Lowest Elevation	318.500 ft	CK Total Cum Depth	-0.100 ft	
Start Elevation	346.400 ft	Start Elevation	340.352 ft	Start Elevation	318.500 ft	Start Elevation	318.500 ft	Start Elevation	336.731 ft	
End Elevation	340.352 ft	End Elevation	318.500 ft	End Elevation	318.500 ft	End Elevation	336.731 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***	***554.6181174***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+28.45	Start Station	2+36.36	Start Station	2+91.97	Start Station	5+00.35	**OK STATIONING**
PVC Station	0+28.45	PTV Station	2+36.36	PCV Station	2+91.97	PTV Station	5+00.35	Exit Station	5+54.618	**Plan Length Check**
Cum Plan Length	28.45	Cum Plan Length	236.36	Cum Plan Length	291.97 ft	Cum Plan Length	500.35	Cum Plan Length	554.62	**OK CALCULATION**
Cum Rod Length	29.09	Cum Rod Length	238.53	Cum Rod Length	294.13 ft	Cum Rod Length	503.57	Cum Rod Length	558.68	**Elevation Change Check**
Cum Depth	-6.05	Cum Depth	-27.90	Cum Depth	-27.90 ft	Cum Depth	-9.6693	Cum Depth	-0.10	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-0.10 ft**
Minimum Design Elevation =	**318.50 ft**
Invert Depth below exit =	**27.80 ft**
Invert Depth below entry =	**27.90 ft**
Path Length =	**558.68 ft**
Plan Length =	**554.62 ft**
Minimum Plan Length (No Tangent) =	**499.01 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

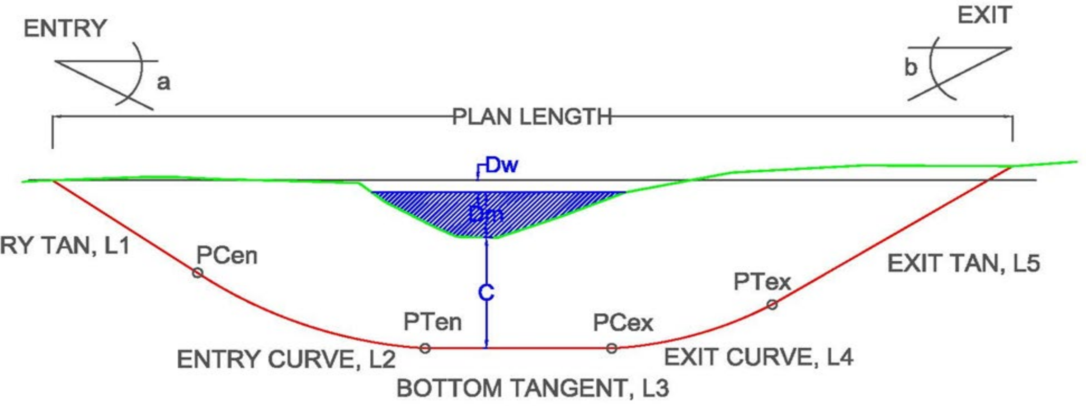
NOTES:

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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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 72 Circuit #1
Mariaville Rd

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#72 CIR #1_APC_20220729.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	55.1 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	55.6 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	29.1 ft	β =	12.0 °	0.2094	
LT =	658.7 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 =	346.30 ft	
Ballast Water El., H_W =	346.30 ft	
Lowest Invert El., El_m =	318.50 ft	

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.05611015	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.412 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	1.58 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

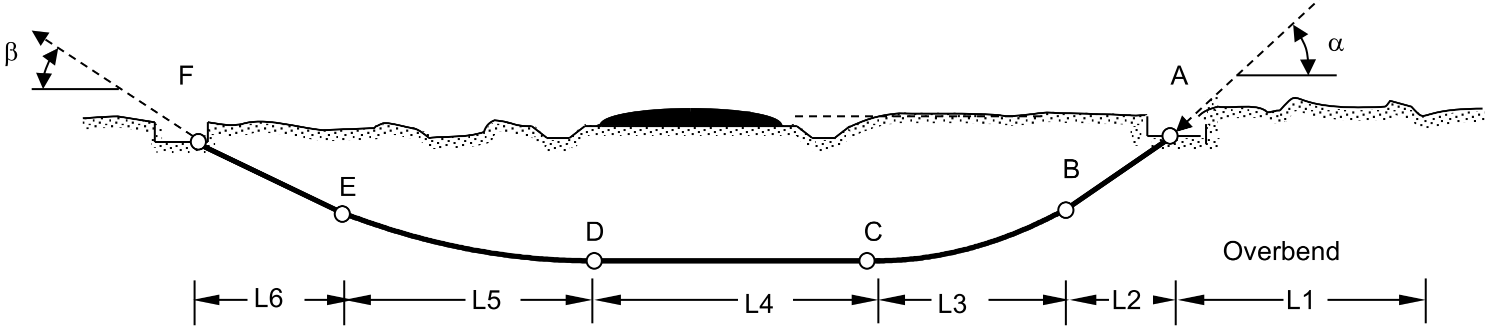
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	43.07 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.31 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 346.40 ft

Pipe Entry El = 346.30 ft



POINT	**Calculated Pull Force** 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	 Ballast
A	1,164 lb	107 psi	OK	1,164 lb	107 psi	OK	OK	OK
B	1,631 lb	41 psi	OK	1,734 lb	44 psi	OK	OK	OK
C	3,229 lb	114 psi	OK	2,426 lb	93 psi	OK	OK	OK
D	2,919 lb	74 psi	OK	2,116 lb	53 psi	OK	OK	OK
E	6,961 lb	214 psi	OK	4,111 lb	142 psi	OK	OK	OK
F	7,574 lb	191 psi	OK	4,391 lb	111 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 101.85 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.952111779	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.093122768	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	214 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	3.01	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	15.06	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"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 72 Circuit #1
Mariaville Rd

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#72 CIR #1_APC_20220729.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 72 Circuit #1
Mariaville Rd

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification	445574C	Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	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 =	2.826 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} =	0.044 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 =	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.38 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-0.83 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-0.97 lb/ft	BG-W_{D2}

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	2.72 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#72 CIR #1_APC_20220729.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDPE PROPERTIES

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

HDD 72 Circuit #1
Mariaville Rd

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^{o}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, ^{o}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	27.90 ft	Ballast depth to invert, H_B	27.80 ft	Drill Fluid depth to invert, H_{DF}	27.80 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	12.11 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	15.14 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	15.53 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	12.11 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 = $(P_A+P_a)-P_{DF1}$	91.84 psi	17.78 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.45 psi	17.39 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.95 psi	29.89 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.56 psi	29.50 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 = $(P_A+P_a)-P_W$	94.87 psi	20.81 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 **Pg 3 of 3**

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 72 Circuit #1
Mariaville Rd

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 5,321 lb **Useing SSAS = 4,371 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
$fr = ((5.57-(r+1.09)^2)^.5)-1.09$ = 0.95211
$r = \sigma_i/2*(SSAS)$ = 0.09312
P_{CRR} = 254.6 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 127.3 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 112.18 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 123.90 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft

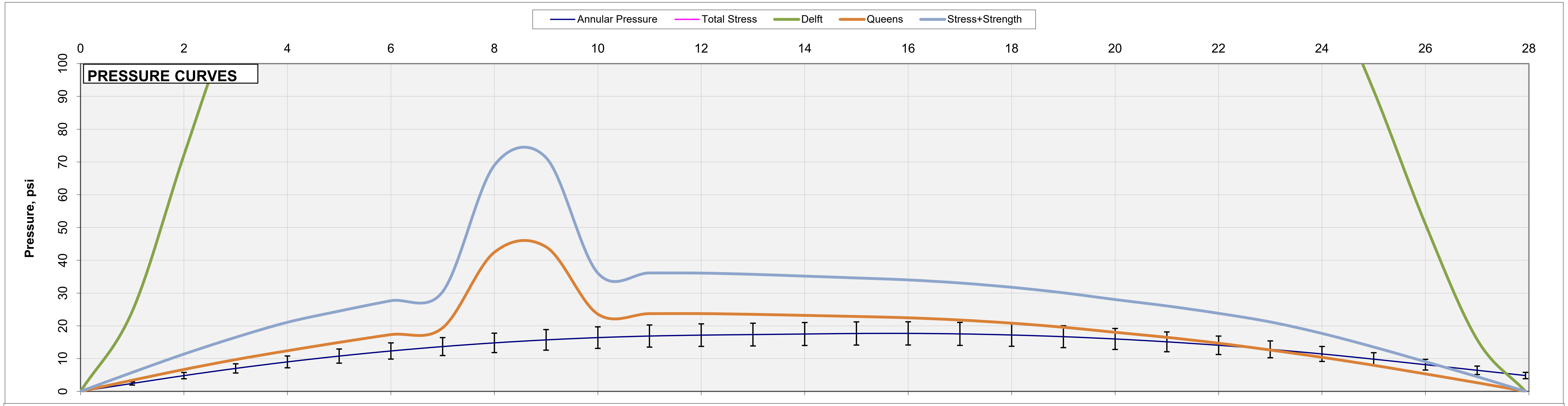
Example from Table T5, σ_i = 214 psi

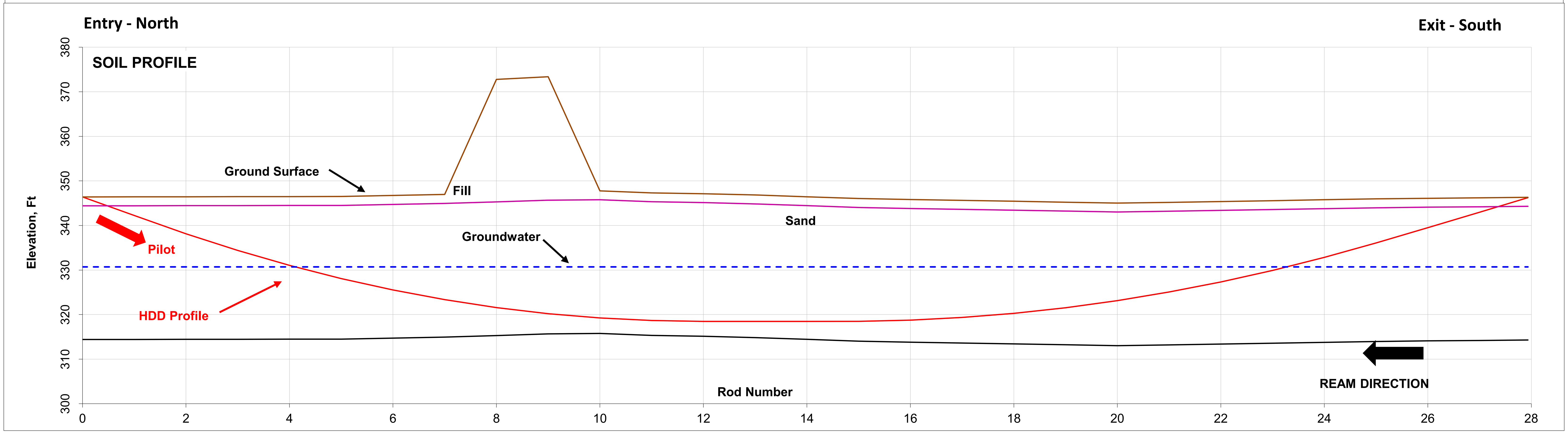
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND
FORMATION PRESSURE CURVES
HDD 72 Circuit #1
Mariaville Rd

Revision 1

FIGURE 1

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BRIERLEY ASSOCIATES
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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 72 Circuit #2**
Mariaville Rd

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: 7-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	5+54.62	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	626995.5067	1443062.5587	346.20 ft
Horizontal Curve PI	627104.7988	1442807.6951	
Exit	627214.0724	1442552.8234	348.30 ft
Depth to Mudline	0.00 ft	Clearance Depth =	27.70 ft
Measured Plan Length at ties =	554.6179 ft		
Coordinate Length =	554.6179 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	330.70 ft
Mudline Elev.*	346.20 ft
Lowest centerline Elev.	318.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	626995.5067	1443062.5587	2+77.31	627104.7988	1442807.6951	E 156.78910 N	277.31		
Curve	2+77.31	627104.7988	1442807.6951	2+77.31	627104.7988	1442807.6951	E 156.79327 N	0.00	0.00	0.004 deg.
Tangent	2+77.31	627104.7988	1442807.6951	5+54.62	627214.0724	1442552.8234	E 156.79327 N	277.31		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	277.31	Input Radius, ft.	0.00	Plan Length, ft.	277.31	
Entry Azimuth, deg.^{5}	N 156.78910 E	Curve, deg	0.004 deg.	Exit Azimuth, deg.^{5}	N 156.79327 E	
Entry Azimuth, rad.^{5}	2.73649	Curve, rad	0.00007	Exit Azimuth, rad.^{5}	2.73656	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	627214.0724	***Check***
PCH Easting	627104.7988	Arc Length, ft.	0.00	Northing	1442552.8234	***Delta***
PCH Northing	1442807.6951	Chord Azimuth, deg	156.7912			**0.0000**
		PI Easting =	627104.7988			**0.0000**
		PI Northing =	1442807.6951			**OK CALC**
		PTH Easting =	627104.7988			
		PTH Northing =	1442807.6951			**Exit Station**
						5+54.62
Cum Plan Length	277.31	Cum Plan Length	277.31	Cum Plan Length	554.6179241	**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	348.30 ft	336.73 ft	-10.00 deg	-10.00 deg	0.00 deg	66.62 ft	0.00 ft
Entry Curve	336.73 ft	318.50 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	318.50 ft	318.50 ft	0.00 deg	0.00 deg	0.00 deg	45.20 ft	0.00 ft
Exit Curve	318.50 ft	340.35 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	340.35 ft	346.20 ft	12.00 deg	12.00 deg	0.00 deg	28.13 ft	0.00 ft
					Total Check =	**558.83 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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	348.30	
		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	27.511 ft	Plan Length	207.912 ft	Plan Length	45.20484 ft	Plan Length	208.378 ft	Plan Length	65.613 ft	554.618 ft
Rod Length	28.125 ft	Arc Rod Length	209.440 ft	Rod Length	45.20484 ft	Arc Rod Length	209.440 ft	Rod Length	66.625 ft	558.834 ft
Vertical Depth	-5.848 ft	Curve Δ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	11.569 ft	2.100 ft
		Lowest Elevation	318.500 ft			Lowest Elevation	318.500 ft	CK Total Cum Depth	2.100 ft	
Start Elevation	346.200 ft	Start Elevation	340.352 ft	Start Elevation	318.500 ft	Start Elevation	318.500 ft	Start Elevation	336.731 ft	
End Elevation	340.352 ft	End Elevation	318.500 ft	End Elevation	318.500 ft	End Elevation	336.731 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***	***554.6179241***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+27.51	Start Station	2+35.42	Start Station	2+80.63	Start Station	4+89.01	**OK STATIONING**
PVC Station	0+27.51	PTV Station	2+35.42	PCV Station	2+80.63	PTV Station	4+89.01	Exit Station	5+54.618	**Plan Length Check**
Cum Plan Length	27.51	Cum Plan Length	235.42	Cum Plan Length	280.63 ft	Cum Plan Length	489.01	Cum Plan Length	554.62	**OK CALCULATION**
Cum Rod Length	28.13	Cum Rod Length	237.56	Cum Rod Length	282.77 ft	Cum Rod Length	492.21	Cum Rod Length	558.83	**Elevation Change Check**
Cum Depth	-5.85	Cum Depth	-27.70	Cum Depth	-27.70 ft	Cum Depth	-9.4693	Cum Depth	2.10	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**2.10 ft**
Minimum Design Elevation =	**318.50 ft**
Invert Depth below exit =	**29.80 ft**
Invert Depth below entry =	**27.70 ft**
Path Length =	**558.83 ft**
Plan Length =	**554.62 ft**
Minimum Plan Length (No Tangent) =	**509.41 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

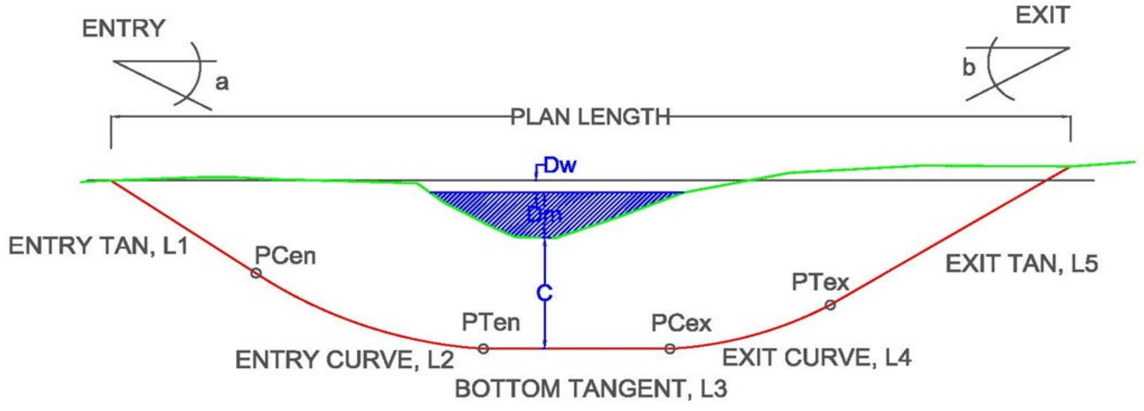
NOTES:

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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BRIERLEY ASSOCIATES
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"Creating Space Underground"

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 72 Circuit #2
Mariaville Rd

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#72 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	66.6 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	45.2 ft	χ =	0.0 ˚	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	28.1 ft	β =	12.0 ˚	0.2094	
LT =	658.8 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}	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 =	346.20 ft		
Ballast Water El., H_W =	346.20 ft		
Lowest Invert El., El_m =	318.50 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 =	1.17 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

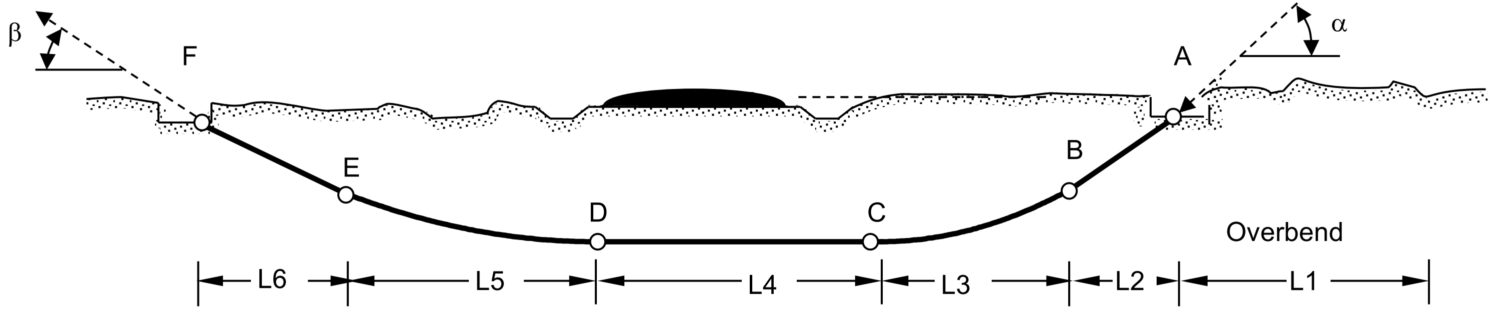
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 346.20 ft

Pipe Entry El = 348.30 ft



POINT	Calculated Pull Force						ASSESS	
	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	 Ballast
A	1,053 lb	88 psi	OK	1,053 lb	88 psi	OK	OK	OK
B	1,563 lb	44 psi	OK	1,654 lb	46 psi	OK	OK	OK
C	2,924 lb	106 psi	OK	2,205 lb	86 psi	OK	OK	OK
D	2,595 lb	72 psi	OK	1,876 lb	52 psi	OK	OK	OK
E	6,158 lb	201 psi	OK	3,609 lb	130 psi	OK	OK	OK
F	6,691 lb	187 psi	OK	3,848 lb	107 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 102.21 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.955441236	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.087357274	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	201 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	3.00	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	15.00	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
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 72 Circuit #2
Mariaville Rd

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#72 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 Pg 1 of 3

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

HDPE PROPERTIES

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

HDD 72 Circuit #2
Mariaville Rd

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification	445574C		Design resin with minimum PENT test of 10,000 hours
Standard Dimension	10		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	8.220 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	1.194 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	35.84514492		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
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} =	0.369 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 =	15.7	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 forces

Dry Weight Pipe on ground, W_P =	15.70 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	23.00 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.70 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDD 72 Circuit #2

Mariaville Rd

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^{o}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, ^{o}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	29.80 ft	Ballast depth to invert, H_B	27.70 ft	Drill Fluid depth to invert, H_{DF}	27.70 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}{}^*(H_B+D_o/24)/144$	12.20 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}{}^*(H_{MDF}+D_o/24)/144$	15.25 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}{}^*(H_{MDF}+D_o/24)/144$	15.64 psi
Water, $P_W = \gamma_{INT}{}^*(H_{DF}+D_o/24)/144$	12.20 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 = $(P_A+P_a)-P_{DF1}$	91.73 psi	17.67 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.34 psi	17.28 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.93 psi	29.87 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.53 psi	29.48 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 = $(P_A+P_a)-P_W$	94.78 psi	20.72 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 **Pg 3 of 3**

HDPE PROPERTIES

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

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HDD 72 Circuit #2
Mariaville Rd

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 50,200 lb
Ultimate Pull Strength, UPS = 125,499 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.95544
$r = \sigma_i/2*(SSAS)$ = 0.08736
P_{CRR} = 255.5 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 127.8 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 112.51 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 124.32 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft

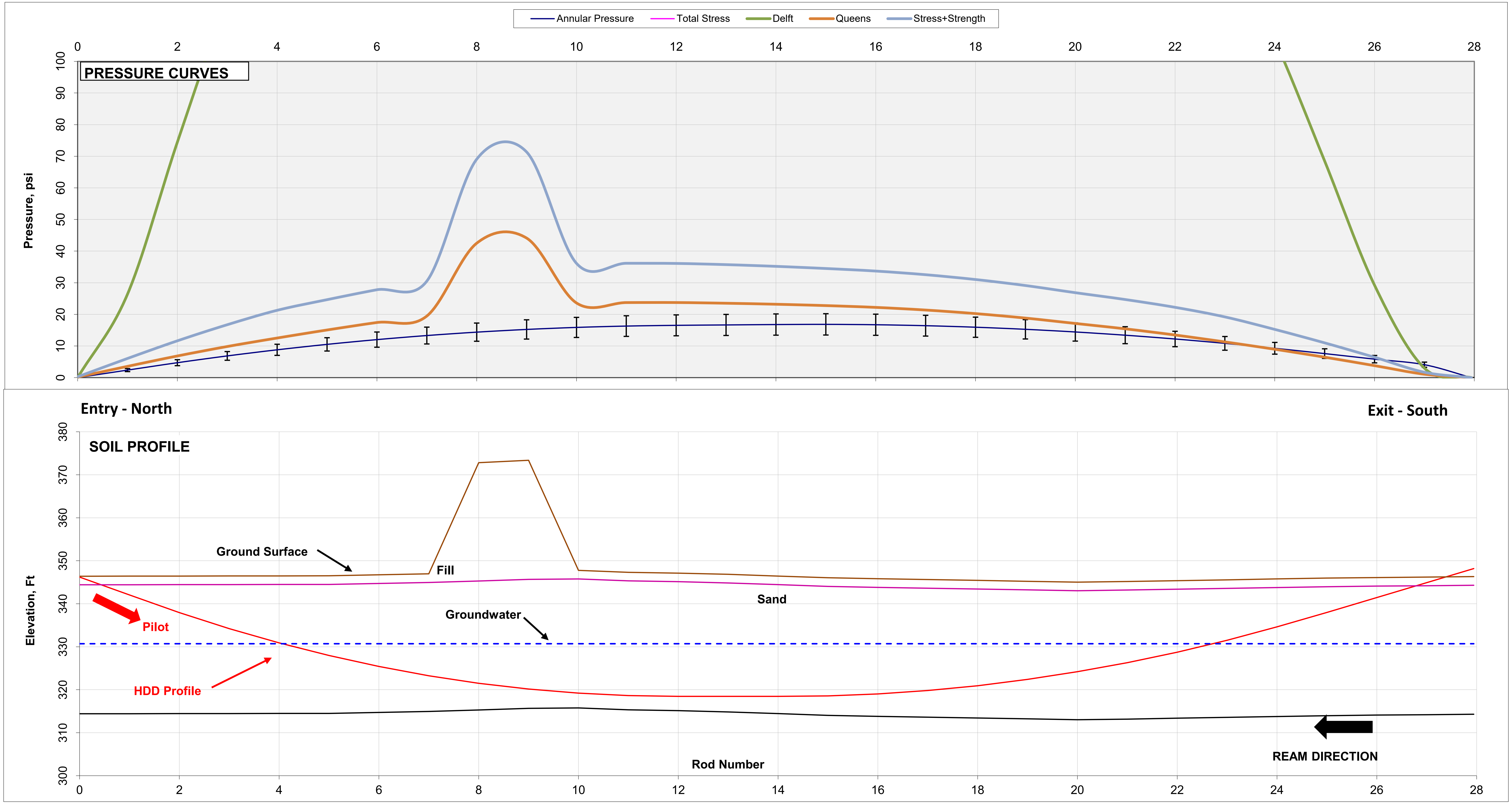
Example from Table T5, σ_i = 201 psi

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
100 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND
FORMATION PRESSURE CURVES
HDD 72 Circuit #2
Mariaville Rd

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#72 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 73 Circuit #1**
Route 7

ISSUE: **Design Submittal**

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: 17-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/17/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	5+21.96	FT

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

	East	North	Elevation
Entry	627750.0780	1441031.1919	336.80 ft
Horizontal Curve PI	627865.1414	1440796.9446	
Exit	627980.2048	1440562.6972	332.70 ft
Depth to Mudline	4.10 ft	Clearance Depth =	27.80 ft
Measured Plan Length at ties =	521.9632 ft		
Coordinate Length =	521.9632 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	332.00 ft
Mudline Elev.*	332.70 ft
Lowest centerline Elev.	304.90 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	627750.0780	1441031.1919	2+60.98	627865.1414	1440796.9446	E 153.83951 N	260.98		
Curve	2+60.98	627865.1414	1440796.9446	2+60.98	627865.1414	1440796.9446	E 153.83952 N	0.00	0.00	0.000 deg.
Tangent	2+60.98	627865.1414	1440796.9446	5+21.96	627980.2048	1440562.6972	E 153.83952 N	260.98		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	260.98	Input Radius, ft.	0.00	Plan Length, ft.	260.98	
Entry Azimuth, deg.[5]	N 153.83951 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 153.83952 E	
Entry Azimuth, rad.[5]	2.68501	Curve, rad	0.00000	Exit Azimuth, rad.[5]	2.68501	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	627980.2048	**Check**
PCH Easting	627865.1414	Arc Length, ft.	0.00	Northing	1440562.6972	**Delta**
PCH Northing	1440796.9446	Chord Azimuth, deg	153.8395			**0.0000**
		PI Easting =	627865.1414			**0.0000**
		PI Northing =	1440796.9446			**OK CALC**
		PTH Easting =	627865.1414			
		PTH Northing =	1440796.9446			**Exit Station**
						5+21.96
Cum Plan Length	260.98	Cum Plan Length	260.98	Cum Plan Length	521.9632439	**OK STA**

Pull Geometry

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

	Elevations		Vertical Angle				
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Path Length**	**Curve Radius**
Entry Tangent	332.70 ft	321.61 ft	-10.00 deg	-10.00 deg	0.00 deg	63.86 ft	0.00 ft
Entry Curve	321.61 ft	304.90 ft	-10.00 deg	0.00 deg	10.00 deg	191.99 ft	1100.00 ft
Bottom Tangent	304.90 ft	304.90 ft	0.00 deg	0.00 deg	0.00 deg	2.37 ft	0.00 ft
Exit Curve	304.90 ft	328.94 ft	0.00 deg	12.00 deg	12.00 deg	230.38 ft	1100.00 ft
Exit Tangent	328.94 ft	336.80 ft	12.00 deg	12.00 deg	0.00 deg	37.82 ft	0.00 ft
					Total Check =	**526.41 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	1100.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	332.70	
		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	36.989 ft	Plan Length	228.703 ft	Plan Length	2.37172 ft	Plan Length	191.013 ft	Plan Length	62.886 ft	521.963 ft
Rod Length	37.816 ft	Arc Rod Length	230.383 ft	Rod Length	2.37172 ft	Arc Rod Length	191.986 ft	Rod Length	63.856 ft	526.414 ft
Vertical Depth	-7.862 ft	Curve Δ Vert Depth	-24.038 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	16.711 ft	Vertical Depth	11.089 ft	-4.100 ft
		Lowest Elevation	304.900 ft			Lowest Elevation	304.900 ft	CK Total Cum Depth	-4.100 ft	
Start Elevation	336.800 ft	Start Elevation	328.938 ft	Start Elevation	304.900 ft	Start Elevation	304.900 ft	Start Elevation	321.611 ft	
End Elevation	328.938 ft	End Elevation	304.900 ft	End Elevation	304.900 ft	End Elevation	321.611 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***	***521.9632439***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+36.99	Start Station	2+65.69	Start Station	2+68.06	Start Station	4+59.08
PVC Station	0+36.99	PTV Station	2+65.69	PCV Station	2+68.06	PTV Station	4+59.08	Exit Station	5+21.963
Cum Plan Length	36.99	Cum Plan Length	265.69	Cum Plan Length	268.06 ft	Cum Plan Length	459.08	Cum Plan Length	521.96
Cum Rod Length	37.82	Cum Rod Length	268.20	Cum Rod Length	270.57 ft	Cum Rod Length	462.56	Cum Rod Length	526.41
Cum Depth	-7.86	Cum Depth	-31.90	Cum Depth	-31.90 ft	Cum Depth	-15.1885	Cum Depth	-4.10

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-4.10 ft**
Minimum Design Elevation =	**304.90 ft**
Invert Depth below exit =	**27.80 ft**
Invert Depth below entry =	**31.90 ft**
Path Length =	**526.41 ft**
Plan Length =	**521.96 ft**
Minimum Plan Length (No Tangent) =	**519.59 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

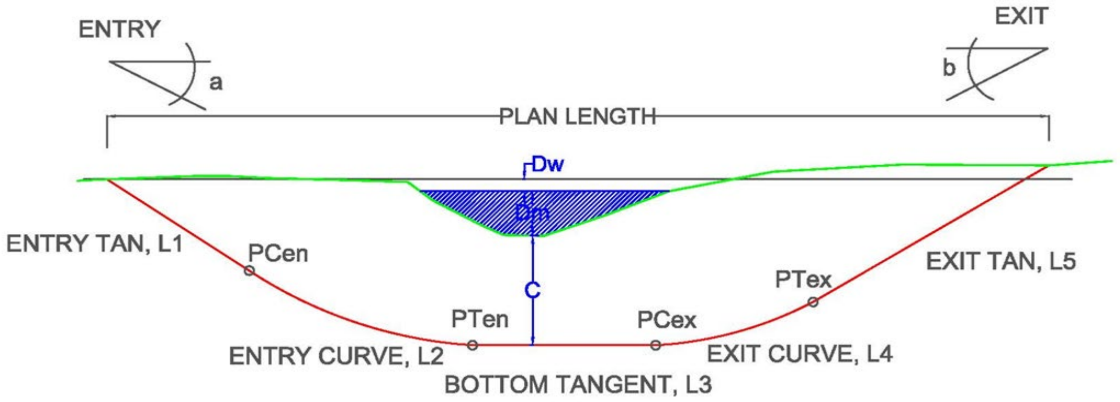
NOTES:

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

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"
Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 73 Circuit #1
Route 7

Revision 1 TBD

Pull Geometry

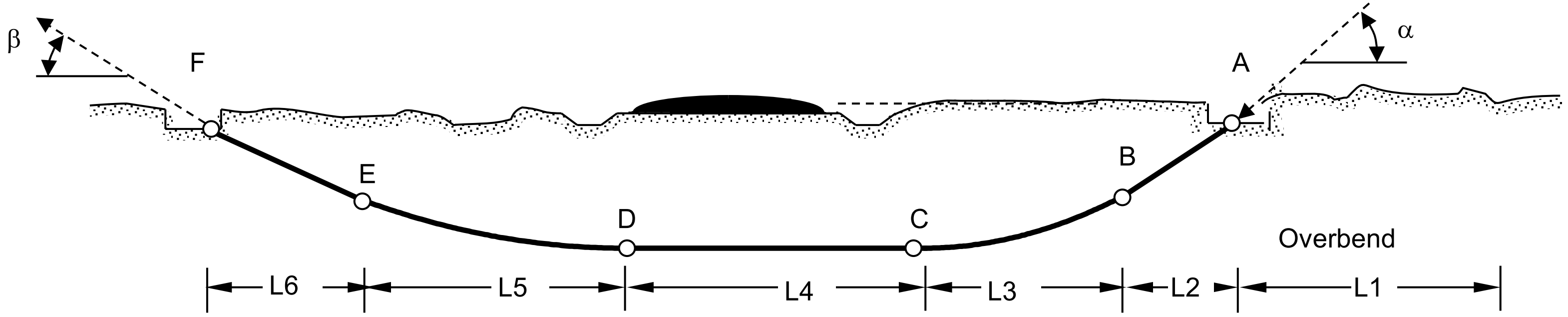
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	63.9 ft	α =	-10.0 °	-0.1745	
L3 =	192.0 ft				1,100.0 ft
L4 =	2.4 ft	χ =	0.0 °	0.0000	
L5 =	230.4 ft				1,100.0 ft
L6 =	37.8 ft	β =	12.0 °	0.2094	
LT =	626.4 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Entry El = 336.80 ft

Pipe Exit El = 332.70 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 =	332.70 ft	
Ballast Water El., H_W =	332.70 ft	
Lowest Invert El., El_m =	304.90 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	 Ballast
A	1,107 lb	157 psi	OK	1,107 lb	157 psi	OK	OK	OK
B	1,657 lb	42 psi	OK	1,775 lb	45 psi	OK	OK	OK
C	3,129 lb	114 psi	OK	2,426 lb	96 psi	OK	OK	OK
D	2,485 lb	63 psi	OK	1,783 lb	45 psi	OK	OK	OK
E	6,892 lb	209 psi	OK	3,971 lb	135 psi	OK	OK	OK
F	7,347 lb	185 psi	OK	4,217 lb	106 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 101.99 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.953430858	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.090843058	r = $\sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	209 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	3.01	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	15.06	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

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

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	1.68 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

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

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

ISSUE: Issued for Construction (IFC)

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 73 Circuit #1
Route 7

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #1_APC_20220726.xlsb]T3 Plastic Pull

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

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

HDD 73 Circuit #1

Route 7

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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 =	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 =	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	0.84	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =			-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =			4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =			-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =			-1.24 lb/ft	$BG-W_{D2}$

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #1_APC_20220726.xlsb]T3 Plastic Pull

TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 73 Circuit #1

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

Route 7

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 = 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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 31.90 ft   Ballast depth to invert, H_B 27.80 ft   Drill Fluid depth to invert, H_{DF} 27.80 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$ 12.11 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$ 15.14 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$ 15.53 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$ 12.11 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 = $(P_A+P_a)-P_{DF1}$	91.84 psi	30.94 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.45 psi	30.56 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.95 psi	43.05 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.56 psi	42.67 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.87 psi	33.97 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 73 Circuit #1

Route 7

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

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

Designed Pull Duration Time = 12 hr — Quantity of pipes, Q = 1

Yield Strength Factor, f_Y = 0.4 — Recommended (FS = 2.5) — Pull Temperature, F = 73 deg.

Pull Time factor, f_T = 1 — Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y 0.4 — **SAFE PULL STRENTH, SPS = 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 = 0.95343

r = σ_i/2*(SSAS) = 0.09084 — Example from Table T5, σ_i = 209 psi

P_{CRR} = 255.0 psi

FS = 2.0

$P_{ACRR} = P_{CRR}/FS$ = 127.5 psi — Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 124.46 psi — Pull Back Condition - Option 3 — **OK as >0**

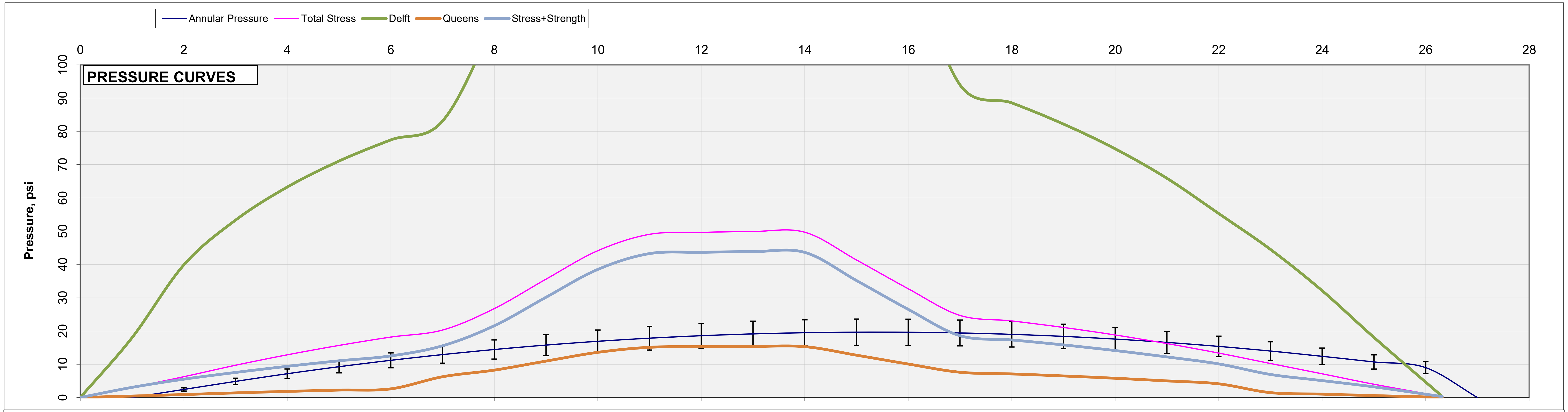
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 124.08 psi — Pull Back Condition - Option 4 — **OK as >0**

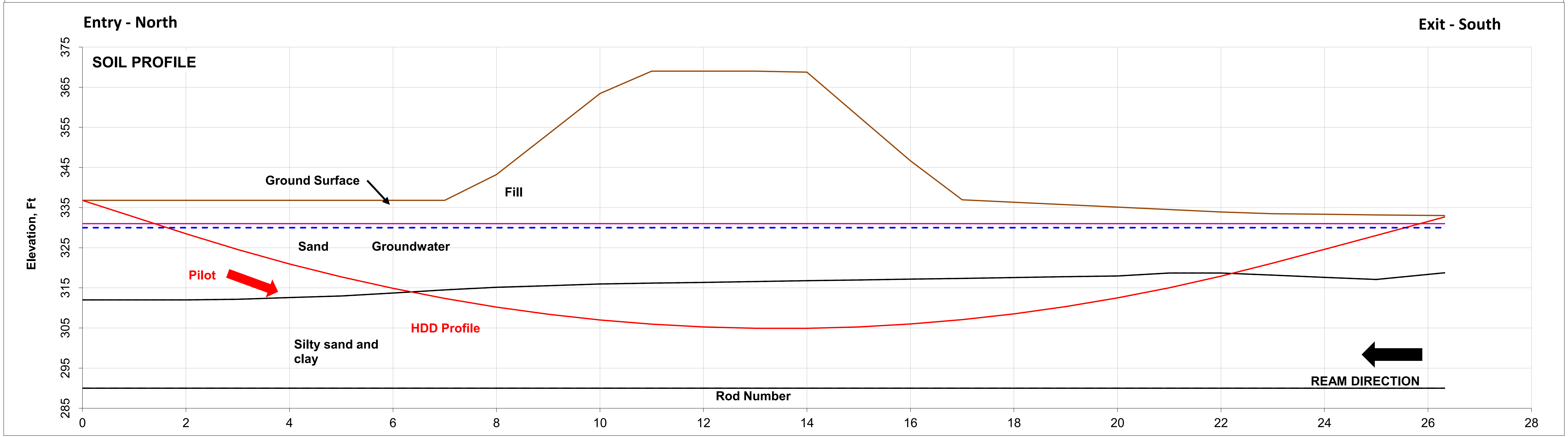
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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





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.

ISSUED: Issued for Construction (IFC)

Basis of annulur pressure calculations

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

Print Date ; 3/17/2023 14:42

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 73 Circuit #1
Route 7

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #1_APC_20220726.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 73 Circuit #2**
Route 7

ISSUE: **Design Submittal**

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: 17-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/17/2023	1	Issued for Construction	KRF

PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT
Exit Station	**5+31.80**	FT

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

	East	North	Elevation
Entry	627763.1184	1441038.6047	336.60 ft
Horizontal Curve PI	627890.6161	1440805.2663	
Exit	628018.1138	1440571.9280	332.90 ft
Depth to Mudline	3.70 ft	Clearance Depth =	29.20 ft

Measured Plan Length at ties = 531.7986 ft

Coordinate Length = 531.7986 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	332.00 ft
Mudline Elev.*	332.90 ft
Lowest centerline Elev.	303.70 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			**End**						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	627763.1184	1441038.6047	2+65.90	627890.6161	1440805.2663	E 151.34751 N	265.90		
Curve	2+65.90	627890.6161	1440805.2663	2+65.90	627890.6161	1440805.2663	E 151.34750 N	0.00	0.00	0.000 deg.
Tangent	2+65.90	627890.6161	1440805.2663	5+31.80	628018.1138	1440571.9280	E 151.34750 N	265.90		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		***Horizontal Curve Segment***		***Exit Tangent Segment***		
Plan Length, ft.	265.90	Input Radius, ft.	0.00	Plan Length, ft.	265.90	
Entry Azimuth, deg.^{5}	N 151.34751 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 151.34750 E	
Entry Azimuth, rad.^{5}	2.64151	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.64151	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	628018.1138	***Check***
PCH Easting	627890.6161	Arc Length, ft.	0.00	Northing	1440571.9280	***Delta***
PCH Northing	1440805.2663	Chord Azimuth, deg	151.3475			**0.0000**
		PI Easting =	627890.6161			**0.0000**
		PI Northing =	1440805.2663			**OK CALC**
		PTH Easting =	627890.6161			
		PTH Northing =	1440805.2663			**Exit Station** **5+31.80**
Cum Plan Length	265.90	Cum Plan Length	265.90	Cum Plan Length	531.7986427	**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**	**∆ Angle**	**Length**	**Radius**
Entry Tangent	332.90 ft	320.41 ft	-10.00 deg	-10.00 deg	0.00 deg	71.92 ft	0.00 ft
Entry Curve	320.41 ft	303.70 ft	-10.00 deg	0.00 deg	10.00 deg	191.99 ft	1100.00 ft
Bottom Tangent	303.70 ft	303.70 ft	0.00 deg	0.00 deg	0.00 deg	0.44 ft	0.00 ft
Exit Curve	303.70 ft	327.74 ft	0.00 deg	12.00 deg	12.00 deg	230.38 ft	1100.00 ft
Exit Tangent	327.74 ft	336.60 ft	12.00 deg	12.00 deg	0.00 deg	42.63 ft	0.00 ft
					Total Check =	**537.35 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	1100.00	End Vert Angle	0.000 deg.	Radius	1100.00	Exit Elevation	332.90
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	41.694 ft	Plan Length	228.703 ft	Plan Length	-0.43731 ft	Plan Length	191.013 ft	Plan Length	70.826 ft
Rod Length	42.626 ft	Arc Rod Length	230.383 ft	Rod Length	0.43731 ft	Arc Rod Length	191.986 ft	Rod Length	71.919 ft
Vertical Depth	-8.862 ft	Curve ∆ Vert Depth	-24.038 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	16.711 ft	Vertical Depth	12.489 ft
		Lowest Elevation	303.700 ft			Lowest Elevation	303.700 ft	CK Total Cum Depth	-3.700 ft
Start Elevation	336.600 ft	Start Elevation	327.738 ft	Start Elevation	303.700 ft	Start Elevation	303.700 ft	Start Elevation	320.411 ft
End Elevation	327.738 ft	End Elevation	303.700 ft	End Elevation	303.700 ft	End Elevation	320.411 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***	***531.7986427***
SUMMARY VERTICLE CURVE CALCULATIONS									
Start Station	0+00.00	Start Station	0+41.69	Start Station	2+70.40	Start Station	2+69.96	Start Station	4+60.97
PVC Station	0+41.69	PTV Station	2+70.40	PCV Station	2+69.96	PTV Station	4+60.97	Exit Station	5+31.799
Cum Plan Length	41.69	Cum Plan Length	270.40	Cum Plan Length	269.96 ft	Cum Plan Length	460.97	Cum Plan Length	531.80
Cum Rod Length	42.63	Cum Rod Length	273.01	Cum Rod Length	273.45 ft	Cum Rod Length	465.43	Cum Rod Length	537.35
Cum Depth	-8.86	Cum Depth	-32.90	Cum Depth	-32.90 ft	Cum Depth	-16.1885	Cum Depth	-3.70

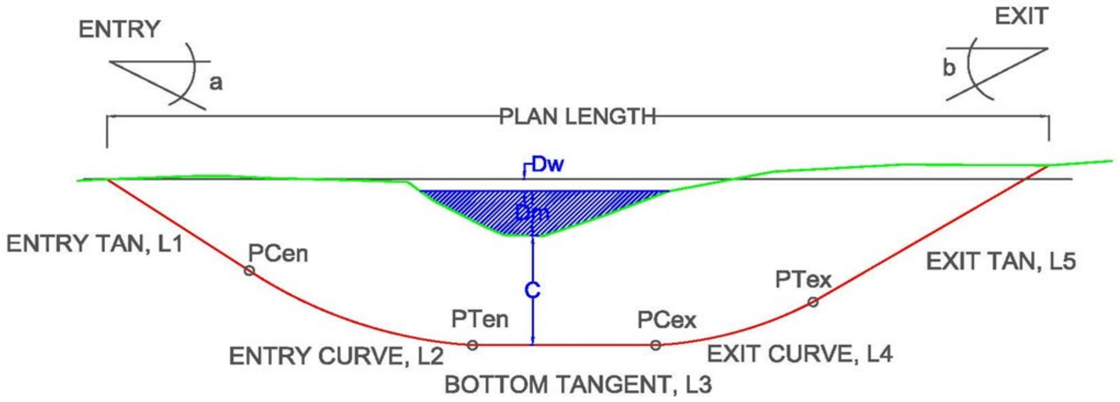
SUMS
531.799 ft
537.351 ft
-3.700 ft

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-3.70 ft**
Minimum Design Elevation =	**303.70 ft**
Invert Depth below exit =	**29.20 ft**
Invert Depth below entry =	**32.90 ft**
Path Length =	**537.35 ft**
Plan Length =	**531.80 ft**
Minimum Plan Length (No Tangent) =	**532.24 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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Limited Liability Company
"Creating Space Underground"
Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 73 Circuit #2
Route 7

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

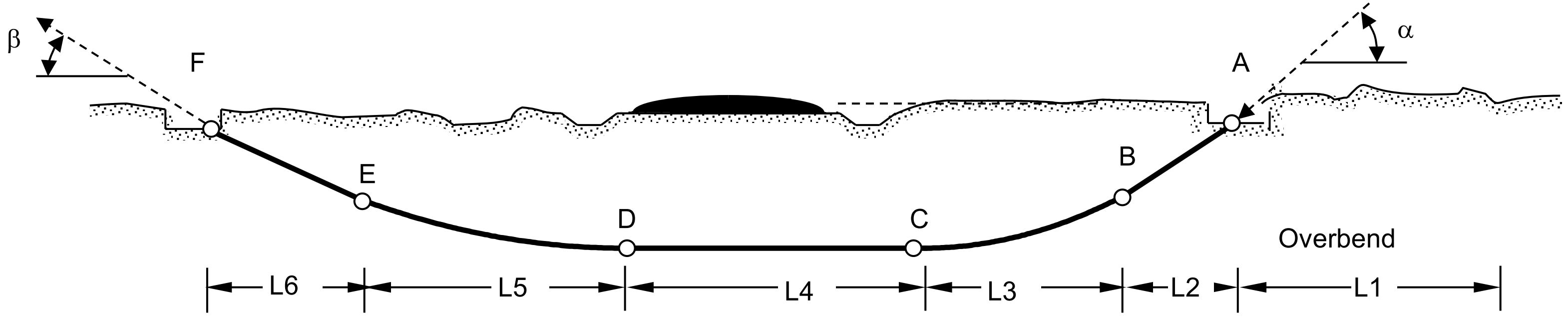
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	71.9 ft	α =	-10.0 ˚	-0.1745	
L3 =	192.0 ft				1,100.0 ft
L4 =	0.4 ft	χ =	0.0 ˚	0.0000	
L5 =	230.4 ft				1,100.0 ft
L6 =	42.6 ft	β =	12.0 ˚	0.2094	
LT =	637.4 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Entry El = 336.60 ft

Pipe Exit El = 332.90 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 PIPE PIPE/BUNDLE

Material Density, γ 59.28 pcf

Outside Diameter, D_{OD} 10.75 Pipe or Bundle

Pipe Dry Weight, W_P = 15.70 lb/ft Pipe or Bundle

Min. Wall Thickness, t_m 1.194 in For design installation pull stress

DR = D_O/t_{min} = 9 D_{OD} Stress 10.75 inches

Avg. Inside Diameter, D_{IA} 8.22 in Bundle Multiplier F_D 1.0000

12 Hr Pullback Modulus, E_T = 65,000 psi @T = 73 deg F

Poisson Ratio, μ = 0.45

Ovality Factor, f_o = 0.84 2%

Buckling Safety, N = 2.5

Hydrostatic Design Stress, HDS = 1,008 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 = 332.90 ft

Ballast Water El., H_W = 332.90 ft

Lowest Invert El., El_m = 303.70 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 = 1.22 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	 Ballast
A	1,018 lb	125 psi	OK	1,018 lb	125 psi	OK	OK	OK
B	1,611 lb	45 psi	OK	1,731 lb	48 psi	OK	OK	OK
C	2,867 lb	106 psi	OK	2,246 lb	89 psi	OK	OK	OK
D	2,268 lb	63 psi	OK	1,646 lb	46 psi	OK	OK	OK
E	6,156 lb	198 psi	OK	3,530 lb	125 psi	OK	OK	OK
F	6,681 lb	186 psi	OK	3,797 lb	106 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 102.28 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.956123685 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.086170849 $r = \sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 198 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 3.16 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 15.82 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
Limited Liability Company
"Creating Space Underground"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 73 Circuit #2
Route 7

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

HDPE PROPERTIES

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

HDD 73 Circuit #2

Route 7

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification	445574C		Design resin with minimum PENT test of 10,000 hours
Standard Dimension	10		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	8.219 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	1.194 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	35.85681985		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	405.27 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.630 cf/LF		$V_{Do} = \pi*(D_o/2)^2/144$
Unit Inside Volume, V_{Di} =	0.368 cf/LF		$V_{Di} = \pi*(D_i/2)^2/144$
HDB =	1,600 psi		Based on PPI Publication TR-4/2015 and ASTM 2837
Design Factor for HDB, DF =	0.63		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 =	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	65,000 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	0.84	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

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

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

Buoyant forces

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

TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 73 Circuit #2

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

Route 7

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	267.4 psi
$P_a = P_{CR}/FS$	107.0 psi	107.0 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	32.90 ft	Ballast depth to invert, H_B	29.20 ft	Drill Fluid depth to invert, H_{DF}	29.20 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	12.85 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	16.06 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	16.47 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	12.85 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 = $(P_A+P_a)-P_{DF1}$	90.92 psi	90.92 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	90.50 psi	90.50 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.76 psi	103.76 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.35 psi	103.35 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	106.97 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.13 psi	94.13 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 73 Circuit #2

Route 7

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.
SAFE PULL STRENTH, SPS = 50,200 lb
Ultimate Pull Strength, UPS = 125,499 lb
Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.95612
r = σ_i/2*(SSAS) = 0.08617
P_{CRR} = 255.7 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 127.9 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 124.64 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 124.23 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 198 psi

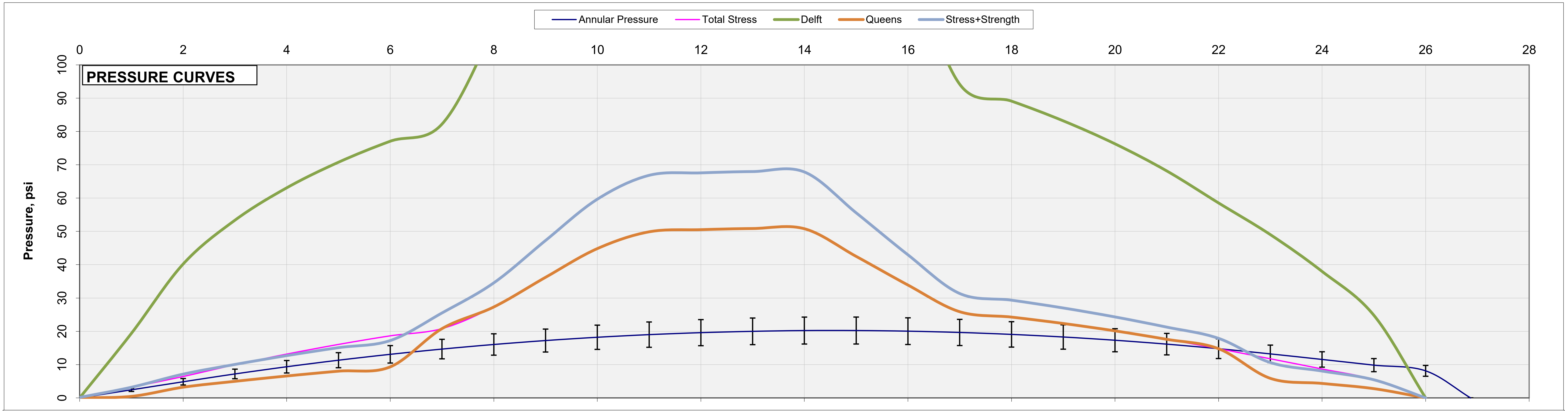
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

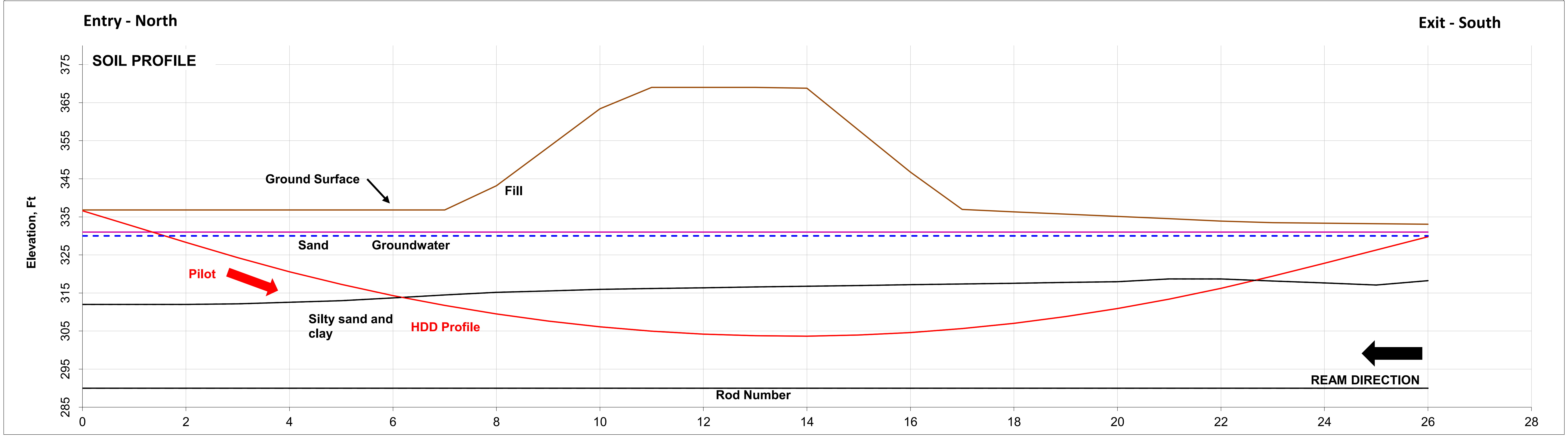
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #2_APC_20221023.xlsb]T3 Plastic Pull





ISSUED: Issued for Construction (IFC)

Notes:

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

Basis of annular pressure calculations

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

Print Date ; 3/17/2023 15:02

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 73 Circuit #2
Route 7

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#73 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75 Conduit #1**
Guilderland Ave.

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: 1-Mar-2023

Date	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
2/24/2023	1	Issued for Construction	ABL

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	29.5 ft	α =	-12.0 °	-0.2094	
L3 =	188.5 ft				900.0 ft
L4 =	306.9 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	103.1 ft	β =	10.0 °	0.1745	
LT =	902.5 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 = 312.80 ft

Ballast Water El., H_W = 312.80 ft

Lowest Invert El., El_m = 285.70 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 = 1.10 lb/ft Comparison Only @ 8psi

Calculated Buoyant Forces

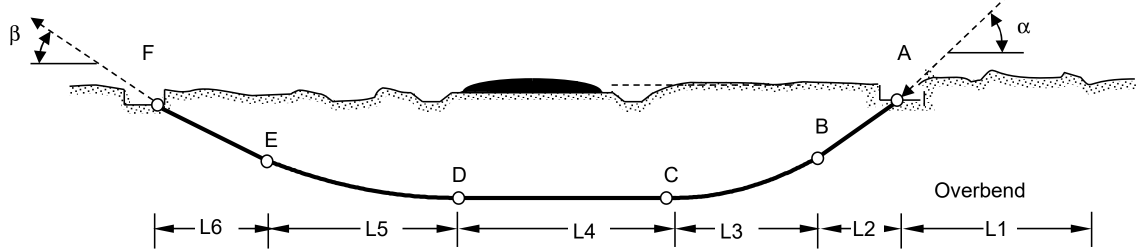
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Entry

(schematic, to show definition of variables only)

Pipe Exit El = 318.80 ft

Pipe Entry El = 311.50 ft



POINT	Calculated Pull Force 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	Ballast
A	1,600 lb	169 psi	OK	1,600 lb	169 psi	OK	OK	OK
B	1,878 lb	47 psi	OK	1,906 lb	48 psi	OK	OK	OK
C	3,235 lb	124 psi	OK	2,536 lb	107 psi	OK	OK	OK
D	4,180 lb	105 psi	OK	3,481 lb	88 psi	OK	OK	OK
E	7,465 lb	227 psi	OK	5,176 lb	169 psi	OK	OK	OK
F	8,990 lb	227 psi	OK	5,968 lb	151 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 101.51 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 45,606 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.948897985 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.098652601 r = $\sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 227 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** = 2.94 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** = 14.68 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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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75 Conduit #1
Guilderland Ave.

Revision 1 TBD

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TABLE 4 Pg 1 of 3

HDPE PROPERTIES

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

HDD 75 Conduit #1
Guilderland Ave.

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE 4710	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 =	3.801889456	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
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%	4%	See Sheets 4 of 5 for design ovality
Factor of Safety, FS =	2.5	2.5	Industry Practice
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours
Ovality factor f_o =	0.84	0.5	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 forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Shee
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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

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"Creating Space Underground"

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

HDD 75 Conduit #1
Guilderland Ave.

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	68.6 psi
$P_a = P_{CR}/FS$	107.0 psi	27.4 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	33.10 ft	Ballast depth to invert, H_B	25.80 ft	Drill Fluid depth to invert, H_{DF}	25.80 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	11.24 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	14.05 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	14.41 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	11.24 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 = $(P_A+P_a)-P_{DF1}$	92.92 psi	13.38 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	92.56 psi	13.02 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	104.16 psi	24.62 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.80 psi	24.26 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	27.43 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	95.73 psi	16.19 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.

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#75 CIR #1_APC_20220729.xlsb]T1 Comments

TABLE 4 **Pg 3 of 3**

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 75 Conduit #1
Guilderland Ave.

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

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

Designed Pull Duration Time = 12 hr
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF
Safe Pull Strength, SPS Pipe = 5,321 lb **Useing SSAS = 4,371 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.94890
r = σ_i/2*(SSAS) = 0.09865
P_{CRR} = 253.8 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 126.9 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 112.83 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 112.47 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 227 psi

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

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	7+98.06	FT

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

	East	North	Elevation
Entry	631180.3035	1432902.5198	311.50 ft
Horizontal Curve PI	631002.7227	1433250.1337	
Exit	630858.1207	1433631.4804	318.80 ft
Depth to Mudline	-1.30 ft	Clearance Depth =	27.10 ft
Measured Plan Length at ties =	798.0557 ft		
Coordinate Length =	798.0557 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	265.00 ft
Mudline Elev.*	312.80 ft
Lowest centerline Elev.	285.70 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	631180.3035	1432902.5198	3+24.37	631032.7396	1433191.3758	E 332.93949 N	324.37		
Curve	3+24.37	631032.7396	1433191.3758	4+56.19	630979.3288	1433311.8284	E 339.23389 N	131.83	1200.00	6.294 deg.
Tangent	4+56.19	630979.3288	1433311.8284	7+98.06	630858.1207	1433631.4804	E 339.23389 N	341.86		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	324.37	Input Radius, ft.	1200.00	Plan Length, ft.	341.86	
Entry Azimuth, deg.[5]	N 332.93949 E	Curve, deg	6.294 deg.	Exit Azimuth, deg.[5]	N 339.23389 E	
Entry Azimuth, rad.[5]	5.81089	Curve, rad	0.10986	Exit Azimuth, rad.[5]	5.92075	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	131.76	Easting	630858.1207	**Check**
PCH Easting	631032.7396	Arc Length, ft.	131.83	Northing	1433631.4804	**Delta**
PCH Northing	1433191.3758	Chord Azimuth, deg	336.0867			**0.0000**
		PI Easting =	631002.7227			**0.0000**
		PI Northing =	1433250.1337			**OK CALC**
		PTH Easting =	630979.3288			
		PTH Northing =	1433311.8284			**Exit Station**
						7+98.06
Cum Plan Length	324.37	Cum Plan Length	456.19	Cum Plan Length	798.0556565	**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	311.50 ft	305.37 ft	-12.00 deg	-12.00 deg	0.00 deg	29.50 ft	0.00 ft
Entry Curve	305.37 ft	285.70 ft	-12.00 deg	0.00 deg	12.00 deg	188.50 ft	900.00 ft
Bottom Tangent	285.70 ft	285.70 ft	0.00 deg	0.00 deg	0.00 deg	306.87 ft	0.00 ft
Exit Curve	285.70 ft	300.89 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	300.89 ft	318.80 ft	10.00 deg	10.00 deg	0.00 deg	103.13 ft	0.00 ft
					Total Check =	**802.53 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	215.97	324.37	No, Horiz > Entry V(Tan+Curve)
Exit	275.21	341.86	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	900.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	318.80	
		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	28.853 ft	Plan Length	187.121 ft	Plan Length	306.87430 ft	Plan Length	173.648 ft	Plan Length	101.560 ft	798.056 ft
Rod Length	29.497 ft	Arc Rod Length	188.496 ft	Rod Length	306.87430 ft	Arc Rod Length	174.533 ft	Rod Length	103.127 ft	802.527 ft
Vertical Depth	-6.133 ft	Curve Δ Vert Depth	-19.667 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	17.908 ft	7.300 ft
		Lowest Elevation	285.700 ft			Lowest Elevation	285.700 ft	CK Total Cum Depth	7.300 ft	
Start Elevation	311.500 ft	Start Elevation	305.367 ft	Start Elevation	285.700 ft	Start Elevation	285.700 ft	Start Elevation	300.892 ft	
End Elevation	305.367 ft	End Elevation	285.700 ft	End Elevation	285.700 ft	End Elevation	300.892 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***	***798.0556565***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+28.85	Start Station	2+15.97	Start Station	5+22.85	Start Station	6+96.50	**OK STATIONING**
PVC Station	0+28.85	PTV Station	2+15.97	PCV Station	5+22.85	PTV Station	6+96.50	Exit Station	7+98.056	**Plan Length Check**
Cum Plan Length	28.85	Cum Plan Length	215.97	Cum Plan Length	522.85 ft	Cum Plan Length	696.50	Cum Plan Length	798.06	**OK CALCULATION**
Cum Rod Length	29.50	Cum Rod Length	217.99	Cum Rod Length	524.87 ft	Cum Rod Length	699.40	Cum Rod Length	802.53	**Elevation Change Check**
Cum Depth	-6.13	Cum Depth	-25.80	Cum Depth	-25.80 ft	Cum Depth	-10.6078	Cum Depth	7.30	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**7.30 ft**
Minimum Design Elevation =	**285.70 ft**
Invert Depth below exit =	**33.10 ft**
Invert Depth below entry =	**25.80 ft**
Path Length =	**802.53 ft**
Plan Length =	**798.06 ft**
Minimum Plan Length (No Tangent) =	**491.18 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

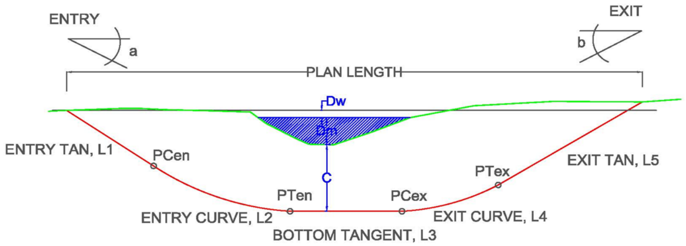
NOTES:

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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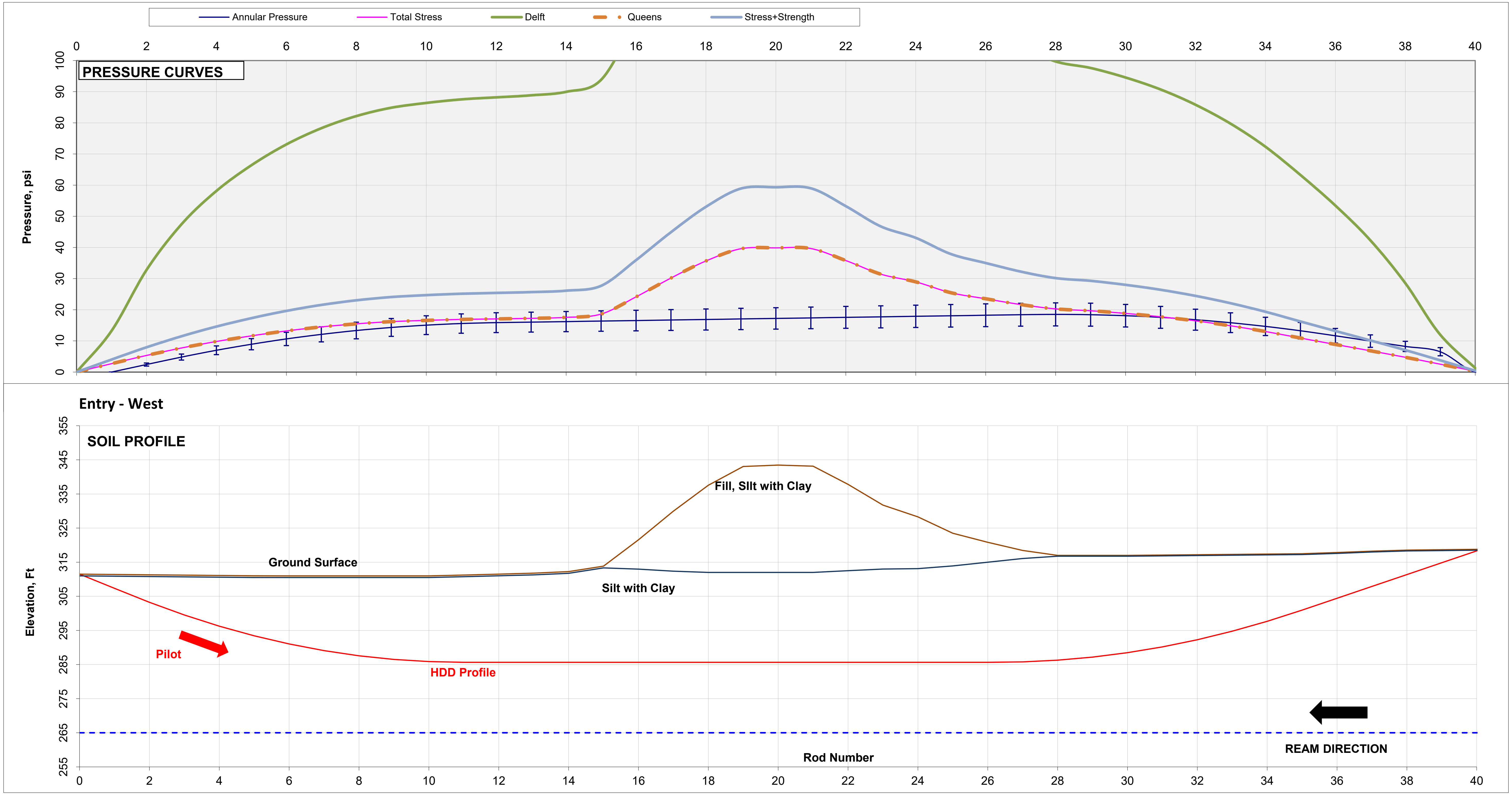
BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 75 Conduit #1
Guilderland Ave.

Revision 1 TBD



ISSUED: Issued for Construction (IFC)

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

Basis of annulur pressure calculations

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

Bore Logs
A179.6-1
K-179.6

Print Date ; 3/1/2023 12:47

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75 Conduit #1
Guilderland Ave.

Revision 1

FIGURE 1

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#75 CIR #1_APC_20220729.xlsb]T1 Comments

HORIZONTAL DIRECTIONAL CONCEPTUAL DRILL DESIGN

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

CROSSING: **HDD 75 Conduit #2**
Guilderland Ave.

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: 1-Mar-2023

Date	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
2/24/2023	1	Issued for Construction	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	7+96.41	FT

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

	East	North	Elevation
Entry	631193.6614	1432909.3437	312.60 ft
Horizontal Curve PI	631016.4558	1433256.2232	
Exit	630872.1462	1433636.7987	318.90 ft
Depth to Mudline	2.60 ft	Clearance Depth =	24.90 ft
Measured Plan Length at ties =	796.4062 ft		
Coordinate Length =	796.4062 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	265.00 ft
Mudline Elev.*	310.00 ft
Lowest centerline Elev.	285.10 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	631193.6614	1432909.3437	3+23.54	631046.4726	1433197.4653	E 332.93949 N	323.54		
Curve	3+23.54	631046.4726	1433197.4653	4+55.37	630993.0619	1433317.9178	E 339.23388 N	131.83	1200.00	6.294 deg.
Tangent	4+55.37	630993.0619	1433317.9178	7+96.41	630872.1462	1433636.7987	E 339.23388 N	341.04		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	323.54	Input Radius, ft.	1200.00	Plan Length, ft.	341.04	
Entry Azimuth, deg.[5]	N 332.93949 E	Curve, deg	6.294 deg.	Exit Azimuth, deg.[5]	N 339.23388 E	
Entry Azimuth, rad.[5]	5.81089	Curve, rad	0.10986	Exit Azimuth, rad.[5]	5.92075	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	131.76	Easting	630872.1462	***Check***
PCH Easting	631046.4726	Arc Length, ft.	131.83	Northing	1433636.7987	***Delta***
PCH Northing	1433197.4653	Chord Azimuth, deg	336.0867			**0.0000**
		PI Easting =	631016.4558			**0.0000**
		PI Northing =	1433256.2232			**OK CALC**
		PTH Easting =	630993.0619			
		PTH Northing =	1433317.9178			**Exit Station**
						7+96.41
Cum Plan Length	323.54	Cum Plan Length	455.37	Cum Plan Length	796.4061931	**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	312.60 ft	304.77 ft	-12.00 deg	-12.00 deg	0.00 deg	37.67 ft	0.00 ft
Entry Curve	304.77 ft	285.10 ft	-12.00 deg	0.00 deg	12.00 deg	188.50 ft	900.00 ft
Bottom Tangent	285.10 ft	285.10 ft	0.00 deg	0.00 deg	0.00 deg	293.26 ft	0.00 ft
Exit Curve	285.10 ft	300.29 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	300.29 ft	318.90 ft	10.00 deg	10.00 deg	0.00 deg	107.16 ft	0.00 ft
					Total Check =	801.12 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	223.97	323.54	No, Horiz > Entry V(Tan+Curve)
Exit	279.18	341.04	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	900.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	318.90	
		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	36.851 ft	Plan Length	187.121 ft	Plan Length	293.25706 ft	Plan Length	173.648 ft	Plan Length	105.530 ft	796.406 ft
Rod Length	37.674 ft	Arc Rod Length	188.496 ft	Rod Length	293.25706 ft	Arc Rod Length	174.533 ft	Rod Length	107.158 ft	801.117 ft
Vertical Depth	-7.833 ft	Curve Δ Vert Depth	-19.667 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	18.608 ft	6.300 ft
		Lowest Elevation	285.100 ft			Lowest Elevation	285.100 ft	CK Total Cum Depth	6.300 ft	
Start Elevation	312.600 ft	Start Elevation	304.767 ft	Start Elevation	285.100 ft	Start Elevation	285.100 ft	Start Elevation	300.292 ft	
End Elevation	304.767 ft	End Elevation	285.100 ft	End Elevation	285.100 ft	End Elevation	300.292 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***	***796.4061931***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+36.85	Start Station	2+23.97	Start Station	5+17.23	Start Station	6+90.88	**OK STATIONING**
PVC Station	0+36.85	PTV Station	2+23.97	PCV Station	5+17.23	PTV Station	6+90.88	Exit Station	7+96.406	**Plan Length Check**
Cum Plan Length	36.85	Cum Plan Length	223.97	Cum Plan Length	517.23 ft	Cum Plan Length	690.88	Cum Plan Length	796.41	**OK CALCULATION**
Cum Rod Length	37.67	Cum Rod Length	226.17	Cum Rod Length	519.43 ft	Cum Rod Length	693.96	Cum Rod Length	801.12	**Elevation Change Check**
Cum Depth	-7.83	Cum Depth	-27.50	Cum Depth	-27.50 ft	Cum Depth	-12.3078	Cum Depth	6.30	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**6.30 ft**
Minimum Design Elevation =	**285.10 ft**
Invert Depth below exit =	**33.80 ft**
Invert Depth below entry =	**27.50 ft**
Path Length =	**801.12 ft**
Plan Length =	**796.41 ft**
Minimum Plan Length (No Tangent) =	**503.15 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

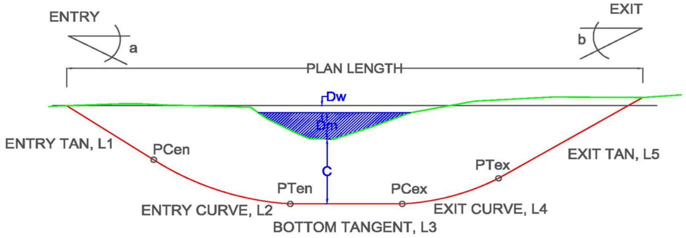
NOTES:

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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"Creating Space Underground"

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 75 Conduit #2
Guilderland Ave.

Revision 1 TBD

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#75 CIR #2_APC_20221023.xlsb]F1A APCL

Pull Geometry

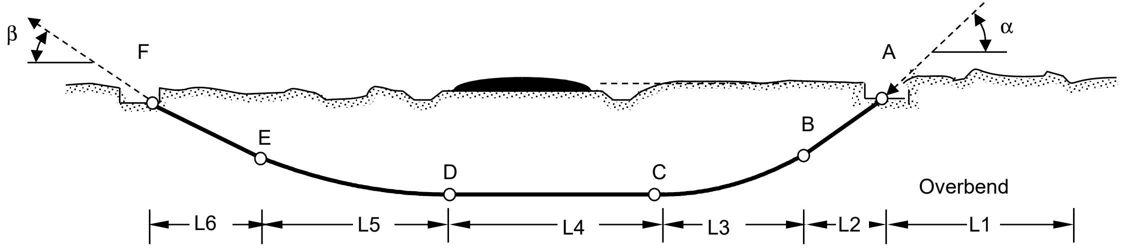
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	37.7 ft	α =	-12.0 °	-0.2094	
L3 =	188.5 ft				900.0 ft
L4 =	293.3 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	107.2 ft	β =	10.0 °	0.1745	
LT =	901.1 ft				

Pipe Entry Location - Drill Entry

(schematic, to show definition of variables only)

Pipe Exit El = 318.90 ft

Pipe Entry El = 312.60 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} 8.22 in Bundle Multiplier F_D 1.0000

12 Hr Pullback Modulus, E_T = 65,000 psi @T = 73 deg F

Poisson Ratio, μ = 0.45

Ovality Factor, f_o = 0.84 2%

Buckling Safety, N = 2.5

Hydrostatic Design Stress, HDS = 1,000 psi HDB/2

Pressure Rating, $PR_{(80F)}$ = 250 psi PR = $2HDSF_TA_F/(DR-1)$ $[F_T=1]$

INPUT: Assumed Fluid Densities/Elevations

Ballast Density 62.4 pcf

Drill Fluid Density 78 pcf *Estimated for pull*

Drill fluid elevation, H_F = 312.20 ft

Ballast Water El., H_W = 312.20 ft

Lowest Invert El., El_m = 285.10 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 = 0.82 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	1,445 lb	137 psi	OK	1,445 lb	137 psi	OK	OK	OK
B	1,789 lb	50 psi	OK	1,819 lb	51 psi	OK	OK	OK
C	2,940 lb	114 psi	OK	2,314 lb	97 psi	OK	OK	OK
D	3,723 lb	104 psi	OK	3,097 lb	86 psi	OK	OK	OK
E	6,618 lb	214 psi	OK	4,555 lb	156 psi	OK	OK	OK
F	7,983 lb	223 psi	OK	5,258 lb	147 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 101.62 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.949957018 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.096834177 $r = \sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 223 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 2.94 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 14.68 psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

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

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75 Conduit #2
Guilderland Ave.

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

Revision 1 TBD

TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

HDD 75 Conduit #2
Guilderland Ave.

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

INPUTS
Pipe Material Properties

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

Design Working Pressure, P_{WORK}	250 psi	Test Pressure, P_{TEST}	0 psig	At high point	
Quantity of Pipes in Hole, Q =	1				
Pipe Material	PE 4710	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 =	35.84514492	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$			
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 =	15.7	Lb/LF			
Tensile Yield, Ty psi =	3,500 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638		
Load Duration	**Short Term**	**Long Term**			
Duration Time	10 hours	50 yrs			
Design Temperature, °F	73 deg F	73 deg F	Assumed		
Design Ovality, %	2%	4%	See Sheets 4 of 5 for design ovality		
Factor of Safety, FS =	2.5	2.5	Industry Practice		
Modulus for given load duration, E =	65,000 psi	28,000 psi	Based on PPI Handbook Ch. 3 and WL Plastics WL118-0314		
Poisson Ratio, υ =	0.45	0.45	WL118: Use 0.35 if load duration is less than 12 hours		
Ovality factor f_o =	0.84	0.5	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

Buoyant forces

Dry Weight Pipe on ground, W_P =	15.70 lb/ft	From MFG. Data Shee
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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

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

HDD 75 Conduit #2
Guilderland Ave.

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	68.6 psi
$P_a = P_{CR}/FS$	107.0 psi	27.4 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 33.80 ft Ballast depth to invert, H_B 27.50 ft Drill Fluid depth to invert, H_{DF} 27.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi

Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$ 12.11 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$ 15.14 psi

Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$ 15.53 psi

Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$ 12.11 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 = $(P_A+P_a)-P_{DF1}$	91.84 psi	12.29 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.45 psi	11.90 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.95 psi	24.40 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.56 psi	24.01 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	27.43 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.86 psi	15.32 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 **Pg 3 of 3**

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 75 Conduit #2

Guilderland Ave.

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

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y 0.4

Temperature factor, f_{temp} = 1

Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi

Safe Allowable Stress, SAS = 1,400 psi SAS = $Ty*f_{temp}*DF$

Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1

Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 50,200 lb

Ultimate Pull Strength, UPS = 125,499 lb

Suggested SSAS = 1,150 psi

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

SAS = 1,400 psi

Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum

fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.94996

r = σ_i/2*(SSAS) = 0.09683

P_{CRR} = 254.1 psi

FS = 2.0

$P_{ACRR} = P_{CRR}/FS$ = 127.0 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 111.89 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 111.50 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi

Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 223 psi

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

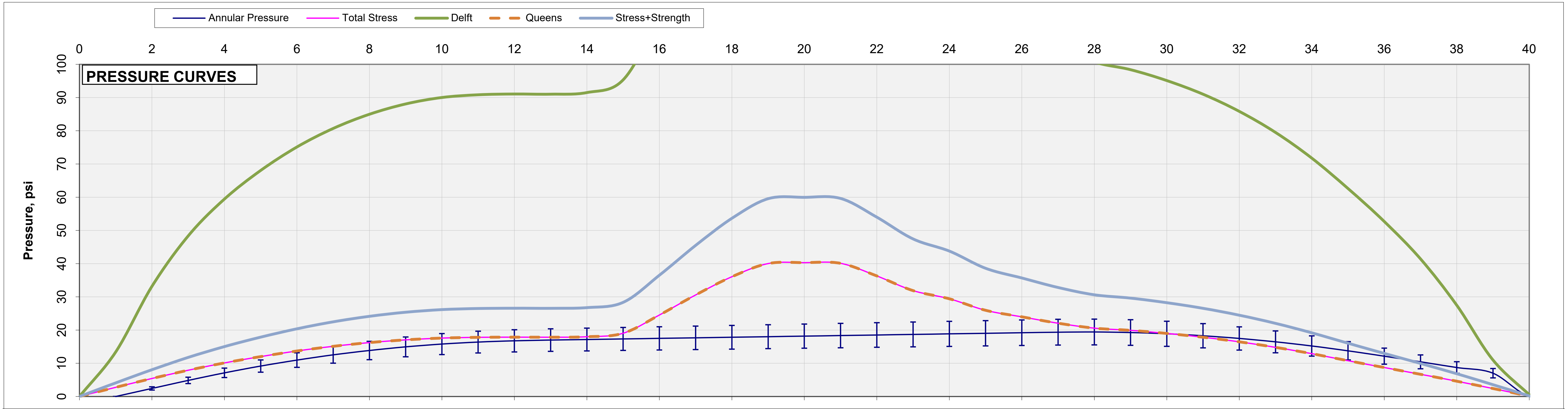
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

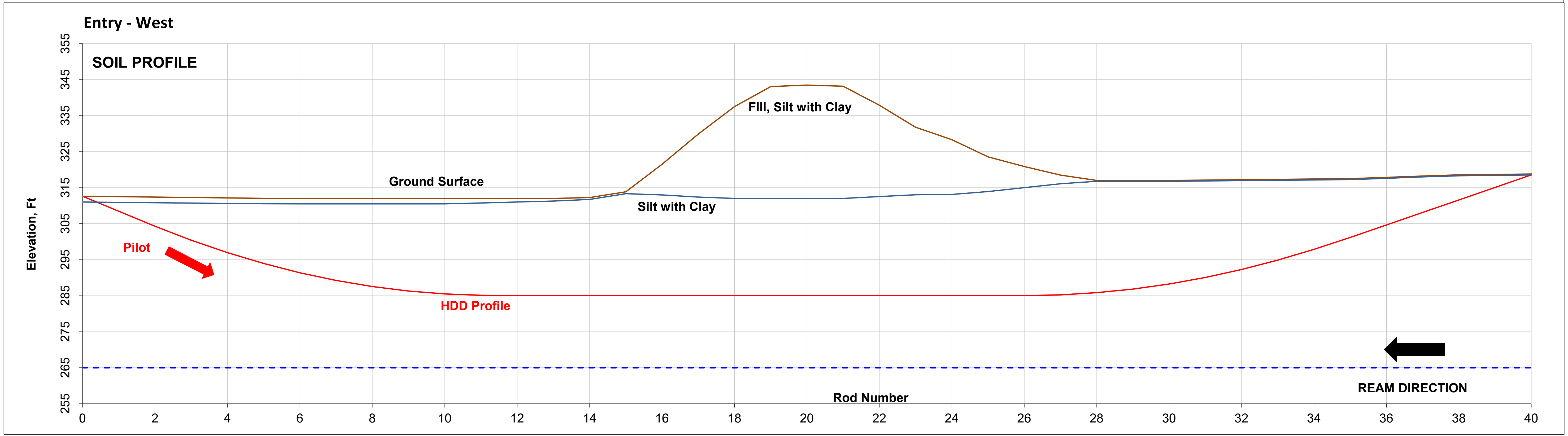
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

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





https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#75 CIR #2_APC_20221023.xlsb]T4 Formation Pressure

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.

ISSUED: Issued for Construction (IFC)

Basis of annular pressure calculations

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

Bore Logs
A179.6-1
K-179.6

Print Date ; 3/1/2023 12:56

BRIERLEY ASSOCIATES
Creating Space Underground
167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND
FORMATION PRESSURE CURVES
HDD 75 Conduit #2
Guilderland Ave.

Revision 1

FIGURE 1

BRIERLEY
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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75A Conduit #2**
Stream Crossing

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: 1-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
2/27/2023	1	Issued for Construction	ABL

PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT
Exit Station	**22+41.97**	FT

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

	East	North	Elevation
Entry	633356.9420	1427671.9820	303.70 ft
Horizontal Curve PI	633767.0817	1426628.7196	
Exit	634177.2213	1425585.4571	309.50 ft

Depth to Mudline 0.00 ft Clearance Depth = 40.90 ft

Measured Plan Length at ties = 2241.9733 ft

Coordinate Length = 2241.9733 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	303.70 ft
Mudline Elev.*	303.70 ft
Lowest centerline Elev.	262.80 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	633356.9420	1427671.9820	11+20.99	633767.0817	1426628.7196	E 158.53863 N	1120.99		
Curve	11+20.99	633767.0817	1426628.7196	11+20.99	633767.0817	1426628.7196	E 158.53864 N	0.00	0.00	0.000 deg.
Tangent	11+20.99	633767.0817	1426628.7196	22+41.97	634177.2213	1425585.4571	E 158.53864 N	1120.99		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment

Plan Length, ft.	1120.99
Entry Azimuth, deg.^{5}	N 158.53863 E
Entry Azimuth, rad.^{5}	2.76702
Calculate PCH	`
PCH Easting	633767.0817
PCH Northing	1426628.7196
Cum Plan Length	1120.99

Horizontal Curve Segment

Input Radius, ft.	0.00
Curve, deg	0.000 deg.
Curve, rad	0.00000
Calculate PTH	
Chord Length, ft.	0.00
Arc Length, ft.	0.00
Chord Azimuth, deg	158.5386
PI Easting =	633767.0817
PI Northing =	1426628.7196
PTH Easting =	633767.0817
PTH Northing =	1426628.7196
Cum Plan Length	1120.99

Exit Tangent Segment

Plan Length, ft.	1120.99
Exit Azimuth, deg.^{5}	N 158.53864 E
Exit Azimuth, rad.^{5}	2.76702
Calculate Exit	
Easting	634177.2213
Northing	1425585.4571
Cum Plan Length	2241.973302

Check
Delta
0.0000
0.0000
OK CALC

Exit Station
22+41.97
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	309.50 ft	281.03 ft	-10.00 deg	-10.00 deg	0.00 deg	163.95 ft	0.00 ft
Entry Curve	281.03 ft	262.80 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	262.80 ft	262.80 ft	0.00 deg	0.00 deg	0.00 deg	1553.59 ft	0.00 ft
Exit Curve	262.80 ft	289.02 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	289.02 ft	303.70 ft	12.00 deg	12.00 deg	0.00 deg	70.59 ft	0.00 ft
					Total Check =	2248.90 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 Angle	-12.000 deg.
Calculate Vertical PCV	
Plan Length	69.050 ft
Rod Length	70.593 ft
Vertical Depth	-14.677 ft
Start Elevation	303.700 ft
End Elevation	289.023 ft
End Vert Angle	-12.000 deg

Entry Vert. Curve Segment 2

Vertical Radius	1200.00
Vert. Curve, deg.	12.000 deg.
Calculate Vertical PTV	
Plan Length	249.494 ft
Arc Rod Length	251.327 ft
Curve Δ Vert Depth	-26.223 ft
Lowest Elevation	262.800 ft
Start Elevation	289.023 ft
End Elevation	262.800 ft
End Vert Angle	0.000 deg

Middle Tangent Segment 3

End Vert Angle	0.000 deg.
Inclined Bottom Tan	NO
Calculate Vertical PCV	
Plan Length	1,553.59359 ft
Rod Length	1,553.59359 ft
Vertical Depth	0.00000 ft
Start Elevation	262.800 ft
End Elevation	262.800 ft
End Vert Angle	0.000 deg

Exit Vert. Curve Segment 4

Radius	1200.00
Angle Change	10.000 deg.
Calculate Vertical PTV	
Plan Length	208.378 ft
Arc Rod Length	209.440 ft
Curve Δ Vert Depth	18.231 ft
Lowest Elevation	262.800 ft
Start Elevation	262.800 ft
End Elevation	281.031 ft
End Vert Angle	10.000 deg

Exit Tangent Segment 5

Exit Elevation	309.50
Design Exit Angle	10.00 deg
Calculate Exit	
Plan Length	161.457 ft
Rod Length	163.948 ft
Vertical Depth	28.469 ft
CK Total Cum Depth	5.800 ft
Start Elevation	281.031 ft
Ck Exit Elevation	
Prop. Plan Length	***2241.973302***

SUMS

2,241.973 ft
2,248.902 ft
5.800 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+69.05	Start Station	3+18.54	Start Station	18+72.14	Start Station	20+80.52
PVC Station	0+69.05	PTV Station	3+18.54	PCV Station	18+72.14	PTV Station	20+80.52	Exit Station	22+41.973
Cum Plan Length	69.05	Cum Plan Length	318.54	Cum Plan Length	1872.14 ft	Cum Plan Length	2080.52	Cum Plan Length	2241.97
Cum Rod Length	70.59	Cum Rod Length	321.92	Cum Rod Length	1875.51 ft	Cum Rod Length	2084.95	Cum Rod Length	2248.90
Cum Depth	-14.68	Cum Depth	-40.90	Cum Depth	-40.90 ft	Cum Depth	-22.6693	Cum Depth	5.80

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

Summary of Drill Calculations

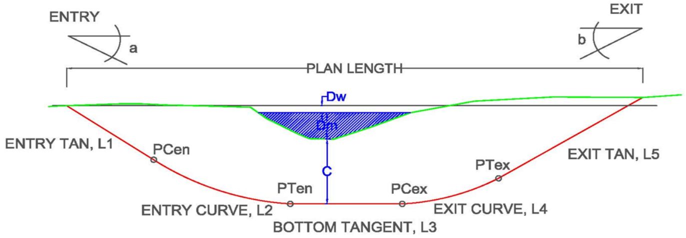
Entry to Exit Elevation Change =	**5.80 ft**
Minimum Design Elevation =	**262.80 ft**
Invert Depth below exit =	**46.70 ft**
Invert Depth below entry =	**40.90 ft**
Path Length =	**2,248.90 ft**
Plan Length =	**2,241.97 ft**
Minimum Plan Length (No Tangent) =	**688.38 ft**
Entry Angle =	**-12.00 deg**
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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167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 75A Conduit #2
Stream Crossing

Revision 1 TBD

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Pull Geometry

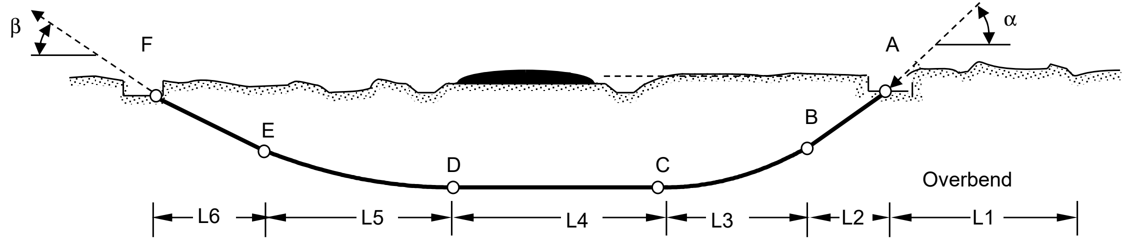
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	163.9 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	1553.6 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	70.6 ft	β =	12.0 °	0.2094	
LT =	2348.9 ft				

Pipe Entry Location - Drill | **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 303.70 ft

Pipe Entry El = 309.50 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	
Pipe/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 =	0.685	4%	
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 =	304.50 ft	
Ballast Water El., H_W =	304.50 ft	
Lowest Invert El., El_m =	262.80 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	4,149 lb	182 psi	OK	4,149 lb	182 psi	OK	OK	OK
B	5,437 lb	137 psi	OK	5,687 lb	143 psi	OK	OK	OK
C	7,205 lb	214 psi	OK	6,565 lb	198 psi	OK	OK	OK
D	14,643 lb	369 psi	OK	14,002 lb	353 psi	OK	OK	OK
E	20,092 lb	539 psi	OK	17,038 lb	462 psi	OK	OK	OK
F	19,067 lb	481 psi	OK	16,826 lb	424 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 75.33 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}{}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	87.24 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.863497337	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.234329323	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	539 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	4.52	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	22.59	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

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

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.39 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

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

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

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Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75A Conduit #2
Stream Crossing

Revision 1 TBD

TABLE 4 Pg 1 of 3

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HDPE PROPERTIES

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

HDD 75A Conduit #2
Stream Crossing

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	4710 HDPE	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" or 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 =	15.68	Lb/LF		
Tensile Yield, Ty psi =	3,500 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638	
Load Duration	**Short Term**	**Long Term**		
Duration Time	10 hours	50 yrs		
Design Temperature, °F	73 deg F	73 deg F	Assumed	
Design Ovality, %	2%	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	0.84	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 forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Shee
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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

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

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

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

HDD 75A Conduit #2
Stream Crossing

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 46.70 ft

Ballast depth to invert, H_B 40.90 ft

Drill Fluid depth to invert, H_{DF} 40.90 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	17.92 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	22.40 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	22.97 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	17.92 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 = $(P_A+P_a)-P_{DF1}$	84.58 psi	23.68 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	84.00 psi	23.11 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.50 psi	41.60 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.92 psi	41.03 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	89.06 psi	28.16 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 **Pg 3 of 3**

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 75A Conduit #2
Stream Crossing

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

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

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

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

(ASTM F-1962 EQ. 22)

Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 1,400 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.86350
$r = \sigma_i / 2 * (SSAS)$ = 0.23433
Example from Table T5, σ_i = 539 psi
P_{CRR} = 230.9 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 115.5 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 93.07 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 92.49 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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

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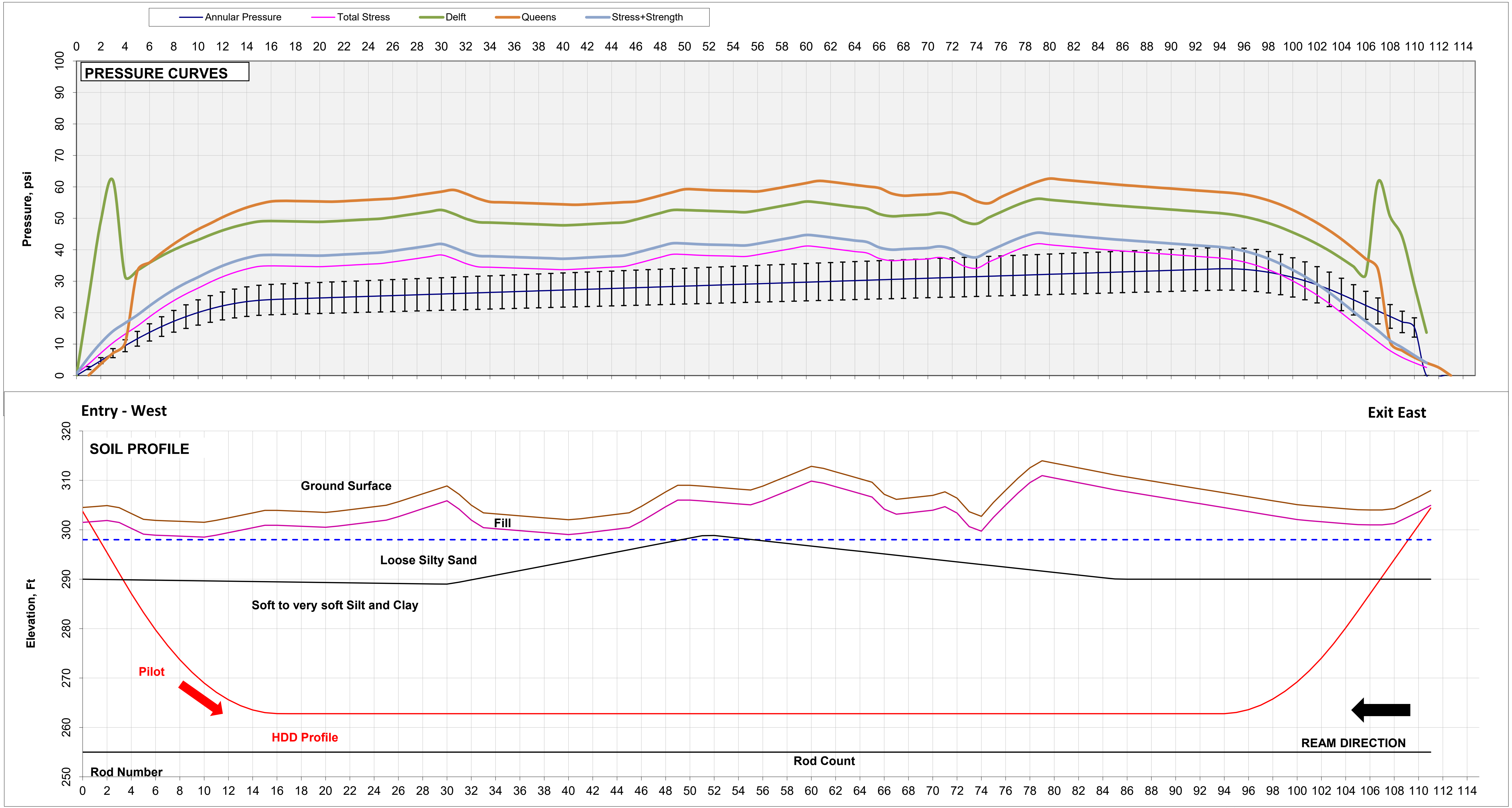

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Notes:

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
100 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs

K-180.8
B180.9-1
K-181.0
SCPT22-180.9
CPT22-181.1

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75A Conduit #2
Stream Crossing

Revision 1

FIGURE 1

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75A Conduit #2**
Stream Crossing

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: 1-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
2/27/2023	1	Issued for Construction	ABL

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	22+41.97	FT

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

	East	North	Elevation
Entry	633356.9420	1427671.9820	303.70 ft
Horizontal Curve PI	633767.0817	1426628.7196	
Exit	634177.2213	1425585.4571	309.50 ft
Depth to Mudline	0.00 ft	Clearance Depth =	40.90 ft
Measured Plan Length at ties =	2241.9733 ft		
Coordinate Length =	2241.9733 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	303.70 ft
Mudline Elev.*	303.70 ft
Lowest centerline Elev.	262.80 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	633356.9420	1427671.9820	11+20.99	633767.0817	1426628.7196	E 158.53863 N	1120.99		
Curve	11+20.99	633767.0817	1426628.7196	11+20.99	633767.0817	1426628.7196	E 158.53864 N	0.00	0.00	0.000 deg.
Tangent	11+20.99	633767.0817	1426628.7196	22+41.97	634177.2213	1425585.4571	E 158.53864 N	1120.99		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1120.99	Input Radius, ft.	0.00	Plan Length, ft.	1120.99	
Entry Azimuth, deg.^{5}	N 158.53863 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 158.53864 E	
Entry Azimuth, rad.^{5}	2.76702	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.76702	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	634177.2213	*Check*
PCH Easting	633767.0817	Arc Length, ft.	0.00	Northing	1425585.4571	*Delta*
PCH Northing	1426628.7196	Chord Azimuth, deg	158.5386			0.0000
		PI Easting =	633767.0817			0.0000
		PI Northing =	1426628.7196			OK CALC
		PTH Easting =	633767.0817			
		PTH Northing =	1426628.7196			Exit Station
						22+41.97
Cum Plan Length	1120.99	Cum Plan Length	1120.99	Cum Plan Length	2241.973302	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	309.50 ft	281.03 ft	-10.00 deg	-10.00 deg	0.00 deg	163.95 ft	0.00 ft
Entry Curve	281.03 ft	262.80 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	262.80 ft	262.80 ft	0.00 deg	0.00 deg	0.00 deg	1553.59 ft	0.00 ft
Exit Curve	262.80 ft	289.02 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	289.02 ft	303.70 ft	12.00 deg	12.00 deg	0.00 deg	70.59 ft	0.00 ft
					Total Check =	2248.90 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	309.50	
		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	69.050 ft	Plan Length	249.494 ft	Plan Length	1,553.59359 ft	Plan Length	208.378 ft	Plan Length	161.457 ft	2,241.973 ft
Rod Length	70.593 ft	Arc Rod Length	251.327 ft	Rod Length	1,553.59359 ft	Arc Rod Length	209.440 ft	Rod Length	163.948 ft	2,248.902 ft
Vertical Depth	-14.677 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	28.469 ft	5.800 ft
		Lowest Elevation	262.800 ft			Lowest Elevation	262.800 ft	CK Total Cum Depth	5.800 ft	
Start Elevation	303.700 ft	Start Elevation	289.023 ft	Start Elevation	262.800 ft	Start Elevation	262.800 ft	Start Elevation	281.031 ft	
End Elevation	289.023 ft	End Elevation	262.800 ft	End Elevation	262.800 ft	End Elevation	281.031 ft	Ck Exit Elevation		
End Vert Angle	-12.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*2241.973302*	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+69.05	Start Station	3+18.54	Start Station	18+72.14	Start Station	20+80.52	**OK STATIONING**
PVC Station	0+69.05	PTV Station	3+18.54	PCV Station	18+72.14	PTV Station	20+80.52	Exit Station	22+41.973	**Plan Length Check**
Cum Plan Length	69.05	Cum Plan Length	318.54	Cum Plan Length	1872.14 ft	Cum Plan Length	2080.52	Cum Plan Length	2241.97	**OK CALCULATION**
Cum Rod Length	70.59	Cum Rod Length	321.92	Cum Rod Length	1875.51 ft	Cum Rod Length	2084.95	Cum Rod Length	2248.90	**Elevation Change Check**
Cum Depth	-14.68	Cum Depth	-40.90	Cum Depth	-40.90 ft	Cum Depth	-22.6693	Cum Depth	5.80	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**5.80 ft**
Minimum Design Elevation =	**262.80 ft**
Invert Depth below exit =	**46.70 ft**
Invert Depth below entry =	**40.90 ft**
Path Length =	**2,248.90 ft**
Plan Length =	**2,241.97 ft**
Minimum Plan Length (No Tangent) =	**688.38 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

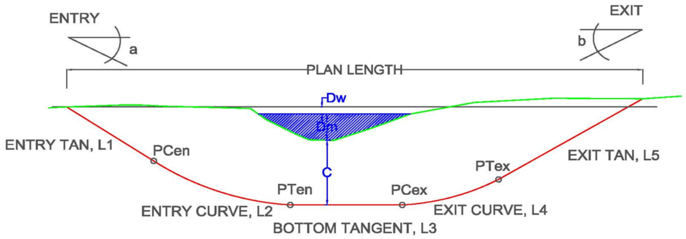
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 75A Conduit #2
Stream 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 =	163.9 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	1553.6 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	70.6 ft	β =	12.0 °	0.2094	
LT =	2348.9 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	
Pipe/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 =	0.685	4%	
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 =	304.50 ft	
Ballast Water El., H_W =	304.50 ft	
Lowest Invert El., El_m =	262.80 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 =	0.39 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

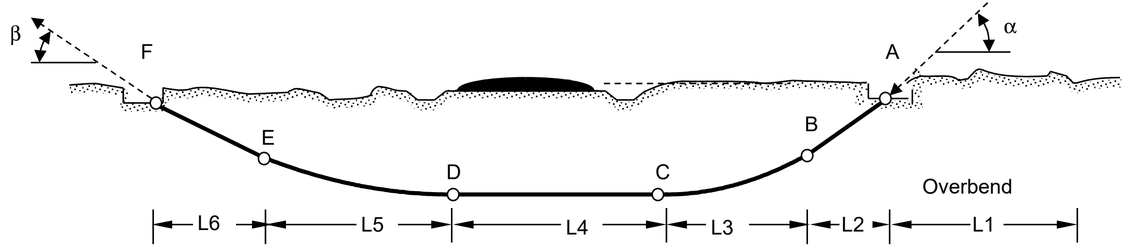
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 303.70 ft

Pipe Entry El = 309.50 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	Ballast
A	4,149 lb	182 psi	OK	4,149 lb	182 psi	OK	OK	OK
B	5,437 lb	137 psi	OK	5,687 lb	143 psi	OK	OK	OK
C	7,205 lb	214 psi	OK	6,565 lb	198 psi	OK	OK	OK
D	14,643 lb	369 psi	OK	14,002 lb	353 psi	OK	OK	OK
E	20,092 lb	539 psi	OK	17,038 lb	462 psi	OK	OK	OK
F	19,067 lb	481 psi	OK	16,826 lb	424 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **P_{PA} > ΔP invert** **$P_{PA} = P_AF_R$ =** 75.33 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	87.24 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.863497337	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.234329323	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	539 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	4.52	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	22.59	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. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75A Conduit #2
Stream Crossing

Revision 1 TBD

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 75A Conduit #2

Stream 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	4710 HDPE		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" or 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 =	15.68	Lb/LF	
Tensile Yield, Ty psi =	3,500 psi	@73°F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, °F	73 deg F	73 deg F	Assumed
Design Ovality, %	2%	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	0.84	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 forces

Dry Weight Pipe on ground, W_P =	15.68 lb/ft	From MFG. Data Shee
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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

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

TABLE 4

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HDPE PROPERTIES

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

HDD 75A Conduit #2
Stream Crossing

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	46.70 ft	Ballast depth to invert, H_B	40.90 ft	Drill Fluid depth to invert, H_{DF}	40.90 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	17.92 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	22.40 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	22.97 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	17.92 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 = $(P_A+P_a)-P_{DF1}$	84.58 psi	23.68 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	84.00 psi	23.11 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.50 psi	41.60 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.92 psi	41.03 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	89.06 psi	28.16 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.

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#75A CIR #2_APC_20221023.xlsb]Cover

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

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HDD 75A Conduit #2

Stream Crossing

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

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y 0.4

Temperature factor, f_{temp} = 1

Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi

Safe Allowable Stress, SAS = 1,400 psi SAS = $Ty*f_{temp}*DF$

Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1

Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 50,200 lb

Ultimate Pull Strength, UPS = 125,499 lb

Suggested SSAS = 1,150 psi

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

SAS = 1,400 psi

Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum

fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.86350

r = σ_i/2*(SSAS) = 0.23433

P_{CRR} = 230.9 psi

FS = 2.0

$P_{ACRR} = P_{CRR}/FS$ = 115.5 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 93.07 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 92.49 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi

Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 539 psi

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

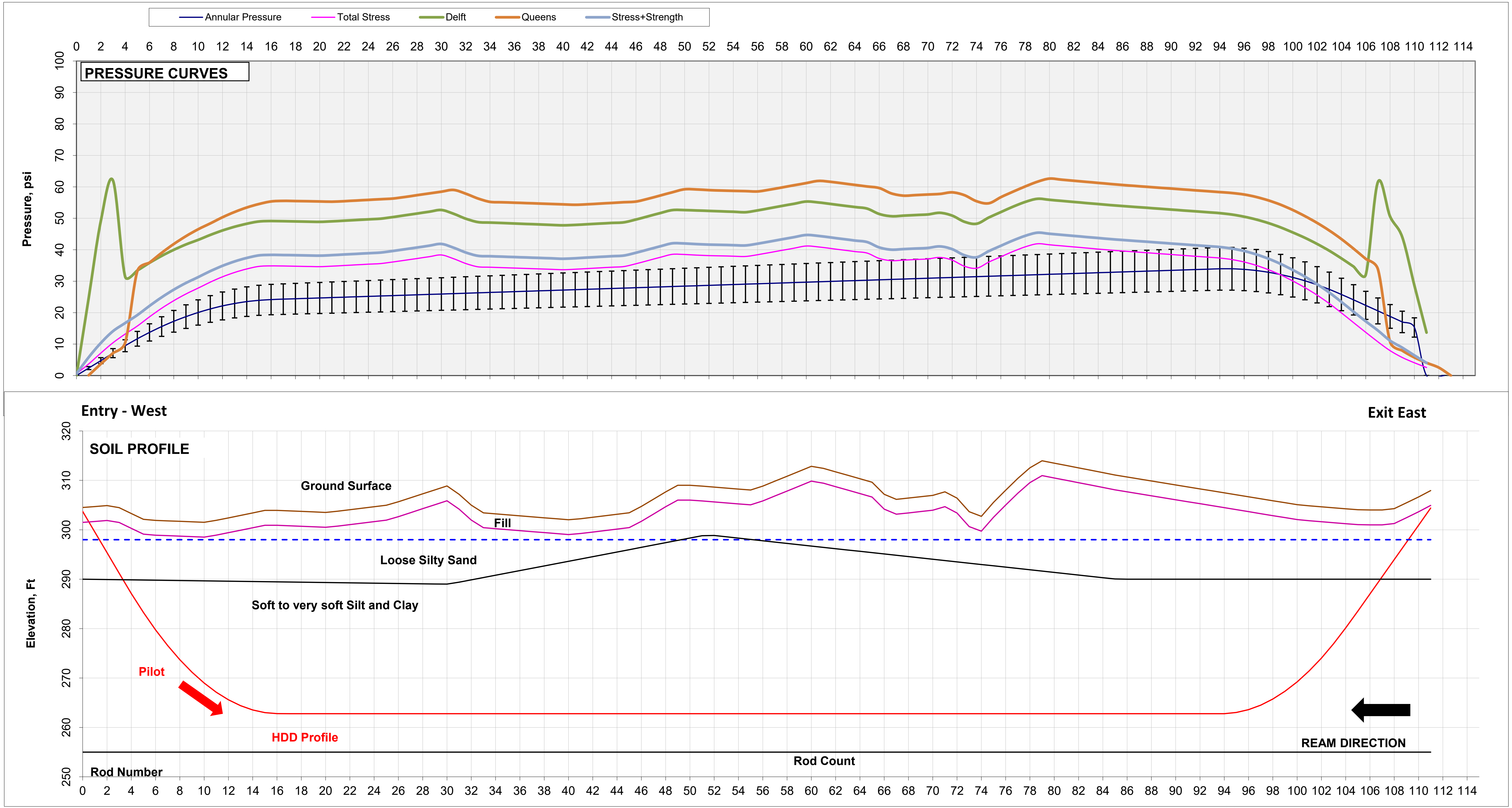
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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



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
100 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs
K-180.8
B180.9-1
K-181.0
SCPT22-180.9
CPT22-181.1

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Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75A Conduit #2
Stream Crossing

Revision 1

FIGURE 1

BRIERLEY ASSOCIATES
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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75A.A Circuit #1**
Wetlands Crossing

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	7+00.14	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	632014.7979	1430913.2356	299.40 ft
Horizontal Curve PI	631881.3518	1431236.3518	
Exit	631747.9057	1431560.5062	305.40 ft
Depth to Mudline	0.00 ft	Clearance Depth =	28.00 ft
Measured Plan Length at ties =	700.1363 ft		
Coordinate Length =	700.1363 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	299.00 ft
Mudline Elev.*	299.40 ft
Lowest centerline Elev.	271.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	632014.7979	1430913.2356	3+49.59	631881.3518	1431236.3518	E 337.55951 N	349.59		
Curve	3+49.59	631881.3518	1431236.3518	3+49.59	631881.3518	1431236.3518	E 337.62428 N	0.00	0.00	0.065 deg.
Tangent	3+49.59	631881.3518	1431236.3518	7+00.14	631747.9057	1431560.5062	E 337.62428 N	350.55		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	349.59	Input Radius, ft.	0.00	Plan Length, ft.	350.55	
Entry Azimuth, deg.^{5}	N 337.55951 E	Curve, deg	0.065 deg.	Exit Azimuth, deg.^{5}	N 337.62428 E	
Entry Azimuth, rad.^{5}	5.89152	Curve, rad	0.00113	Exit Azimuth, rad.^{5}	5.89266	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	631747.9057	**Check**
PCH Easting	631881.3518	Arc Length, ft.	0.00	Northing	1431560.5062	**Delta**
PCH Northing	1431236.3518	Chord Azimuth, deg	337.5919			**0.0000**
		PI Easting =	631881.3518			**0.0000**
		PI Northing =	1431236.3518			**OK CALC**
		PTH Easting =	631881.3518			
		PTH Northing =	1431236.3518			**Exit Station**
						7+00.14
Cum Plan Length	349.59	Cum Plan Length	349.59	Cum Plan Length	700.1362958	**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	305.40 ft	289.63 ft	-10.00 deg	-10.00 deg	0.00 deg	90.81 ft	0.00 ft
Entry Curve	289.63 ft	271.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	271.40 ft	271.40 ft	0.00 deg	0.00 deg	0.00 deg	165.49 ft	0.00 ft
Exit Curve	271.40 ft	293.25 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	293.25 ft	299.40 ft	12.00 deg	12.00 deg	0.00 deg	29.57 ft	0.00 ft
					Total Check =	**704.75 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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	305.40	
		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	28.922 ft	Plan Length	207.912 ft	Plan Length	165.49244 ft	Plan Length	208.378 ft	Plan Length	89.432 ft	700.136 ft
Rod Length	29.568 ft	Arc Rod Length	209.440 ft	Rod Length	165.49244 ft	Arc Rod Length	209.440 ft	Rod Length	90.812 ft	704.752 ft
Vertical Depth	-6.148 ft	Curve Δ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	15.769 ft	6.000 ft
		Lowest Elevation	271.400 ft			Lowest Elevation	271.400 ft	CK Total Cum Depth	6.000 ft	
Start Elevation	299.400 ft	Start Elevation	293.252 ft	Start Elevation	271.400 ft	Start Elevation	271.400 ft	Start Elevation	289.631 ft	
End Elevation	293.252 ft	End Elevation	271.400 ft	End Elevation	271.400 ft	End Elevation	289.631 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***	***700.1362958***	

SUMMARY VERTICLE CURVE CALCULATIONS

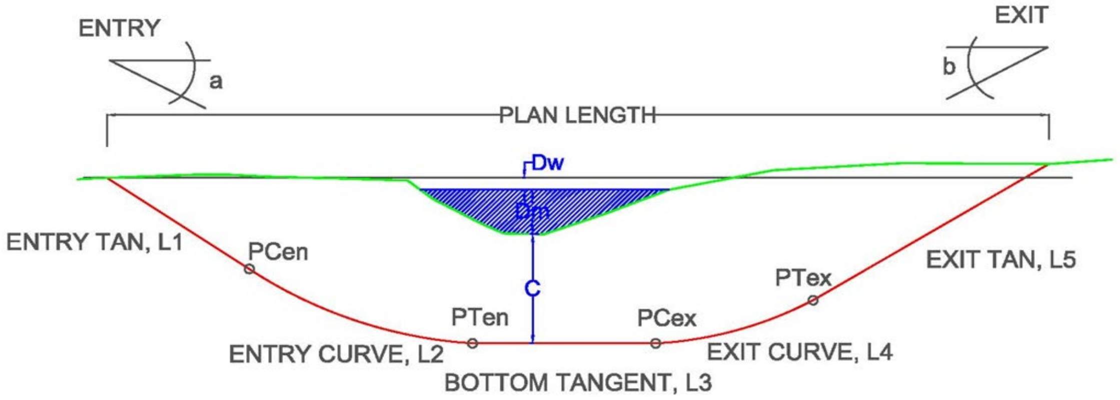
										Stationing Check
Start Station	0+00.00	Start Station	0+28.92	Start Station	2+36.83	Start Station	4+02.33	Start Station	6+10.70	**OK STATIONING**
PVC Station	0+28.92	PTV Station	2+36.83	PCV Station	4+02.33	PTV Station	6+10.70	Exit Station	7+00.136	**Plan Length Check**
Cum Plan Length	28.92	Cum Plan Length	236.83	Cum Plan Length	402.33 ft	Cum Plan Length	610.70	Cum Plan Length	700.14	**OK CALCULATION**
Cum Rod Length	29.57	Cum Rod Length	239.01	Cum Rod Length	404.50 ft	Cum Rod Length	613.94	Cum Rod Length	704.75	**Elevation Change Check**
Cum Depth	-6.15	Cum Depth	-28.00	Cum Depth	-28.00 ft	Cum Depth	-9.7693	Cum Depth	6.00	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change = 6.00 ft
Minimum Design Elevation = 271.40 ft
Invert Depth below exit = 34.00 ft
Invert Depth below entry = 28.00 ft
Path Length = 704.75 ft
Plan Length = 700.14 ft
Minimum Plan Length (No Tangent) = 534.64 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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167 S. River Road, Suite 8
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Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 75A.A Circuit #1
Wetlands Crossing

Revision 1
TBD

Pull Geometry

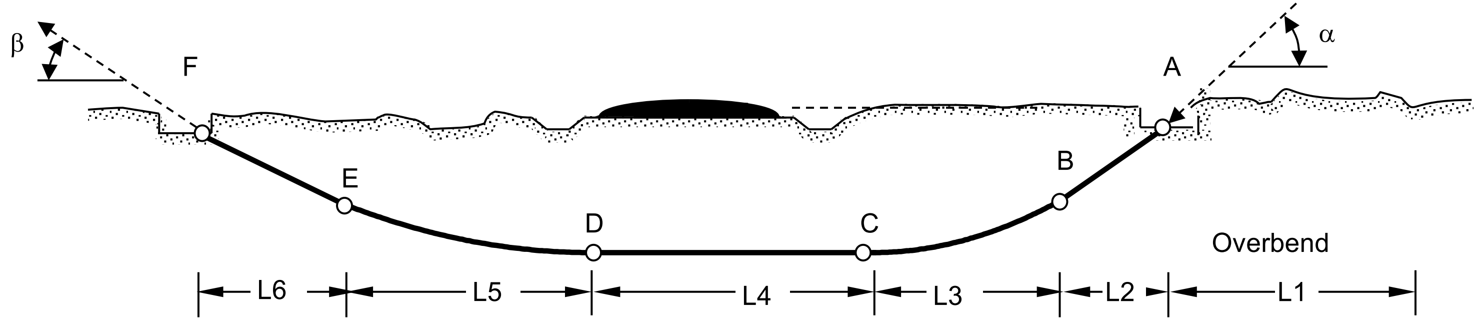
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	90.8 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	165.5 ft	χ =	0.0 ˚	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	29.6 ft	β =	12.0 ˚	0.2094	
LT =	804.8 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 299.40 ft

Pipe Entry El = 305.40 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	
Pipe/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 =	0.685	4%	
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 =	299.40 ft		
Ballast Water El., H_W =	299.40 ft		
Lowest Invert El., El_m =	271.40 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 =	1.25 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							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	Ballast
A	1,422 lb	113 psi	OK	1,422 lb	113 psi	OK	OK	OK
B	2,113 lb	53 psi	OK	2,217 lb	56 psi	OK	OK	OK
C	3,733 lb	126 psi	OK	2,941 lb	106 psi	OK	OK	OK
D	4,001 lb	101 psi	OK	3,209 lb	81 psi	OK	OK	OK
E	8,101 lb	243 psi	OK	5,284 lb	172 psi	OK	OK	OK
F	8,734 lb	220 psi	OK	5,576 lb	141 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, P_{PA} > ΔP invert **$P_{PA} = P_AF_R$ =** 82.42 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	87.24 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.944815242	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.105628258	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	243 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	3.03	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	15.17	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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75A.A Circuit #1
Wetlands Crossing

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75A.A CIR #1_APC_20221024.xlsb]T3 Plastic Pull

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 75A.A Circuit #1
Wetlands Crossing

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification	445574C	Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	3		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.000 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	2.675 in	Standard Manufacturer's Data Sheets	
Minimum Wall, t_{min} =	0.389 in	Standard Manufacturer's Data Sheets	
Wall Section Area, A_W =	3.190849685	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
Unit OD Surface Area, in^2/LF, A_{OD} =	113.10 in^2/LF	$A_{OD} = 12*\pi*D_{OD}$	
Unit Outside Volume, V_{Do} =	0.049 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 =	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	0.84	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} =	-2.17 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-2.27 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	0.27 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	0.17 lb/ft	$BG-W_{D2}$

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} =	3.83 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	3.93 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

TABLE 4

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 75A.A Circuit #1

Wetlands Crossing

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 = 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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 34.00 ft

Ballast depth to invert, H_B 28.00 ft

Drill Fluid depth to invert, H_{DF} 28.00 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi

Full Ballast, $P_B = \gamma_{INT}^*(H_B+D_o/24)/144$ 12.19 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}^*(H_{MDF}+D_o/24)/144$ 15.23 psi

Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}^*(H_{MDF}+D_o/24)/144$ 15.63 psi

Water, $P_W = \gamma_{INT}^*(H_{DF}+D_o/24)/144$ 12.19 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 = $(P_A+P_a)-P_{DF1}$	91.74 psi	30.85 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.35 psi	30.46 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.93 psi	43.03 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.54 psi	42.64 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.79 psi	33.89 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 **Pg 3 of 3**

HDPE PROPERTIES

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

HDD 75A.A Circuit #1
Wetlands Crossing

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

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

Designed Pull Duration Time = 12 hr
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF
Safe Pull Strength, SPS Pipe = 3,910 lb **Useing SSAS = 3,211 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.
SAFE PULL STRENTH, SPS = 3,910 lb
Ultimate Pull Strength, UPS = 9,774 lb
Suggested SSAS = 1,150 psi

Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR} * f_r$
(ASTM F-1962 EQ. 22)

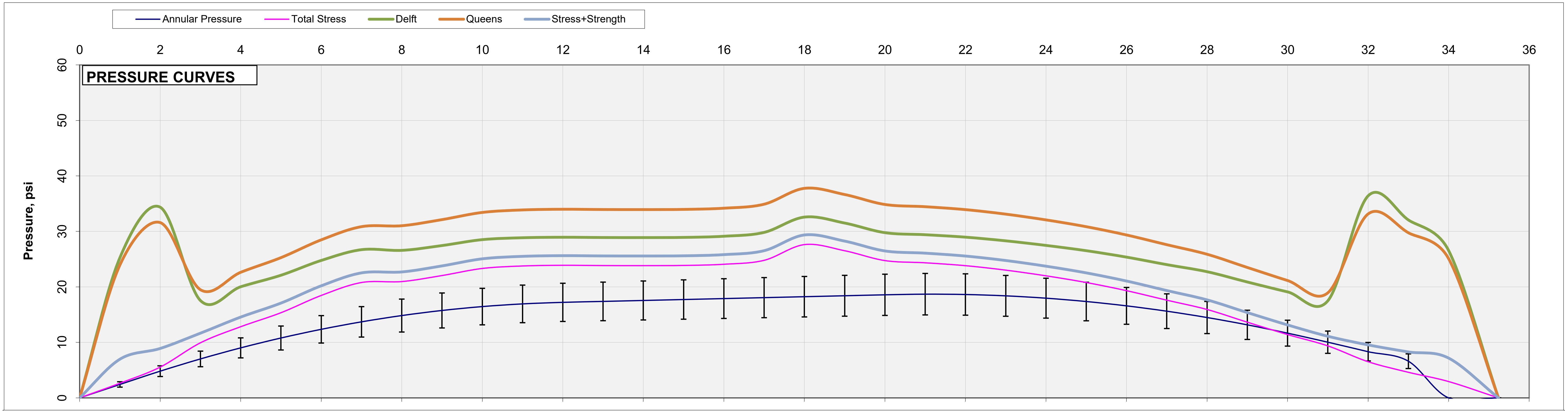
Pull Duration Time = 12 Hr
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.94482
r = σ_i/2*(SSAS) = 0.10563
P_{CRR} = 252.7 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 126.3 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} = 111.11 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} = 110.71 psi Pull Back Condition - Option 4 **OK as >0**

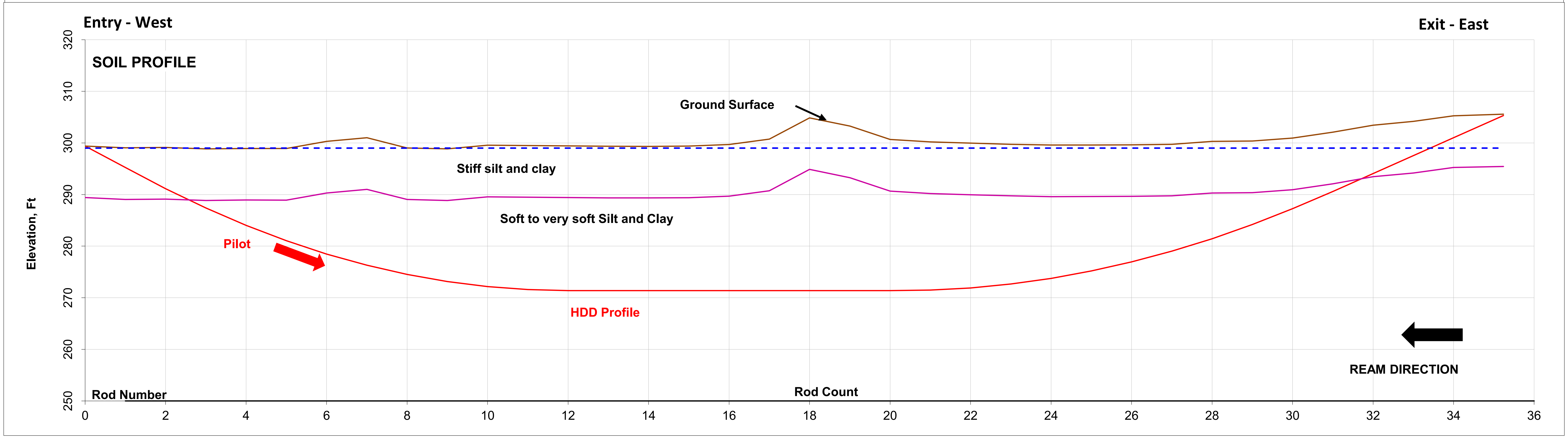
Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 243 psi

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 annular pressure calculations

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

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75A.A Circuit #1
Wetlands Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75A.A CIR #1_APC_20221024.xlsb]T3 Plastic Pull

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75A.A Circuit #2**
Wetlands Crossing

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	6+95.43	FT

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

	East	North	Elevation
Entry	632014.7979	1430918.9294	299.00 ft
Horizontal Curve PI	631895.2242	1431242.5768	
Exit	631747.9057	1431560.5062	303.70 ft
Depth to Mudline	0.00 ft	Clearance Depth =	27.60 ft

Measured Plan Length at ties = 695.4321 ft
Coordinate Length = 695.4321 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	299.00 ft
Mudline Elev.*	299.00 ft
Lowest centerline Elev.	271.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	632014.7979	1430918.9294	3+45.03	631895.2242	1431242.5768	E 339.72291 N	345.03		
Curve	3+45.03	631895.2242	1431242.5768	3+45.03	631895.2242	1431242.5768	E 335.13847 N	0.00	0.00	-4.584 deg.
Tangent	3+45.03	631895.2242	1431242.5768	6+95.43	631747.9057	1431560.5062	E 335.13847 N	350.40		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	345.03	Input Radius, ft.	0.00	Plan Length, ft.	350.40	
Entry Azimuth, deg.[5]	N 339.72291 E	Curve, deg	-4.584 deg.	Exit Azimuth, deg.[5]	N 335.13847 E	
Entry Azimuth, rad.[5]	5.92928	Curve, rad	-0.08001	Exit Azimuth, rad.[5]	5.84927	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	631747.9057	**Check**
PCH Easting	631895.2242	Arc Length, ft.	0.00	Northing	1431560.5062	**Delta**
PCH Northing	1431242.5768	Chord Azimuth, deg	337.4307			**0.0000**
		PI Easting =	631895.2242			**0.0000**
		PI Northing =	1431242.5768			**OK CALC**
		PTH Easting =	631895.2242			
		PTH Northing =	1431242.5768			**Exit Station**
						6+95.43
Cum Plan Length	345.03	Cum Plan Length	345.03	Cum Plan Length	695.432125	**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	303.70 ft	289.63 ft	-10.00 deg	-10.00 deg	0.00 deg	81.02 ft	0.00 ft
Entry Curve	289.63 ft	271.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	271.40 ft	271.40 ft	0.00 deg	0.00 deg	0.00 deg	172.31 ft	0.00 ft
Exit Curve	271.40 ft	293.25 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	293.25 ft	299.00 ft	12.00 deg	12.00 deg	0.00 deg	27.64 ft	0.00 ft
					Total Check =	**699.86 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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	303.70	
		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	27.040 ft	Plan Length	207.912 ft	Plan Length	172.31130 ft	Plan Length	208.378 ft	Plan Length	79.791 ft	695.432 ft
Rod Length	27.644 ft	Arc Rod Length	209.440 ft	Rod Length	172.31130 ft	Arc Rod Length	209.440 ft	Rod Length	81.022 ft	699.857 ft
Vertical Depth	-5.748 ft	Curve Δ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	14.069 ft	4.700 ft
		Lowest Elevation	271.400 ft			Lowest Elevation	271.400 ft	CK Total Cum Depth	4.700 ft	
Start Elevation	299.000 ft	Start Elevation	293.252 ft	Start Elevation	271.400 ft	Start Elevation	271.400 ft	Start Elevation	289.631 ft	
End Elevation	293.252 ft	End Elevation	271.400 ft	End Elevation	271.400 ft	End Elevation	289.631 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*	695.432125	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+27.04	Start Station	2+34.95	Start Station	4+07.26	Start Station	6+15.64	**OK STATIONING**
PVC Station	0+27.04	PTV Station	2+34.95	PCV Station	4+07.26	PTV Station	6+15.64	Exit Station	6+95.432	**Plan Length Check**
Cum Plan Length	27.04	Cum Plan Length	234.95	Cum Plan Length	407.26 ft	Cum Plan Length	615.64	Cum Plan Length	695.43	**OK CALCULATION**
Cum Rod Length	27.64	Cum Rod Length	237.08	Cum Rod Length	409.40 ft	Cum Rod Length	618.83	Cum Rod Length	699.86	**Elevation Change Check**
Cum Depth	-5.75	Cum Depth	-27.60	Cum Depth	-27.60 ft	Cum Depth	-9.3693	Cum Depth	4.70	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**4.70 ft**
Minimum Design Elevation =	**271.40 ft**
Invert Depth below exit =	**32.30 ft**
Invert Depth below entry =	**27.60 ft**
Path Length =	**699.86 ft**
Plan Length =	**695.43 ft**
Minimum Plan Length (No Tangent) =	**523.12 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

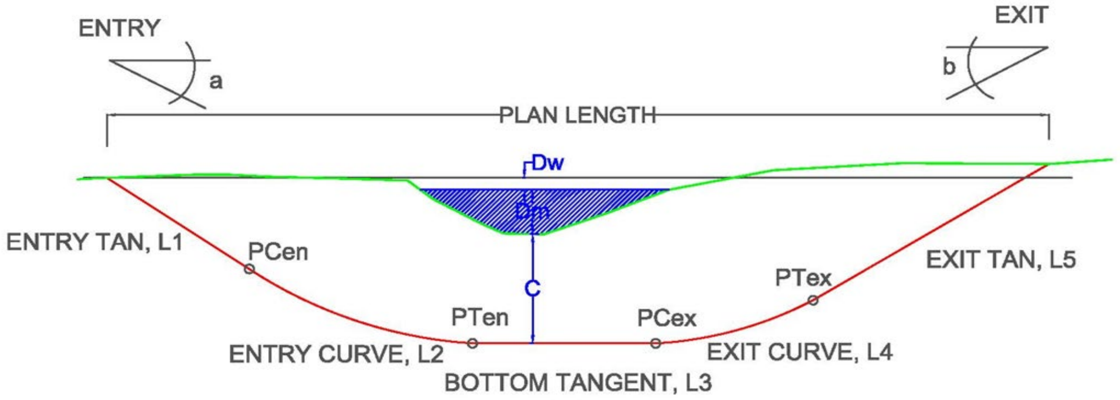
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 75A.A Circuit #2
Wetlands Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75A.A CIR #2_APC_20221024.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	81.0 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	172.3 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	27.6 ft	β =	12.0 °	0.2094	
LT =	799.9 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	
Pipe/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}	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 =	0.685	4%	
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 =	299.00 ft	
Ballast Water El., H_W =	299.00 ft	
Lowest Invert El., El_m =	7.00 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 =	0.94 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

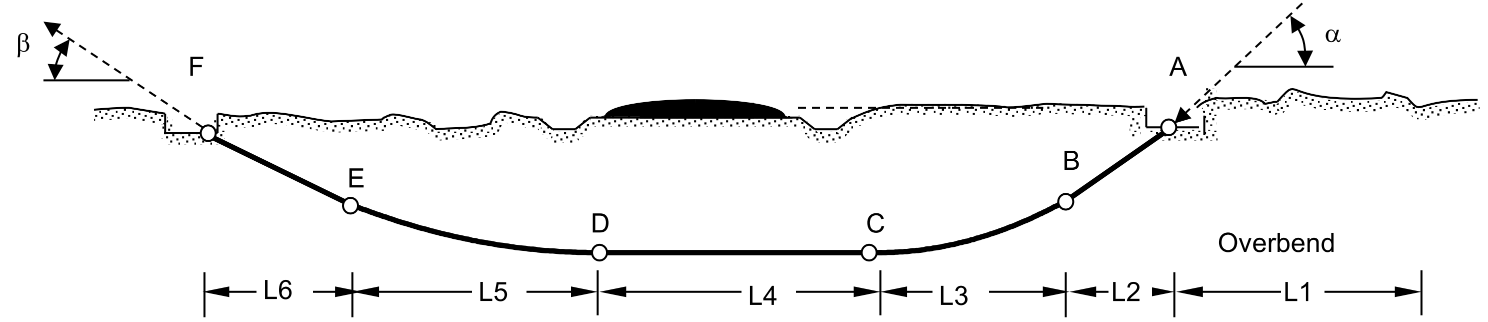
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill EXIT

(schematic, to show definition of variables only)

Pipe Exit El = 299.00 ft

Pipe Entry El = 303.70 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	1,278 lb	94 psi	OK	1,278 lb	94 psi	OK	OK	OK
B	1,863 lb	52 psi	OK	1,953 lb	54 psi	OK	OK	OK
C	3,237 lb	115 psi	OK	2,517 lb	94 psi	OK	OK	OK
D	3,515 lb	98 psi	OK	2,795 lb	78 psi	OK	OK	OK
E	7,128 lb	228 psi	OK	4,577 lb	157 psi	OK	OK	OK
F	7,651 lb	213 psi	OK	4,812 lb	134 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 82.75 psi

Ballasted	OK
No Ballast	REJECT

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	$SSPS = \sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	87.24 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.948629062	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.099113766	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	228 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	31.63	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	158.17	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

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

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75A.A Circuit #2
Wetlands Crossing

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75A.A CIR #2_APC_20221024.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 75A.A 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	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 =	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 =	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	0.84	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

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

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

Buoyant forces

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

TABLE 4 **Pg 2 of 3**

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HDPE PROPERTIES

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

HDD 75A.A Circuit #2
Wetlands Crossing

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	32.30 ft	Ballast depth to invert, H_B	27.60 ft	Drill Fluid depth to invert, H_{DF}	27.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	12.15 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	15.19 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	15.58 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	12.15 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 = $(P_A+P_a)-P_{DF1}$	91.78 psi	30.89 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.39 psi	30.50 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.94 psi	43.04 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.55 psi	42.65 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.82 psi	33.93 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

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HDD 75A.A Circuit #2
Wetlands Crossing

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

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

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

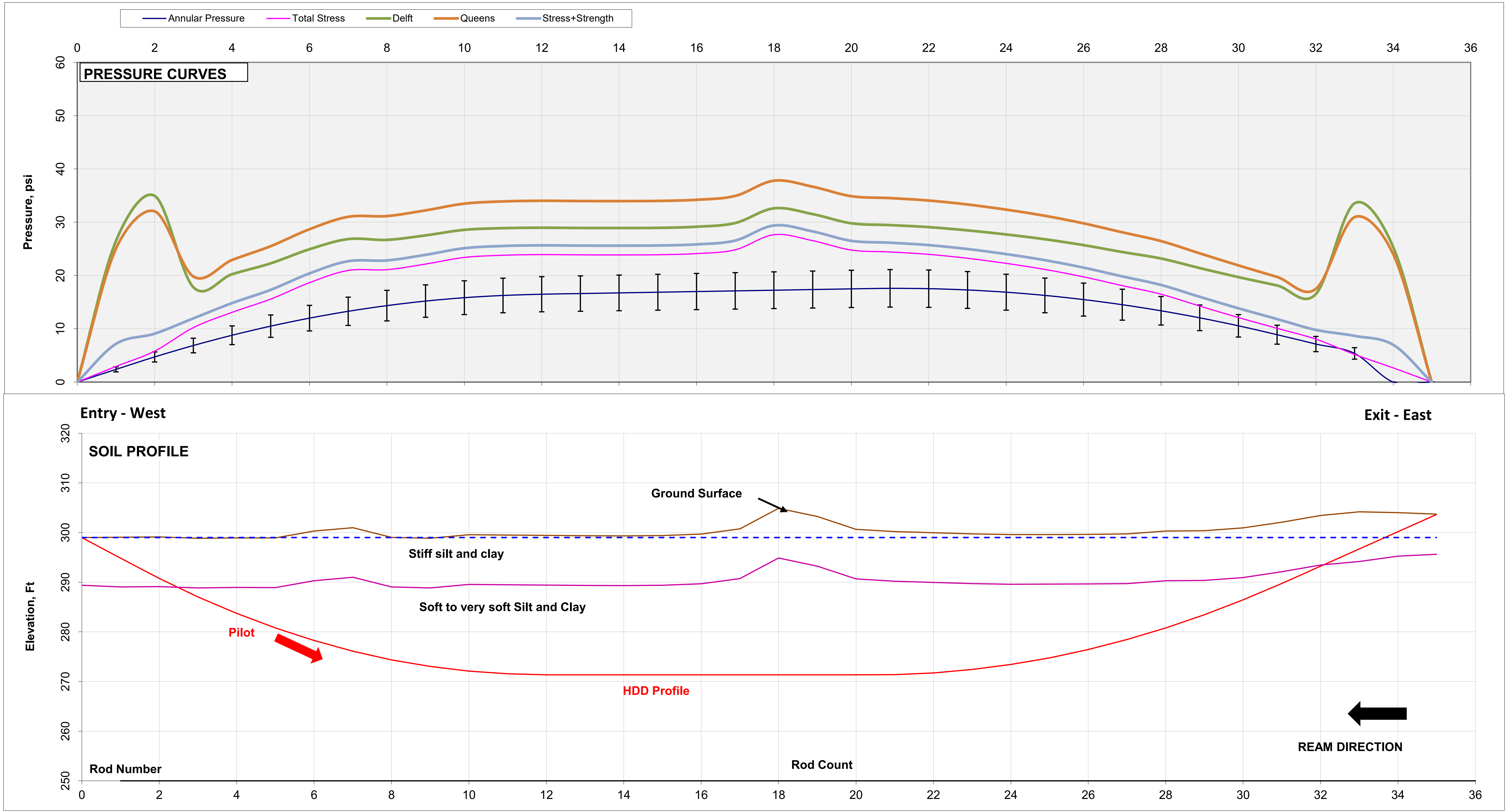
Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR} * f_r$
(ASTM F-1962 EQ. 22)

Pull Duration Time = 12 Hr — Pcr = 267.4 psi
SAS = 1,400 psi — Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi — Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.94863
r = σ_i/2*(SSAS) = 0.09911 — Example from Table T5, σ_i = 228 psi
P_{CRR} = 253.7 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 126.8 psi — Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 111.66 psi — Pull Back Condition - Option 3 — **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 111.27 psi — Pull Back Condition - Option 4 — **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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



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Notes:

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

Basis of annular pressure calculations

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

Print Date ; 3/13/2023 8:40

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75A.A Circuit #2
Wetlands Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75A.A CIR #2_APC_20221024.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75B Circuit #1**
Stream Crossing

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	7+29.24	FT

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

	East	North	Elevation
Entry	636678.8366	1419610.3196	291.40 ft
Horizontal Curve PI	636547.9285	1419950.6297	
Exit	636417.0205	1420290.9399	287.30 ft
Depth to Mudline	4.10 ft	Clearance Depth =	42.70 ft
Measured Plan Length at ties =	729.2405 ft		
Coordinate Length =	729.2405 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	276.00 ft
Mudline Elev.*	287.30 ft
Lowest centerline Elev.	244.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	636678.8366	1419610.3196	3+64.62	636547.9285	1419950.6297	E 338.95961 N	364.62		
Curve	3+64.62	636547.9285	1419950.6297	3+64.62	636547.9285	1419950.6297	E 338.95963 N	0.00	0.00	0.000 deg.
Tangent	3+64.62	636547.9285	1419950.6297	7+29.24	636417.0205	1420290.9399	E 338.95963 N	364.62		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	364.62	Input Radius, ft.	0.00	Plan Length, ft.	364.62	
Entry Azimuth, deg.^{5}	N 338.95961 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 338.95963 E	
Entry Azimuth, rad.^{5}	5.91596	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	5.91596	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	636417.0205	**Check**
PCH Easting	636547.9285	Arc Length, ft.	0.00	Northing	1420290.9399	**Delta**
PCH Northing	1419950.6297	Chord Azimuth, deg	338.9596			**0.0000**
		PI Easting =	636547.9285			**0.0000**
		PI Northing =	1419950.6297			**OK CALC**
		PTH Easting =	636547.9285			
						Exit Station
		PTH Northing =	1419950.6297			**7+29.24**
Cum Plan Length	364.62	Cum Plan Length	364.62	Cum Plan Length	729.2404699	**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	287.30 ft	259.79 ft	-10.00 deg	-10.00 deg	0.00 deg	158.41 ft	0.00 ft
Entry Curve	259.79 ft	244.60 ft	-10.00 deg	0.00 deg	10.00 deg	174.53 ft	1000.00 ft
Bottom Tangent	244.60 ft	244.60 ft	0.00 deg	0.00 deg	0.00 deg	109.89 ft	0.00 ft
Exit Curve	244.60 ft	279.46 ft	0.00 deg	16.00 deg	16.00 deg	251.33 ft	900.00 ft
Exit Tangent	279.46 ft	291.40 ft	16.00 deg	16.00 deg	0.00 deg	43.30 ft	0.00 ft
					Total Check =	**737.46 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	-16.000 deg.	Vertical Radius	900.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	287.30
		Vert. Curve, deg.	16.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	41.624 ft	Plan Length	248.074 ft	Plan Length	109.89033 ft	Plan Length	173.648 ft	Plan Length	156.004 ft
Rod Length	43.302 ft	Arc Rod Length	251.327 ft	Rod Length	109.89033 ft	Arc Rod Length	174.533 ft	Rod Length	158.411 ft
Vertical Depth	-11.936 ft	Curve Δ Vert Depth	-34.864 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	27.508 ft
		Lowest Elevation	244.600 ft			Lowest Elevation	244.600 ft	CK Total Cum Depth	-4.100 ft
Start Elevation	291.400 ft	Start Elevation	279.464 ft	Start Elevation	244.600 ft	Start Elevation	244.600 ft	Start Elevation	259.792 ft
End Elevation	279.464 ft	End Elevation	244.600 ft	End Elevation	244.600 ft	End Elevation	259.792 ft	Ck Exit Elevation	
End Vert Angle	-16.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	729.2404699

SUMS
729.240 ft
737.463 ft
-4.100 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+41.62	Start Station	2+89.70	Start Station	3+99.59	Start Station	5+73.24
PVC Station	0+41.62	PTV Station	2+89.70	PCV Station	3+99.59	PTV Station	5+73.24	Exit Station	7+29.240
Cum Plan Length	41.62	Cum Plan Length	289.70	Cum Plan Length	399.59 ft	Cum Plan Length	573.24	Cum Plan Length	729.24
Cum Rod Length	43.30	Cum Rod Length	294.63	Cum Rod Length	404.52 ft	Cum Rod Length	579.05	Cum Rod Length	737.46
Cum Depth	-11.94	Cum Depth	-46.80	Cum Depth	-46.80 ft	Cum Depth	-31.6078	Cum Depth	-4.10

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-4.10 ft**
Minimum Design Elevation =	**244.60 ft**
Invert Depth below exit =	**42.70 ft**
Invert Depth below entry =	**46.80 ft**
Path Length =	**737.46 ft**
Plan Length =	**729.24 ft**
Minimum Plan Length (No Tangent) =	**619.35 ft**
Entry Angle =	**-16.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

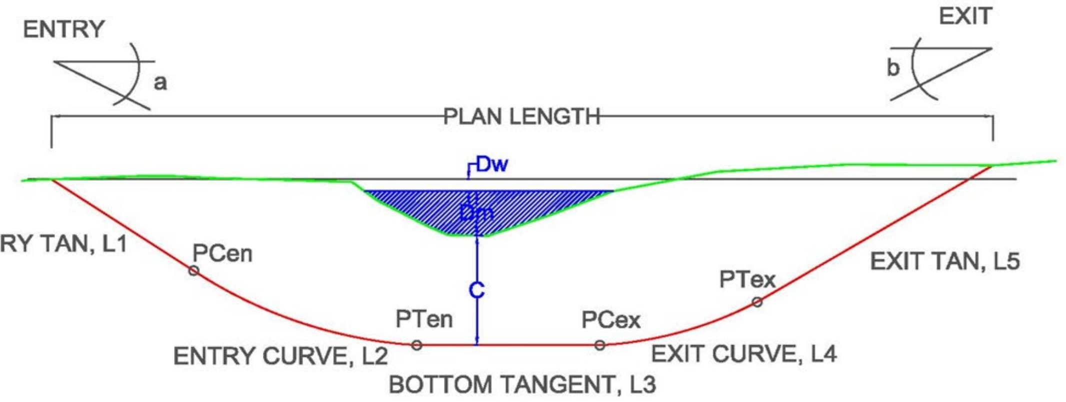
NOTES:

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:	**Issued for Construction (IFC)**

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 75B Circuit #1
Stream Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75B CIR #1_APC_20221024.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	158.4 ft	α =	-10.0 °	-0.1745	
L3 =	174.5 ft				1,000.0 ft
L4 =	109.9 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				900.0 ft
L6 =	43.3 ft	β =	16.0 °	0.2793	
LT =	837.5 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

Pipe/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 = 0.685 4%

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 = 287.30 ft

Ballast Water El., H_W = 287.30 ft

Lowest Invert El., El_m = 244.60 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 = 1.20 lb/ft Comparison Only @ 8psi

Calculated Buoyant Forces

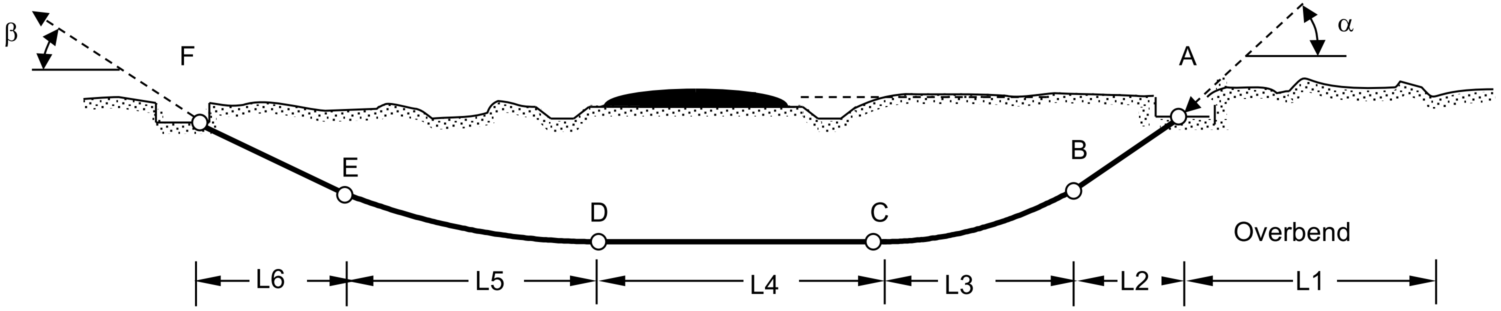
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 291.40 ft

Pipe Entry El = 287.30 ft



Calculated Pull Force							ASSESS	
POINT	Pull Force, F_D	Max Tensile	ASSESS	Pull Force, F_B	Max Tensile	ASSESS	F_x < SPS	
	No Ballast	Stress, σ_T	$\sigma_T < \sigma_{PM}$	Ballasted Pipe	Stress, σ_T	$\sigma_T < \sigma_{PM}$	Air	Ballast
A	1,479 lb	115 psi	OK	1,479 lb	115 psi	OK	OK	OK
B	2,888 lb	73 psi	OK	3,180 lb	80 psi	OK	OK	OK
C	4,288 lb	147 psi	OK	3,842 lb	136 psi	OK	OK	OK
D	4,164 lb	105 psi	OK	3,718 lb	94 psi	OK	OK	OK
E	9,544 lb	284 psi	OK	6,415 lb	205 psi	OK	OK	OK
F	10,252 lb	259 psi	OK	6,750 lb	170 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 81.51 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 45,606 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 87.24 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.93432214 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.123309471 r = $\sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 284 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 4.63 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 23.13 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75B Circuit #1
Stream Crossing

Revision 1 TBD

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

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

HDD 75B Circuit #1
Stream Crossing

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification	445574C		Design resin with minimum PENT test of 10,000 hours
Standard Dimension	3		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	3.000 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	2.675 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	0.389 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	3.190849685		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
Unit OD Surface Area, in^2/LF, A_{OD} =	113.10 in^2/LF		$A_{OD} = 12*\pi*D_{OD}$
Unit Outside Volume, V_{Do} =	0.049 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 =	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	0.84	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 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} =	3.83 lb/ft	$W_{D1} = V_{Do}*\gamma_{EXT1}$
Heavy Displaced Fluid Weight, W_{D2} =	3.93 lb/ft	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-2.17 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-2.27 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	0.27 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	0.17 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

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HDD 75B Circuit #1

Stream Crossing

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	46.80 ft	Ballast depth to invert, H_B	42.70 ft	Drill Fluid depth to invert, H_{DF}	42.70 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	18.56 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	23.20 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	23.79 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	18.56 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 = $(P_A+P_a)-P_{DF1}$	83.78 psi	22.88 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	83.18 psi	22.29 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.34 psi	41.44 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.74 psi	40.85 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	88.42 psi	27.52 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 75B Circuit #1
Stream Crossing

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T * f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty * f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty * f_{temp} * DF$
Safe Pull Strength, SPS Pipe = 3,910 lb **Useing SSAS = 3,211 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.
SAFE PULL STRENTH, SPS = 3,910 lb
Ultimate Pull Strength, UPS = 9,774 lb
Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.93432
r = σ_i/2*(SSAS) = 0.12331
P_{CRR} = 249.9 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 124.9 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ = 101.74 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ = 101.14 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 284 psi

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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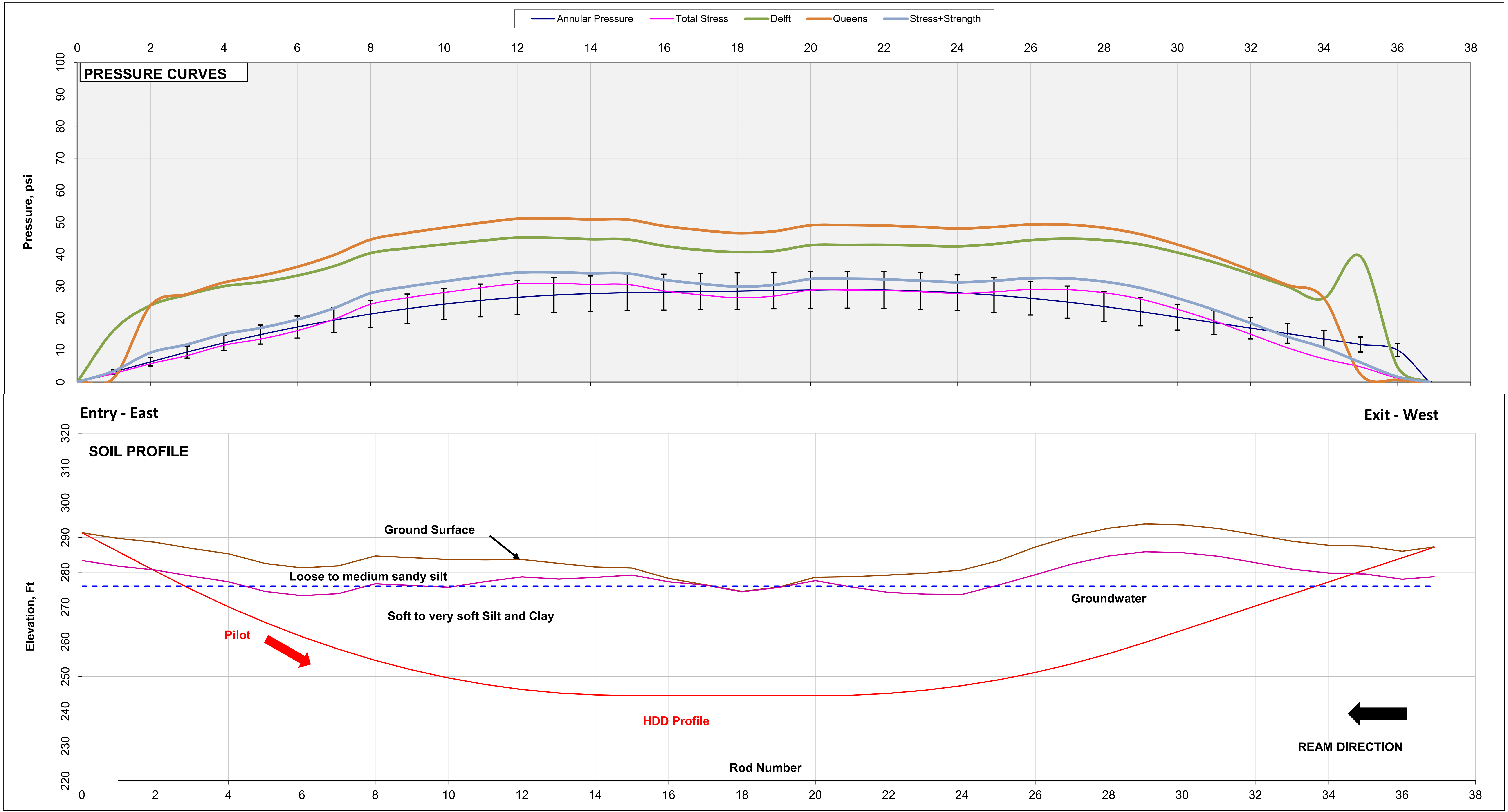

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Notes:

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 annular pressure calculations

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

Print Date ; 3/13/2023 8:43

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75B Circuit #1
Stream Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75B CIR #1_APC_20221024.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 75B Circuit #2**
Stream Crossing

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	7+28.77	FT

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

	East	North	Elevation
Entry	636692.6688	1419616.1408	289.70 ft
Horizontal Curve PI	636561.8455	1419956.2307	
Exit	636431.0222	1420296.3206	287.90 ft

Depth to Mudline 1.80 ft Clearance Depth = 45.10 ft

Measured Plan Length at ties = 728.7685 ft

Coordinate Length = 728.7685 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.* 276.00 ft

Mudline Elev.* 287.90 ft

Lowest centerline Elev. 242.80 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	636692.6688	1419616.1408	3+64.38	636561.8455	1419956.2307	E 338.95963 N	364.38		
Curve	3+64.38	636561.8455	1419956.2307	3+64.38	636561.8455	1419956.2307	E 338.95963 N	0.00	0.00	0.000 deg.
Tangent	3+64.38	636561.8455	1419956.2307	7+28.77	636431.0222	1420296.3206	E 338.95963 N	364.38		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	364.38	Input Radius, ft.	0.00	Plan Length, ft.	364.38	
Entry Azimuth, deg.[5]	N 338.95963 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 338.95963 E	
Entry Azimuth, rad.[5]	5.91596	Curve, rad	0.00000	Exit Azimuth, rad.[5]	5.91596	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	636431.0222	***Check***
PCH Easting	636561.8455	Arc Length, ft.	0.00	Northing	1420296.3206	***Delta***
PCH Northing	1419956.2307	Chord Azimuth, deg	338.9596			**0.0000**
		PI Easting =	636561.8455			**0.0000**
		PI Northing =	1419956.2307			**OK CALC**
		PTH Easting =	636561.8455			
		PTH Northing =	1419956.2307			**Exit Station**
						7+28.77
Cum Plan Length	364.38	Cum Plan Length	364.38	Cum Plan Length	728.7684842	**OK STA**

Pull Geometry

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

	Elevations		Vertical Angle				
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Path Length**	**Curve Radius**
Entry Tangent	289.70 ft	277.66 ft	-16.00 deg	-16.00 deg	0.00 deg	43.66 ft	0.00 ft
Entry Curve	277.66 ft	242.80 ft	-16.00 deg	0.00 deg	16.00 deg	251.33 ft	900.00 ft
Bottom Tangent	242.80 ft	242.80 ft	0.00 deg	0.00 deg	0.00 deg	95.46 ft	0.00 ft
Exit Curve	242.80 ft	257.99 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	257.99 ft	287.90 ft	10.00 deg	10.00 deg	0.00 deg	172.23 ft	0.00 ft
					Total Check =	**737.22 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	-16.000 deg.	Vertical Radius	900.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	287.90	
		Vert. Curve, deg.	16.000 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	41.973 ft	Plan Length	248.074 ft	Plan Length	95.45852 ft	Plan Length	173.648 ft	Plan Length	169.615 ft	728.768 ft
Rod Length	43.664 ft	Arc Rod Length	251.327 ft	Rod Length	95.45852 ft	Arc Rod Length	174.533 ft	Rod Length	172.232 ft	737.215 ft
Vertical Depth	-12.036 ft	Curve Δ Vert Depth	-34.864 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	29.908 ft	-1.800 ft
		Lowest Elevation	242.800 ft			Lowest Elevation	242.800 ft	CK Total Cum Depth	-1.800 ft	
Start Elevation	289.700 ft	Start Elevation	277.664 ft	Start Elevation	242.800 ft	Start Elevation	242.800 ft	Start Elevation	257.992 ft	
End Elevation	277.664 ft	End Elevation	242.800 ft	End Elevation	242.800 ft	End Elevation	257.992 ft	Ck Exit Elevation		
End Vert Angle	-16.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***728.7684842***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+41.97	Start Station	2+90.05	Start Station	3+85.51	Start Station	5+59.15
PVC Station	0+41.97	PTV Station	2+90.05	PCV Station	3+85.51	PTV Station	5+59.15	Exit Station	7+28.768
Cum Plan Length	41.97	Cum Plan Length	290.05	Cum Plan Length	385.51 ft	Cum Plan Length	559.15	Cum Plan Length	728.77
Cum Rod Length	43.66	Cum Rod Length	294.99	Cum Rod Length	390.45 ft	Cum Rod Length	564.98	Cum Rod Length	737.22
Cum Depth	-12.04	Cum Depth	-46.90	Cum Depth	-46.90 ft	Cum Depth	-31.7078	Cum Depth	-1.80

Stationing Check
OK STATIONING

Plan Length Check
OK CALCULATION

Elevation Change Check
OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-1.80 ft**
Minimum Design Elevation =	**242.80 ft**
Invert Depth below exit =	**45.10 ft**
Invert Depth below entry =	**46.90 ft**
Path Length =	**737.22 ft**
Plan Length =	**728.77 ft**
Minimum Plan Length (No Tangent) =	**633.31 ft**
Entry Angle =	**-16.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

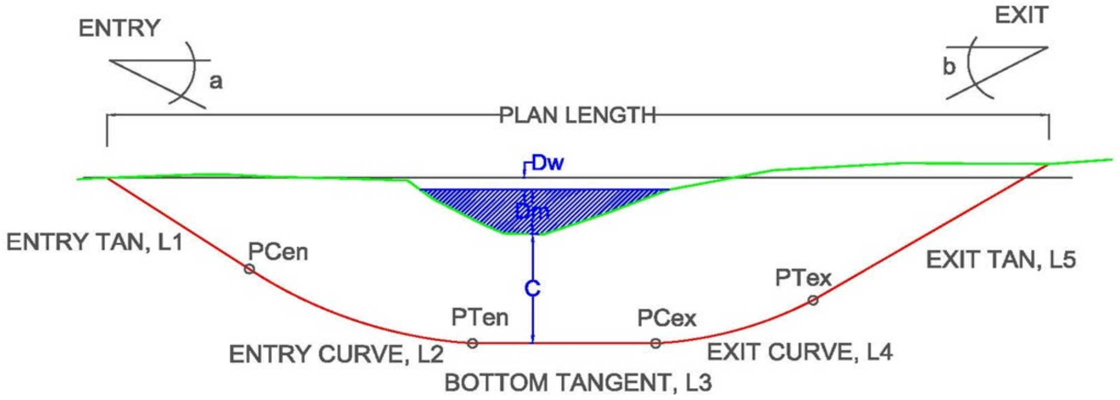
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 75B Circuit #2
Stream Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75B CIR #2_APC_20221024.xlsb]T3 Plastic Pull

Pull Geometry

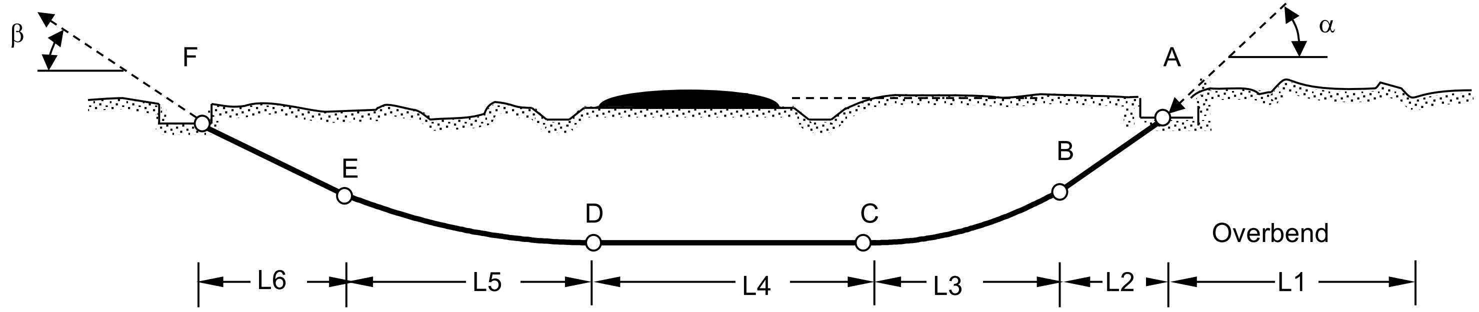
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	43.7 ft	α =	-16.0 °	-0.2793	
L3 =	251.3 ft				900.0 ft
L4 =	95.5 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	172.2 ft	β =	10.0 °	0.1745	
LT =	837.2 ft				

Pipe Entry Location - Drill ENTRY

(schematic, to show definition of variables only)

Pipe Exit El = 287.90 ft

Pipe Entry El = 289.70 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		
Pipe/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}	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 =	0.685	4%		
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 =	287.90 ft		
Ballast Water El., H_W =	287.90 ft		
Lowest Invert El., El_m =	7.00 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 =	0.89 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							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	 Ballast
A	1,352 lb	96 psi	OK	1,352 lb	96 psi	OK	OK	OK
B	1,896 lb	53 psi	OK	1,866 lb	52 psi	OK	OK	OK
C	3,145 lb	120 psi	OK	2,441 lb	100 psi	OK	OK	OK
D	2,872 lb	80 psi	OK	2,168 lb	60 psi	OK	OK	OK
E	5,736 lb	189 psi	OK	3,592 lb	129 psi	OK	OK	OK
F	8,817 lb	246 psi	OK	5,010 lb	140 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 82.35 psi

Ballasted	OK
No Ballast	REJECT

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	87.24 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.944043459	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.106940771	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	246 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	30.43	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	152.15	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

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

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 75B Circuit #2
Stream Crossing

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75B CIR #2_APC_20221024.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 75B Circuit #2
Stream Crossing

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	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 =	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 =	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	0.84	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

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

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

Buoyant forces

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75B CIR #2_APC_20221024.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

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HDD 75B Circuit #2

Stream Crossing

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 46.90 ft

Ballast depth to invert, H_B 45.10 ft

Drill Fluid depth to invert, H_{DF} 45.10 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	19.74 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	24.67 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.30 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	19.74 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 = $(P_A+P_a)-P_{DF1}$	82.30 psi	21.41 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.67 psi	20.78 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.04 psi	41.15 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.41 psi	40.51 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	87.24 psi	26.34 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 75B Circuit #2

Stream Crossing

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

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

Designed Pull Duration Time = 12 hr

Quantity of pipes, Q = 1

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Temperature, F = 73 deg.

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y 0.4

SAFE PULL STRENTH, SPS = 50,200 lb

Temperature factor, f_{temp} = 1

Ultimate Pull Strength, UPS = 125,499 lb

Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi

Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF

Suggested SSAS = 1,150 psi

Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

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

(ASTM F-1962 EQ. 22)

Pull Duration Time = 12 Hr

Pcr = 267.4 psi

SAS = 1,400 psi

Design Depth in DF, H_{MDF} = 0.0 ft

Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum

fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.94404

r = σ_i/2*(SSAS) = 0.10694

Example from Table T5, σ_i = 246 psi

P_{CRR} = 252.5 psi

FS = 2.0

P_{ACRR} = P_{CRR}/FS = 126.2 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 101.56 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 100.93 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

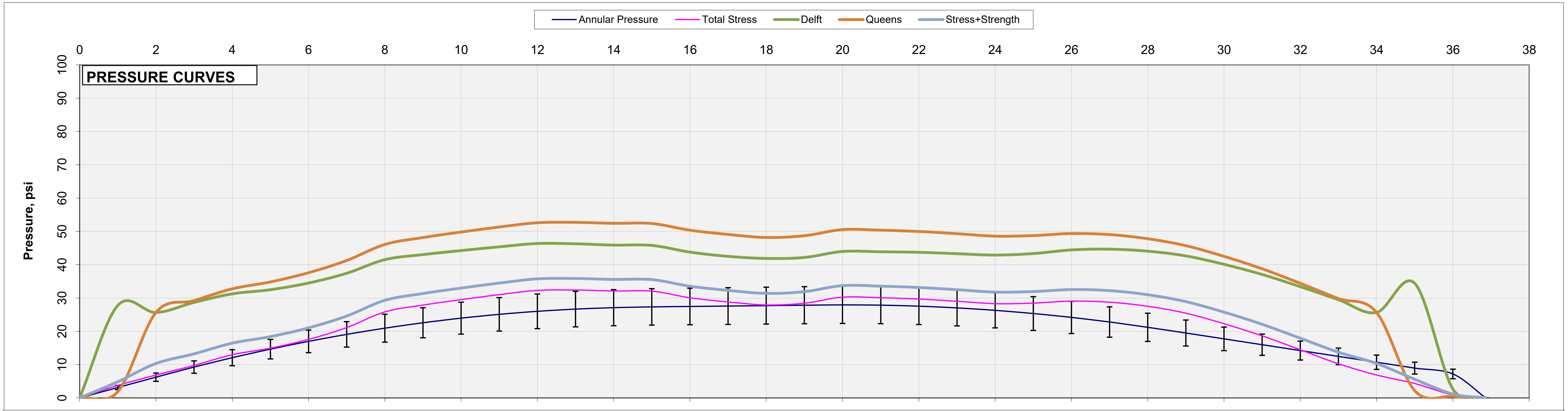
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

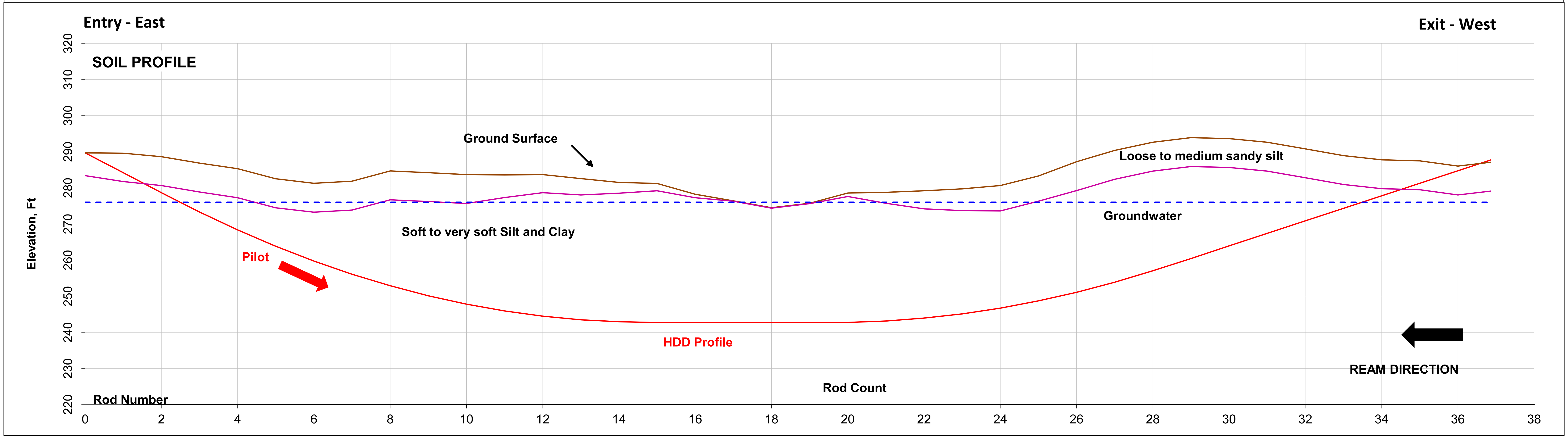
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

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

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

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





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Notes:

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

Basis of annular pressure calculations

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

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 75B Circuit #2
Stream Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#75B CIR #2_APC_20221024.xlsb]T3 Plastic Pull

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 77 Circuit #1**
CSX RR Crossing

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: 28-Feb-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
2/28/2023	1	Issued for Construction	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	13+80.33	FT

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

	East	North	Elevation
Entry	637165.1630	1414844.9899	296.20 ft
Horizontal Curve PI	637161.9861	1415535.1467	
Exit	637158.8093	1416225.3003	283.70 ft

Depth to Mudline 5.90 ft Clearance Depth = 27.10 ft

Measured Plan Length at ties = 1380.3250 ft -480.325

Coordinate Length = 1380.3250 ft 580.325

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	283.70 ft
Mudline Elev.*	290.30 ft
Lowest centerline Elev.	263.20 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	637165.1630	1414844.9899	6+90.16	637161.9861	1415535.1467	E 359.73626 N	690.16		
Curve	6+90.16	637161.9861	1415535.1467	6+90.16	637161.9861	1415535.1467	E 359.73627 N	0.00	0.00	0.000 deg.
Tangent	6+90.16	637161.9861	1415535.1467	13+80.33	637158.8093	1416225.3003	E 359.73627 N	690.16		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	690.16	Input Radius, ft.	0.00	Plan Length, ft.	690.16	
Entry Azimuth, deg.[5]	N 359.73626 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 359.73627 E	
Entry Azimuth, rad.[5]	6.27858	Curve, rad	0.00000	Exit Azimuth, rad.[5]	6.27858	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	0.00	Easting	637158.8093	***Check***
PCH Easting	637161.9861	Arc Length, ft.	0.00	Northing	1416225.3003	***Delta***
PCH Northing	1415535.1467	Chord Azimuth, deg	359.7363			**0.0000**
		PI Easting =	637161.9861			**0.0000**
		PI Northing =	1415535.1467			**OK CALC**
		PTH Easting =	637161.9861			
		PTH Northing =	1415535.1467			**Exit Station**
						13+80.33
Cum Plan Length	690.16	Cum Plan Length	690.16	Cum Plan Length	1380.325023	**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	296.20 ft	282.87 ft	-12.00 deg	-12.00 deg	0.00 deg	64.13 ft	0.00 ft
Entry Curve	282.87 ft	263.20 ft	-12.00 deg	0.00 deg	12.00 deg	188.50 ft	900.00 ft
Bottom Tangent	263.20 ft	263.20 ft	0.00 deg	0.00 deg	0.00 deg	926.73 ft	0.00 ft
Exit Curve	263.20 ft	278.39 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	278.39 ft	283.70 ft	10.00 deg	10.00 deg	0.00 deg	30.57 ft	0.00 ft
					Total Check =	**1384.45 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	900.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	283.70
		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**	
Plan Length	62.726 ft	Plan Length	187.121 ft	Plan Length	926.72848 ft	Plan Length	173.648 ft	Plan Length	30.102 ft
Rod Length	64.127 ft	Arc Rod Length	188.496 ft	Rod Length	926.72848 ft	Arc Rod Length	174.533 ft	Rod Length	30.566 ft
Vertical Depth	-13.333 ft	Curve Δ Vert Depth	-19.667 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	5.308 ft
		Lowest Elevation	263.200 ft			Lowest Elevation	263.200 ft	CK Total Cum Depth	-12.500 ft
Start Elevation	296.200 ft	Start Elevation	282.867 ft	Start Elevation	263.200 ft	Start Elevation	263.200 ft	Start Elevation	278.392 ft
End Elevation	282.867 ft	End Elevation	263.200 ft	End Elevation	263.200 ft	End Elevation	278.392 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***	***1380.325023***

SUMS
1,380.325 ft
1,384.451 ft
-12.500 ft

Summary of Drill Calculations

Entry to Exit Elevation Change =	-12.50 ft
Minimum Design Elevation =	263.20 ft
Invert Depth below exit =	20.50 ft
Invert Depth below entry =	33.00 ft
Path Length =	1,384.45 ft
Plan Length =	1,380.33 ft
Minimum Plan Length (No Tangent) =	453.60 ft
Entry Angle =	-12.00 deg
Exit Angle =	10.00 deg
Compound Curve at Entry =	NO
Compound Curve at Exit =	NO

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+62.73	Start Station	2+49.85	Start Station	11+76.58	Start Station	13+50.22
PVC Station	0+62.73	PTV Station	2+49.85	PCV Station	11+76.58	PTV Station	13+50.22	Exit Station	13+80.325
Cum Plan Length	62.73	Cum Plan Length	249.85	Cum Plan Length	1176.58 ft	Cum Plan Length	1350.22	Cum Plan Length	1380.33
Cum Rod Length	64.13	Cum Rod Length	252.62	Cum Rod Length	1179.35 ft	Cum Rod Length	1353.88	Cum Rod Length	1384.45
Cum Depth	-13.33	Cum Depth	-33.00	Cum Depth	-33.00 ft	Cum Depth	-17.8078	Cum Depth	-12.50

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

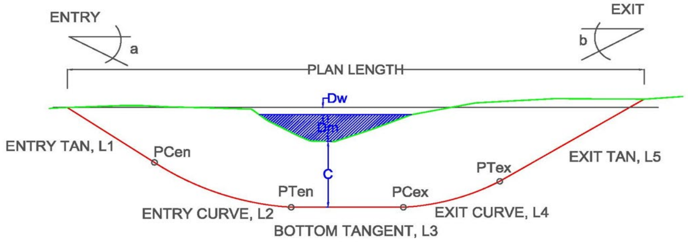
NOTES:

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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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 77 Circuit #1
CSX RR Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#77 CIR #1_APC_20220812.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	64.1 ft	α =	-12.0 °	-0.2094	
L3 =	188.5 ft				900.0 ft
L4 =	926.7 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	30.6 ft	β =	10.0 °	0.1745	
LT =	1484.5 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 =	283.00 ft		
Ballast Water El., H_W =	283.00 ft		
Lowest Invert El., El_m =	263.20 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 =	0.64 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

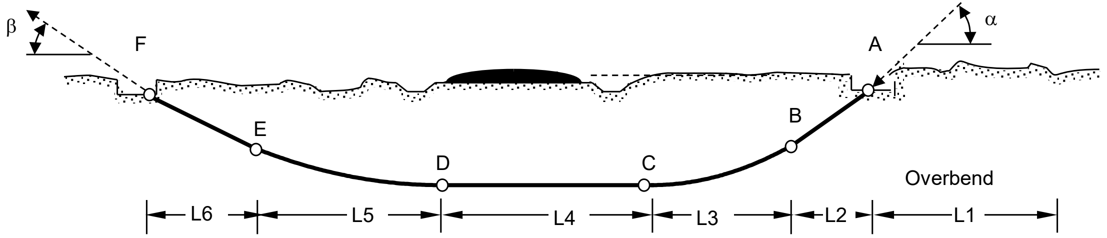
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Entry

(schematic, to show definition of variables only)

Pipe Exit El = 283.70 ft

Pipe Entry El = 296.20 ft



	Calculated Pull Force						ASSESS	
POINT	Pull Force, F_D	Max Tensile Stress, σ_T	ASSESS	Pull Force, F_B	Max Tensile Stress, σ_T	ASSESS	F_x < SPS	
	No Ballast		$\sigma_T < \sigma_{PM}$	Ballasted Pipe		$\sigma_T < \sigma_{PM}$	Air	Ballast
A	2,632 lb	195 psi	OK	2,632 lb	195 psi	OK	OK	OK
B	2,976 lb	75 psi	OK	2,976 lb	75 psi	OK	OK	OK
C	4,391 lb	154 psi	OK	3,664 lb	135 psi	OK	OK	OK
D	8,742 lb	221 psi	OK	8,014 lb	202 psi	OK	OK	OK
E	12,231 lb	347 psi	OK	9,912 lb	289 psi	OK	OK	OK
F	12,783 lb	322 psi	OK	10,180 lb	257 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 98.15 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	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 =	0.91751862	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.150914578	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	347 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	2.15	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	10.73	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: Issued for Construction (IFC)

BRIERLEY ASSOCIATES Limited Liability Company "Creating Space Underground"	Champlain Hudson Power Express Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem Schenectady County, NY
	TABLE 3 - PULL ASSESSMENT **ANTICIPATED PULLING FORCE - HDPE PULL** **HDD 77 Circuit #1** **CSX RR Crossing**
Brierley Associates 167 S. River Road, Suite 8 Bedford, NH 03110	Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#77 CIR #1_APC_20220812.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

HDD 77 Circuit #1
CSX RR Crossing

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	4710 HDPE	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 =	3.80188946	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

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HDPE PROPERTIES

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

HDD 77 Circuit #1
CSX RR Crossing

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF = 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, ^oF = 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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 33.00 ft
Ballast depth to invert, H_B 20.50 ft
Drill Fluid depth to invert, H_{DF} 20.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$ 8.95 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$ 11.18 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$ 11.47 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$ 8.95 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 = $(P_A+P_a)-P_{DF1}$	95.79 psi	34.90 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	95.51 psi	34.61 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	104.74 psi	43.84 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	104.45 psi	43.56 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	98.03 psi	37.13 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

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

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

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

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

HDD 77 Circuit #1
CSX RR Crossing

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

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

Designed Pull Duration Time = 12 hr
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF
Safe Pull Strength, SPS Pipe = 5,321 lb

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi
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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.91752
r = σ_i/2*(SSAS) = 0.15091
P_{CRR} = 245.4 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 122.7 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 111.51 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 111.22 psi Pull Back Condition - Option 4 **OK as >0**

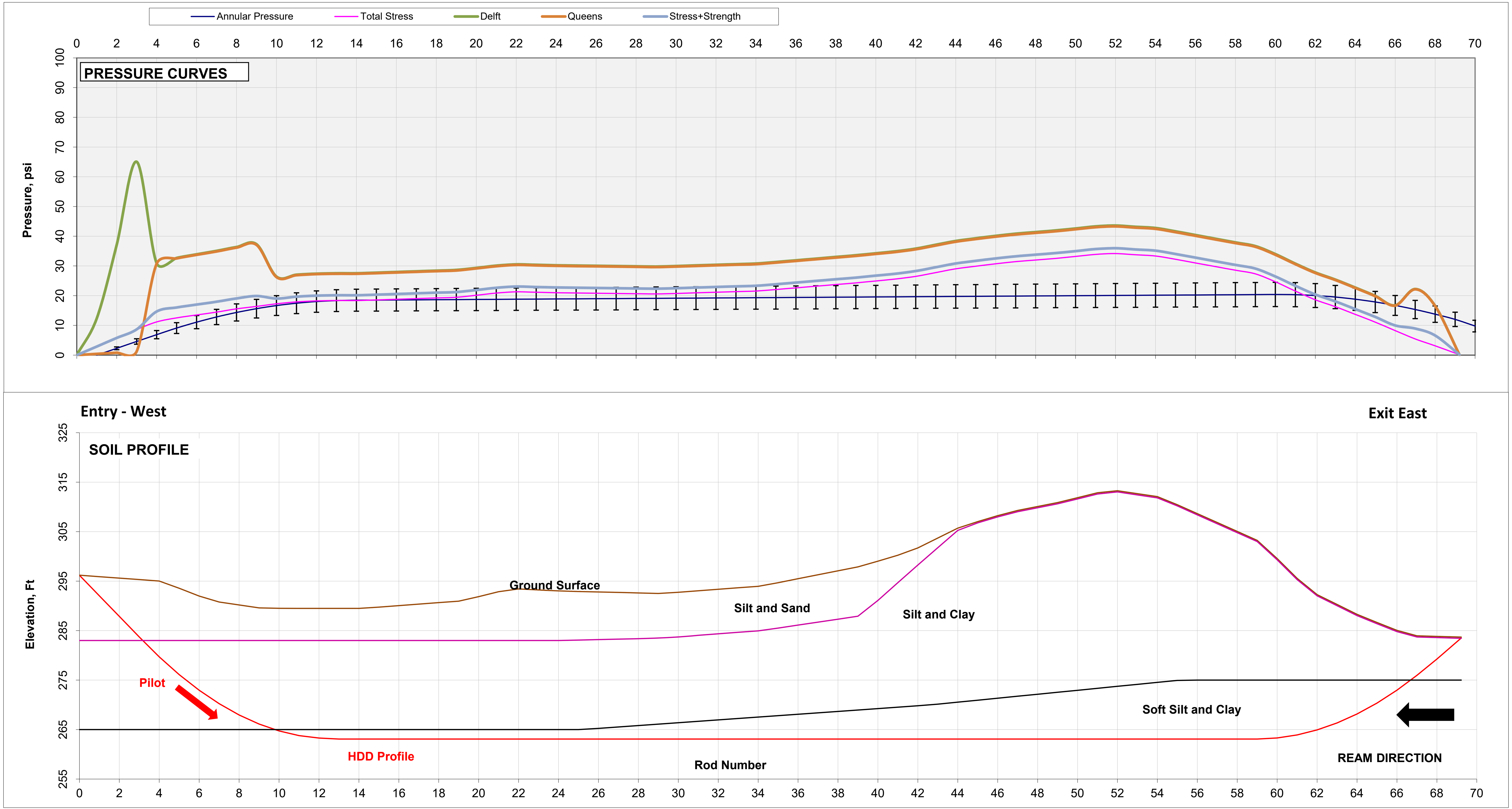
Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 347 psi

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

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

Bore Logs
B183.2-1
K183.3
K183.4

Print Date ; 2/28/2023 13:22

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 77 Circuit #1
CSX RR Crossing

Revision 1

FIGURE 1

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 77 Circuit #2**
CSX RR Crossing

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: 28-Feb-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
2/28/2023	1	Issued for Construction	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT
Exit Station	**13+80.33**	FT

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

	East	North	Elevation
Entry	637147.1620	1414844.9070	295.30 ft
Horizontal Curve PI	637143.9863	1415535.0638	
Exit	637140.8095	1416225.2206	283.50 ft

Depth to Mudline	11.60 ft	Clearance Depth =	17.20 ft
Measured Plan Length at ties =	1380.3282 ft		-480.328
Coordinate Length =	1380.3282 ft		580.328
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	283.70 ft
Mudline Elev.*	283.70 ft
Lowest centerline Elev.	266.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	637147.1620	1414844.9070	6+90.16	637143.9863	1415535.0638	E 359.73636 N	690.16		
Curve	6+90.16	637143.9863	1415535.0638	6+90.16	637143.9863	1415535.0638	E 359.73627 N	0.00	0.00	0.000 deg.
Tangent	6+90.16	637143.9863	1415535.0638	13+80.33	637140.8095	1416225.2206	E 359.73627 N	690.16		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	690.16	Input Radius, ft.	0.00	Plan Length, ft.	690.16	
Entry Azimuth, deg.[5]	N 359.73636 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 359.73627 E	
Entry Azimuth, rad.[5]	6.27858	Curve, rad	0.00000	Exit Azimuth, rad.[5]	6.27858	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	637140.8095	***Check***
PCH Easting	637143.9863	Arc Length, ft.	0.00	Northing	1416225.2206	***Delta***
PCH Northing	1415535.0638	Chord Azimuth, deg	359.7363			**0.0000**
		PI Easting =	637143.9863			**0.0000**
		PI Northing =	1415535.0638			**OK CALC**
		PTH Easting =	637143.9863			
		PTH Northing =	1415535.0638			**Exit Station**
						13+80.33
Cum Plan Length	690.16	Cum Plan Length	690.16	Cum Plan Length	1380.328218	**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**	**∆ Angle**	**Length**	**Radius**
Entry Tangent	295.30 ft	286.17 ft	-12.00 deg	-12.00 deg	0.00 deg	43.93 ft	0.00 ft
Entry Curve	286.17 ft	266.50 ft	-12.00 deg	0.00 deg	12.00 deg	188.50 ft	900.00 ft
Bottom Tangent	266.50 ft	266.50 ft	0.00 deg	0.00 deg	0.00 deg	966.34 ft	0.00 ft
Exit Curve	266.50 ft	281.69 ft	0.00 deg	10.00 deg	10.00 deg	174.53 ft	1000.00 ft
Exit Tangent	281.69 ft	283.50 ft	10.00 deg	10.00 deg	0.00 deg	10.41 ft	0.00 ft
					Total Check =	**1383.71 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	900.00	End Vert Angle	0.000 deg.	Radius	1000.00	Exit Elevation	283.50
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	42.967 ft	Plan Length	187.121 ft	Plan Length	966.34060 ft	Plan Length	173.648 ft	Plan Length	10.252 ft
Rod Length	43.927 ft	Arc Rod Length	188.496 ft	Rod Length	966.34060 ft	Arc Rod Length	174.533 ft	Rod Length	10.410 ft
Vertical Depth	-9.133 ft	Curve ∆ Vert Depth	-19.667 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	15.192 ft	Vertical Depth	1.808 ft
		Lowest Elevation	266.500 ft			Lowest Elevation	266.500 ft	CK Total Cum Depth	-11.800 ft
Start Elevation	295.300 ft	Start Elevation	286.167 ft	Start Elevation	266.500 ft	Start Elevation	266.500 ft	Start Elevation	281.692 ft
End Elevation	286.167 ft	End Elevation	266.500 ft	End Elevation	266.500 ft	End Elevation	281.692 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***	***1380.328218***

SUMS
1,380.328 ft
1,383.706 ft
-11.800 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+42.97	Start Station	2+30.09	Start Station	11+96.43	Start Station	13+70.08
PVC Station	0+42.97	PTV Station	2+30.09	PCV Station	11+96.43	PTV Station	13+70.08	Exit Station	13+80.328
Cum Plan Length	42.97	Cum Plan Length	230.09	Cum Plan Length	1196.43 ft	Cum Plan Length	1370.08	Cum Plan Length	1380.33
Cum Rod Length	43.93	Cum Rod Length	232.42	Cum Rod Length	1198.76 ft	Cum Rod Length	1373.30	Cum Rod Length	1383.71
Cum Depth	-9.13	Cum Depth	-28.80	Cum Depth	-28.80 ft	Cum Depth	-13.6078	Cum Depth	-11.80

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-11.80 ft**
Minimum Design Elevation =	**266.50 ft**
Invert Depth below exit =	**17.00 ft**
Invert Depth below entry =	**28.80 ft**
Path Length =	**1,383.71 ft**
Plan Length =	**1,380.33 ft**
Minimum Plan Length (No Tangent) =	**413.99 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

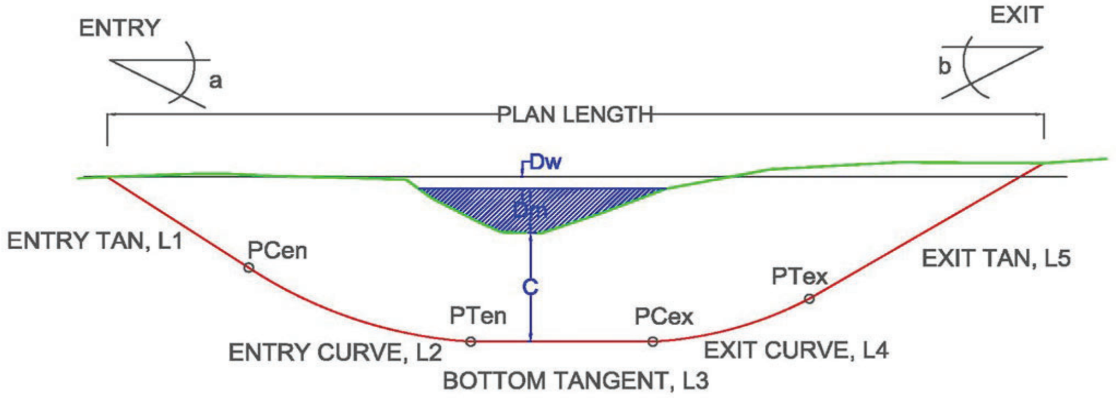
NOTES:

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 77 Circuit #2
CSX RR Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#77 CIR #2_APC_20221024.xlsb]T2 Path 1

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	43.9 ft	α =	-12.0 °	-0.2094	
L3 =	188.5 ft				900.0 ft
L4 =	966.3 ft	χ =	0.0 °	0.0000	
L5 =	174.5 ft				1,000.0 ft
L6 =	10.4 ft	β =	10.0 °	0.1745	
LT =	1483.7 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}	14.25	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}	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 =	1,000 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 =	283.00 ft	
Ballast Water El., H_W =	283.00 ft	
Lowest Invert El., El_m =	266.50 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 =	0.64 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

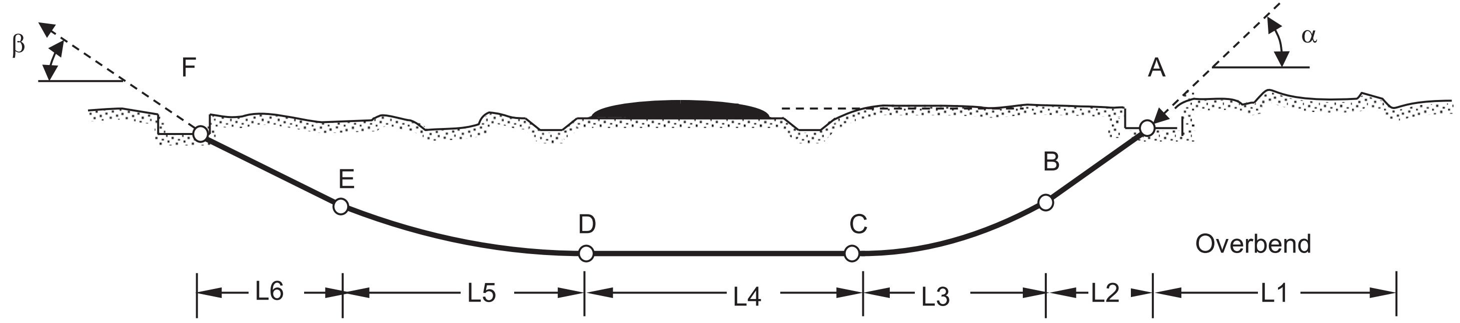
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Entry

(schematic, to show definition of variables only)

Pipe Exit El = 283.50 ft

Pipe Entry El = 295.30 ft



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	2,379 lb	195 psi	OK	2,379 lb	195 psi	OK	OK	OK
B	2,559 lb	71 psi	OK	2,559 lb	71 psi	OK	OK	OK
C	3,863 lb	151 psi	OK	3,261 lb	134 psi	OK	OK	OK
D	8,020 lb	224 psi	OK	7,417 lb	207 psi	OK	OK	OK
E	11,226 lb	352 psi	OK	9,188 lb	295 psi	OK	OK	OK
F	11,376 lb	317 psi	OK	9,265 lb	258 psi	OK	OK	OK

Table title: Calculated Pull Force

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 98.02 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.916258771	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.152950419	r = $\sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	352 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	1.79	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	8.94	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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Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 77 Circuit #2
CSX RR Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#77 CIR #2_APC_20221024.xlsb]T2 Path 1

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 77 Circuit #2
CSX RR 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	4710 HDPE	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 =	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	0.84	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 forces

Dry Weight Pipe on ground, W_P =	1.66 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-47.50 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-48.76 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	24.65 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-24.51 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-25.77 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

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HDPE PROPERTIES

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

HDD 77 Circuit #2
CSX RR Crossing

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 28.80 ft

Ballast depth to invert, H_B 17.00 ft

Drill Fluid depth to invert, H_{DF} 17.00 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	7.56 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	9.45 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	9.69 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	7.56 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 = $(P_A+P_a)-P_{DF1}$	97.52 psi	36.63 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	97.28 psi	36.39 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	105.08 psi	44.19 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	104.84 psi	43.95 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	99.41 psi	38.52 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#77 CIR #2_APC_20221024.xlsb]T2 Path 1

TABLE 4 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

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HDD 77 Circuit #2

CSX RR Crossing

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

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

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

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

(ASTM F-1962 EQ. 22)

Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 1,400 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.91626
r = σ_i/2*(SSAS) = 0.15295
Example from Table T5, σ_i = 352 psi
P_{CRR} = 245.0 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 122.5 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 113.07 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 112.83 psi Pull Back Condition - Option 4 **OK as >0**

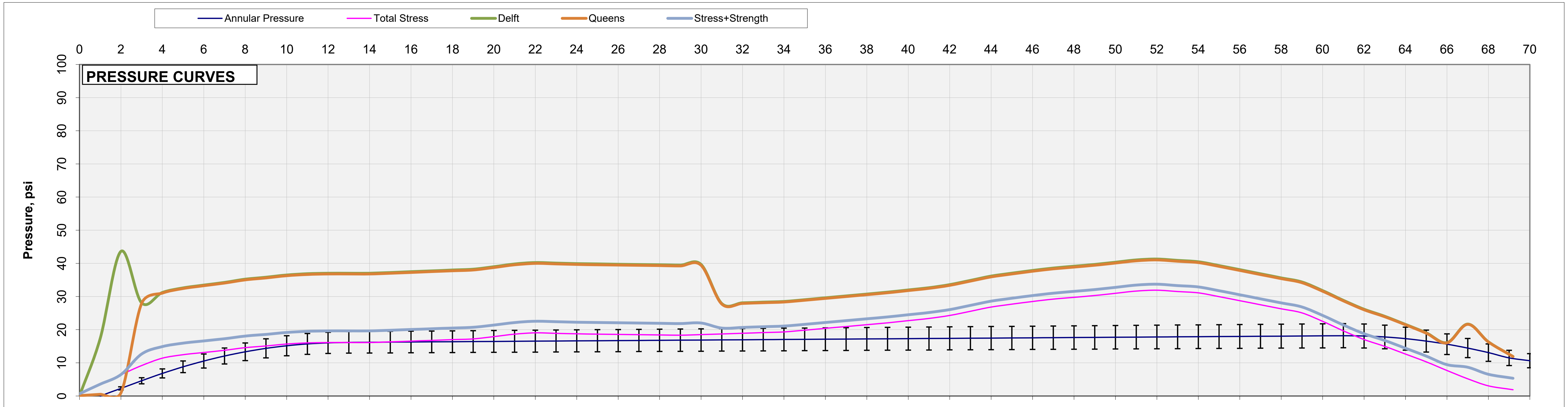
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

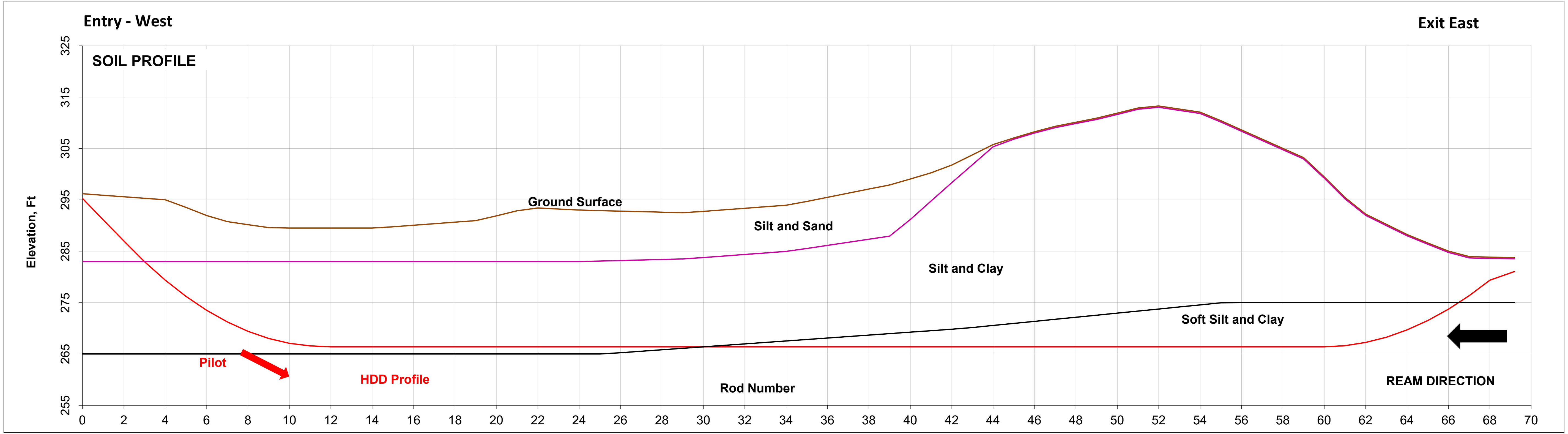
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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

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

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





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Notes:

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

Basis of annulur pressure calculations

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

Bore Logs

B183.2-1
K183.3
K183.4

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 77 Circuit #2
CSX RR Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#77 CIR #1_APC_20220812.xlsb]F1A APCL

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 78 Circuit #1**
CSX RR & Route 146 Crossing

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: 16-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/16/2023	1	Issued for Construction	KRF

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #1_APC_20220812.xlsb]T3 Plastic Pull

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	19+58.32	FT

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

	East	North	Elevation
Entry	637480.9964	1411246.6271	319.70 ft
Horizontal Curve PI	637788.7411	1410063.2389	
Exit	637936.1824	1409342.5726	323.40 ft
Depth to Mudline	0.00 ft	Clearance Depth =	50.06 ft

Measured Plan Length at ties = 1958.3187 ft

Coordinate Length = 1958.3187 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	309.00 ft
Mudline Elev.*	319.70 ft
Lowest centerline Elev.	269.64 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	637480.9964	1411246.6271	11+70.12	637775.4962	1410114.1702	E 165.42289 N	1170.12		
Curve	11+70.12	637775.4962	1410114.1702	12+75.35	637799.2892	1410011.6815	E 168.43741 N	105.23	2000.00	3.015 deg.
Tangent	12+75.35	637799.2892	1410011.6815	19+58.32	637936.1824	1409342.5726	E 168.43741 N	682.97		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1170.12	Input Radius, ft.	2000.00	Plan Length, ft.	682.97	
Entry Azimuth, deg.[5]	N 165.42289 E	Curve, deg	3.015 deg.	Exit Azimuth, deg.[5]	N 168.43741 E	
Entry Azimuth, rad.[5]	2.88717	Curve, rad	0.05261	Exit Azimuth, rad.[5]	2.93979	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	105.21	Easting	637936.1824	**Check**
PCH Easting	637775.4962	Arc Length, ft.	105.23	Northing	1409342.5726	**Delta**
PCH Northing	1410114.1702	Chord Azimuth, deg	166.9301			**0.0000**
		PI Easting =	637788.7411			**0.0000**
		PI Northing =	1410063.2389			**OK CALC**
		PTH Easting =	637799.2892			
		PTH Northing =	1410011.6815			**Exit Station**
						19+58.32
Cum Plan Length	1170.12	Cum Plan Length	1275.35	Cum Plan Length	1958.318657	**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	323.40 ft	287.87 ft	-10.00 deg	-10.00 deg	0.00 deg	204.61 ft	0.00 ft
Entry Curve	287.87 ft	269.64 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	269.64 ft	269.64 ft	0.00 deg	0.00 deg	0.00 deg	1207.83 ft	0.00 ft
Exit Curve	269.64 ft	291.49 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	291.49 ft	319.70 ft	12.00 deg	12.00 deg	0.00 deg	135.67 ft	0.00 ft
					Total Check =	**1966.98 ft**	**OK**

Compound Curve Assessment

Start	**Vert. Plan**	**Horiz. Plan**	
Entry	340.62	1170.12	No, Horiz > Entry V(Tan+Curve)
Exit	409.87	682.97	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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	323.40	
		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	132.706 ft	Plan Length	207.912 ft	Plan Length	1,207.82613 ft	Plan Length	208.378 ft	Plan Length	201.497 ft	1,958.319 ft
Rod Length	135.671 ft	Arc Rod Length	209.440 ft	Rod Length	1,207.82613 ft	Arc Rod Length	209.440 ft	Rod Length	204.605 ft	1,966.981 ft
Vertical Depth	-28.208 ft	Curve Δ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	35.529 ft	3.700 ft
		Lowest Elevation	269.640 ft			Lowest Elevation	269.640 ft	CK Total Cum Depth	3.700 ft	
Start Elevation	319.700 ft	Start Elevation	291.492 ft	Start Elevation	269.640 ft	Start Elevation	269.640 ft	Start Elevation	287.871 ft	
End Elevation	291.492 ft	End Elevation	269.640 ft	End Elevation	269.640 ft	End Elevation	287.871 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***	***1958.318657***	

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.70 ft**
Minimum Design Elevation =	**269.64 ft**
Invert Depth below exit =	**53.76 ft**
Invert Depth below entry =	**50.06 ft**
Path Length =	**1,966.98 ft**
Plan Length =	**1,958.32 ft**
Minimum Plan Length (No Tangent) =	**750.49 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+32.71	Start Station	3+40.62	Start Station	15+48.44	Start Station	17+56.82	**Stationing Check** **OK STATIONING**
PVC Station	1+32.71	PTV Station	3+40.62	PCV Station	15+48.44	PTV Station	17+56.82	Exit Station	19+58.319	**Plan Length Check**
Cum Plan Length	132.71	Cum Plan Length	340.62	Cum Plan Length	1548.44 ft	Cum Plan Length	1756.82	Cum Plan Length	1958.32	**OK CALCULATION**
Cum Rod Length	135.67	Cum Rod Length	345.11	Cum Rod Length	1552.94 ft	Cum Rod Length	1762.38	Cum Rod Length	1966.98	**Elevation Change Check**
Cum Depth	-28.21	Cum Depth	-50.06	Cum Depth	-50.06 ft	Cum Depth	-31.8293	Cum Depth	3.70	**OK CALCULATION**

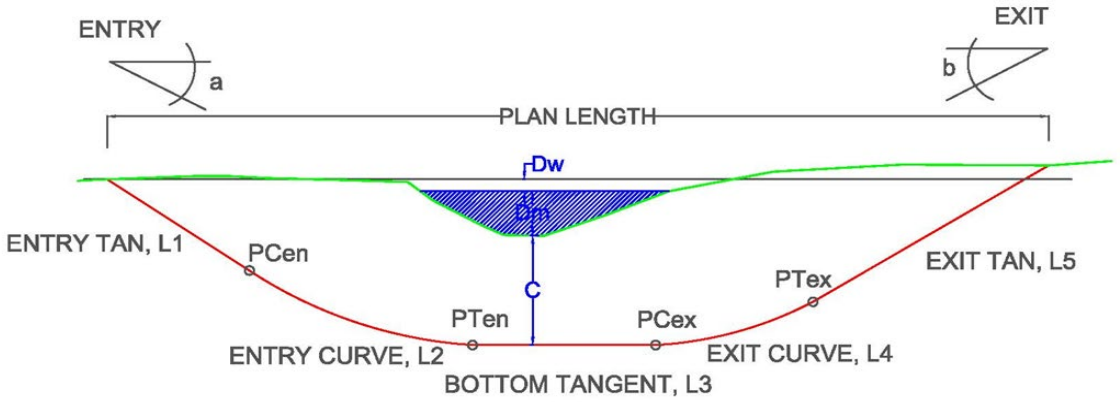
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 78 Circuit #1
CSX RR & Route 146 Crossing

Revision 1 TBD

Pull Geometry

Lengths (Path)	Angles			Radius, R
L1 = 100.0 ft	Overbend	deg	radian	500.0 ft
L2 = 204.6 ft	α =	-10.0 ˚	-0.1745	
L3 = 209.4 ft				1,200.0 ft
L4 = 1207.8 ft	χ =	0.0 ˚	0.0000	
L5 = 209.4 ft				1,000.0 ft
L6 = 135.7 ft	β =	12.0 ˚	0.2094	
LT = 2067.0 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 =	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 =	101 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	25 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 =	319.70 ft	
Ballast Water El., H_W =	319.70 ft	
Lowest Invert El., El_m =	269.64 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 =	0.45 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

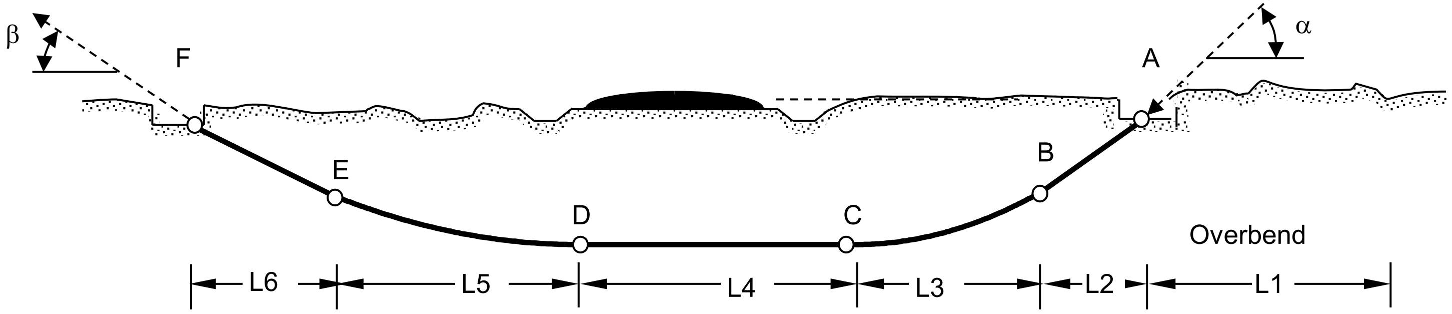
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 319.70 ft

Pipe Entry El = 323.40 ft



Calculated Pull Force							ASSESS	
POINT	Pull Force, F_D No Ballast	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	Pull Force, F_B Ballasted Pipe	Max Tensile Stress, σ_T	ASSESS $\sigma_T < \sigma_{PM}$	F_x < SPS Air	F_x < SPS Ballast
A	3,651 lb	169 psi	OK	3,651 lb	169 psi	OK	OK	OK
B	5,351 lb	135 psi	OK	5,690 lb	144 psi	OK	OK	OK
C	7,116 lb	212 psi	OK	6,568 lb	198 psi	OK	OK	OK
D	12,689 lb	320 psi	OK	12,142 lb	306 psi	OK	OK	OK
E	17,256 lb	474 psi	OK	14,697 lb	409 psi	OK	OK	OK
F	20,157 lb	508 psi	OK	16,036 lb	404 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 93.33 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.87243003	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.221056207	r = $\sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	508 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	5.42	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	27.12	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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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 78 Circuit #1
CSX RR & Route 146 Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #1_APC_20220812.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 78 Circuit #1
CSX RR & Route 146 Crossing

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Limited Liability Company
"Creating Space Underground"
167 South River Road, Suite 8
Bedford, NH 03110
Ph 603-206-5775

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 =	3.801889456		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
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 =	0.06		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	101 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	0.84	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 forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Shee
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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

TABLE 4 Pg 2 of 3

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 78 Circuit #1

CSX RR & Route 146 Crossing

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ASSOCIATES
Limited Liability Company

"Creating Space Underground"
167 South River Road, Suite 8
Bedford, NH 03110
Ph 603-206-5775

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 =	25 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	50 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	38 psi	$P_{RS} = 1.5*PR$

ASSESSMENT PRESSURE RATING	
REJECT	**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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	53.76 ft	Ballast depth to invert, H_B	50.06 ft	Drill Fluid depth to invert, H_{DF}	50.06 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	21.76 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	27.19 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	27.89 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	21.76 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 = $(P_A+P_a)-P_{DF1}$	79.78 psi	18.89 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	79.08 psi	18.19 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.54 psi	40.64 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.84 psi	39.95 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	85.22 psi	24.33 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 78 Circuit #1
CSX RR & Route 146 Crossing

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Limited Liability Company
"Creating Space Underground"
167 South River Road
Suite 8, Bedford, NH 03110
Ph 603-206-5775

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

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

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**SAFE PULL STRENTH, SPS =**	**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)

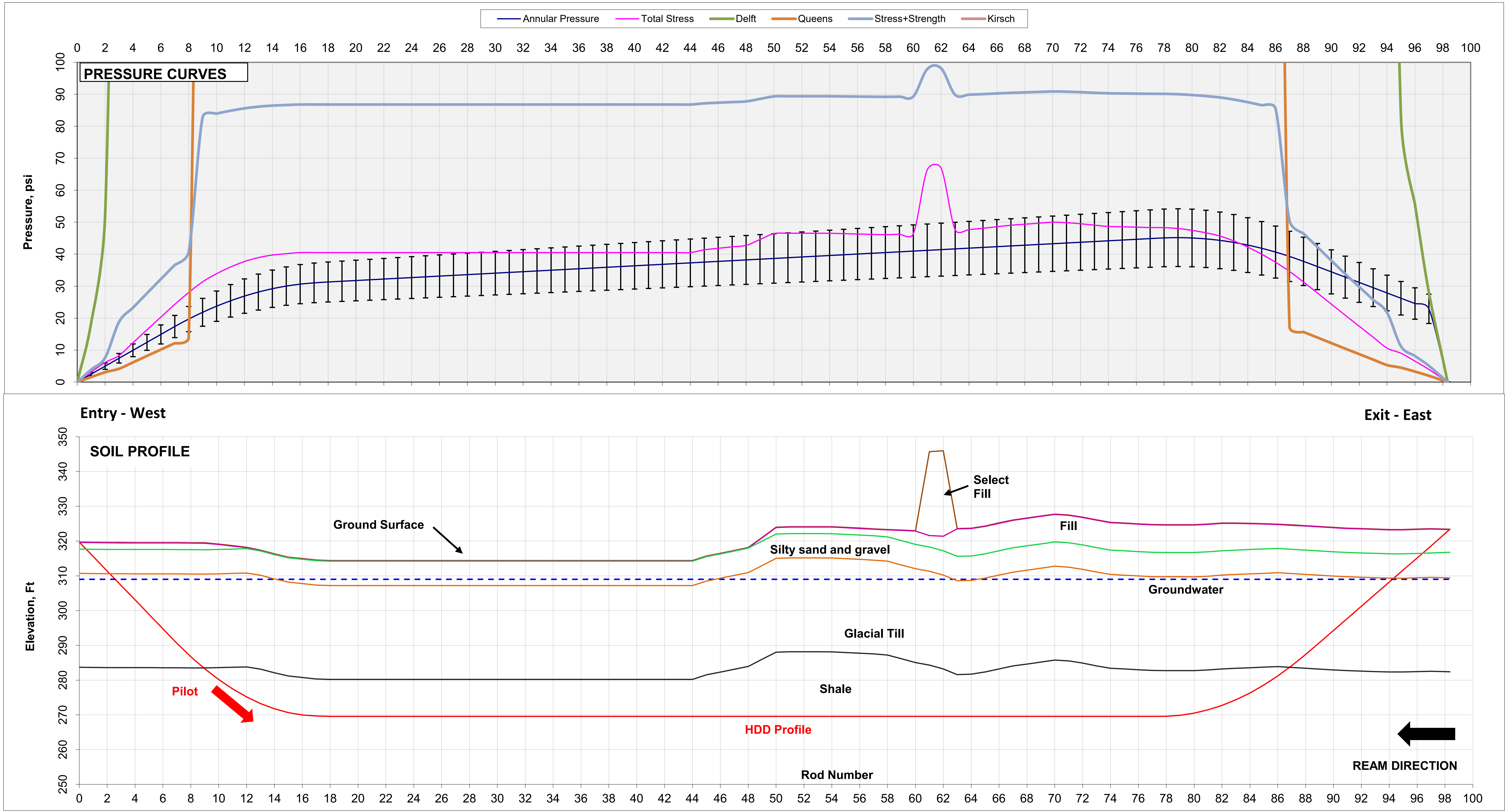
Pull Duration Time =	12 Hr		Pcr =	267.4 psi
SAS =	1,400 psi		Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum		
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.87243			
r = σ_i/2*(SSAS) =	0.22106		Example from Table T5, σ_i =	508 psi
P_{CRR} =	233.3 psi			
FS =	2.0			
P_{ACRR} = P_{CRR}/FS =	116.7 psi	Allowable Reduced Short Term Buckling pressure during pull		
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1}	89.47 psi	Pull Back Condition - Option 3	**OK as >0**	
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2}	88.77 psi	Pull Back Condition - Option 4	**OK as >0**	

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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



ISSUED: Issued for Construction (IFC)

Notes:

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

Basis of annulur pressure calculations

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

Print Date ; 3/16/2023 11:21

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 78 Circuit #1
CSX RR & Route 146 Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #1_APC_20220812.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 78 Circuit #2**
CSX RR & Route 146 Crossing

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: 16-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/16/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT	
Exit Station	**19+59.29**	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	637496.1190	1411250.5662	319.50 ft
Horizontal Curve PI	637803.7003	1410079.4732	
Exit	637950.8800	1409345.5694	323.40 ft
Depth to Mudline	0.00 ft	Clearance Depth =	50.10 ft
Measured Plan Length at ties =	1959.2939 ft		
Coordinate Length =	1959.2939 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	309.00 ft
Mudline Elev.*	319.50 ft
Lowest centerline Elev.	269.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	637496.1190	1411250.5662	11+51.87	637788.7272	1410136.4822	E 165.28394 N	1151.87		
Curve	11+51.87	637788.7272	1410136.4822	12+69.72	637815.2901	1410021.6814	E 168.66012 N	117.85	2000.00	3.376 deg.
Tangent	12+69.72	637815.2901	1410021.6814	19+59.29	637950.8800	1409345.5694	E 168.66012 N	689.57		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	1151.87	Input Radius, ft.	2000.00	Plan Length, ft.	689.57	
Entry Azimuth, deg.[5]	N 165.28394 E	Curve, deg	3.376 deg.	Exit Azimuth, deg.[5]	N 168.66012 E	
Entry Azimuth, rad.[5]	2.88475	Curve, rad	0.05893	Exit Azimuth, rad.[5]	2.94367	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	117.83	Easting	637950.8800	***Check***
PCH Easting	637788.7272	Arc Length, ft.	117.85	Northing	1409345.5694	***Delta***
PCH Northing	1410136.4822	Chord Azimuth, deg	166.9720			**0.0000**
		PI Easting =	637803.7003			**0.0000**
		PI Northing =	1410079.4732			**OK CALC**
		PTH Easting =	637815.2901			
		PTH Northing =	1410021.6814			**Exit Station** **19+59.29**
Cum Plan Length	1151.87	Cum Plan Length	1269.72	Cum Plan Length	1959.293929	**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**	**∆ Angle**	**Length**	**Radius**
Entry Tangent	323.40 ft	287.63 ft	-10.00 deg	-10.00 deg	0.00 deg	205.99 ft	0.00 ft
Entry Curve	287.63 ft	269.40 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	269.40 ft	269.40 ft	0.00 deg	0.00 deg	0.00 deg	1207.25 ft	0.00 ft
Exit Curve	269.40 ft	291.25 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	291.25 ft	319.50 ft	12.00 deg	12.00 deg	0.00 deg	135.86 ft	0.00 ft
					Total Check =	**1967.98 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	340.81	1151.87	No, Horiz > Entry V(Tan+Curve)
Exit	411.24	689.57	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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	323.40	
		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	132.895 ft	Plan Length	207.912 ft	Plan Length	1,207.25211 ft	Plan Length	208.378 ft	Plan Length	202.858 ft	1,959.294 ft
Rod Length	135.863 ft	Arc Rod Length	209.440 ft	Rod Length	1,207.25211 ft	Arc Rod Length	209.440 ft	Rod Length	205.987 ft	1,967.982 ft
Vertical Depth	-28.248 ft	Curve ∆ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	18.231 ft	Vertical Depth	35.769 ft	3.900 ft
		Lowest Elevation	269.400 ft			Lowest Elevation	269.400 ft	CK Total Cum Depth	3.900 ft	
Start Elevation	319.500 ft	Start Elevation	291.252 ft	Start Elevation	269.400 ft	Start Elevation	269.400 ft	Start Elevation	287.631 ft	
End Elevation	291.252 ft	End Elevation	269.400 ft	End Elevation	269.400 ft	End Elevation	287.631 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***	***1959.293929***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+32.89	Start Station	3+40.81	Start Station	15+48.06	Start Station	17+56.44
PVC Station	1+32.89	PTV Station	3+40.81	PCV Station	15+48.06	PTV Station	17+56.44	Exit Station	19+59.294
Cum Plan Length	132.89	Cum Plan Length	340.81	Cum Plan Length	1548.06 ft	Cum Plan Length	1756.44	Cum Plan Length	1959.29
Cum Rod Length	135.86	Cum Rod Length	345.30	Cum Rod Length	1552.56 ft	Cum Rod Length	1761.99	Cum Rod Length	1967.98
Cum Depth	-28.25	Cum Depth	-50.10	Cum Depth	-50.10 ft	Cum Depth	-31.8693	Cum Depth	3.90

Stationing Check
OK STATIONING

Plan Length Check
OK CALCULATION

Elevation Change Check
OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.90 ft**
Minimum Design Elevation =	**269.40 ft**
Invert Depth below exit =	**54.00 ft**
Invert Depth below entry =	**50.10 ft**
Path Length =	**1,967.98 ft**
Plan Length =	**1,959.29 ft**
Minimum Plan Length (No Tangent) =	**752.04 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

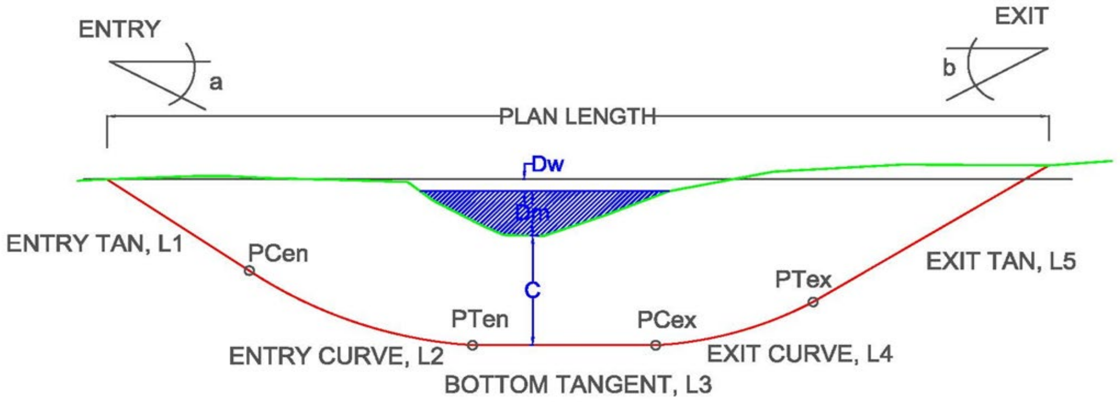
NOTES:

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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 78 Circuit #2
CSX RR & Route 146 Crossing

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	206.0 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	1207.3 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	135.9 ft	β =	12.0 °	0.2094	
LT =	2068.0 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 Pipe PIPE/BUNDLE

Material Density, γ 59.28 pcf

Outside Diameter, D_{OD} 10.75 Pipe or Bundle

Pipe Dry Weight, W_P = 15.70 lb/ft Pipe or Bundle

Min. Wall Thickness, t_m 1.194 in For design installation pull stress

DR = D_O/t_{min} = 9 D_{OD} Stress 10.75 inches

Avg. Inside Diameter, D_{IA} 8.22 in Bundle Multiplier F_D 1.0000

12 Hr Pullback Modulus, E_T = 65,000 psi @T = 73 deg F

Poisson Ratio, μ = 0.45

Ovality Factor, f_o = 0.84 2%

Buckling Safety, N = 2.5

Hydrostatic Design Stress, HDS = 1,008 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 = 319.50 ft

Ballast Water El., H_W = 319.50 ft

Lowest Invert El., El_m = 269.40 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 = 0.33 lb/ft Comparison Only @ 8psi

Calculated Buoyant Forces

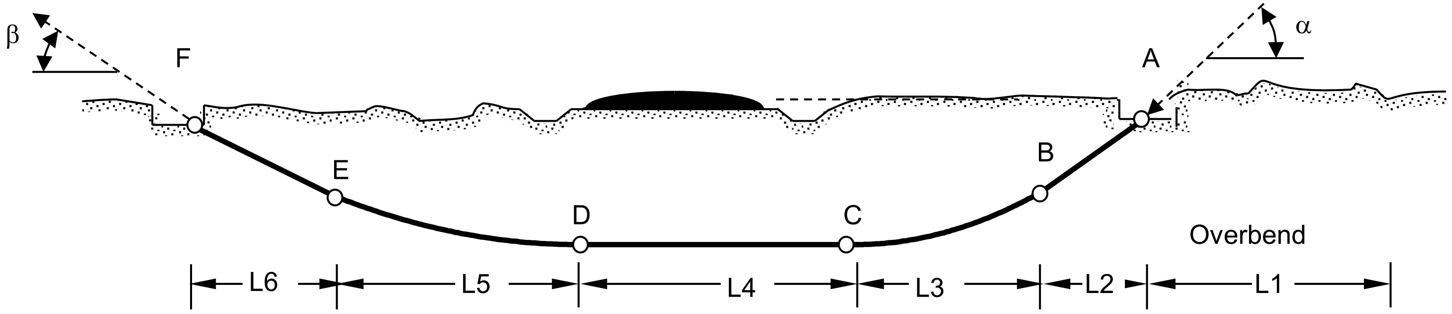
	Pipe	
	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 319.50 ft

Pipe Entry El = 323.40 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	 Ballast
A	3,304 lb	150 psi	OK	3,304 lb	150 psi	OK	OK	OK
B	4,924 lb	137 psi	OK	5,230 lb	146 psi	OK	OK	OK
C	6,435 lb	204 psi	OK	5,940 lb	190 psi	OK	OK	OK
D	11,472 lb	320 psi	OK	10,978 lb	306 psi	OK	OK	OK
E	15,513 lb	462 psi	OK	13,200 lb	397 psi	OK	OK	OK
F	18,084 lb	504 psi	OK	14,358 lb	401 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 93.45 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb $SSPS = \sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.873570993 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.219346767 $r = \sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 504 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** = 5.43 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** = 27.14 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
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 78 Circuit #2
CSX RR & Route 146 Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 78 Circuit #2

CSX RR & Route 146 Crossing

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INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification	445574C		Design resin with minimum PENT test of 10,000 hours
Standard Dimension	10		
Pipe measurement standard	IPS		IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in		Standard Manufacturer's Data Sheets
Avg. Inside Diameter, D_i =	8.219 in		Standard Manufacturer's Data Sheets
Minimum Wall, t_{min} =	1.194 in		Standard Manufacturer's Data Sheets
Wall Section Area, A_W =	35.84514492		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
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 =	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	0.84	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

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

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

Buoyant forces

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

HDPE PROPERTIES

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

HDD 78 Circuit #2
CSX RR & Route 146 Crossing

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 54.00 ft

Ballast depth to invert, H_B 50.10 ft

Drill Fluid depth to invert, H_{DF} 50.10 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	21.90 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	27.38 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	28.08 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	21.90 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 = $(P_A+P_a)-P_{DF1}$	79.59 psi	18.70 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	78.89 psi	18.00 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.50 psi	40.61 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.80 psi	39.90 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	85.07 psi	24.18 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 78 Circuit #2
CSX RR & Route 146 Crossing

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 1,120 psi
Safe Allowable Stress, SAS = 448 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 16,064 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.
SAFE PULL STRENTH, SPS = 16,064 lb
Ultimate Pull Strength, UPS = 40,160 lb
Suggested SSAS = 1,150 psi

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
SAS = 448 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.87357
$r = \sigma_i/2*(SSAS)$ = 0.21935
P_{CRR} = 233.6 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 116.8 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ = 89.43 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ = 88.73 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 504 psi

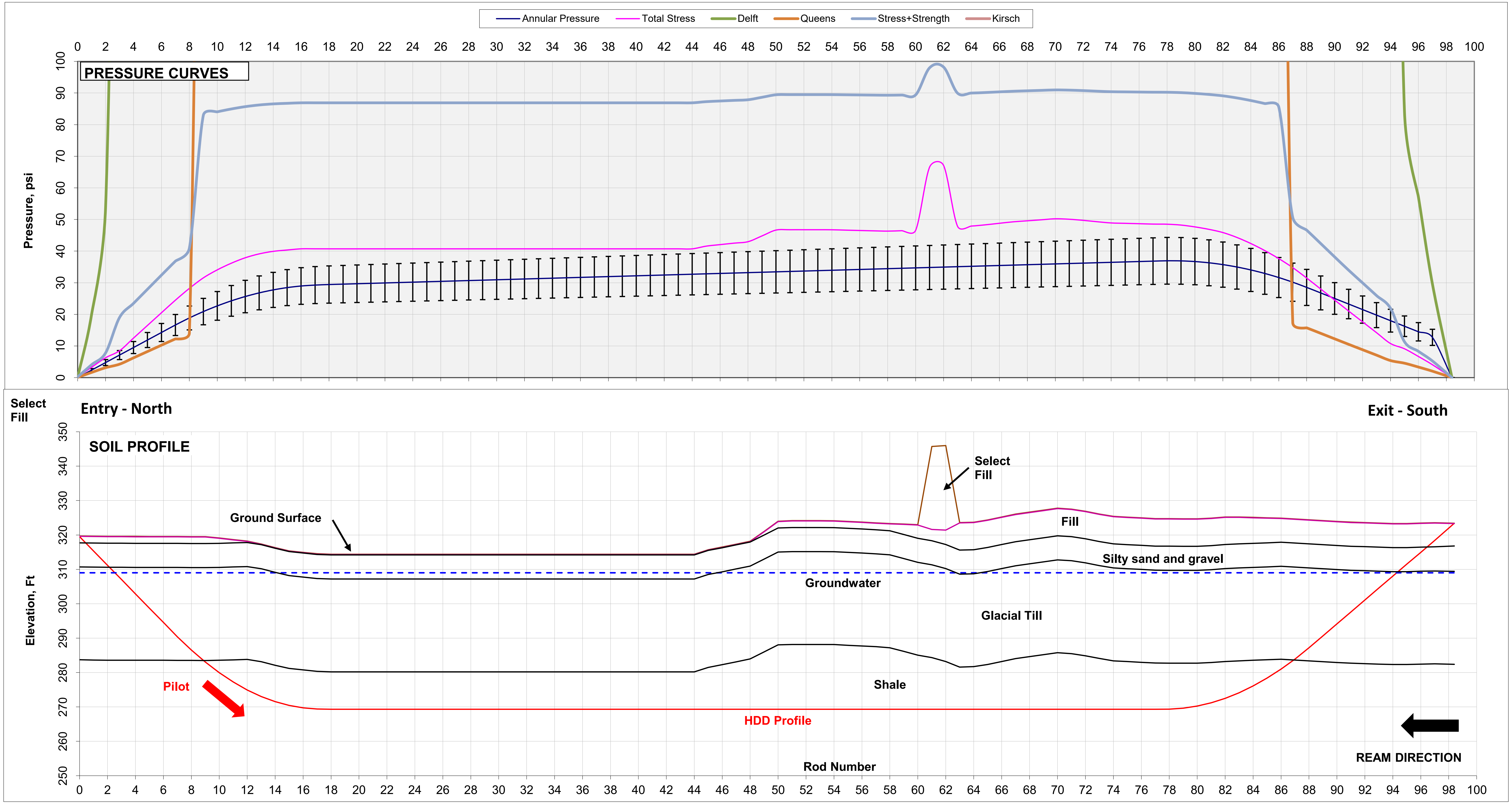
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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
100 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 78 Circuit #2
CSX RR & Route 146 Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#78 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 79B Circuit #1**
CSX RR & Black Creek Crossing

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: 7-Mar-2023

Date	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT
Exit Station	**12+38.05**	FT

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

	East	North	Elevation
Entry	638317.2897	1407389.5614	319.00 ft
Horizontal Curve PI	638282.6701	1407867.9935	
Exit	638113.4201	1408607.6032	321.20 ft
Depth to Mudline	0.00 ft	Clearance Depth =	42.00 ft
Measured Plan Length at ties =	1238.0539 ft		
Coordinate Length =	1238.0539 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	316.00 ft
Mudline Elev.*	319.00 ft
Lowest centerline Elev.	277.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	638317.2897	1407389.5614	3+87.87	638289.2966	1407776.4171	E 355.86126 N	387.87		
Curve	3+87.87	638289.2966	1407776.4171	5+71.14	638262.1887	1407957.4958	E 347.11054 N	183.27	1200.00	-8.751 deg.
Tangent	5+71.14	638262.1887	1407957.4958	12+38.05	638113.4201	1408607.6032	E 347.11054 N	666.91		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	387.87	Input Radius, ft.	1200.00	Plan Length, ft.	666.91	
Entry Azimuth, deg.[5]	N 355.86126 E	Curve, deg	-8.751 deg.	Exit Azimuth, deg.[5]	N 347.11054 E	
Entry Azimuth, rad.[5]	6.21095	Curve, rad	-0.15273	Exit Azimuth, rad.[5]	6.05822	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	183.10	Easting	638113.4201	***Check***
PCH Easting	638289.2966	Arc Length, ft.	183.27	Northing	1408607.6032	***Delta***
PCH Northing	1407776.4171	Chord Azimuth, deg	351.4859			**0.0000**
		PI Easting =	638282.6701			**0.0000**
		PI Northing =	1407867.9935			**OK CALC**
		PTH Easting =	638262.1887			
		PTH Northing =	1407957.4958			**Exit Station**
						12+38.05
Cum Plan Length	387.87	Cum Plan Length	571.14	Cum Plan Length	1238.053851	**OK STA**

Pull Geometry

Pipe Entry	**EXIT**	**Enter the pipe entry location into the hole: Entry/Exit**					
	Elevations		**Vertical Angle**			**Path Length**	**Curve Radius**
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**		
Entry Tangent	321.20 ft	295.23 ft	-10.00 deg	-10.00 deg	0.00 deg	149.55 ft	0.00 ft
Entry Curve	295.23 ft	277.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	277.00 ft	277.00 ft	0.00 deg	0.00 deg	0.00 deg	578.88 ft	0.00 ft
Exit Curve	277.00 ft	309.67 ft	0.00 deg	14.00 deg	14.00 deg	268.78 ft	1100.00 ft
Exit Tangent	309.67 ft	319.00 ft	14.00 deg	14.00 deg	0.00 deg	38.55 ft	0.00 ft
					Total Check =	**1245.20 ft**	**OK**

Compound Curve Assessment

Start	**Vert. Plan**	**Horiz. Plan**	
Entry	303.52	387.87	No, Horiz > Entry V(Tan+Curve)
Exit	355.66	666.91	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	1100.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	321.20	
		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	37.402 ft	Plan Length	266.114 ft	Plan Length	578.88098 ft	Plan Length	208.378 ft	Plan Length	147.279 ft	1,238.054 ft
Rod Length	38.547 ft	Arc Rod Length	268.781 ft	Rod Length	578.88098 ft	Arc Rod Length	209.440 ft	Rod Length	149.551 ft	1,245.199 ft
Vertical Depth	-9.325 ft	Curve Δ Vert Depth	-32.675 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	25.969 ft	2.200 ft
		Lowest Elevation	277.000 ft			Lowest Elevation	277.000 ft	CK Total Cum Depth	2.200 ft	
Start Elevation	319.000 ft	Start Elevation	309.675 ft	Start Elevation	277.000 ft	Start Elevation	277.000 ft	Start Elevation	295.231 ft	
End Elevation	309.675 ft	End Elevation	277.000 ft	End Elevation	277.000 ft	End Elevation	295.231 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***	***1238.053851***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+37.40	Start Station	3+03.52	Start Station	8+82.40	Start Station	10+90.77	**OK STATIONING**
PVC Station	0+37.40	PTV Station	3+03.52	PCV Station	8+82.40	PTV Station	10+90.77	Exit Station	12+38.054	**Plan Length Check**
Cum Plan Length	37.40	Cum Plan Length	303.52	Cum Plan Length	882.40 ft	Cum Plan Length	1090.77	Cum Plan Length	1238.05	**OK CALCULATION**
Cum Rod Length	38.55	Cum Rod Length	307.33	Cum Rod Length	886.21 ft	Cum Rod Length	1095.65	Cum Rod Length	1245.20	**Elevation Change Check**
Cum Depth	-9.33	Cum Depth	-42.00	Cum Depth	-42.00 ft	Cum Depth	-23.7693	Cum Depth	2.20	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**2.20 ft**
Minimum Design Elevation =	**277.00 ft**
Invert Depth below exit =	**44.20 ft**
Invert Depth below entry =	**42.00 ft**
Path Length =	**1,245.20 ft**
Plan Length =	**1,238.05 ft**
Minimum Plan Length (No Tangent) =	**659.17 ft**
Entry Angle =	**-14.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

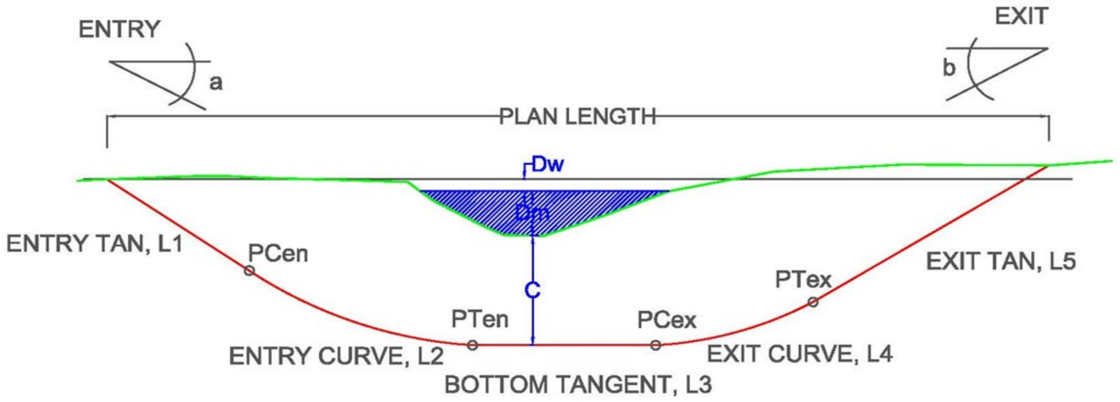
NOTES:

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
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Bedford, NH 03110

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

TABLE 2
DRILL PATH DESIGN CALCULATION
HDD 79B Circuit #1
CSX RR & Black Creek Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #1_APC__20220816.xlsb]T3 Plastic Pull

Pull Geometry

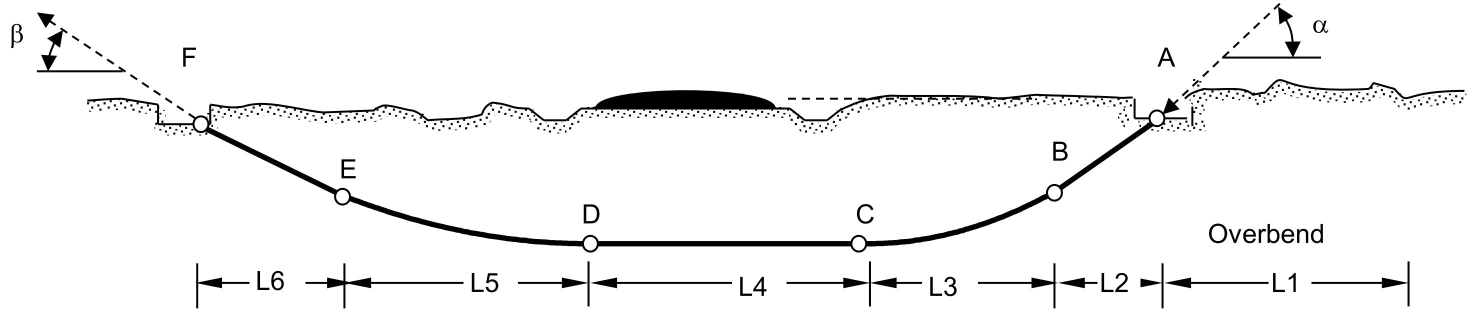
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	149.6 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	578.9 ft	χ =	0.0 °	0.0000	
L5 =	268.8 ft				1,100.0 ft
L6 =	38.5 ft	β =	14.0 °	0.2443	
LT =	1345.2 ft				

Pipe Entry Location - Drill | **EXIT**

(schematic, to show definition of variables only)

Pipe Exit El = 319.00 ft

Pipe Entry El = 321.20 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$_T$A$_F$/(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 =	319.00 ft	
Ballast Water El., H_W =	319.00 ft	
Lowest Invert El., El_m =	277.00 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} =		17.36 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	 Ballast
A	2,376 lb	189 psi	OK	2,376 lb	189 psi	OK	OK	OK
B	3,637 lb	92 psi	OK	3,890 lb	98 psi	OK	OK	OK
C	5,325 lb	166 psi	OK	4,688 lb	150 psi	OK	OK	OK
D	7,650 lb	193 psi	OK	7,013 lb	177 psi	OK	OK	OK
E	13,340 lb	372 psi	OK	9,974 lb	287 psi	OK	OK	OK
F	14,210 lb	358 psi	OK	10,369 lb	262 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert**	$\mathbf{P_{PA} = P_A F_R}$ = 97.44 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 =	0.910904773	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.161551073	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	372 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	4.55	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	22.75	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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 79B Circuit #1
CSX RR & Black Creek Crossing

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #1_APC__20220816.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 79B Circuit #1
CSX RR & Black Creek Crossing

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification	445574C	Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	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 =	3.801889456	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
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 =	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #1_APC__20220816.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

BRIERLEY ASSOCIATES
Limited Liability Company

"Creating Space Underground"

HDD 79B Circuit #1

CSX RR & Black Creek Crossing

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	44.20 ft	Ballast depth to invert, H_B	42.00 ft	Drill Fluid depth to invert, H_{DF}	42.00 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	18.26 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	22.83 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	23.41 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	18.26 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 = $(P_A+P_a)-P_{DF1}$	84.15 psi	23.25 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	83.56 psi	22.67 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.41 psi	41.52 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.82 psi	40.93 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	88.71 psi	27.82 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 79B Circuit #1
CSX RR & Black Creek Crossing

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

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

Designed Pull Duration Time = 12 hr
Quantity of pipes, Q = 1
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Temperature, F = 73 deg.
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ 0.4
SAFE PULL STRENTH, SPS = 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

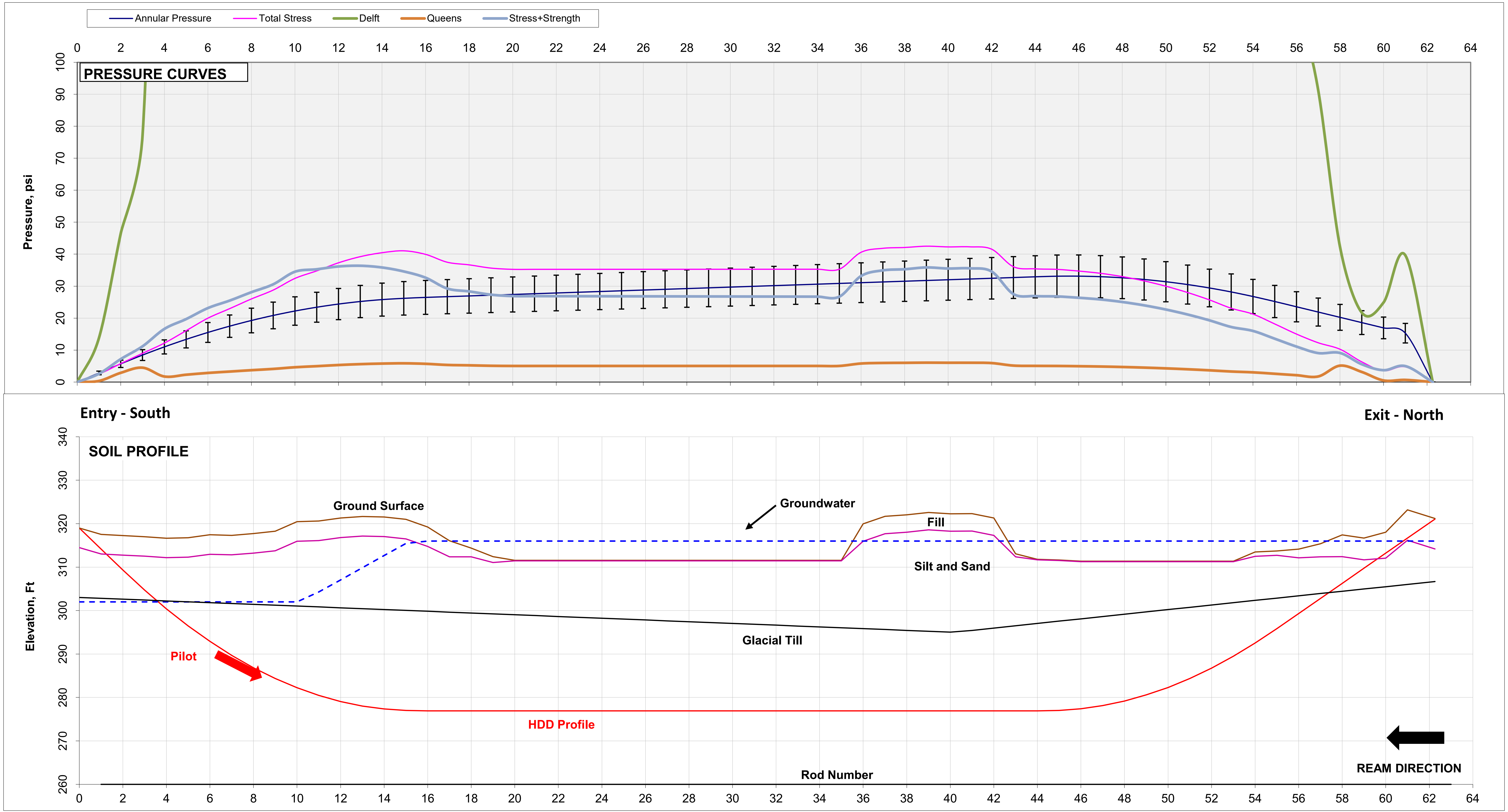
Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, $P_{CRR} = P_{CR}*f_r$
(ASTM F-1962 EQ. 22)

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 = 0.91090
$r = \sigma_i/2*(SSAS)$ = 0.16155
Example from Table T5, σ_i = 372 psi
P_{CRR} = 243.6 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 121.8 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 98.98 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 98.39 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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



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

Basis of annular pressure calculations

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

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BRIERLEY ASSOCIATES
Creating Space Underground
167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 79B Circuit #1
CSX RR & Black Creek Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #1_APC__20220816.xlsb]T3 Plastic Pull

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 79B Circuit #2**
CSX RR & Black Creek Crossing

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: 7-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	12+40.77	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	638332.4329	1407390.3613	318.10 ft
Horizontal Curve PI	638295.5467	1407884.3713	
Exit	638128.6750	1408611.1906	321.20 ft
Depth to Mudline	0.00 ft	Clearance Depth =	41.10 ft
Measured Plan Length at ties =		1240.7685 ft	
Coordinate Length =		1240.7685 ft	
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	300.00 ft
Mudline Elev.*	318.10 ft
Lowest centerline Elev.	277.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	638332.4329	1407390.3613	4+04.52	638302.3124	1407793.7593	E 355.72983 N	404.52		
Curve	4+04.52	638302.3124	1407793.7593	5+85.90	638275.2140	1407972.9314	E 347.06945 N	181.38	1200.00	-8.660 deg.
Tangent	5+85.90	638275.2140	1407972.9314	12+40.77	638128.6750	1408611.1906	E 347.06945 N	654.87		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	404.52	Input Radius, ft.	1200.00	Plan Length, ft.	654.87	
Entry Azimuth, deg.[5]	N 355.72983 E	Curve, deg	-8.660 deg.	Exit Azimuth, deg.[5]	N 347.06945 E	
Entry Azimuth, rad.[5]	6.20866	Curve, rad	-0.15115	Exit Azimuth, rad.[5]	6.05750	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	181.21	Easting	638128.6750	***Check***
PCH Easting	638302.3124	Arc Length, ft.	181.38	Northing	1408611.1906	***Delta***
PCH Northing	1407793.7593	Chord Azimuth, deg	351.3996			**0.0000**
		PI Easting =	638295.5467			**0.0000**
		PI Northing =	1407884.3713			**OK CALC**
		PTH Easting =	638275.2140			
		PTH Northing =	1407972.9314			**Exit Station**
						12+40.77
Cum Plan Length	404.52	Cum Plan Length	585.90	Cum Plan Length	1240.76853	**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	321.20 ft	295.23 ft	-10.00 deg	-10.00 deg	0.00 deg	149.55 ft	0.00 ft
Entry Curve	295.23 ft	277.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	277.00 ft	277.00 ft	0.00 deg	0.00 deg	0.00 deg	585.21 ft	0.00 ft
Exit Curve	277.00 ft	309.67 ft	0.00 deg	14.00 deg	14.00 deg	268.78 ft	1100.00 ft
Exit Tangent	309.67 ft	318.10 ft	14.00 deg	14.00 deg	0.00 deg	34.83 ft	0.00 ft
					Total Check =	**1247.80 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	299.91	404.52	No, Horiz > Entry V(Tan+Curve)
Exit	355.66	654.87	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	1100.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	321.20	
		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	33.792 ft	Plan Length	266.114 ft	Plan Length	585.20536 ft	Plan Length	208.378 ft	Plan Length	147.279 ft	1,240.769 ft
Rod Length	34.827 ft	Arc Rod Length	268.781 ft	Rod Length	585.20536 ft	Arc Rod Length	209.440 ft	Rod Length	149.551 ft	1,247.803 ft
Vertical Depth	-8.425 ft	Curve Δ Vert Depth	-32.675 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	25.969 ft	3.100 ft
		Lowest Elevation	277.000 ft			Lowest Elevation	277.000 ft	CK Total Cum Depth	3.100 ft	
Start Elevation	318.100 ft	Start Elevation	309.675 ft	Start Elevation	277.000 ft	Start Elevation	277.000 ft	Start Elevation	295.231 ft	
End Elevation	309.675 ft	End Elevation	277.000 ft	End Elevation	277.000 ft	End Elevation	295.231 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***	***1240.76853***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+33.79	Start Station	2+99.91	Start Station	8+85.11	Start Station	10+93.49	**Stationing Check**
PVC Station	0+33.79	PTV Station	2+99.91	PCV Station	8+85.11	PTV Station	10+93.49	Exit Station	12+40.769	**OK STATIONING**
Cum Plan Length	33.79	Cum Plan Length	299.91	Cum Plan Length	885.11 ft	Cum Plan Length	1093.49	Cum Plan Length	1240.77	**Plan Length Check**
Cum Rod Length	34.83	Cum Rod Length	303.61	Cum Rod Length	888.81 ft	Cum Rod Length	1098.25	Cum Rod Length	1247.80	**OK CALCULATION**
Cum Depth	-8.43	Cum Depth	-41.10	Cum Depth	-41.10 ft	Cum Depth	-22.8693	Cum Depth	3.10	**Elevation Change Check**
										OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.10 ft**
Minimum Design Elevation =	**277.00 ft**
Invert Depth below exit =	**44.20 ft**
Invert Depth below entry =	**41.10 ft**
Path Length =	**1,247.80 ft**
Plan Length =	**1,240.77 ft**
Minimum Plan Length (No Tangent) =	**655.56 ft**
Entry Angle =	**-14.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

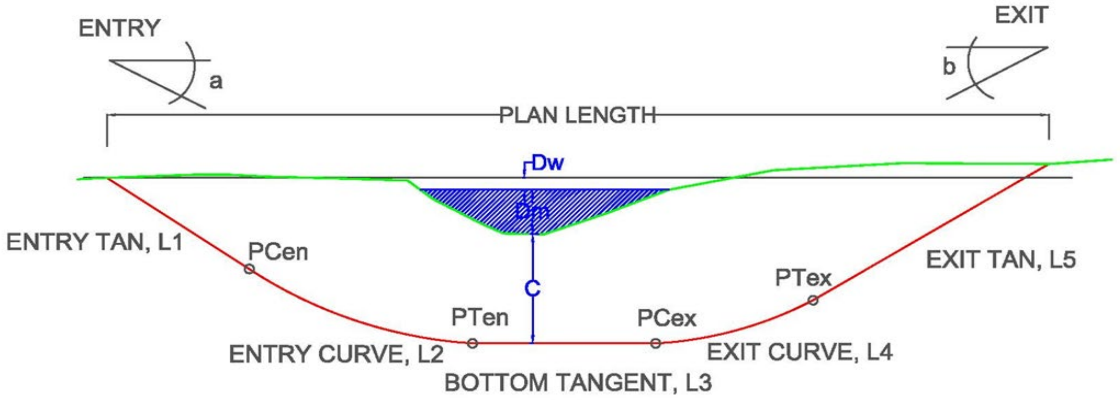
NOTES:

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
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Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 79B Circuit #2
CSX RR & Black Creek Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #2_APC__20221023.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	149.6 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	585.2 ft	χ =	0.0 °	0.0000	
L5 =	268.8 ft				1,100.0 ft
L6 =	34.8 ft	β =	14.0 °	0.2443	
LT =	1347.8 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}	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 =	318.10 ft	
Ballast Water El., H_W =	318.10 ft	
Lowest Invert El., El_m =	277.00 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 =	0.52 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

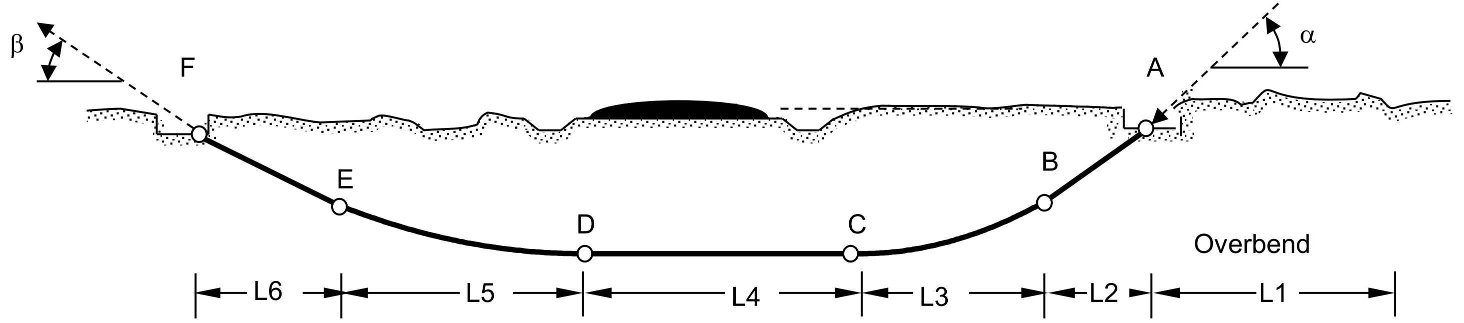
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill EXIT

(schematic, to show definition of variables only)

Pipe Exit El = 318.10 ft

Pipe Entry El = 321.20 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	Ballast
A	2,153 lb	118 psi	OK	2,153 lb	118 psi	OK	OK	OK
B	3,333 lb	93 psi	OK	3,553 lb	99 psi	OK	OK	OK
C	4,773 lb	157 psi	OK	4,188 lb	141 psi	OK	OK	OK
D	6,912 lb	193 psi	OK	6,328 lb	177 psi	OK	OK	OK
E	11,941 lb	360 psi	OK	8,889 lb	274 psi	OK	OK	OK
F	12,638 lb	353 psi	OK	9,198 lb	257 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 97.79 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.914149914	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.156347913	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	360 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	4.45	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	22.26	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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 79B Circuit #2
CSX RR & Black Creek Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #2_APC__20221023.xlsb]T3 Plastic Pull

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 79B Circuit #2

CSX RR & Black Creek Crossing

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 =	3.801889456	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
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 =	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	0.84	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 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	$W_B = V_{Di}*\gamma_{INT}$
xpected 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

TABLE 4 Pg 2 of 3

HDPE PROPERTIES

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

HDD 79B Circuit #2
CSX RR & Black Creek Crossing

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^{o}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, ^{o}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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 44.20 ft
Ballast depth to invert, H_B 41.10 ft
Drill Fluid depth to invert, H_{DF} 41.10 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$ 17.87 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$ 22.34 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$ 22.91 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$ 17.87 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 = $(P_A+P_a)-P_{DF1}$	84.63 psi	23.74 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	84.06 psi	23.17 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.51 psi	41.61 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.93 psi	41.04 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	89.10 psi	28.21 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

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HDD 79B Circuit #2

CSX RR & Black Creek Crossing

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

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

Designed Pull Duration Time = 12 hr

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y = 0.4

Temperature factor, f_{temp} = 1

Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi

Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF

Safe Pull Strength, SPS Pipe = 5,321 lb **Useing SSAS = 4,371 lb**

Quantity of pipes, Q = 1

Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb

Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi

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

SAS = 1,400 psi

Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum

fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.91415

r = σ_i/2*(SSAS) = 0.15635

P_{CRR} = 244.5 psi

FS = 2.0

P_{ACRR} = P_{CRR}/FS = 122.2 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 99.90 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 99.32 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi

Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 360 psi

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

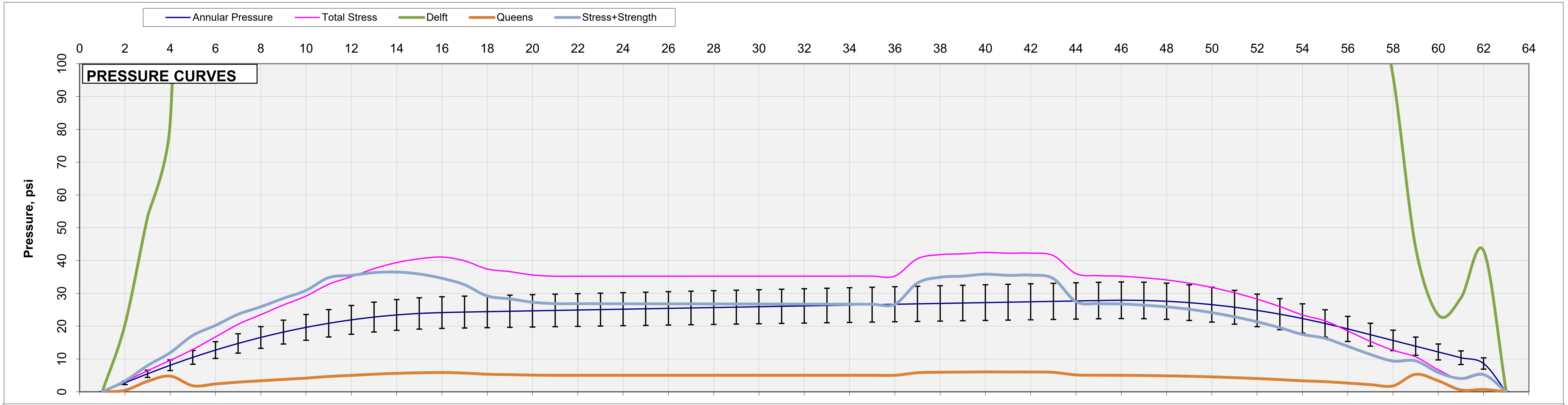
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

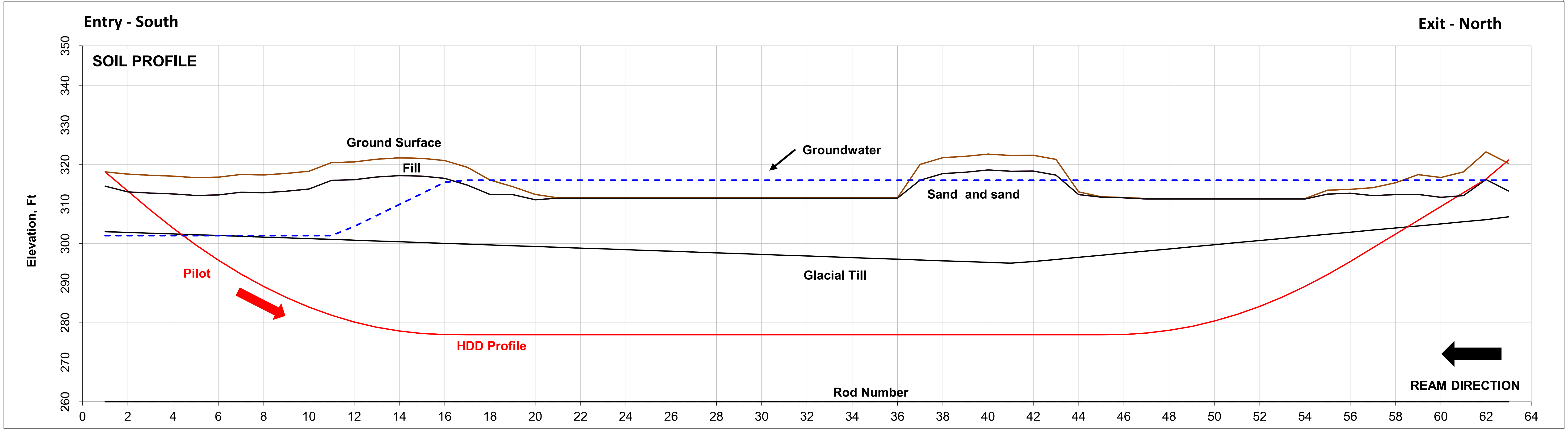
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

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





ISSUED: Issued for Construction (IFC)

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

Basis of annulur pressure calculations

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

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND
FORMATION PRESSURE CURVES
HDD 79B Circuit #2
CSX RR & Black Creek Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#79B CIR #2_APC__20221023.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 80 Circuit #1**
CSX RR & Black Creek Crossing

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: 7-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/7/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT	
Exit Station	**18+77.52**	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	638819.3569	1405391.6628	319.70 ft
Horizontal Curve PI	639019.7239	1404716.3820	
Exit	639572.0898	1403680.6414	322.90 ft
Depth to Mudline	0.00 ft	Clearance Depth =	30.10 ft
Measured Plan Length at ties =	1877.5211 ft		
Coordinate Length =	1877.5211 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	317.00 ft
Mudline Elev.*	319.70 ft
Lowest centerline Elev.	289.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	638819.3569	1405391.6628	6+03.29	638990.9682	1404813.2949	E 163.47350 N	603.29		
Curve	6+03.29	638990.9682	1404813.2949	8+04.78	639067.2933	1404627.1847	E 151.92877 N	201.49	1000.00	-11.545 deg.
Tangent	8+04.78	639067.2933	1404627.1847	18+77.52	639572.0898	1403680.6414	E 151.92877 N	1072.74		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	603.29	Input Radius, ft.	1000.00	Plan Length, ft.	1072.74	
Entry Azimuth, deg.^{5}	N 163.47350 E	Curve, deg	-11.545 deg.	Exit Azimuth, deg.^{5}	N 151.92877 E	
Entry Azimuth, rad.^{5}	2.85315	Curve, rad	-0.20149	Exit Azimuth, rad.^{5}	2.65166	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	201.15	Easting	639572.0898	***Check***
PCH Easting	638990.9682	Arc Length, ft.	201.49	Northing	1403680.6414	***Delta***
PCH Northing	1404813.2949	Chord Azimuth, deg	157.7011			**0.0000**
		PI Easting =	639019.7239			**0.0000**
		PI Northing =	1404716.3820			**OK CALC**
		PTH Easting =	639067.2933			
		PTH Northing =	1404627.1847			**Exit Station** **18+77.52**
Cum Plan Length	603.29	Cum Plan Length	804.78	Cum Plan Length	1877.5211	**OK STA**

Pull Geometry

Pipe Entry	**Exit**	**Enter the pipe entry location into the hole: Entry/Exit**					
	Elevations		**Vertical Angle**			**Path Length**	**Curve Radius**
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**		
Entry Tangent	322.90 ft	307.83 ft	-10.00 deg	-10.00 deg	0.00 deg	86.78 ft	0.00 ft
Entry Curve	307.83 ft	289.60 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	289.60 ft	289.60 ft	0.00 deg	0.00 deg	0.00 deg	1336.97 ft	0.00 ft
Exit Curve	289.60 ft	311.45 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	311.45 ft	319.70 ft	12.00 deg	12.00 deg	0.00 deg	39.67 ft	0.00 ft
					Total Check =	**1882.30 ft**	**OK**

Compound Curve Assessment

Start	**Vert. Plan**	**Horiz. Plan**	
Entry	246.71	603.29	No, Horiz > Entry V(Tan+Curve)
Exit	293.84	1072.74	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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	322.90	
		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	38.802 ft	Plan Length	207.912 ft	Plan Length	1,336.96742 ft	Plan Length	208.378 ft	Plan Length	85.462 ft	1,877.521 ft
Rod Length	39.669 ft	Arc Rod Length	209.440 ft	Rod Length	1,336.96742 ft	Arc Rod Length	209.440 ft	Rod Length	86.781 ft	1,882.296 ft
Vertical Depth	-8.248 ft	Curve Δ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	15.069 ft	3.200 ft
		Lowest Elevation	289.600 ft			Lowest Elevation	289.600 ft	CK Total Cum Depth	3.200 ft	
Start Elevation	319.700 ft	Start Elevation	311.452 ft	Start Elevation	289.600 ft	Start Elevation	289.600 ft	Start Elevation	307.831 ft	
End Elevation	311.452 ft	End Elevation	289.600 ft	End Elevation	289.600 ft	End Elevation	307.831 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***	***1877.5211***	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	0+38.80	Start Station	2+46.71	Start Station	15+83.68	Start Station	17+92.06	
PVC Station	0+38.80	PTV Station	2+46.71	PCV Station	15+83.68	PTV Station	17+92.06	Exit Station	18+77.521	
Cum Plan Length	38.80	Cum Plan Length	246.71	Cum Plan Length	1583.68 ft	Cum Plan Length	1792.06	Cum Plan Length	1877.52	
Cum Rod Length	39.67	Cum Rod Length	249.11	Cum Rod Length	1586.08 ft	Cum Rod Length	1795.52	Cum Rod Length	1882.30	
Cum Depth	-8.25	Cum Depth	-30.10	Cum Depth	-30.10 ft	Cum Depth	-11.8693	Cum Depth	3.20	

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.20 ft**
Minimum Design Elevation =	**289.60 ft**
Invert Depth below exit =	**33.30 ft**
Invert Depth below entry =	**30.10 ft**
Path Length =	**1,882.30 ft**
Plan Length =	**1,877.52 ft**
Minimum Plan Length (No Tangent) =	**540.55 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

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

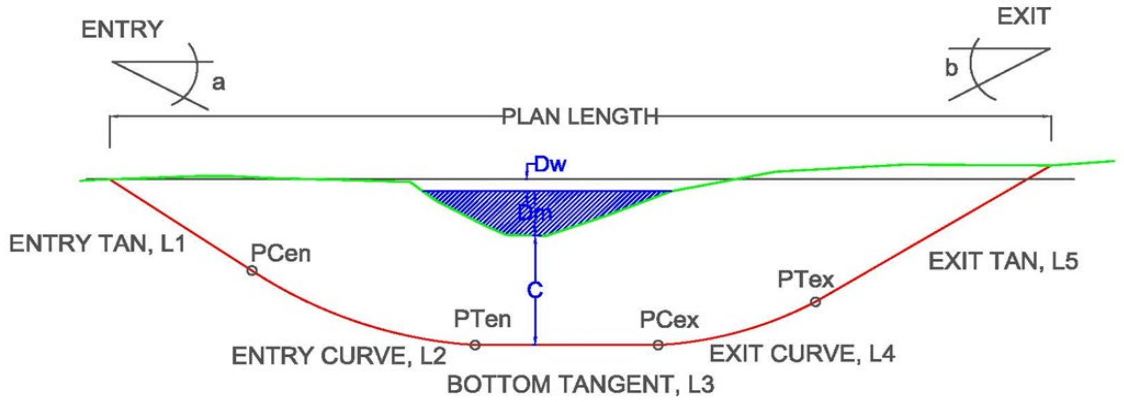
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 80 Circuit #1
CSX RR & Black Creek Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #1_APC_20220819.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	86.8 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	1337.0 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	39.7 ft	β =	12.0 °	0.2094	
LT =	1982.3 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 =	319.70 ft	
Ballast Water El., H_W =	319.70 ft	
Lowest Invert El., El_m =	289.60 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 =	0.47 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

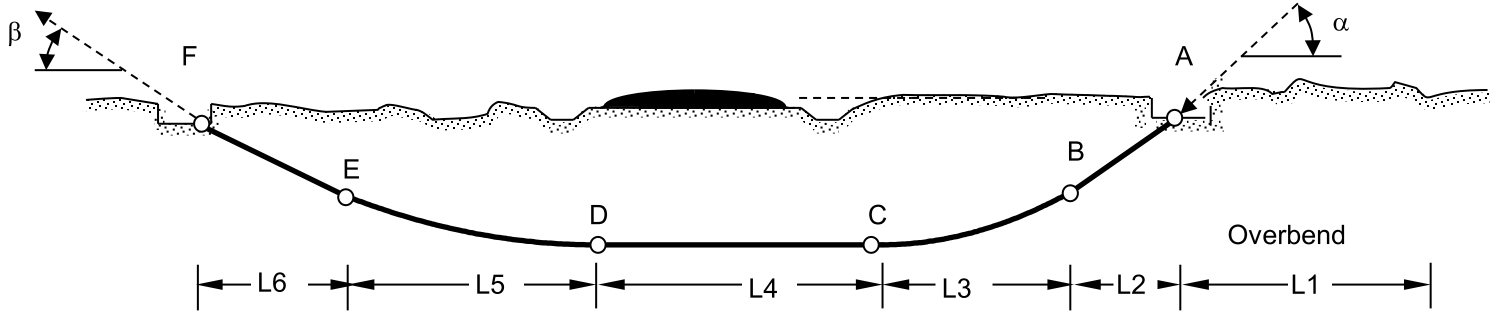
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 319.70 ft

Pipe Entry El = 322.90 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	Ballast
A	3,502 lb	166 psi	OK	3,502 lb	166 psi	OK	OK	OK
B	4,130 lb	104 psi	OK	4,256 lb	107 psi	OK	OK	OK
C	5,839 lb	179 psi	OK	5,070 lb	160 psi	OK	OK	OK
D	12,265 lb	309 psi	OK	11,496 lb	290 psi	OK	OK	OK
E	16,809 lb	463 psi	OK	14,016 lb	392 psi	OK	OK	OK
F	17,657 lb	445 psi	OK	14,408 lb	363 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 94.74 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.885599772	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.201125688	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	463 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	3.26	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	16.30	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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Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 80 Circuit #1
CSX RR & Black Creek Crossing

Revision 1 TBD

TABLE 4 **Pg 1 of 3**

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HDPE PROPERTIES

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

HDD 80 Circuit #1
CSX RR & Black Creek Crossing

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 =	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 =	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	0.84	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #1_APC_20220819.xlsb]T3 Plastic Pull

TABLE 4 Pg 2 of 3

HDPE PROPERTIES

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Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

HDD 80 Circuit #1
CSX RR & Black Creek Crossing

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	33.30 ft	Ballast depth to invert, H_B	30.10 ft	Drill Fluid depth to invert, H_{DF}	30.10 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	13.11 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	16.38 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	16.80 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	13.11 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 = $(P_A+P_a)-P_{DF1}$	90.59 psi	29.70 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	90.17 psi	29.28 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.70 psi	42.80 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.28 psi	42.38 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	93.87 psi	32.97 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 **Pg 3 of 3**

HDPE PROPERTIES

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

HDD 80 Circuit #1
CSX RR & Black Creek Crossing

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 5,321 lb

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi
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)

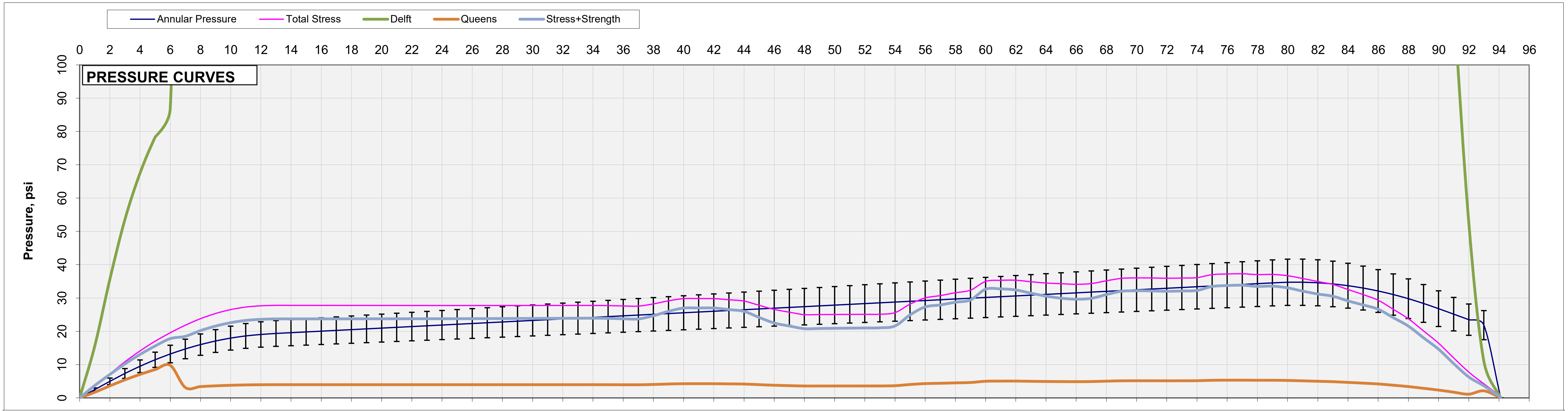
Pull Duration Time = 12 Hr
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
$fr = ((5.57-(r+1.09)^2)^.5)-1.09$ = 0.88560
$r = \sigma_i/2*(SSAS)$ = 0.20113
P_{CRR} = 236.8 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 118.4 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ = 102.04 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ = 101.62 psi Pull Back Condition - Option 4 **OK as >0**

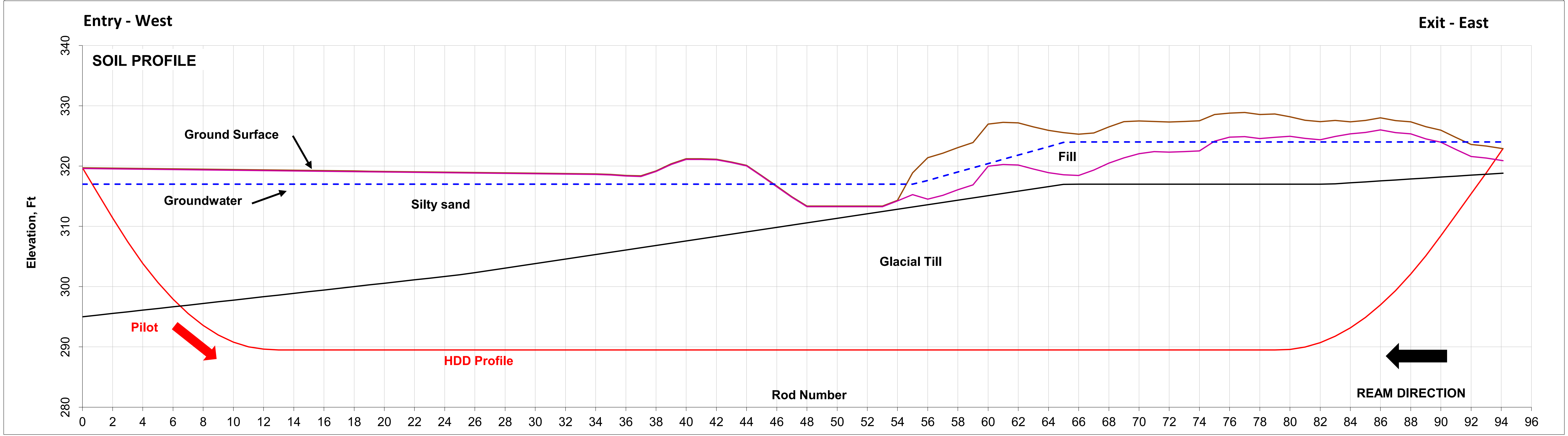
Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 463 psi

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 annular pressure calculations

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

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 80 Circuit #1
CSX RR & Black Creek Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #1_APC_20220819.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 80 Circuit #2**
CSX RR & Black Creek Crossing

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	18+73.04	FT	

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

	East	North	Elevation
Entry	638833.6869	1405395.8188	320.00 ft
Horizontal Curve PI	639024.6637	1404770.3490	
Exit	639585.5311	1403687.4117	324.40 ft

Depth to Mudline 0.00 ft Clearance Depth = 30.50 ft

Measured Plan Length at ties = 1873.0354 ft

Coordinate Length = 1873.0354 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	317.00 ft
Mudline Elev.*	320.00 ft
Lowest centerline Elev.	289.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	638833.6869	1405395.8188	5+62.96	638998.0847	1404857.3981	E 163.02082 N	562.96		
Curve	5+62.96	638998.0847	1404857.3981	7+44.49	639066.5215	1404689.5288	E 152.61977 N	181.53	1000.00	-10.401 deg.
Tangent	7+44.49	639066.5215	1404689.5288	18+73.04	639585.5311	1403687.4117	E 152.61977 N	1128.54		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	562.96	Input Radius, ft.	1000.00	Plan Length, ft.	1128.54	
Entry Azimuth, deg.[5]	N 163.02082 E	Curve, deg	-10.401 deg.	Exit Azimuth, deg.[5]	N 152.61977 E	
Entry Azimuth, rad.[5]	2.84525	Curve, rad	-0.18153	Exit Azimuth, rad.[5]	2.66372	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	181.28	Easting	639585.5311	***Check***
PCH Easting	638998.0847	Arc Length, ft.	181.53	Northing	1403687.4117	***Delta***
PCH Northing	1404857.3981	Chord Azimuth, deg	157.8203			**0.0000**
		PI Easting =	639024.6637			**0.0000**
		PI Northing =	1404770.3490			**OK CALC**
		PTH Easting =	639066.5215			
		PTH Northing =	1404689.5288			**Exit Station**
						18+73.04
Cum Plan Length	562.96	Cum Plan Length	744.49	Cum Plan Length	1873.035357	**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	324.40 ft	307.73 ft	-10.00 deg	-10.00 deg	0.00 deg	95.99 ft	0.00 ft
Entry Curve	307.73 ft	289.50 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	289.50 ft	289.50 ft	0.00 deg	0.00 deg	0.00 deg	1321.53 ft	0.00 ft
Exit Curve	289.50 ft	311.35 ft	0.00 deg	12.00 deg	12.00 deg	209.44 ft	1000.00 ft
Exit Tangent	311.35 ft	320.00 ft	12.00 deg	12.00 deg	0.00 deg	41.59 ft	0.00 ft
					Total Check =	**1877.99 ft**	**OK**

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	248.60	562.96	No, Horiz > Entry V(Tan+Curve)
Exit	302.91	1128.54	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	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	324.40	
		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	40.684 ft	Plan Length	207.912 ft	Plan Length	1,321.52577 ft	Plan Length	208.378 ft	Plan Length	94.536 ft	1,873.035 ft
Rod Length	41.593 ft	Arc Rod Length	209.440 ft	Rod Length	1,321.52577 ft	Arc Rod Length	209.440 ft	Rod Length	95.995 ft	1,877.992 ft
Vertical Depth	-8.648 ft	Curve Δ Vert Depth	-21.852 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	16.669 ft	4.400 ft
		Lowest Elevation	289.500 ft			Lowest Elevation	289.500 ft	CK Total Cum Depth	4.400 ft	
Start Elevation	320.000 ft	Start Elevation	311.352 ft	Start Elevation	289.500 ft	Start Elevation	289.500 ft	Start Elevation	307.731 ft	
End Elevation	311.352 ft	End Elevation	289.500 ft	End Elevation	289.500 ft	End Elevation	307.731 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***	***1873.035357***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+40.68	Start Station	2+48.60	Start Station	15+70.12	Start Station	17+78.50	**Stationing Check** **OK STATIONING**
PVC Station	0+40.68	PTV Station	2+48.60	PCV Station	15+70.12	PTV Station	17+78.50	Exit Station	18+73.035	
Cum Plan Length	40.68	Cum Plan Length	248.60	Cum Plan Length	1570.12 ft	Cum Plan Length	1778.50	Cum Plan Length	1873.04	**Plan Length Check** **OK CALCULATION**
Cum Rod Length	41.59	Cum Rod Length	251.03	Cum Rod Length	1572.56 ft	Cum Rod Length	1782.00	Cum Rod Length	1877.99	**Elevation Change Check** **OK CALCULATION**
Cum Depth	-8.65	Cum Depth	-30.50	Cum Depth	-30.50 ft	Cum Depth	-12.2693	Cum Depth	4.40	

Summary of Drill Calculations

Entry to Exit Elevation Change =	**4.40 ft**
Minimum Design Elevation =	**289.50 ft**
Invert Depth below exit =	**34.90 ft**
Invert Depth below entry =	**30.50 ft**
Path Length =	**1,877.99 ft**
Plan Length =	**1,873.04 ft**
Minimum Plan Length (No Tangent) =	**551.51 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

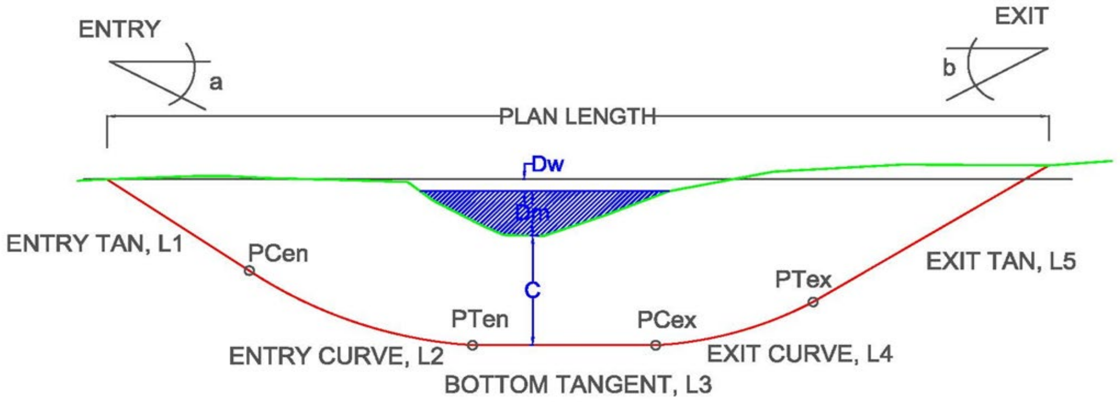
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 80 Circuit #2
CSX RR & Black Creek Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

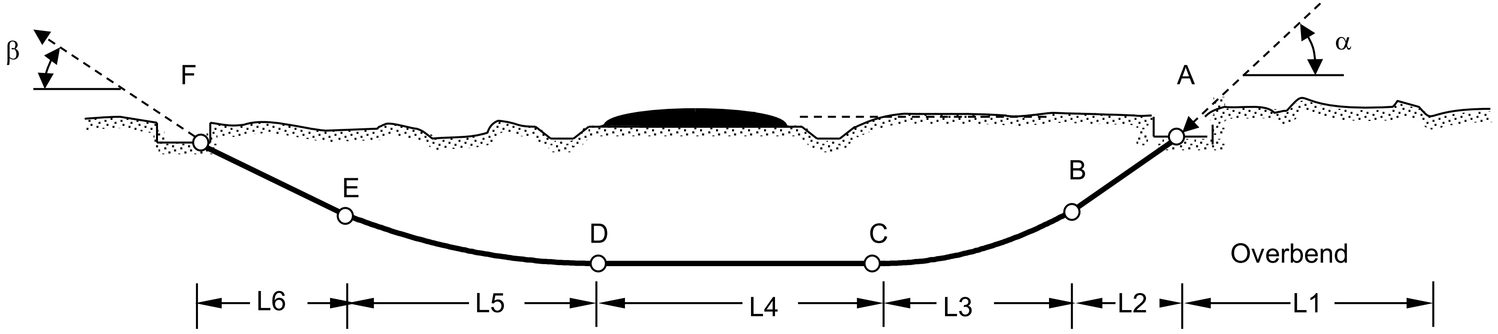
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	96.0 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	1321.5 ft	χ =	0.0 ˚	0.0000	
L5 =	209.4 ft				1,000.0 ft
L6 =	41.6 ft	β =	12.0 ˚	0.2094	
LT =	1978.0 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 320.00 ft

Pipe Entry El = 324.40 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}	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 =	320.00 ft		
Ballast Water El., H_W =	320.00 ft		
Lowest Invert El., El_m =	289.50 ft		

Calculated Pull Force

POINT	Pull Force, F_D	Max Tensile Stress, σ_T	ASSESS	Pull Force, F_B	Max Tensile Stress, σ_T	ASSESS	ASSESS F_x < SPS	
	No Ballast		$\sigma_T < \sigma_{PM}$	Ballasted Pipe		$\sigma_T < \sigma_{PM}$	Air	Ballast
A	3,160 lb	146 psi	OK	3,160 lb	146 psi	OK	OK	OK
B	3,816 lb	106 psi	OK	3,934 lb	110 psi	OK	OK	OK
C	5,277 lb	171 psi	OK	4,586 lb	152 psi	OK	OK	OK
D	11,012 lb	307 psi	OK	10,321 lb	288 psi	OK	OK	OK
E	15,027 lb	448 psi	OK	12,507 lb	378 psi	OK	OK	OK
F	15,815 lb	441 psi	OK	12,862 lb	359 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 95.17 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.889633401	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.194932527	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	448 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	3.30	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	16.52	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.

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 =	0.35 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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 80 Circuit #2
CSX RR & Black Creek Crossing

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 80 Circuit #2
CSX RR & Black Creek Crossing

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Bedford, NH 03110
Ph 603-206-5775

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 =	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 =	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	0.84	Reference 1: Based on Selected Design Ovality
Temperature factor, f_t =	1.00	1.00	Source: WL Plastics WL118

Project Fluids

	Pipe Internal Ballast	Expected External Fluid	Heavy External Fluid	
Fluids	Fresh Water	Drill Fluid 1	Drill Fluid 2	
	γ_{INT}	γ_{EXT1}	γ_{EXT2}	
Density, γ =	62.4	78	80	
Buoyant Unballasted Fluid 1, B_{B1} =			-33.48 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =			-34.74 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =			38.67 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =			-10.49 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, BB_{B2} =			-11.75 lb/ft	$BG-W_{D2}$

Buoyant forces

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4

HDPE PROPERTIES

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

HDD 80 Circuit #2
CSX RR & Black Creek Crossing

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Bedford, NH 03110
Ph 603-206-5775

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^{o}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, ^{o}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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 34.90 ft
Ballast depth to invert, H_B 30.50 ft
Drill Fluid depth to invert, H_{DF} 30.50 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$ 13.41 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$ 16.76 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$ 17.19 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$ 13.41 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 = $(P_A+P_a)-P_{DF1}$	90.21 psi	29.32 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	89.78 psi	28.89 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.62 psi	42.73 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.19 psi	42.30 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	93.56 psi	32.67 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 80 Circuit #2

CSX RR & Black Creek 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 = π*DF*(Ty)*D_o^2*((1/DR)-(1/DR^2))

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

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

(ASTM F-1962 EQ. 22)

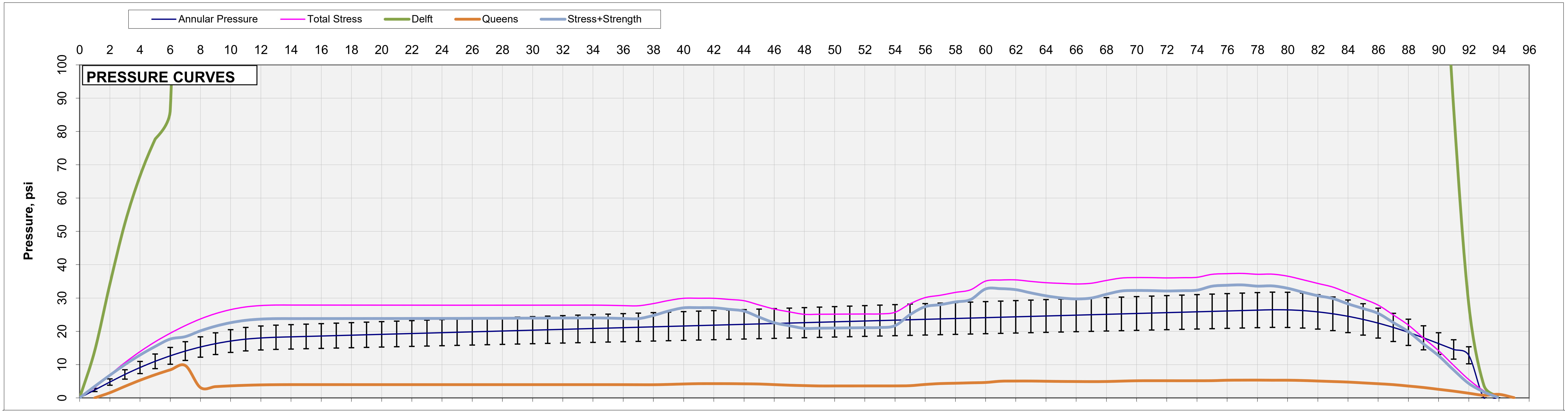
Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 1,400 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.88963
r = σ_i/2*(SSAS) = 0.19493
Example from Table T5, σ_i = 448 psi
P_{CRR} = 237.9 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 119.0 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 102.20 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 101.77 psi Pull Back Condition - Option 4 **OK as >0**

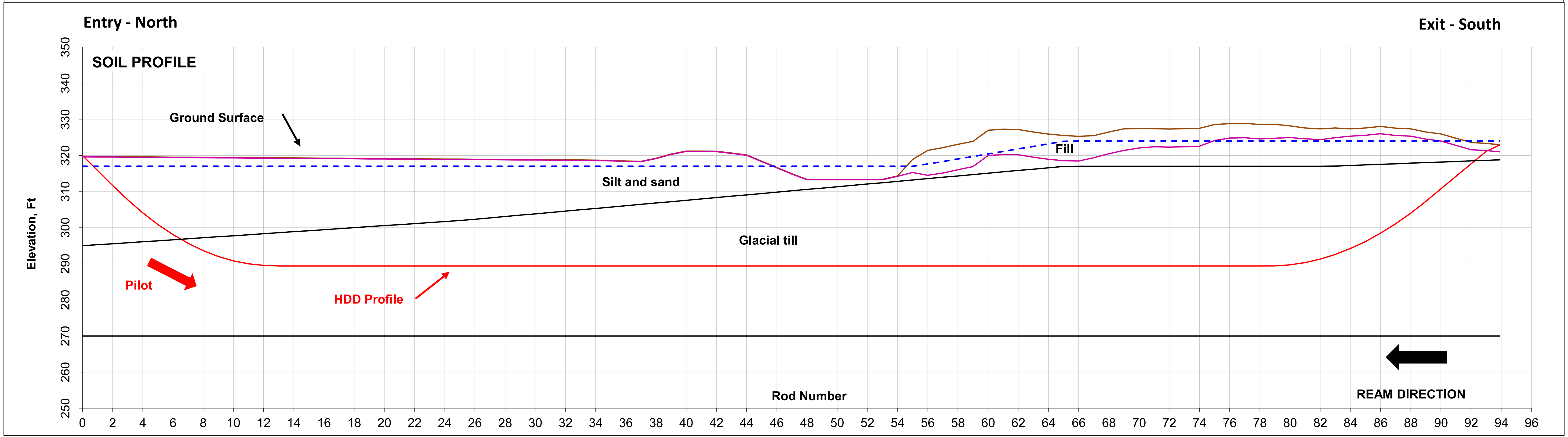
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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





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Notes:

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

Basis of annular pressure calculations

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

Print Date ; 3/13/2023 9:00

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 80 Circuit #2
CSX RR & Black Creek Crossing

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#80 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 81 Circuit #1**
S. Main St. and Grove St.

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: 13-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	**0+00.00**	FT	
Exit Station	**10+29.26**	FT	

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

	East	North	Elevation
Entry	645307.1958	1393560.8185	318.00 ft
Horizontal Curve PI	645585.3872	1393127.8584	
Exit	645863.5785	1392694.8983	330.20 ft
Depth to Mudline	0.00 ft	Clearance Depth =	27.00 ft
Measured Plan Length at ties =	1029.2616 ft		
Coordinate Length =	1029.2616 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	307.00 ft
Mudline Elev.*	318.00 ft
Lowest centerline Elev.	291.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	645307.1958	1393560.8185	5+14.63	645585.3872	1393127.8584	E 147.27789 N	514.63		
Curve	5+14.63	645585.3872	1393127.8584	5+14.63	645585.3872	1393127.8584	E 147.27790 N	0.00	0.00	0.000 deg.
Tangent	5+14.63	645585.3872	1393127.8584	10+29.26	645863.5785	1392694.8983	E 147.27790 N	514.63		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		***Horizontal Curve Segment***		***Exit Tangent Segment***		
Plan Length, ft.	514.63	Input Radius, ft.	0.00	Plan Length, ft.	514.63	
Entry Azimuth, deg.[5]	N 147.27789 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 147.27790 E	
Entry Azimuth, rad.[5]	2.57048	Curve, rad	0.00000	Exit Azimuth, rad.[5]	2.57048	
		Calculate PTH		**Calculate Exit**		
Calculate PCH `		Chord Length, ft.	0.00	Easting	645863.5785	***Check***
PCH Easting	645585.3872	Arc Length, ft.	0.00	Northing	1392694.8983	***Delta***
PCH Northing	1393127.8584	Chord Azimuth, deg	147.2779			**0.0000**
		PI Easting =	645585.3872			**0.0000**
		PI Northing =	1393127.8584			**OK CALC**
		PTH Easting =	645585.3872			
		PTH Northing =	1393127.8584			**Exit Station**
						10+29.26
Cum Plan Length	514.63	Cum Plan Length	514.63	Cum Plan Length	1029.261629	**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	330.20 ft	309.23 ft	-10.00 deg	-10.00 deg	0.00 deg	120.76 ft	0.00 ft
Entry Curve	309.23 ft	291.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	291.00 ft	291.00 ft	0.00 deg	0.00 deg	0.00 deg	476.40 ft	0.00 ft
Exit Curve	291.00 ft	307.54 ft	0.00 deg	11.00 deg	11.00 deg	172.79 ft	900.00 ft
Exit Tangent	307.54 ft	318.00 ft	11.00 deg	11.00 deg	0.00 deg	54.84 ft	0.00 ft
					Total Check =	**1034.23 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	-11.000 deg.	Vertical Radius	900.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	330.20	
		Vert. Curve, deg.	11.000 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	53.835 ft	Plan Length	171.728 ft	Plan Length	476.39788 ft	Plan Length	208.378 ft	Plan Length	118.923 ft	1,029.262 ft
Rod Length	54.843 ft	Arc Rod Length	172.788 ft	Rod Length	476.39788 ft	Arc Rod Length	209.440 ft	Rod Length	120.757 ft	1,034.225 ft
Vertical Depth	-10.464 ft	Curve Δ Vert Depth	-16.536 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	20.969 ft	12.200 ft
		Lowest Elevation	291.000 ft			Lowest Elevation	291.000 ft	CK Total Cum Depth	12.200 ft	
Start Elevation	318.000 ft	Start Elevation	307.536 ft	Start Elevation	291.000 ft	Start Elevation	291.000 ft	Start Elevation	309.231 ft	
End Elevation	307.536 ft	End Elevation	291.000 ft	End Elevation	291.000 ft	End Elevation	309.231 ft	Ck Exit Elevation		
End Vert Angle	-11.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***1029.261629***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+53.84	Start Station	2+25.56	Start Station	7+01.96	Start Station	9+10.34	**OK STATIONING**
PVC Station	0+53.84	PTV Station	2+25.56	PCV Station	7+01.96	PTV Station	9+10.34	Exit Station	10+29.262	**Plan Length Check**
Cum Plan Length	53.84	Cum Plan Length	225.56	Cum Plan Length	701.96 ft	Cum Plan Length	910.34	Cum Plan Length	1029.26	**OK CALCULATION**
Cum Rod Length	54.84	Cum Rod Length	227.63	Cum Rod Length	704.03 ft	Cum Rod Length	913.47	Cum Rod Length	1034.23	**Elevation Change Check**
Cum Depth	-10.46	Cum Depth	-27.00	Cum Depth	-27.00 ft	Cum Depth	-8.7693	Cum Depth	12.20	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**12.20 ft**
Minimum Design Elevation =	**291.00 ft**
Invert Depth below exit =	**39.20 ft**
Invert Depth below entry =	**27.00 ft**
Path Length =	**1,034.23 ft**
Plan Length =	**1,029.26 ft**
Minimum Plan Length (No Tangent) =	**552.86 ft**
Entry Angle =	**-11.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

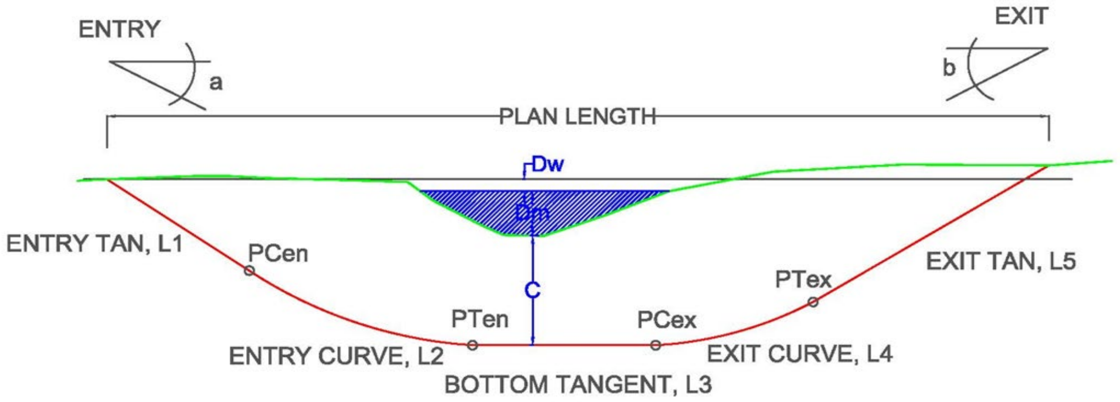
NOTES:

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:	**Issued for Construction (IFC)**

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 81 Circuit #1
S. Main St. and Grove St.

Revision 1 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	400.0 ft
L2 =	120.8 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	476.4 ft	χ =	0.0 ˚	0.0000	
L5 =	172.8 ft				900.0 ft
L6 =	54.8 ft	β =	11.0 ˚	0.1920	
LT =	1134.2 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 =	17.36 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
Drill fluid elevation, H_F =	318.00 ft	
Ballast Water El., H_W =	318.00 ft	
Lowest Invert El., El_m =	291.00 ft	

Estimated for pull

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 =	0.85 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

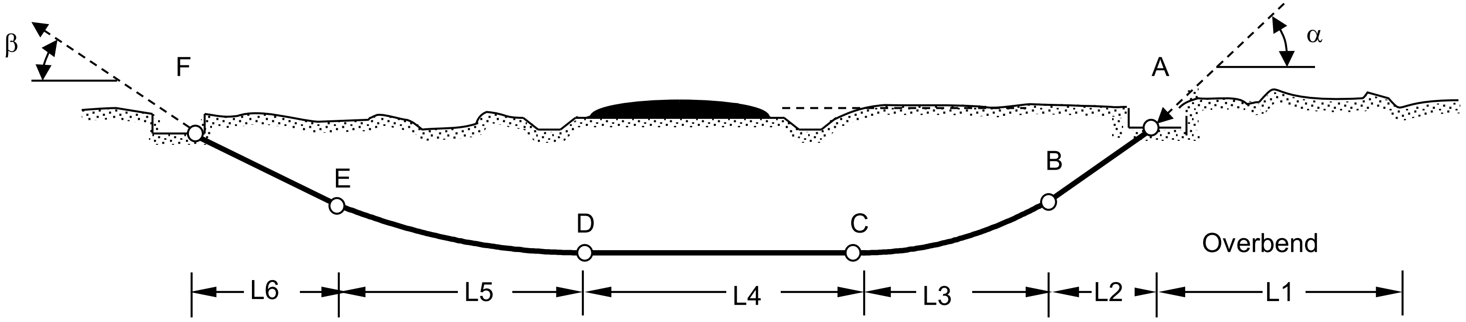
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 318.00 ft

Pipe Entry El = 330.20 ft



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	 Ballast
A	2,004 lb	147 psi	OK	2,004 lb	147 psi	OK	OK	OK
B	2,852 lb	72 psi	OK	2,945 lb	74 psi	OK	OK	OK
C	4,505 lb	146 psi	OK	3,701 lb	126 psi	OK	OK	OK
D	6,432 lb	162 psi	OK	5,629 lb	142 psi	OK	OK	OK
E	9,883 lb	292 psi	OK	7,451 lb	231 psi	OK	OK	OK
F	11,022 lb	278 psi	OK	7,981 lb	201 psi	OK	OK	OK

Calculated Pull Force

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 99.71 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.932087208	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.127030536	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	292 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	2.93	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	14.63	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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 81 Circuit #1
S. Main St. and Grove St.

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#81 CIR #1_APC_20220819.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY
HDD 81 Circuit #1
S. Main St. and Grove St.

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INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification	445574C		Design resin with minimum PENT test of 10,000 hours
Standard Dimension	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 =	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#81 CIR #1_APC_20220819.xlsb]T3 Plastic Pull

TABLE 4 Pg 2 of 3

HDPE PROPERTIES

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

HDD 81 Circuit #1
S. Main St. and Grove St.

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	39.20 ft	Ballast depth to invert, H_B	27.00 ft	Drill Fluid depth to invert, H_{DF}	27.00 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	11.76 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	14.70 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	15.08 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	11.76 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 = $(P_A+P_a)-P_{DF1}$	92.27 psi	31.38 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.89 psi	31.00 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	104.03 psi	43.14 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.66 psi	42.76 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	95.21 psi	34.32 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 **Pg 3 of 3**

HDPE PROPERTIES

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

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S. Main St. and Grove St.

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

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

Designed Pull Duration Time = 12 hr
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF
Safe Pull Strength, SPS Pipe = 5,321 lb **Useing SSAS = 4,371 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.93209
r = σ_i/2*(SSAS) = 0.12703
P_{CRR} = 249.3 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 124.6 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 109.93 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 109.56 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 292 psi

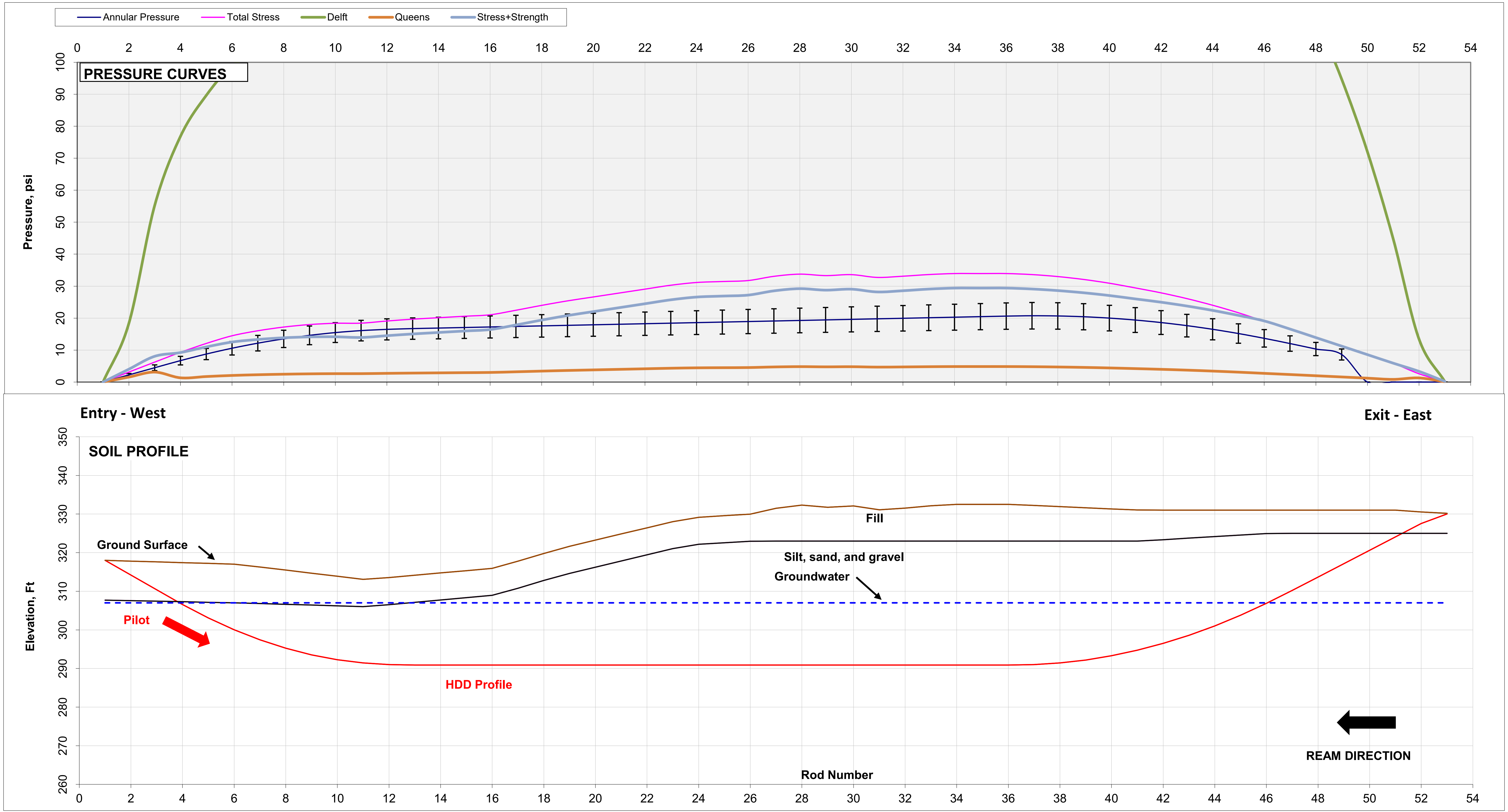
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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 annular pressure calculations

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

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Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 81 Circuit #1
S. Main St. and Grove St.

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#81 CIR #1_APC_20220819.xlsb]T3 Plastic Pull

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 81 Circuit #1**
S. Main St. and Grove St.

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: 13-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	10+54.20	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	645306.4677	1393589.6996	315.50 ft
Horizontal Curve PI	645591.3991	1393146.2483	
Exit	645876.3305	1392702.7969	329.90 ft
Depth to Mudline	0.00 ft	Clearance Depth =	19.30 ft
Measured Plan Length at ties =	1054.2011 ft		
Coordinate Length =	1054.2011 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	307.00 ft
Mudline Elev.*	315.50 ft
Lowest centerline Elev.	296.20 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	645306.4677	1393589.6996	5+27.10	645591.3991	1393146.2483	E 147.27798 N	527.10		
Curve	5+27.10	645591.3991	1393146.2483	5+27.10	645591.3991	1393146.2483	E 147.27799 N	0.00	0.00	0.000 deg.
Tangent	5+27.10	645591.3991	1393146.2483	10+54.20	645876.3305	1392702.7969	E 147.27799 N	527.10		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	527.10	Input Radius, ft.	0.00	Plan Length, ft.	527.10	
Entry Azimuth, deg.[5]	N 147.27798 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 147.27799 E	
Entry Azimuth, rad.[5]	2.57049	Curve, rad	0.00000	Exit Azimuth, rad.[5]	2.57049	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	645876.3305	**Check**
PCH Easting	645591.3991	Arc Length, ft.	0.00	Northing	1392702.7969	**Delta**
PCH Northing	1393146.2483	Chord Azimuth, deg	147.2780			**0.0000**
		PI Easting =	645591.3991			**0.0000**
		PI Northing =	1393146.2483			**OK CALC**
		PTH Easting =	645591.3991			
		PTH Northing =	1393146.2483			**Exit Station**
						10+54.20
Cum Plan Length	527.10	Cum Plan Length	527.10	Cum Plan Length	1054.201124	**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	∆ Angle		Length	Radius
Entry Tangent	329.90 ft	314.43 ft	-10.00 deg	-10.00 deg	0.00 deg		89.08 ft	0.00 ft
Entry Curve	314.43 ft	296.20 ft	-10.00 deg	0.00 deg	10.00 deg		209.44 ft	1200.00 ft
Bottom Tangent	296.20 ft	296.20 ft	0.00 deg	0.00 deg	0.00 deg		572.14 ft	0.00 ft
Exit Curve	296.20 ft	312.74 ft	0.00 deg	11.00 deg	11.00 deg		172.79 ft	900.00 ft
Exit Tangent	312.74 ft	315.50 ft	11.00 deg	11.00 deg	0.00 deg		14.49 ft	0.00 ft
						Total Check =	1057.94 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	-11.000 deg.	Vertical Radius	900.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	329.90	
		Vert. Curve, deg.	11.000 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	14.222 ft	Plan Length	171.728 ft	Plan Length	572.14249 ft	Plan Length	208.378 ft	Plan Length	87.731 ft	1,054.201 ft
Rod Length	14.488 ft	Arc Rod Length	172.788 ft	Rod Length	572.14249 ft	Arc Rod Length	209.440 ft	Rod Length	89.084 ft	1,057.942 ft
Vertical Depth	-2.764 ft	Curve ∆ Vert Depth	-16.536 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	18.231 ft	Vertical Depth	15.469 ft	14.400 ft
		Lowest Elevation	296.200 ft			Lowest Elevation	296.200 ft	CK Total Cum Depth	14.400 ft	
Start Elevation	315.500 ft	Start Elevation	312.736 ft	Start Elevation	296.200 ft	Start Elevation	296.200 ft	Start Elevation	314.431 ft	
End Elevation	312.736 ft	End Elevation	296.200 ft	End Elevation	296.200 ft	End Elevation	314.431 ft	Ck Exit Elevation		
End Vert Angle	-11.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*1054.201124*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+14.22	Start Station	1+85.95	Start Station	7+58.09	Start Station	9+66.47	**Stationing Check**
PVC Station	0+14.22	PTV Station	1+85.95	PCV Station	7+58.09	PTV Station	9+66.47	Exit Station	10+54.201	**OK STATIONING**
Cum Plan Length	14.22	Cum Plan Length	185.95	Cum Plan Length	758.09 ft	Cum Plan Length	966.47	Cum Plan Length	1054.20	**Plan Length Check**
Cum Rod Length	14.49	Cum Rod Length	187.28	Cum Rod Length	759.42 ft	Cum Rod Length	968.86	Cum Rod Length	1057.94	**OK CALCULATION**
Cum Depth	-2.76	Cum Depth	-19.30	Cum Depth	-19.30 ft	Cum Depth	-1.0693	Cum Depth	14.40	**Elevation Change Check** **OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**14.40 ft**
Minimum Design Elevation =	**296.20 ft**
Invert Depth below exit =	**33.70 ft**
Invert Depth below entry =	**19.30 ft**
Path Length =	**1,057.94 ft**
Plan Length =	**1,054.20 ft**
Minimum Plan Length (No Tangent) =	**482.06 ft**
Entry Angle =	**-11.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

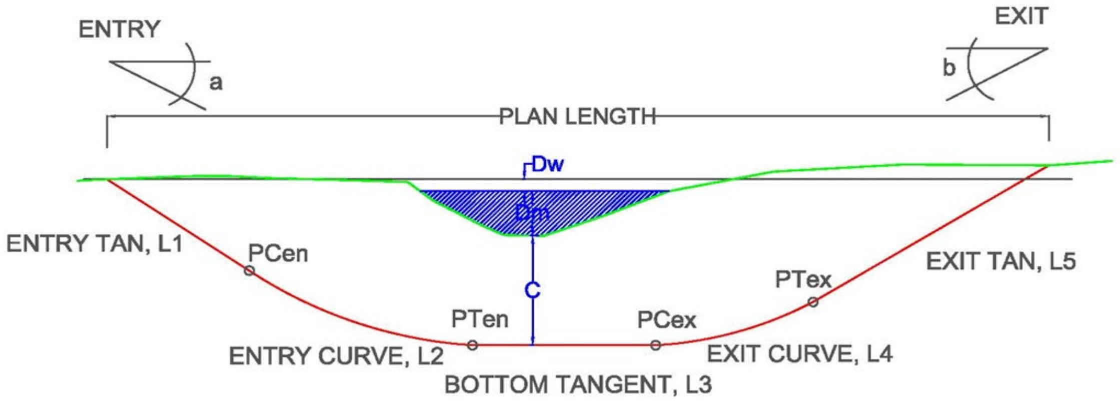
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 81 Circuit #1
S. Main St. and Grove St.

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#81 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	89.1 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	572.1 ft	χ =	0.0 ˚	0.0000	
L5 =	172.8 ft				900.0 ft
L6 =	14.5 ft	β =	11.0 ˚	0.1920	
LT =	1157.9 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} 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 = 315.50 ft

Ballast Water El., H_W = 315.50 ft

Lowest Invert El., El_m = 296.20 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 = 0.62 lb/ft Comparison Only @ 8psi

Calculated Buoyant Forces

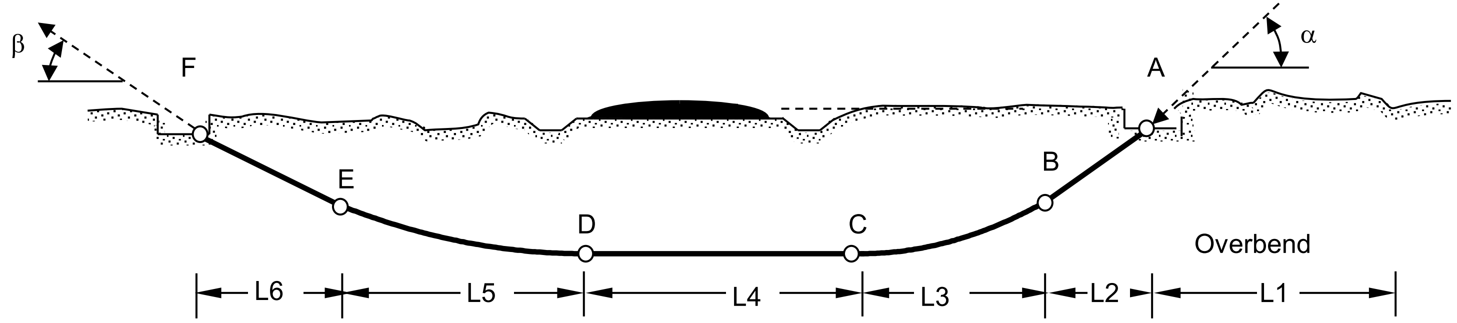
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 315.50 ft

Pipe Entry El = 329.90 ft



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	 Ballast
A	1,850 lb	110 psi	OK	1,850 lb	110 psi	OK	OK	OK
B	2,323 lb	65 psi	OK	2,333 lb	65 psi	OK	OK	OK
C	3,718 lb	128 psi	OK	2,914 lb	106 psi	OK	OK	OK
D	5,982 lb	167 psi	OK	5,179 lb	144 psi	OK	OK	OK
E	9,037 lb	284 psi	OK	6,758 lb	221 psi	OK	OK	OK
F	9,303 lb	260 psi	OK	6,878 lb	192 psi	OK	OK	OK

Table title: **Calculated Pull Force**

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 99.93 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb $SSPS = \sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.93409858 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.123682387 $r = \sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 284 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 2.09 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 10.45 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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Limited Liability Company
"Creating Space Underground"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 81 Circuit #1
S. Main St. and Grove St.

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#81 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 81 Circuit #1
S. Main St. and Grove St.

BRIERLEY ASSOCIATES
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INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710	INPUT RESIN MATERIAL: PE3408, PE3608, PE4710	
ASTM D3350 Cell Classification	445574C	Design resin with minimum PENT test of 10,000 hours	
Standard Dimension	10		
Pipe measurement standard	IPS	IPS "Iron Pipe Size" of DIPS "Ductile Iron Pipe Size"	
DR = OD/Minimum Wall	9		
Outside Diameter, D_o =	10.750 in	Standard Manufacturer's Data Sheets	
Avg. Inside Diameter, D_i =	8.216 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 =	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	0.84	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} =	-47.50 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-48.76 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	24.63 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-24.53 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-25.79 lb/ft	BG-W_{D2}

Buoyant forces

Dry Weight Pipe on ground, W_P =	1.66 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.97 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#81 CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

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HDPE PROPERTIES

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

HDD 81 Circuit #1
S. Main St. and Grove St.

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	33.70 ft	Ballast depth to invert, H_B	19.30 ft	Drill Fluid depth to invert, H_{DF}	19.30 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	8.56 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	10.70 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	10.97 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	8.56 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 = $(P_A+P_a)-P_{DF1}$	96.28 psi	35.38 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	96.00 psi	35.11 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	104.84 psi	43.94 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	104.56 psi	43.67 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	98.42 psi	37.52 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

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 81 Circuit #1
S. Main St. and Grove St.

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

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

Designed Pull Duration Time = 12 hr
Quantity of pipes, Q = 1
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Temperature, F = 73 deg.
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y 0.4
SAFE PULL STRENTH, SPS = 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)

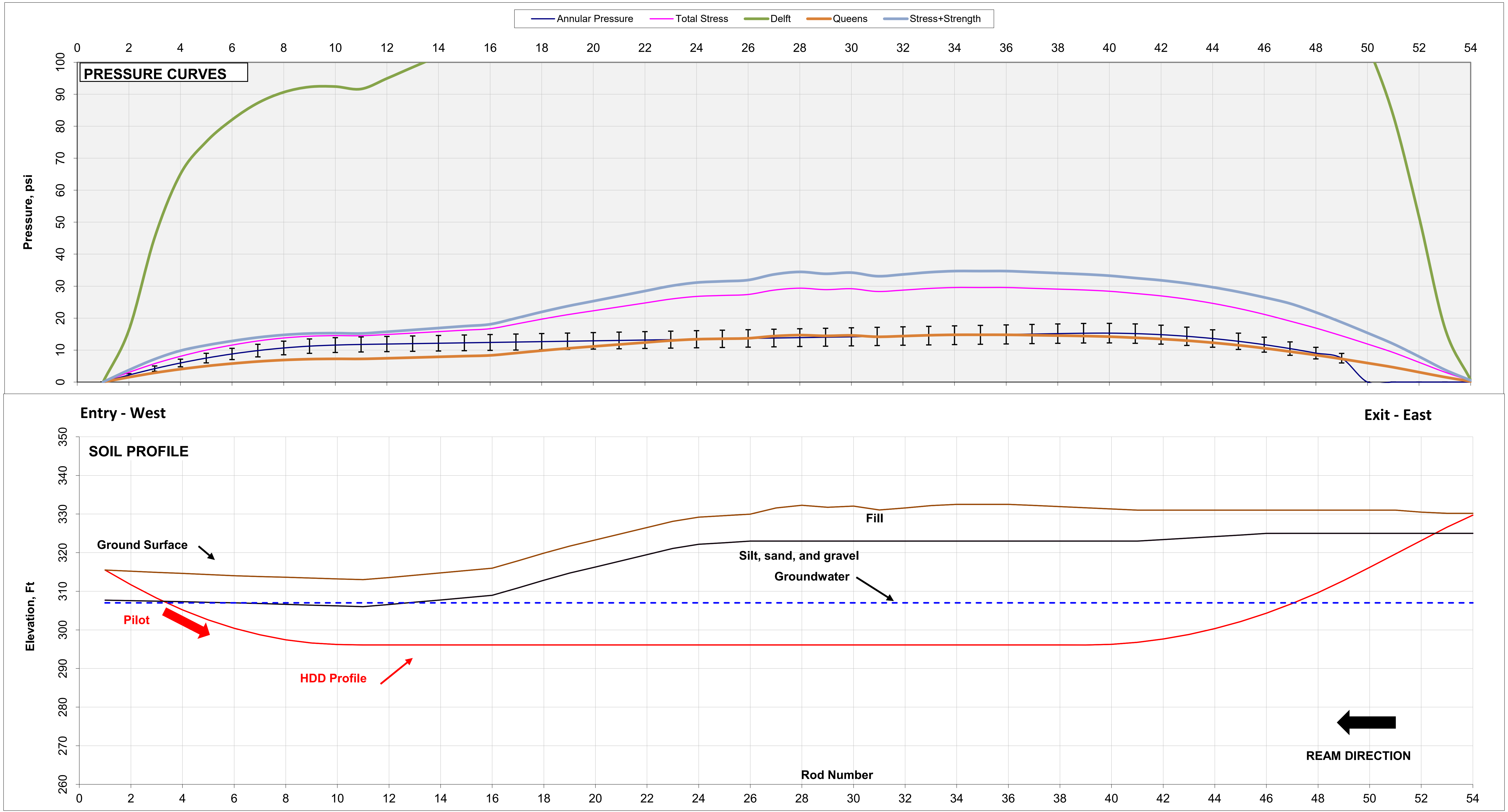
Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 448 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.93410
r = σ_i/2*(SSAS) = 0.12368
Example from Table T5, σ_i = 284 psi
P_{CRR} = 249.8 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 124.9 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 114.21 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 113.94 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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

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

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



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Notes:

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

Basis of annulur pressure calculations

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

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 81 Circuit #1
S. Main St. and Grove St.

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 82-83 Conduit #1**
Vly Creek/Grove Street

ISSUE: **Issued for Constructon (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: 6-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/6/2023	1	Issued for Construction	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	15+73.46	FT

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

	East	North	Elevation
Entry	646341.6005	1391681.7020	319.70 ft
Horizontal Curve PI	646658.1112	1390961.4502	
Exit	646974.6220	1390241.1984	343.40 ft

Depth to Mudline 0.00 ft Clearance Depth = 32.60 ft

Measured Plan Length at ties = 1573.4570 ft

Coordinate Length = 1573.4570 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	312.00 ft
Mudline Elev.*	319.70 ft
Lowest centerline Elev.	287.10 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	646341.6005	1391681.7020	7+86.73	646658.1112	1390961.4502	E 156.27718 N	786.73		
Curve	7+86.73	646658.1112	1390961.4502	7+86.73	646658.1112	1390961.4502	E 156.27717 N	0.00	0.00	0.000 deg.
Tangent	7+86.73	646658.1112	1390961.4502	15+73.46	646974.6220	1390241.1984	E 156.27717 N	786.73		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	786.73	Input Radius, ft.	0.00	Plan Length, ft.	786.73	
Entry Azimuth, deg.^{5}	N 156.27718 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 156.27717 E	
Entry Azimuth, rad.^{5}	2.72755	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.72755	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	646974.6220	***Check***
PCH Easting	646658.1112	Arc Length, ft.	0.00	Northing	1390241.1984	***Delta***
PCH Northing	1390961.4502	Chord Azimuth, deg	156.2772			**0.0000**
		PI Easting =	646658.1112			**0.0000**
		PI Northing =	1390961.4502			**OK CALC**
		PTH Easting =	646658.1112			
		PTH Northing =	1390961.4502			**Exit Station**
						15+73.46
Cum Plan Length	786.73	Cum Plan Length	786.73	Cum Plan Length	1573.456971	**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	343.40 ft	305.33 ft	-10.00 deg	-10.00 deg	0.00 deg	219.23 ft	0.00 ft
Entry Curve	305.33 ft	287.10 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	287.10 ft	287.10 ft	0.00 deg	0.00 deg	0.00 deg	869.68 ft	0.00 ft
Exit Curve	287.10 ft	313.32 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	313.32 ft	319.70 ft	12.00 deg	12.00 deg	0.00 deg	30.67 ft	0.00 ft
					Total Check =	**1580.35 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	343.40	
		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	30.002 ft	Plan Length	249.494 ft	Plan Length	869.68138 ft	Plan Length	208.378 ft	Plan Length	215.902 ft	1,573.457 ft
Rod Length	30.672 ft	Arc Rod Length	251.327 ft	Rod Length	869.68138 ft	Arc Rod Length	209.440 ft	Rod Length	219.232 ft	1,580.353 ft
Vertical Depth	-6.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	38.069 ft	23.700 ft
		Lowest Elevation	287.100 ft			Lowest Elevation	287.100 ft	CK Total Cum Depth	23.700 ft	
Start Elevation	319.700 ft	Start Elevation	313.323 ft	Start Elevation	287.100 ft	Start Elevation	287.100 ft	Start Elevation	305.331 ft	
End Elevation	313.323 ft	End Elevation	287.100 ft	End Elevation	287.100 ft	End Elevation	305.331 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***	***1573.456971***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+30.00	Start Station	2+79.50	Start Station	11+49.18	Start Station	13+57.56	**Stationing Check**
PVC Station	0+30.00	PTV Station	2+79.50	PCV Station	11+49.18	PTV Station	13+57.56	Exit Station	15+73.457	**OK STATIONING**
Cum Plan Length	30.00	Cum Plan Length	279.50	Cum Plan Length	1149.18 ft	Cum Plan Length	1357.56	Cum Plan Length	1573.46	**Plan Length Check**
Cum Rod Length	30.67	Cum Rod Length	282.00	Cum Rod Length	1151.68 ft	Cum Rod Length	1361.12	Cum Rod Length	1580.35	**OK CALCULATION**
Cum Depth	-6.38	Cum Depth	-32.60	Cum Depth	-32.60 ft	Cum Depth	-14.3693	Cum Depth	23.70	**Elevation Change Check**
										OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**23.70 ft**
Minimum Design Elevation =	**287.10 ft**
Invert Depth below exit =	**56.30 ft**
Invert Depth below entry =	**32.60 ft**
Path Length =	**1,580.35 ft**
Plan Length =	**1,573.46 ft**
Minimum Plan Length (No Tangent) =	**703.78 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

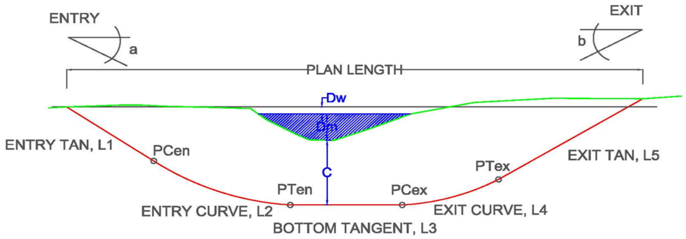
NOTES:

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. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 82-83 Conduit #1
Vly Creek/Grove Street

Revision 1 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	219.2 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	869.7 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	30.7 ft	β =	12.0 °	0.2094	
LT =	1680.4 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 =	319.70 ft	
Ballast Water El., H_W =	319.70 ft	
Lowest Invert El., El_m =	287.10 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 =	0.56 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

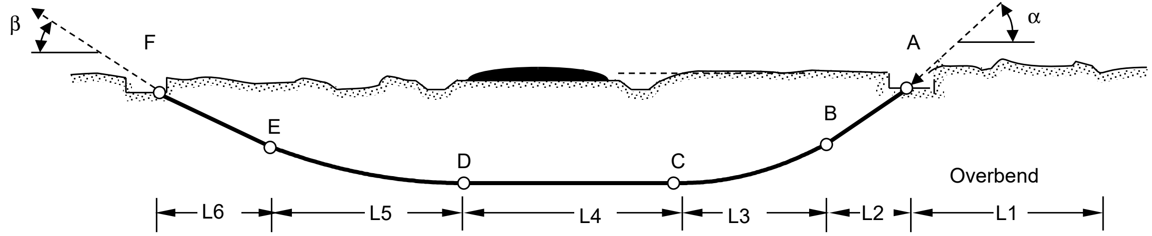
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	17.36 Lb/LF	42.80 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-37.01 Lb/LF	-11.58 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 319.70 ft

Pipe Entry El = 343.40 ft



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	Ballast
A	2,968 lb	204 psi	OK	2,968 lb	204 psi	OK	OK	OK
B	4,507 lb	114 psi	OK	4,660 lb	118 psi	OK	OK	OK
C	6,234 lb	189 psi	OK	5,492 lb	171 psi	OK	OK	OK
D	10,137 lb	256 psi	OK	9,396 lb	237 psi	OK	OK	OK
E	15,344 lb	419 psi	OK	12,184 lb	339 psi	OK	OK	OK
F	16,000 lb	404 psi	OK	12,487 lb	315 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 96.04 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.897799078	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.182263662	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	419 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	3.53	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	17.66	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. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 4 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 82-83 Conduit #1
Vly Creek/Grove Street

Revision 1 TBD

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TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY
HDD 82-83 Conduit #1
Vly Creek/Grove Street

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INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	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" or 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 =	3.801889456		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
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	0.84	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

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

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TABLE 4

HDPE PROPERTIES

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

HDD 82-83 Conduit #1
Vly Creek/Grove Street

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^{o}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, ^{o}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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	56.30 ft	Ballast depth to invert, H_B	32.60 ft	Drill Fluid depth to invert, H_{DF}	32.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	14.19 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	17.74 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	18.19 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	14.19 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 = $(P_A+P_a)-P_{DF1}$	89.24 psi	28.34 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	88.78 psi	27.89 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.43 psi	42.53 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.97 psi	42.08 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	92.79 psi	31.89 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

Pg 3 of 3

HDPE PROPERTIES

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

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HDD 82-83 Conduit #1
Vly Creek/Grove Street

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 5,321 lb **Useing SSAS = 4,371 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.89780
$r = \sigma_i/2*(SSAS)$ = 0.18226
P_{CRR} = 240.1 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 120.1 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 102.32 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 101.86 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 419 psi

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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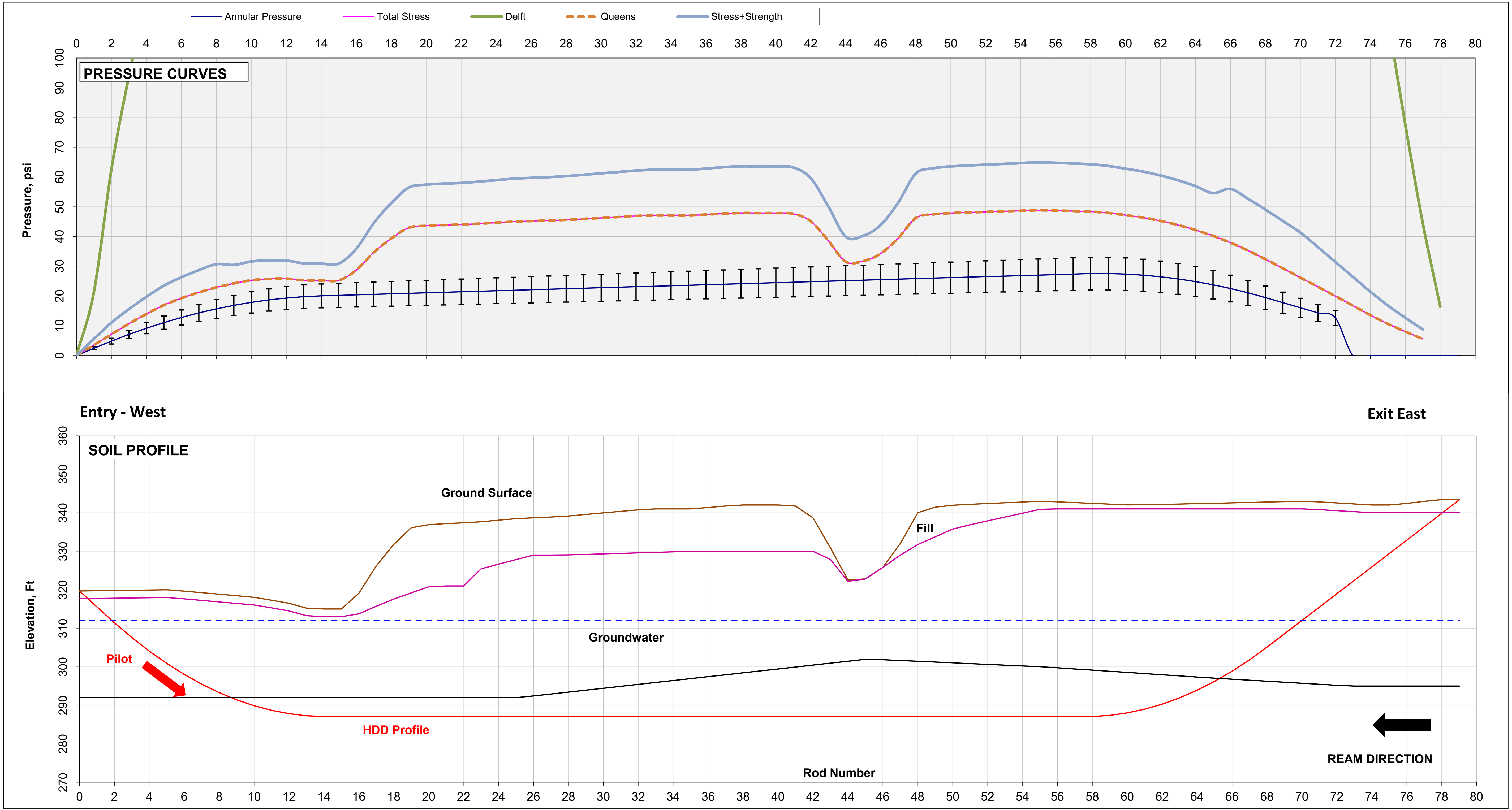

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Notes:

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 82-83 Conduit #1
Vly Creek/Grove Street

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 82-83 Conduit #1**
Vly Creek/Grove Street

ISSUE: **Issued for Constructon (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: 6-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/6/2023	1	Issued for Construction	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	15+73.46	FT

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

	East	North	Elevation
Entry	646341.6005	1391681.7020	319.70 ft
Horizontal Curve PI	646658.1112	1390961.4502	
Exit	646974.6220	1390241.1984	343.40 ft

Depth to Mudline 0.00 ft Clearance Depth = 32.60 ft

Measured Plan Length at ties = 1573.4570 ft

Coordinate Length = 1573.4570 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.* 312.00 ft

Mudline Elev.* 319.70 ft

Lowest centerline Elev. 287.10 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	646341.6005	1391681.7020	7+86.73	646658.1112	1390961.4502	E 156.27718 N	786.73		
Curve	7+86.73	646658.1112	1390961.4502	7+86.73	646658.1112	1390961.4502	E 156.27717 N	0.00	0.00	0.000 deg.
Tangent	7+86.73	646658.1112	1390961.4502	15+73.46	646974.6220	1390241.1984	E 156.27717 N	786.73		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	786.73	Input Radius, ft.	0.00	Plan Length, ft.	786.73	
Entry Azimuth, deg.^{5}	N 156.27718 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 156.27717 E	
Entry Azimuth, rad.^{5}	2.72755	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.72755	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	646974.6220	***Check***
PCH Easting	646658.1112	Arc Length, ft.	0.00	Northing	1390241.1984	***Delta***
PCH Northing	1390961.4502	Chord Azimuth, deg	156.2772			**0.0000**
		PI Easting =	646658.1112			**0.0000**
		PI Northing =	1390961.4502			**OK CALC**
		PTH Easting =	646658.1112			
		PTH Northing =	1390961.4502			**Exit Station**
						15+73.46
Cum Plan Length	786.73	Cum Plan Length	786.73	Cum Plan Length	1573.456971	**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	343.40 ft	305.33 ft	-10.00 deg	-10.00 deg	0.00 deg	219.23 ft	0.00 ft
Entry Curve	305.33 ft	287.10 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	287.10 ft	287.10 ft	0.00 deg	0.00 deg	0.00 deg	869.68 ft	0.00 ft
Exit Curve	287.10 ft	313.32 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	313.32 ft	319.70 ft	12.00 deg	12.00 deg	0.00 deg	30.67 ft	0.00 ft
					Total Check =	**1580.35 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	343.40
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	30.002 ft	Plan Length	249.494 ft	Plan Length	869.68138 ft	Plan Length	208.378 ft	Plan Length	215.902 ft
Rod Length	30.672 ft	Arc Rod Length	251.327 ft	Rod Length	869.68138 ft	Arc Rod Length	209.440 ft	Rod Length	219.232 ft
Vertical Depth	-6.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	38.069 ft
		Lowest Elevation	287.100 ft			Lowest Elevation	287.100 ft	CK Total Cum Depth	23.700 ft
Start Elevation	319.700 ft	Start Elevation	313.323 ft	Start Elevation	287.100 ft	Start Elevation	287.100 ft	Start Elevation	305.331 ft
End Elevation	313.323 ft	End Elevation	287.100 ft	End Elevation	287.100 ft	End Elevation	305.331 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***	***1573.456971***

SUMS
1,573.457 ft
1,580.353 ft
23.700 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+30.00	Start Station	2+79.50	Start Station	11+49.18	Start Station	13+57.56
PVC Station	0+30.00	PTV Station	2+79.50	PCV Station	11+49.18	PTV Station	13+57.56	Exit Station	15+73.457
Cum Plan Length	30.00	Cum Plan Length	279.50	Cum Plan Length	1149.18 ft	Cum Plan Length	1357.56	Cum Plan Length	1573.46
Cum Rod Length	30.67	Cum Rod Length	282.00	Cum Rod Length	1151.68 ft	Cum Rod Length	1361.12	Cum Rod Length	1580.35
Cum Depth	-6.38	Cum Depth	-32.60	Cum Depth	-32.60 ft	Cum Depth	-14.3693	Cum Depth	23.70

Stationing Check
OK STATIONING

Plan Length Check
OK CALCULATION

Elevation Change Check
OK CALCULATION

Summary of Drill Calculations

Entry to Exit Elevation Change =	**23.70 ft**
Minimum Design Elevation =	**287.10 ft**
Invert Depth below exit =	**56.30 ft**
Invert Depth below entry =	**32.60 ft**
Path Length =	**1,580.35 ft**
Plan Length =	**1,573.46 ft**
Minimum Plan Length (No Tangent) =	**703.78 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

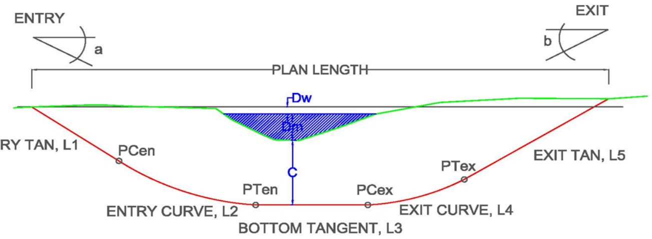
NOTES:

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 82-83 Conduit #1
Vly Creek/Grove Street

Revision 1 TBD

Pull Geometry

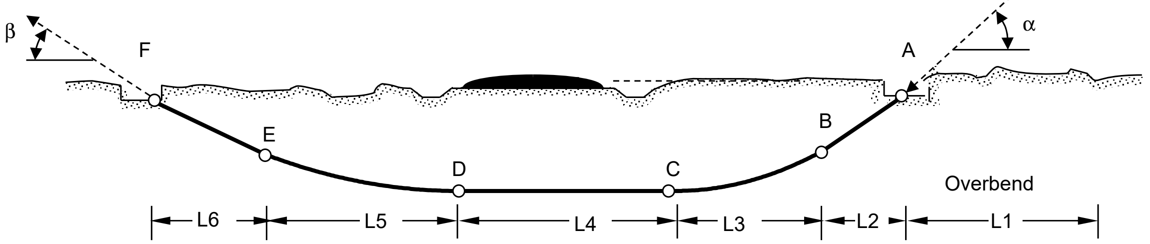
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	219.2 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	869.7 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	30.7 ft	β =	12.0 °	0.2094	
LT =	1680.4 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 319.70 ft

Pipe Entry El = 343.40 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$_T$A$_F$/(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 =	319.70 ft	
Ballast Water El., H_W =	319.70 ft	
Lowest Invert El., El_m =	287.10 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	 Ballast
A	2,968 lb	204 psi	OK	2,968 lb	204 psi	OK	OK	OK
B	4,507 lb	114 psi	OK	4,660 lb	118 psi	OK	OK	OK
C	6,234 lb	189 psi	OK	5,492 lb	171 psi	OK	OK	OK
D	10,137 lb	256 psi	OK	9,396 lb	237 psi	OK	OK	OK
E	15,344 lb	419 psi	OK	12,184 lb	339 psi	OK	OK	OK
F	16,000 lb	404 psi	OK	12,487 lb	315 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 96.04 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}{}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.897799078	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.182263662	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	419 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	3.53	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	17.66	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

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

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.56 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

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

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

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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 4 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 82-83 Conduit #1
Vly Creek/Grove Street

Revision 1 TBD

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

HDD 82-83 Conduit #1
Vly Creek/Grove Street

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" or 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 =	3.801889456		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
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	0.84	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

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

TABLE 4 Pg 2 of 3

HDPE PROPERTIES

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

HDD 82-83 Conduit #1
Vly Creek/Grove Street

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	56.30 ft	Ballast depth to invert, H_B	32.60 ft	Drill Fluid depth to invert, H_{DF}	32.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	14.19 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	17.74 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	18.19 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	14.19 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 = $(P_A+P_a)-P_{DF1}$	89.24 psi	28.34 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	88.78 psi	27.89 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.43 psi	42.53 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.97 psi	42.08 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	92.79 psi	31.89 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. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

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HDD 82-83 Conduit #1
Vly Creek/Grove Street

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

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

Designed Pull Duration Time = 12 hr
Quantity of pipes, Q = 1
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Temperature, F = 73 deg.
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y 0.4
SAFE PULL STRENTH, SPS = 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**

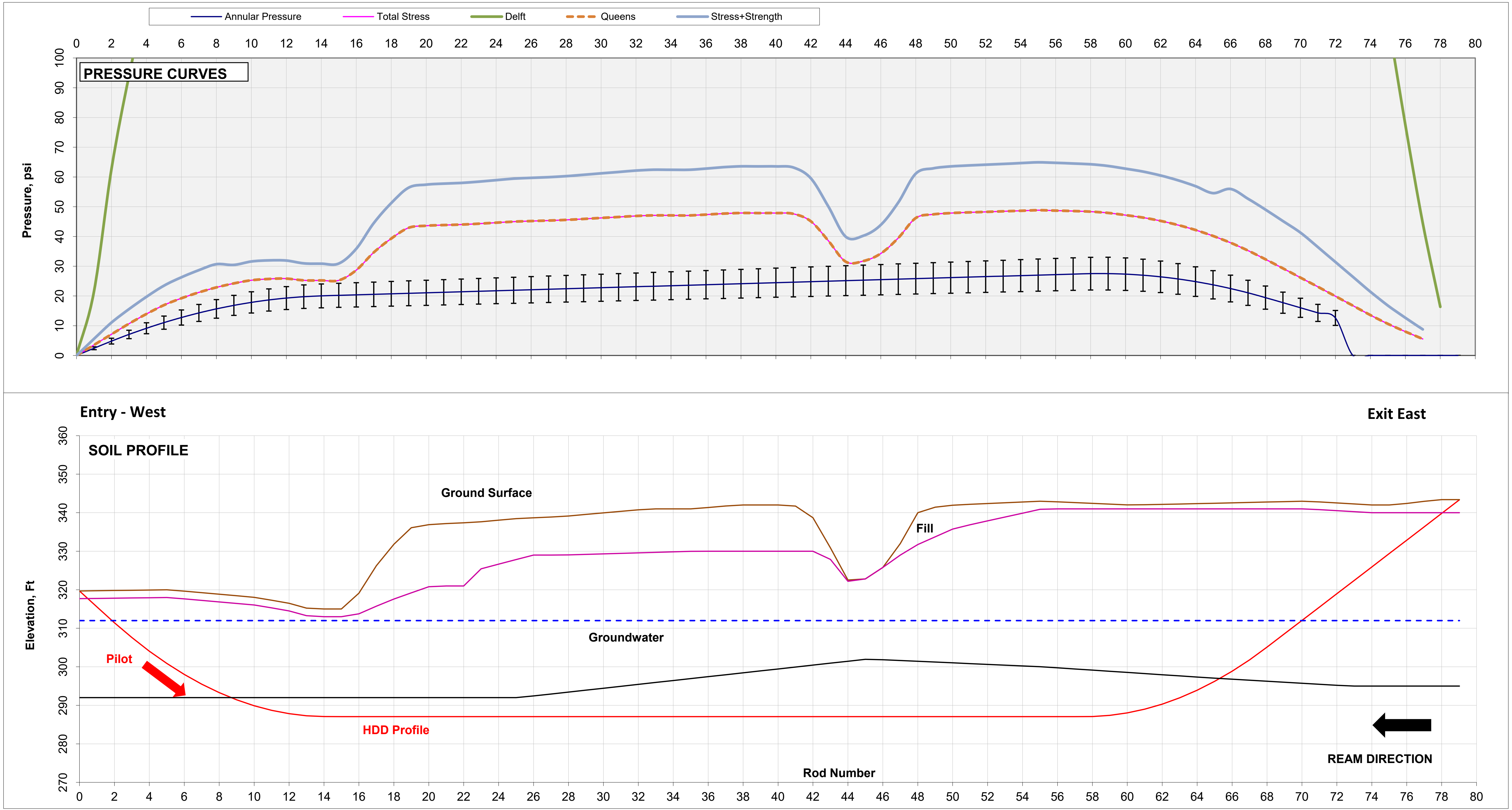
Short Term Critical Unconstrained Buckling Pcr reduced for pull tension, P_{CRR} = P_{CR}*f_r
(ASTM F-1962 EQ. 22)

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 = 0.89780
r = σ_i/2*(SSAS) = 0.18226
Example from Table T5, σ_i = 419 psi
P_{CRR} = 240.1 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 120.1 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 102.32 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 101.86 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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



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.

ISSUED: Issued for Constructon (IFC)

Basis of annulur pressure calculations

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

Print Date ; 3/6/2023 10:51

BRIERLEY ASSOCIATES
Creating Space Underground
167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION
PRESSURE CURVES
HDD 82-83 Conduit #1
Vly Creek/Grove Street

Revision 1

FIGURE 1

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#82-83 CIR #1_APC_20220822.xlsb]F1A APCL

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 82-83 Conduit #2**
Vly Creek/Grove Street

ISSUE: **Issued for Constructon (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: 6-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/6/2023	1	Issued for Construction	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	15+73.13	FT

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

	East	North	Elevation
Entry	646355.5176	1391687.4650	320.60 ft
Horizontal Curve PI	646671.9345	1390967.3524	
Exit	646988.3515	1390247.2399	341.70 ft
Depth to Mudline	0.90 ft	Clearance Depth =	31.70 ft
Measured Plan Length at ties =	1573.1265 ft		
Coordinate Length =	1573.1265 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	319.00 ft
Mudline Elev.*	319.70 ft
Lowest centerline Elev.	288.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	646355.5176	1391687.4650	7+86.56	646671.9345	1390967.3524	E 156.27935 N	786.56		
Curve	7+86.56	646671.9345	1390967.3524	7+86.56	646671.9345	1390967.3524	E 156.27934 N	0.00	0.00	0.000 deg.
Tangent	7+86.56	646671.9345	1390967.3524	15+73.13	646988.3515	1390247.2399	E 156.27934 N	786.56		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	786.56	Input Radius, ft.	0.00	Plan Length, ft.	786.56	
Entry Azimuth, deg.[5]	N 156.27935 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 156.27934 E	
Entry Azimuth, rad.[5]	2.72759	Curve, rad	0.00000	Exit Azimuth, rad.[5]	2.72759	
		Calculate PTH		Calculate Exit		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	646988.3515	*Check*
PCH Easting	646671.9345	Arc Length, ft.	0.00	Northing	1390247.2399	*Delta*
PCH Northing	1390967.3524	Chord Azimuth, deg	156.2793			0.0000
		PI Easting =	646671.9345			0.0000
		PI Northing =	1390967.3524			OK CALC
		PTH Easting =	646671.9345			
		PTH Northing =	1390967.3524			Exit Station
						15+73.13
Cum Plan Length	786.56	Cum Plan Length	786.56	Cum Plan Length	1573.126531	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	341.70 ft	306.23 ft	-10.00 deg	-10.00 deg	0.00 deg	204.26 ft	0.00 ft
Entry Curve	306.23 ft	288.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	288.00 ft	288.00 ft	0.00 deg	0.00 deg	0.00 deg	884.10 ft	0.00 ft
Exit Curve	288.00 ft	314.22 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	314.22 ft	320.60 ft	12.00 deg	12.00 deg	0.00 deg	30.67 ft	0.00 ft
					Total Check =	1579.80 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	341.70	
		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	30.002 ft	Plan Length	249.494 ft	Plan Length	884.09628 ft	Plan Length	208.378 ft	Plan Length	201.156 ft	1,573.127 ft
Rod Length	30.672 ft	Arc Rod Length	251.327 ft	Rod Length	884.09628 ft	Arc Rod Length	209.440 ft	Rod Length	204.260 ft	1,579.795 ft
Vertical Depth	-6.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	35.469 ft	21.100 ft
		Lowest Elevation	288.000 ft			Lowest Elevation	288.000 ft	CK Total Cum Depth	21.100 ft	
Start Elevation	320.600 ft	Start Elevation	314.223 ft	Start Elevation	288.000 ft	Start Elevation	288.000 ft	Start Elevation	306.231 ft	
End Elevation	314.223 ft	End Elevation	288.000 ft	End Elevation	288.000 ft	End Elevation	306.231 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*	*1573.126531*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+30.00	Start Station	2+79.50	Start Station	11+63.59	Start Station	13+71.97
PVC Station	0+30.00	PTV Station	2+79.50	PCV Station	11+63.59	PTV Station	13+71.97	Exit Station	15+73.127
Cum Plan Length	30.00	Cum Plan Length	279.50	Cum Plan Length	1163.59 ft	Cum Plan Length	1371.97	Cum Plan Length	1573.13
Cum Rod Length	30.67	Cum Rod Length	282.00	Cum Rod Length	1166.10 ft	Cum Rod Length	1375.54	Cum Rod Length	1579.80
Cum Depth	-6.38	Cum Depth	-32.60	Cum Depth	-32.60 ft	Cum Depth	-14.3693	Cum Depth	21.10

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**21.10 ft**
Minimum Design Elevation =	**288.00 ft**
Invert Depth below exit =	**53.70 ft**
Invert Depth below entry =	**32.60 ft**
Path Length =	**1,579.80 ft**
Plan Length =	**1,573.13 ft**
Minimum Plan Length (No Tangent) =	**689.03 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

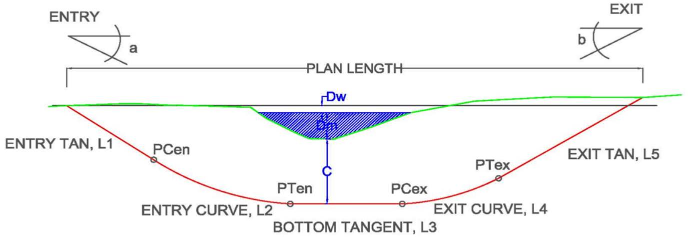
NOTES:

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 82-83 Conduit #2
Vly Creek/Grove Street

Revision 1 TBD

Pull Geometry

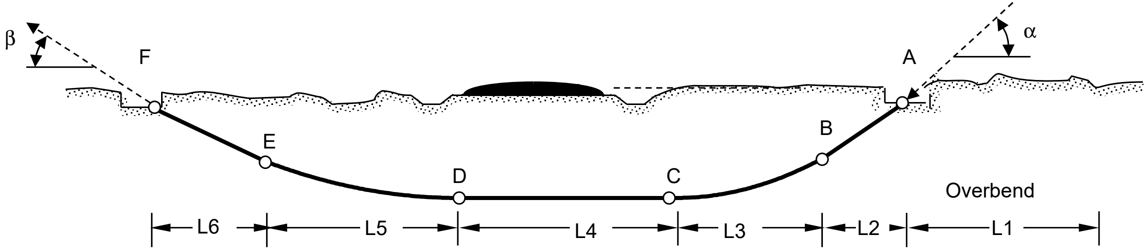
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	204.3 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	884.1 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	30.7 ft	β =	12.0 °	0.2094	
LT =	1679.8 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 320.60 ft

Pipe Entry El = 341.70 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}	8.22 in	Bundle Multiplier F_D	1.0000
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,000 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	250 psi	PR = $2HDSF_TA_F/(DR-1)$ [F_T=1]	

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf
Drill Fluid Density	78	pcf *Estimated for pull*
Drill fluid elevation, H_F =	319.00 ft	
Ballast Water El., H_W =	319.00 ft	
Lowest Invert El., El_m =	288.00 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 =	0.41 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	Ballast
A	2,684 lb	172 psi	OK	2,684 lb	172 psi	OK	OK	OK
B	3,995 lb	111 psi	OK	4,118 lb	115 psi	OK	OK	OK
C	5,464 lb	177 psi	OK	4,778 lb	158 psi	OK	OK	OK
D	9,063 lb	253 psi	OK	8,377 lb	234 psi	OK	OK	OK
E	13,659 lb	405 psi	OK	10,785 lb	325 psi	OK	OK	OK
F	14,117 lb	394 psi	OK	11,005 lb	307 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 96.45 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}{}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.901653373	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.176221483	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	405 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	3.36	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	16.79	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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Limited Liability Company
"Creating Space Underground"

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

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

TABLE 4 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 82-83 Conduit #2
Vly Creek/Grove Street

Revision 1 TBD

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

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

HDD 82-83 Conduit #2
Vly Creek/Grove Street

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" or 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 =	35.84514492	$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$	
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 =	15.7	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	BG-W_{D2}

TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY
HDD 82-83 Conduit #2
Vly Creek/Grove Street

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 53.70 ft

Ballast depth to invert, H_B 32.60 ft

Drill Fluid depth to invert, H_{DF} 32.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	14.32 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	17.90 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	18.36 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	14.32 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 = $(P_A+P_a)-P_{DF1}$	89.07 psi	28.18 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	88.61 psi	27.72 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.39 psi	42.50 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.94 psi	42.04 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	92.65 psi	31.76 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 82-83 Conduit #2

Vly Creek/Grove Street

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

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

Designed Pull Duration Time = 12 hr

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y 0.4

Temperature factor, f_{temp} = 1

Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi

Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF

Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1

Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 50,200 lb

Ultimate Pull Strength, UPS = 125,499 lb

Suggested SSAS = 1,150 psi

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

SAS = 1,400 psi

Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum

fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.90165

r = σ_i/2*(SSAS) = 0.17622

P_{CRR} = 241.1 psi

FS = 2.0

P_{ACRR} = P_{CRR}/FS = 120.6 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 102.67 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 102.21 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi

Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 405 psi

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

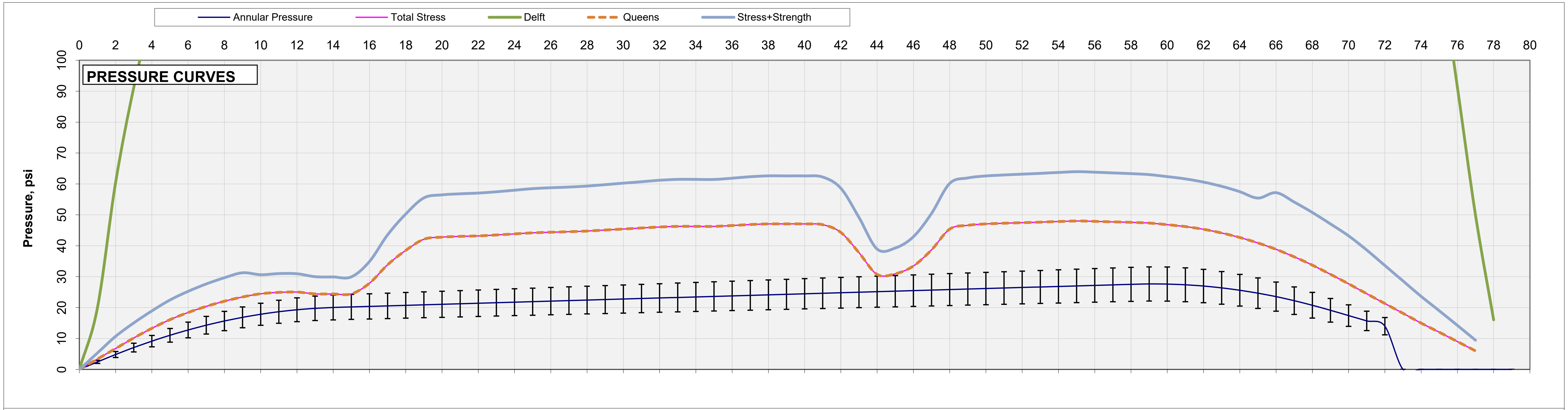
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

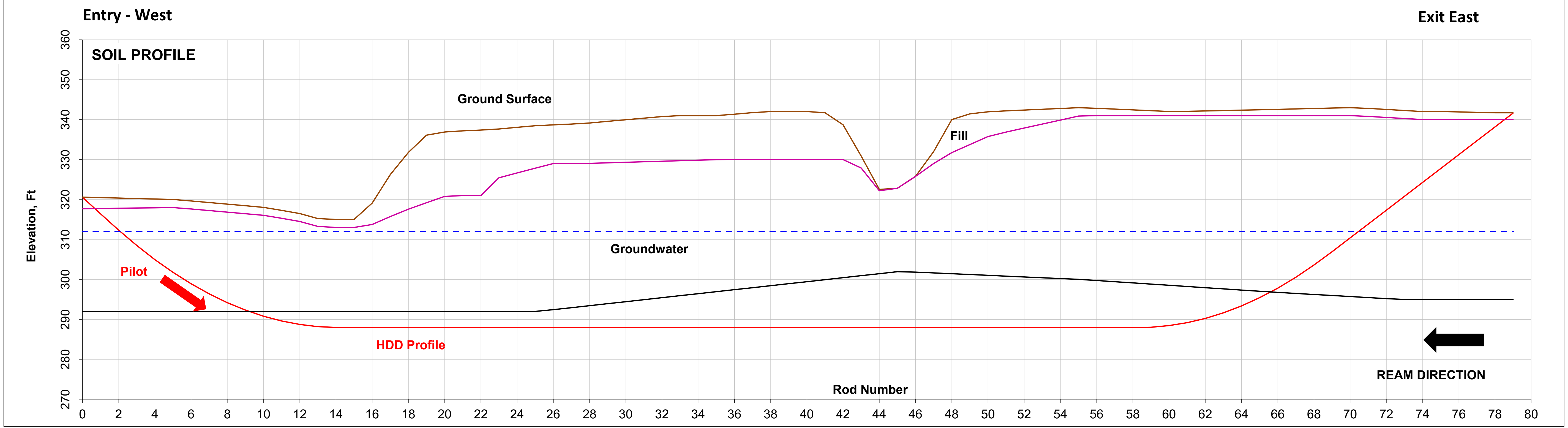
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 3/6/2023 10:48

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 82-83 Conduit #2
Vly Creek/Grove Street

Revision 1

FIGURE 1

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#82-83 CIR #2_APC_20230306.xlsb]Cover

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 83A Circuit #1**
Wetland FA

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: 13-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	7+01.97	FT

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

	East	North	Elevation
Entry	649492.6248	1384261.6161	286.00 ft
Horizontal Curve PI	649322.3718	1384568.5417	
Exit	649152.1189	1384875.4674	295.60 ft
Depth to Mudline	0.00 ft	Clearance Depth =	32.60 ft
Measured Plan Length at ties =	701.9670 ft		
Coordinate Length =	701.9670 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	285.00 ft
Mudline Elev.*	286.00 ft
Lowest centerline Elev.	253.40 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	649492.6248	1384261.6161	3+50.98	649322.3718	1384568.5417	E 330.98267 N	350.98		
Curve	3+50.98	649322.3718	1384568.5417	3+50.98	649322.3718	1384568.5417	E 330.98269 N	0.00	0.00	0.000 deg.
Tangent	3+50.98	649322.3718	1384568.5417	7+01.97	649152.1189	1384875.4674	E 330.98269 N	350.98		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	350.98	Input Radius, ft.	0.00	Plan Length, ft.	350.98	
Entry Azimuth, deg.^{5}	N 330.98267 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 330.98269 E	
Entry Azimuth, rad.^{5}	5.77674	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	5.77674	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	649152.1189	**Check**
PCH Easting	649322.3718	Arc Length, ft.	0.00	Northing	1384875.4674	**Delta**
PCH Northing	1384568.5417	Chord Azimuth, deg	330.9827			**0.0000**
		PI Easting =	649322.3718			**0.0000**
		PI Northing =	1384568.5417			**OK CALC**
		PTH Easting =	649322.3718			
		PTH Northing =	1384568.5417			**Exit Station**
						7+01.97
Cum Plan Length	350.98	Cum Plan Length	350.98	Cum Plan Length	701.9670124	**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	286.00 ft	279.62 ft	-12.00 deg	-12.00 deg	0.00 deg	30.67 ft	0.00 ft
Entry Curve	279.62 ft	253.40 ft	-12.00 deg	0.00 deg	12.00 deg	251.33 ft	1200.00 ft
Bottom Tangent	253.40 ft	253.40 ft	0.00 deg	0.00 deg	0.00 deg	78.16 ft	0.00 ft
Exit Curve	253.40 ft	271.63 ft	0.00 deg	10.00 deg	10.00 deg	209.44 ft	1200.00 ft
Exit Tangent	271.63 ft	295.60 ft	10.00 deg	10.00 deg	0.00 deg	138.03 ft	0.00 ft
					Total Check =	**707.63 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	295.60	
		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	30.002 ft	Plan Length	249.494 ft	Plan Length	78.15650 ft	Plan Length	208.378 ft	Plan Length	135.937 ft	701.967 ft
Rod Length	30.672 ft	Arc Rod Length	251.327 ft	Rod Length	78.15650 ft	Arc Rod Length	209.440 ft	Rod Length	138.034 ft	707.629 ft
Vertical Depth	-6.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	23.969 ft	9.600 ft
		Lowest Elevation	253.400 ft			Lowest Elevation	253.400 ft	CK Total Cum Depth	9.600 ft	
Start Elevation	286.000 ft	Start Elevation	279.623 ft	Start Elevation	253.400 ft	Start Elevation	253.400 ft	Start Elevation	271.631 ft	
End Elevation	279.623 ft	End Elevation	253.400 ft	End Elevation	253.400 ft	End Elevation	271.631 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*	*701.9670124*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+30.00	Start Station	2+79.50	Start Station	3+57.65	Start Station	5+66.03	**Stationing Check** **OK STATIONING**
PVC Station	0+30.00	PTV Station	2+79.50	PCV Station	3+57.65	PTV Station	5+66.03	Exit Station	7+01.967	**Plan Length Check**
Cum Plan Length	30.00	Cum Plan Length	279.50	Cum Plan Length	357.65 ft	Cum Plan Length	566.03	Cum Plan Length	701.97	**OK CALCULATION**
Cum Rod Length	30.67	Cum Rod Length	282.00	Cum Rod Length	360.16 ft	Cum Rod Length	569.60	Cum Rod Length	707.63	**Elevation Change Check**
Cum Depth	-6.38	Cum Depth	-32.60	Cum Depth	-32.60 ft	Cum Depth	-14.3693	Cum Depth	9.60	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**9.60 ft**
Minimum Design Elevation =	**253.40 ft**
Invert Depth below exit =	**42.20 ft**
Invert Depth below entry =	**32.60 ft**
Path Length =	**707.63 ft**
Plan Length =	**701.97 ft**
Minimum Plan Length (No Tangent) =	**623.81 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

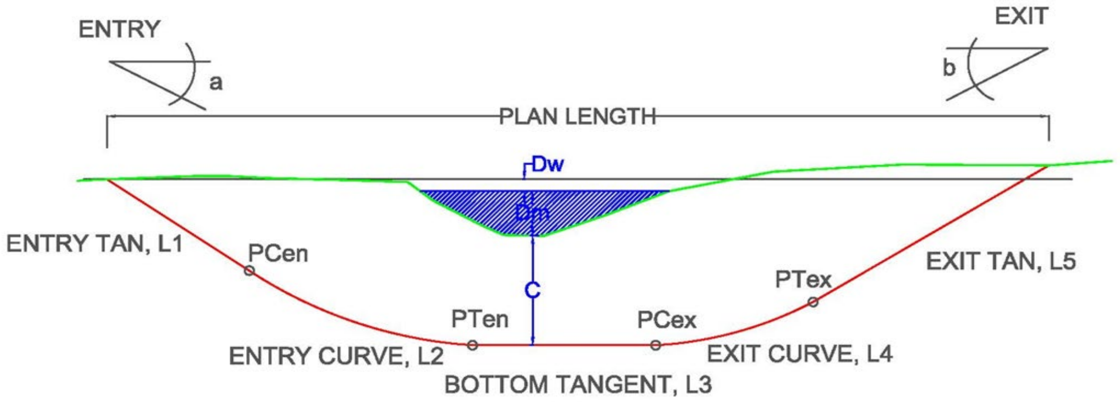
NOTES:

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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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 83A Circuit #1
Wetland FA

Revision 1　TBD

Pull Geometry

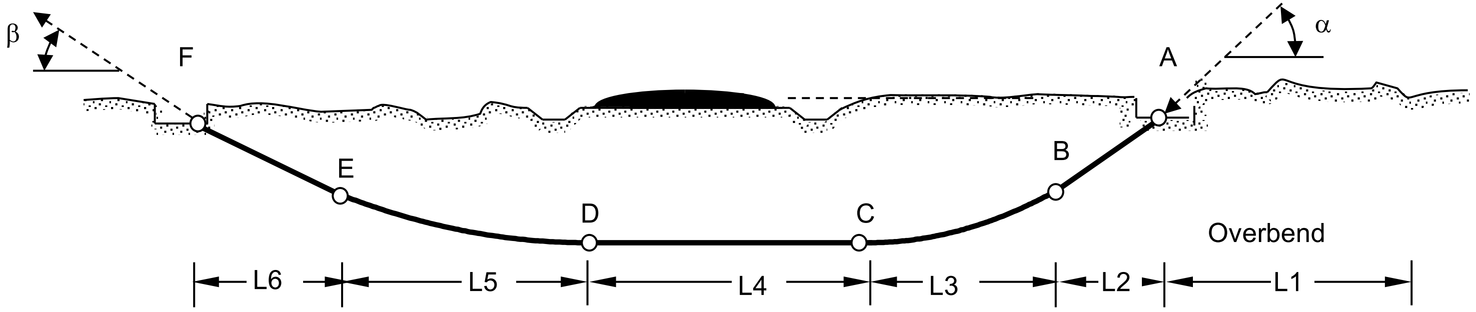
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	30.7 ft	α =	-12.0 °	-0.2094	
L3 =	251.3 ft				1,200.0 ft
L4 =	78.2 ft	χ =	0.0 °	0.0000	
L5 =	209.4 ft				1,200.0 ft
L6 =	138.0 ft	β =	10.0 °	0.1745	
LT =	807.6 ft				

Pipe Entry Location - Drill Entry

(schematic, to show definition of variables only)

Pipe Exit El = 295.60 ft

Pipe Entry El = 286.00 ft



INPUT: Assumed Friction Factors

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

INPUT: Assumed Hydrokinetic Drag

τ_f =	0.005 psi	Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 14.25	BUNDLE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	14.25	Pipe or Bundle	
Pipe Dry Weight, W_P =	17.36 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	BUNDLE	Bundle Multiplier F_D	0.9042
12 Hr Pullback Modulus, E_T =	65,000 psi	@T = 73 deg F	
Poisson Ratio, μ =	0.45		
Ovality Factor, f_o =	0.84	2%	
Buckling Safety, N =	2.5		
Hydrostatic Design Stress, HDS =	1,008 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	252 psi	PR = 2HDSF$_T$A$_F$/(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 =	286.00 ft		
Ballast Water El., H_W =	286.00 ft		
Lowest Invert El., El_m =	253.40 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 =	1.25 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	 Ballast
A	1,432 lb	113 psi	OK	1,432 lb	113 psi	OK	OK	OK
B	1,731 lb	44 psi	OK	1,759 lb	44 psi	OK	OK	OK
C	3,498 lb	120 psi	OK	2,557 lb	97 psi	OK	OK	OK
D	3,109 lb	78 psi	OK	2,168 lb	55 psi	OK	OK	OK
E	6,967 lb	208 psi	OK	4,113 lb	136 psi	OK	OK	OK
F	8,861 lb	224 psi	OK	5,124 lb	129 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_A F_R}$ = 101.60 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 =	0.949756365	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.097178997	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	224 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	3.53	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	17.66	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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Limited Liability Company
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Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 83A Circuit #1
Wetland FA

Revision 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#83A CIR #1_APC_20221025.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDPE PROPERTIES

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

HDD 83A Circuit #1

Wetland FA

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 =	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 =	15.70	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	0.84	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 forces

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

Buoyant Unballasted Fluid 1, B_{B1} =	10.49 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	10.35 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	18.14 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	12.93 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	12.80 lb/ft	$BG-W_{D2}$

TABLE 4

Pg 2 of 3

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 83A Circuit #1

Wetland FA

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	42.20 ft	Ballast depth to invert, H_B	32.60 ft	Drill Fluid depth to invert, H_{DF}	32.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	14.19 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	17.74 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	18.19 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	14.19 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 = $(P_A+P_a)-P_{DF1}$	89.24 psi	28.34 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	88.78 psi	27.89 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.43 psi	42.53 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.97 psi	42.08 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	92.79 psi	31.89 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 **Pg 3 of 3**

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HDPE PROPERTIES

Champlain Hudson Power Express
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Schenectady County, NY

HDD 83A Circuit #1

Wetland FA

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

Source PPI PE Handbook Ch 12 Formula 17 SPS = π*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
FE PULL STRENTH, SPS = 5,321 lb
Temperature factor, f_{temp} = 1
ltimate 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)

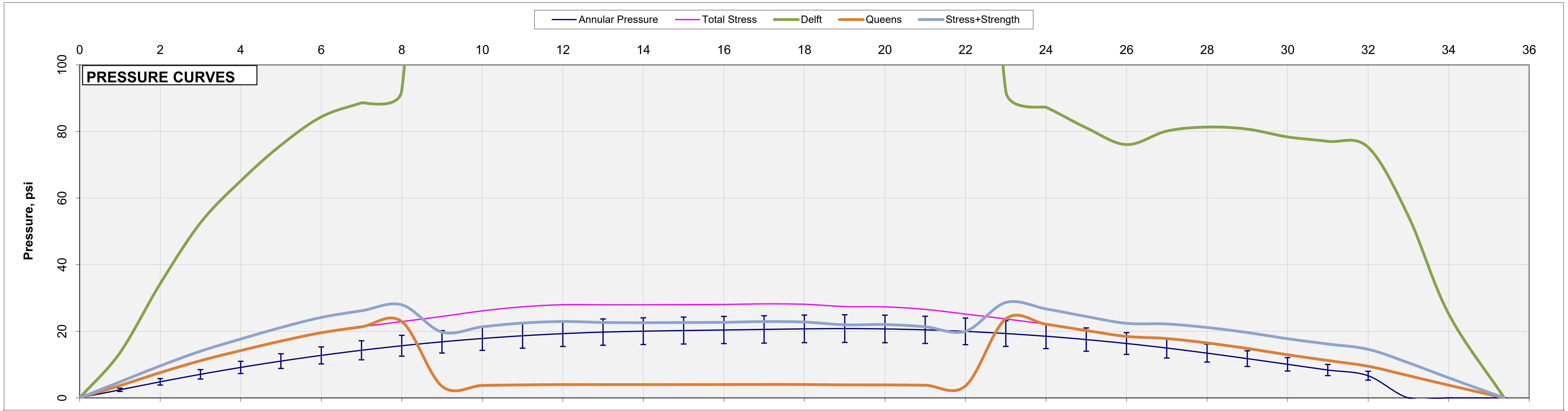
Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 1,400 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.94976
r = σ_i/2*(SSAS) = 0.09718
Example from Table T5, σ_i = 224 psi
P_{CRR} = 254.0 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 127.0 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 123.45 psi Pull Back Condition - C **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 123.00 psi Pull Back Condition - C **OK as >0**

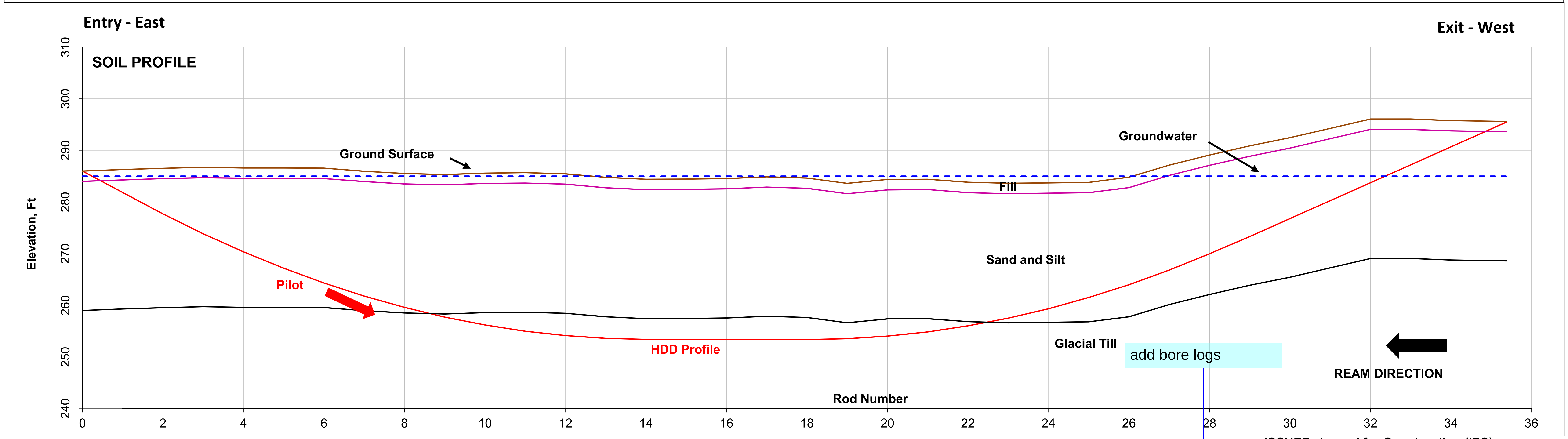
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 3/13/2023 8:14

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 83A Circuit #1
Wetland FA

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#83A CIR #1_APC_20221025.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 83A Circuit #2**
Wetland FA

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

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Figure 1	APC AND FPC CURVES AND ASSUMED GEOLOGIC SECTION

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: 13-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	7+01.97	FT	

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

	East	North	Elevation
Entry	649505.7419	1384268.8922	287.50 ft
Horizontal Curve PI	649335.4889	1384575.8179	
Exit	649165.2360	1384882.7435	295.60 ft
Depth to Mudline	0.00 ft	Clearance Depth =	32.60 ft
Measured Plan Length at ties =	701.9670 ft		
Coordinate Length =	701.9670 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	285.00 ft
Mudline Elev.*	287.50 ft
Lowest centerline Elev.	254.90 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	649505.7419	1384268.8922	3+50.98	649335.4889	1384575.8179	E 330.98268 N	350.98		
Curve	3+50.98	649335.4889	1384575.8179	3+50.98	649335.4889	1384575.8179	E 330.98269 N	0.00	0.00	0.000 deg.
Tangent	3+50.98	649335.4889	1384575.8179	7+01.97	649165.2360	1384882.7435	E 330.98269 N	350.98		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	350.98	Input Radius, ft.	0.00	Plan Length, ft.	350.98	
Entry Azimuth, deg.[5]	N 330.98268 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.[5]	N 330.98269 E	
Entry Azimuth, rad.[5]	5.77674	Curve, rad	0.00000	Exit Azimuth, rad.[5]	5.77674	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	649165.2360	***Check***
PCH Easting	649335.4889	Arc Length, ft.	0.00	Northing	1384882.7435	***Delta***
PCH Northing	1384575.8179	Chord Azimuth, deg	330.9827			**0.0000**
		PI Easting =	649335.4889			**0.0000**
		PI Northing =	1384575.8179			**OK CALC**
		PTH Easting =	649335.4889			
		PTH Northing =	1384575.8179			**Exit Station**
						7+01.97
Cum Plan Length	350.98	Cum Plan Length	350.98	Cum Plan Length	701.9670124	**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**	**∆ Angle**	**Length**	**Radius**
Entry Tangent	295.60 ft	273.13 ft	-10.00 deg	-10.00 deg	0.00 deg	129.40 ft	0.00 ft
Entry Curve	273.13 ft	254.90 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	254.90 ft	254.90 ft	0.00 deg	0.00 deg	0.00 deg	86.66 ft	0.00 ft
Exit Curve	254.90 ft	281.12 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	281.12 ft	287.50 ft	12.00 deg	12.00 deg	0.00 deg	30.67 ft	0.00 ft
					Total Check =	**707.50 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	295.60	
		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	30.002 ft	Plan Length	249.494 ft	Plan Length	86.66342 ft	Plan Length	208.378 ft	Plan Length	127.430 ft	701.967 ft
Rod Length	30.672 ft	Arc Rod Length	251.327 ft	Rod Length	86.66342 ft	Arc Rod Length	209.440 ft	Rod Length	129.396 ft	707.498 ft
Vertical Depth	-6.377 ft	Curve ∆ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	18.231 ft	Vertical Depth	22.469 ft	8.100 ft
		Lowest Elevation	254.900 ft			Lowest Elevation	254.900 ft	CK Total Cum Depth	8.100 ft	
Start Elevation	287.500 ft	Start Elevation	281.123 ft	Start Elevation	254.900 ft	Start Elevation	254.900 ft	Start Elevation	273.131 ft	
End Elevation	281.123 ft	End Elevation	254.900 ft	End Elevation	254.900 ft	End Elevation	273.131 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***	***701.9670124***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+30.00	Start Station	2+79.50	Start Station	3+66.16	Start Station	5+74.54	**Stationing Check** **OK STATIONING**
PVC Station	0+30.00	PTV Station	2+79.50	PCV Station	3+66.16	PTV Station	5+74.54	Exit Station	7+01.967	**Plan Length Check**
Cum Plan Length	30.00	Cum Plan Length	279.50	Cum Plan Length	366.16 ft	Cum Plan Length	574.54	Cum Plan Length	701.97	**OK CALCULATION**
Cum Rod Length	30.67	Cum Rod Length	282.00	Cum Rod Length	368.66 ft	Cum Rod Length	578.10	Cum Rod Length	707.50	**Elevation Change Check**
Cum Depth	-6.38	Cum Depth	-32.60	Cum Depth	-32.60 ft	Cum Depth	-14.3693	Cum Depth	8.10	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**8.10 ft**
Minimum Design Elevation =	**254.90 ft**
Invert Depth below exit =	**40.70 ft**
Invert Depth below entry =	**32.60 ft**
Path Length =	**707.50 ft**
Plan Length =	**701.97 ft**
Minimum Plan Length (No Tangent) =	**615.30 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

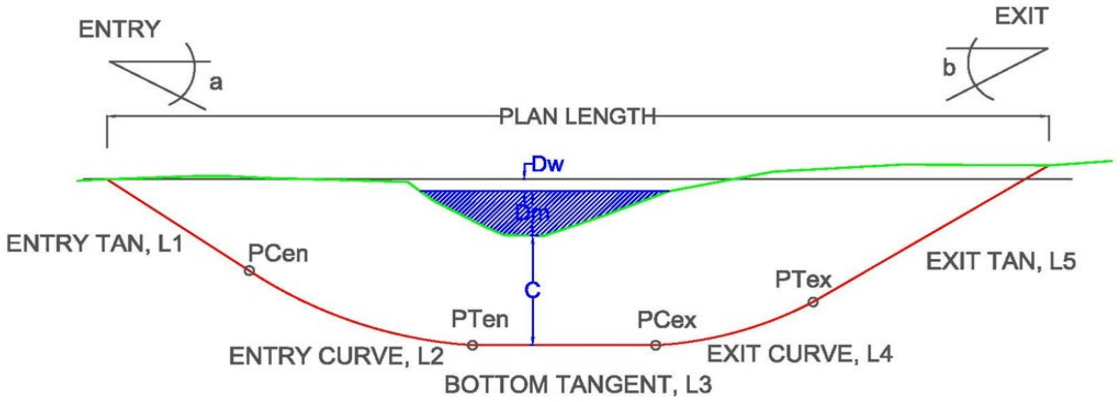
NOTES:

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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Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 83A Circuit #2
Wetland FA

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#83A CIR #2_APC_20230307.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	129.4 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	86.7 ft	χ =	0.0 ˚	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	30.7 ft	β =	12.0 ˚	0.2094	
LT =	807.5 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}	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]	

10-inches othe rinputs appear correct

INPUT: Assumed Fluid Densities/Elevations

Ballast Density	62.4	pcf	
Drill Fluid Density	78	pcf	*Estimated for pull*
Drill fluid elevation, H_F =	287.50 ft		
Ballast Water El., H_W =	287.50 ft		
Lowest Invert El., El_m =	254.90 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 =	0.93 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

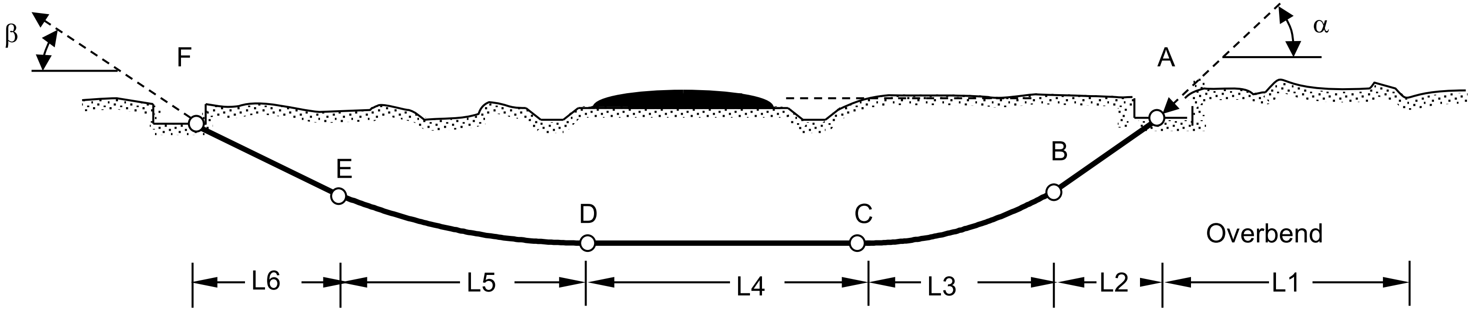
Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =	15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =	-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 287.50 ft

Pipe Entry El = 295.60 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	 Ballast
A	1,290 lb	94 psi	OK	1,290 lb	94 psi	OK	OK	OK
B	2,240 lb	62 psi	OK	2,378 lb	66 psi	OK	OK	OK
C	3,631 lb	126 psi	OK	2,961 lb	107 psi	OK	OK	OK
D	3,428 lb	96 psi	OK	2,758 lb	77 psi	OK	OK	OK
E	7,721 lb	240 psi	OK	4,865 lb	160 psi	OK	OK	OK
F	8,302 lb	232 psi	OK	5,126 lb	143 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 101.16 psi

Ballasted	OK
No Ballast	OK

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

PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.945652609	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.104202017	r = $\sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	240 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	3.53	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	17.66	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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Limited Liability Company
"Creating Space Underground"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 83A Circuit #2
Wetland FA

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

Revision 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#83A CIR #2_APC_20230307.xlsb]T3 Plastic Pull

HDPE PROPERTIES

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

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HDD 83A Circuit #2

Wetland FA

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 =	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 =	15.70	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

TABLE 4 Pg 2 of 3

HDPE PROPERTIES

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

HDD 83A Circuit #2

Wetland FA

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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: 40.70 ft
Ballast depth to invert, H_B: 32.60 ft
Drill Fluid depth to invert, H_{DF}: 32.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	14.32 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	17.90 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	18.36 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	14.32 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 = $(P_A+P_a)-P_{DF1}$	89.07 psi	28.18 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	88.61 psi	27.72 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.39 psi	42.50 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	102.94 psi	42.04 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	92.65 psi	31.76 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#83A CIR #2_APC_20230307.xlsb]T3 Plastic Pull

TABLE 4 **Pg 3 of 3**

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HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 83A Circuit #2

Wetland FA

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

Source PPI PE Handbook Ch 12 Formula 17 SPS = π*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	**FE PULL STRENTH, SPS =**	**50,200 lb**	
Temperature factor, f_{temp} =	1	ltimate Pull Strength, UPS =	########	
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 =	0.94565		
r = σ_i/2*(SSAS) =	0.10420	Example from Table T5, σ_i =	240 psi
P_{CRR} =	252.9 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	126.5 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	122.87 psi	Pull Back Condition - C	**OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$	122.41 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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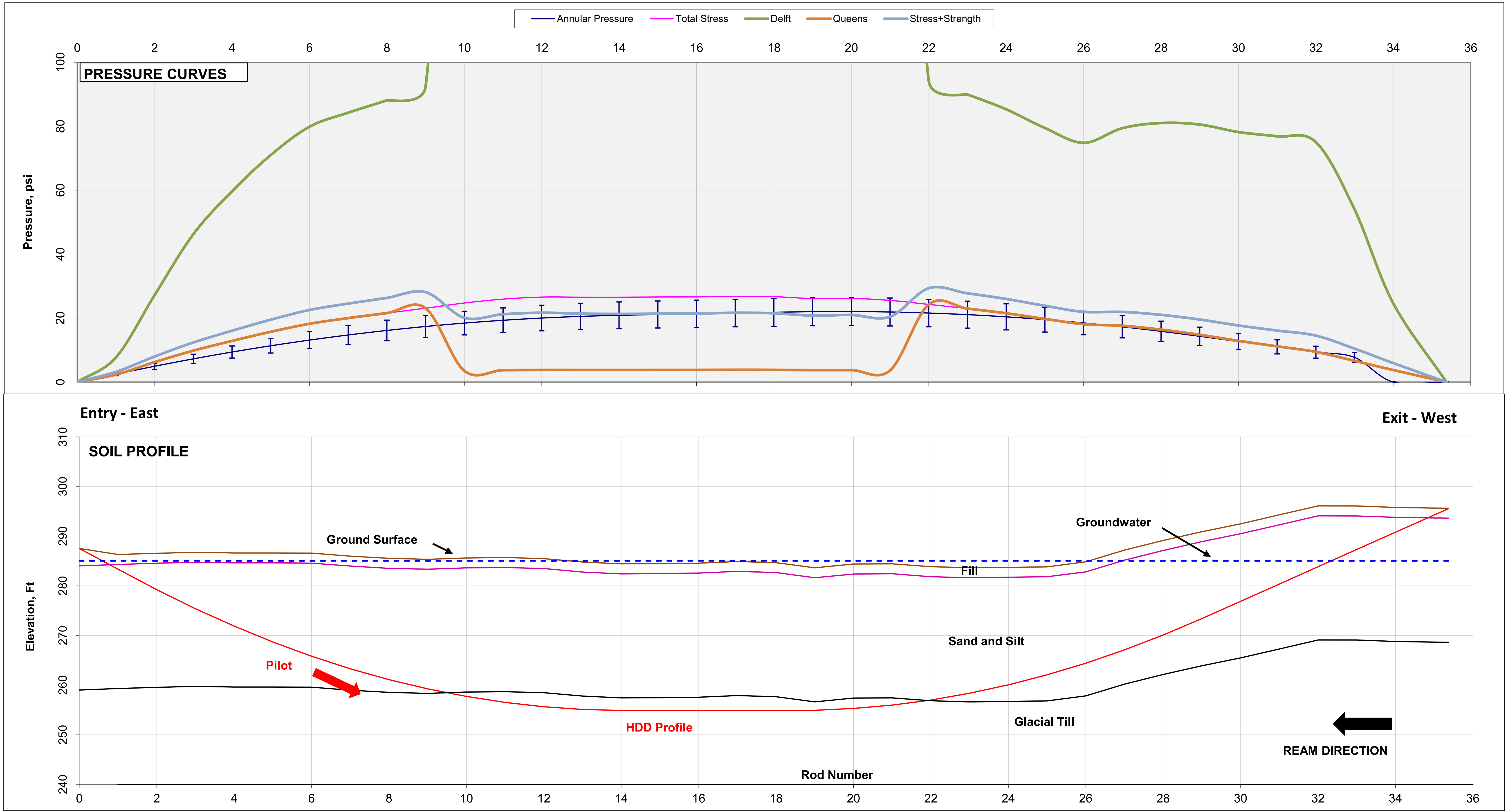

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Notes:

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
400 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 3/13/2023 8:12

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BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 83A Circuit #2
Wetland FA

Revision 1

FIGURE 1

BRIERLEY
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Creating Space Underground

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 84 Conduit #1**
New Scotland Rd

ISSUE: **Issued for Construction**

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: 6-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/6/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	*If no water or mudline then use lower of entry or exit elevation		
Exit Station	10+85.62	FT	Water Surface Elev.*	287.00 ft	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			Mudline Elev.*	287.70 ft	
	East	North	Elevation	Lowest centerline Elev.	244.10 ft
Entry	649756.5890	1383713.6587	288.70 ft		
Horizontal Curve PI	649997.7755	1383227.3745			
Exit	650238.9619	1382741.0902	292.20 ft		
Depth to Mudline	1.00 ft	Clearance Depth =	43.60 ft		
Measured Plan Length at ties =	1085.6211 ft				
Coordinate Length =	1085.6211 ft				
	OK-HORIZONTAL CURVE				

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	649756.5890	1383713.6587	5+42.81	649997.7755	1383227.3745	E 153.61958 N	542.81		
Curve	5+42.81	649997.7755	1383227.3745	5+42.81	649997.7755	1383227.3745	E 153.61959 N	0.00	0.00	0.000 deg.
Tangent	5+42.81	649997.7755	1383227.3745	10+85.62	650238.9619	1382741.0902	E 153.61959 N	542.81		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		***Horizontal Curve Segment***		***Exit Tangent Segment***		
Plan Length, ft.	542.81	Input Radius, ft.	0.00	Plan Length, ft.	542.81	
Entry Azimuth, deg.^{5}	N 153.61958 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 153.61959 E	
Entry Azimuth, rad.^{5}	2.68117	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.68117	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	650238.9619	***Check***
PCH Easting	649997.7755	Arc Length, ft.	0.00	Northing	1382741.0902	***Delta***
PCH Northing	1383227.3745	Chord Azimuth, deg	153.6196			**0.0000**
		PI Easting =	649997.7755			**0.0000**
		PI Northing =	1383227.3745			**OK CALC**
		PTH Easting =	649997.7755			
		PTH Northing =	1383227.3745			**Exit Station**
						10+85.62
Cum Plan Length	542.81	Cum Plan Length	542.81	Cum Plan Length	1085.621067	**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	292.20 ft	262.33 ft	-10.00 deg	-10.00 deg	0.00 deg	172.01 ft	0.00 ft
Entry Curve	262.33 ft	244.10 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	244.10 ft	244.10 ft	0.00 deg	0.00 deg	0.00 deg	371.89 ft	0.00 ft
Exit Curve	244.10 ft	270.32 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	270.32 ft	288.70 ft	12.00 deg	12.00 deg	0.00 deg	88.39 ft	0.00 ft
					Total Check =	**1093.06 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	292.20
		Vert. Curve, deg.	12.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	86.458 ft	Plan Length	249.494 ft	Plan Length	371.89443 ft	Plan Length	208.378 ft	Plan Length	169.397 ft
Rod Length	88.389 ft	Arc Rod Length	251.327 ft	Rod Length	371.89443 ft	Arc Rod Length	209.440 ft	Rod Length	172.010 ft
Vertical Depth	-18.377 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	29.869 ft
		Lowest Elevation	244.100 ft			Lowest Elevation	244.100 ft	CK Total Cum Depth	3.500 ft
Start Elevation	288.700 ft	Start Elevation	270.323 ft	Start Elevation	244.100 ft	Start Elevation	244.100 ft	Start Elevation	262.331 ft
End Elevation	270.323 ft	End Elevation	244.100 ft	End Elevation	244.100 ft	End Elevation	262.331 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***	***1085.621067***

SUMS
1,085.621 ft
1,093.061 ft
3.500 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+86.46	Start Station	3+35.95	Start Station	7+07.85	Start Station	9+16.22
PVC Station	0+86.46	PTV Station	3+35.95	PCV Station	7+07.85	PTV Station	9+16.22	Exit Station	10+85.621
Cum Plan Length	86.46	Cum Plan Length	335.95	Cum Plan Length	707.85 ft	Cum Plan Length	916.22	Cum Plan Length	1085.62
Cum Rod Length	88.39	Cum Rod Length	339.72	Cum Rod Length	711.61 ft	Cum Rod Length	921.05	Cum Rod Length	1093.06
Cum Depth	-18.38	Cum Depth	-44.60	Cum Depth	-44.60 ft	Cum Depth	-26.3693	Cum Depth	3.50

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.50 ft**
Minimum Design Elevation =	**244.10 ft**
Invert Depth below exit =	**48.10 ft**
Invert Depth below entry =	**44.60 ft**
Path Length =	**1,093.06 ft**
Plan Length =	**1,085.62 ft**
Minimum Plan Length (No Tangent) =	**713.73 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

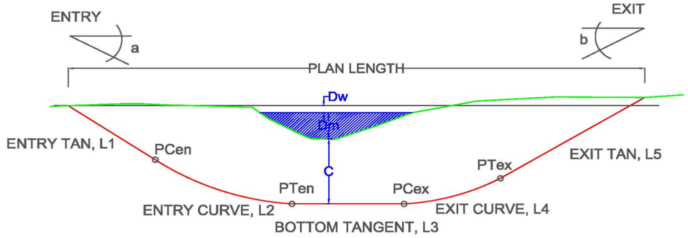
NOTES:

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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"Creating Space Underground"

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 84 Conduit #1
New Scotland Rd

Revision 1 TBD

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Pull Geometry

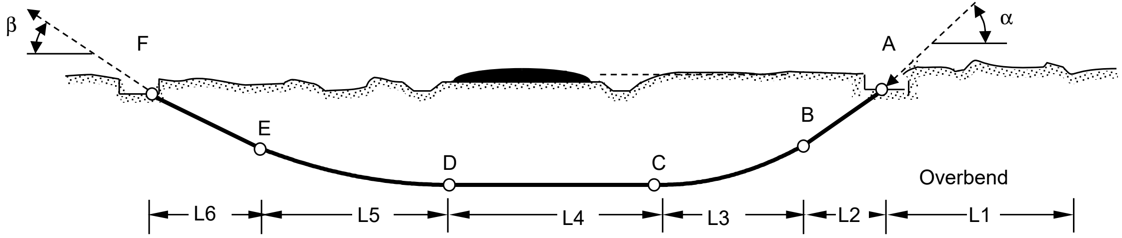
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	172.0 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	371.9 ft	χ =	0.0 ˚	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	88.4 ft	β =	12.0 ˚	0.2094	
LT =	1193.1 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 288.70 ft

Pipe Entry El = 292.20 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 =	287.70 ft	
Ballast Water El., H_W =	287.70 ft	
Lowest Invert El., El_m =	244.10 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 =	0.81 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	2,108 lb	182 psi	OK	2,108 lb	182 psi	OK	OK	OK
B	3,548 lb	89 psi	OK	3,817 lb	96 psi	OK	OK	OK
C	5,231 lb	164 psi	OK	4,612 lb	148 psi	OK	OK	OK
D	6,408 lb	162 psi	OK	5,789 lb	146 psi	OK	OK	OK
E	11,415 lb	320 psi	OK	8,383 lb	244 psi	OK	OK	OK
F	13,218 lb	333 psi	OK	9,224 lb	233 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **$P_{PA} > \Delta P$ invert** **$P_{PA} = P_AF_R$ =** 98.54 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.921188217	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.144958281	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	333 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** =	4.72	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** =	23.62	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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BRIERLEY ASSOCIATES
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"Creating Space Underground"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 84 Conduit #1
New Scotland Rd

Revision 1 TBD

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TABLE 4 **Pg 1 of 3**

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

HDPE PROPERTIES

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

HDD 84 Conduit #1
New Scotland Rd

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 =	3.801889456		$A_W = \pi*((D_o/2)^2-((D_o-2t)/2)^2)$
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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

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"Creating Space Underground"

HDPE PROPERTIES

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

HDD 84 Conduit #1
New Scotland Rd

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 48.10 ft

Ballast depth to invert, H_B 44.60 ft

Drill Fluid depth to invert, H_{DF} 44.60 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	19.39 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	24.24 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	24.86 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	19.39 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 = $(P_A+P_a)-P_{DF1}$	82.74 psi	21.84 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	82.12 psi	21.22 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.13 psi	41.23 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.51 psi	40.61 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	87.59 psi	26.69 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.

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDD 84 Conduit #1

New Scotland Rd

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

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

Designed Pull Duration Time = 12 hr

Quantity of pipes, Q = 1

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Temperature, F = 73 deg.

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y = 0.4

SAFE PULL STRENTH, SPS = 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 = 0.92119

r = σ_i/2*(SSAS) = 0.14496

Example from Table T5, σ_i = 333 psi

P_{CRR} = 246.4 psi

FS = 2.0

P_{ACRR} = P_{CRR}/FS = 123.2 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 98.94 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 98.32 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

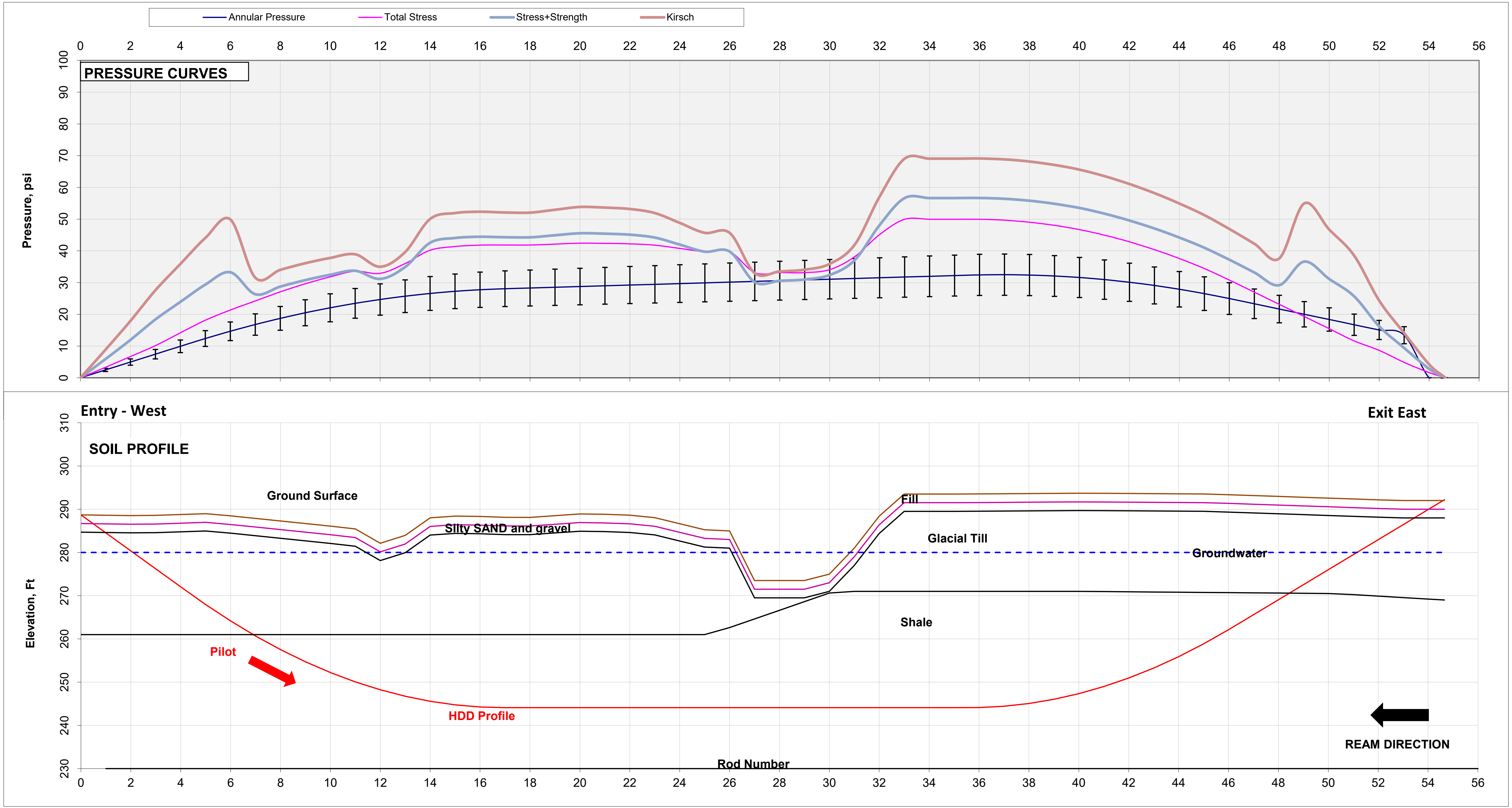
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

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

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#82-83 CIR #2_APC_20230306.xlsb]F1A APCL



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
400 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore logs
B190.0-1
K190.0
B190.1-1
KB-190.2

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BRIERLEY ASSOCIATES
Creating Space Underground
167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 84 Conduit #1
New Scotland Rd

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 84 Conduit #2**
New Scotland Rd

ISSUE: **Issued for Construction**

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: 6-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/6/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	10+85.69	FT

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

	East	North	Elevation
Entry	649769.9239	1383720.5276	288.70 ft
Horizontal Curve PI	650011.3108	1383234.3028	
Exit	650252.6977	1382748.0780	288.30 ft
Depth to Mudline	1.00	Clearance Depth =	45.20 ft

Measured Plan Length at ties = 1085.6928 ft

Coordinate Length = 1085.6928 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	287.00 ft
Mudline Elev.*	287.70 ft
Lowest centerline Elev.	242.50 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	649769.9239	1383720.5276	5+42.85	650011.3108	1383234.3028	E 153.59784 N	542.85		
Curve	5+42.85	650011.3108	1383234.3028	5+42.85	650011.3108	1383234.3028	E 153.59784 N	0.00	0.00	0.000 deg.
Tangent	5+42.85	650011.3108	1383234.3028	10+85.69	650252.6977	1382748.0780	E 153.59784 N	542.85		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	542.85	Input Radius, ft.	0.00	Plan Length, ft.	542.85	
Entry Azimuth, deg.^{5}	N 153.59784 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 153.59784 E	
Entry Azimuth, rad.^{5}	2.68079	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.68079	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	650252.6977	**Check**
PCH Easting	650011.3108	Arc Length, ft.	0.00	Northing	1382748.0780	**Delta**
PCH Northing	1383234.3028	Chord Azimuth, deg	153.5978			**0.0000**
		PI Easting =	650011.3108			**0.0000**
		PI Northing =	1383234.3028			**OK CALC**
		PTH Easting =	650011.3108			
		PTH Northing =	1383234.3028			**Exit Station**
						10+85.69
Cum Plan Length	542.85	Cum Plan Length	542.85	Cum Plan Length	1085.692759	**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	288.30 ft	260.73 ft	-10.00 deg	-10.00 deg	0.00 deg	158.77 ft	0.00 ft
Entry Curve	260.73 ft	242.50 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	242.50 ft	242.50 ft	0.00 deg	0.00 deg	0.00 deg	377.48 ft	0.00 ft
Exit Curve	242.50 ft	268.72 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	268.72 ft	288.70 ft	12.00 deg	12.00 deg	0.00 deg	96.08 ft	0.00 ft
					Total Check =	1093.10 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	288.30	
		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	93.985 ft	Plan Length	249.494 ft	Plan Length	377.48266 ft	Plan Length	208.378 ft	Plan Length	156.353 ft	1,085.693 ft
Rod Length	96.085 ft	Arc Rod Length	251.327 ft	Rod Length	377.48266 ft	Arc Rod Length	209.440 ft	Rod Length	158.765 ft	1,093.100 ft
Vertical Depth	-19.977 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	27.569 ft	-0.400 ft
		Lowest Elevation	242.500 ft			Lowest Elevation	242.500 ft	CK Total Cum Depth	-0.400 ft	
Start Elevation	288.700 ft	Start Elevation	268.723 ft	Start Elevation	242.500 ft	Start Elevation	242.500 ft	Start Elevation	260.731 ft	
End Elevation	268.723 ft	End Elevation	242.500 ft	End Elevation	242.500 ft	End Elevation	260.731 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*	*1085.692759*	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+93.98	Start Station	3+43.48	Start Station	7+20.96	Start Station	9+29.34
PVC Station	0+93.98	PTV Station	3+43.48	PCV Station	7+20.96	PTV Station	9+29.34	Exit Station	10+85.693
Cum Plan Length	93.98	Cum Plan Length	343.48	Cum Plan Length	720.96 ft	Cum Plan Length	929.34	Cum Plan Length	1085.69
Cum Rod Length	96.08	Cum Rod Length	347.41	Cum Rod Length	724.89 ft	Cum Rod Length	934.33	Cum Rod Length	1093.10
Cum Depth	-19.98	Cum Depth	-46.20	Cum Depth	-46.20 ft	Cum Depth	-27.9693	Cum Depth	-0.40

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-0.40 ft**
Minimum Design Elevation =	**242.50 ft**
Invert Depth below exit =	**45.80 ft**
Invert Depth below entry =	**46.20 ft**
Path Length =	**1,093.10 ft**
Plan Length =	**1,085.69 ft**
Minimum Plan Length (No Tangent) =	**708.21 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

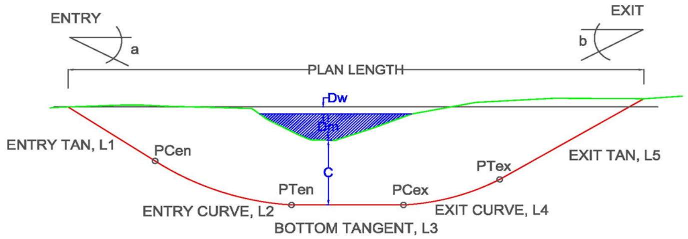
NOTES:

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 84 Conduit #2
New Scotland Rd

Revision 1 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	158.8 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	377.5 ft	χ =	0.0 ˚	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	96.1 ft	β =	12.0 ˚	0.2094	
LT =	1193.1 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	PIPE	PIPE/BUNDLE		
Material Density, γ	59.28 pcf			
Outside Diameter, D_{OD}	14.25	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}	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 =	1,000 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 =	287.70 ft		
Ballast Water El., H_W =	287.70 ft		
Lowest Invert El., El_m =	242.50 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 =	0.81 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

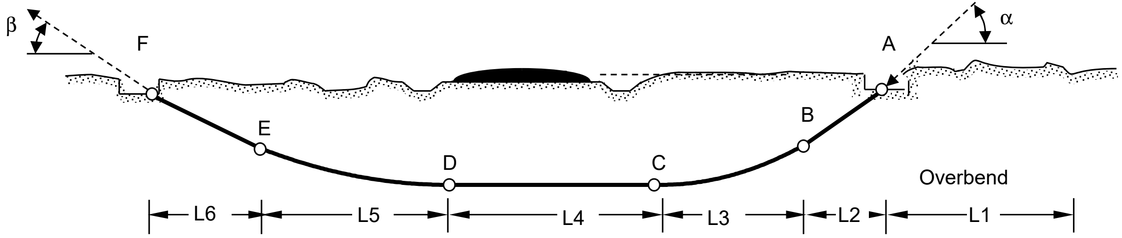
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 288.70 ft

Pipe Entry El = 288.30 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	1,906 lb	182 psi	OK	1,906 lb	182 psi	OK	OK	OK
B	3,115 lb	87 psi	OK	3,374 lb	94 psi	OK	OK	OK
C	4,689 lb	163 psi	OK	4,145 lb	148 psi	OK	OK	OK
D	5,767 lb	161 psi	OK	5,224 lb	146 psi	OK	OK	OK
E	10,361 lb	321 psi	OK	7,637 lb	245 psi	OK	OK	OK
F	12,163 lb	339 psi	OK	8,490 lb	237 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ invert	$P_{PA} = P_AF_R$ =	98.37 psi	Ballasted OK
			No Ballast OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.919605708	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.147531777	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	339 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	4.90	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	24.48	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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Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 84 Conduit #2
New Scotland Rd

Revision 1 TBD

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 84 Conduit #2

New Scotland Rd

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 =	8.218 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 =	15.7	Lb/LF	
Tensile Yield, Ty psi =	3,500 psi	@73^{o}F	Minimum from ASTM D3350 determined by ASTM D638
Load Duration	**Short Term**	**Long Term**	
Duration Time	10 hours	50 yrs	
Design Temperature, ^{o}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	0.84	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 forces

Dry Weight Pipe on ground, W_P =	15.70 lb/ft	From MFG. Data Sheet
Internal Ballast Weight, W_B =	22.98 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.68 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.48 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.74 lb/ft	BG-W_{D2}

HDPE PROPERTIES

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

HDD 84 Conduit #2
New Scotland Rd

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	46.20 ft	Ballast depth to invert, H_B	45.80 ft	Drill Fluid depth to invert, H_{DF}	45.80 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	20.04 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	25.05 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.69 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	20.04 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 = $(P_A+P_a)-P_{DF1}$	81.92 psi	21.03 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.28 psi	20.39 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.96 psi	41.07 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.32 psi	40.43 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	86.93 psi	26.04 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 84 Conduit #2
New Scotland Rd

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 50,200 lb
Ultimate Pull Strength, UPS = 125,499 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
$fr = ((5.57-(r+1.09)^2)^.5)-1.09$ = 0.91961
$r = \sigma_i/2*(SSAS)$ = 0.14753
P_{CRR} = 245.9 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 123.0 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 97.92 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 97.28 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft

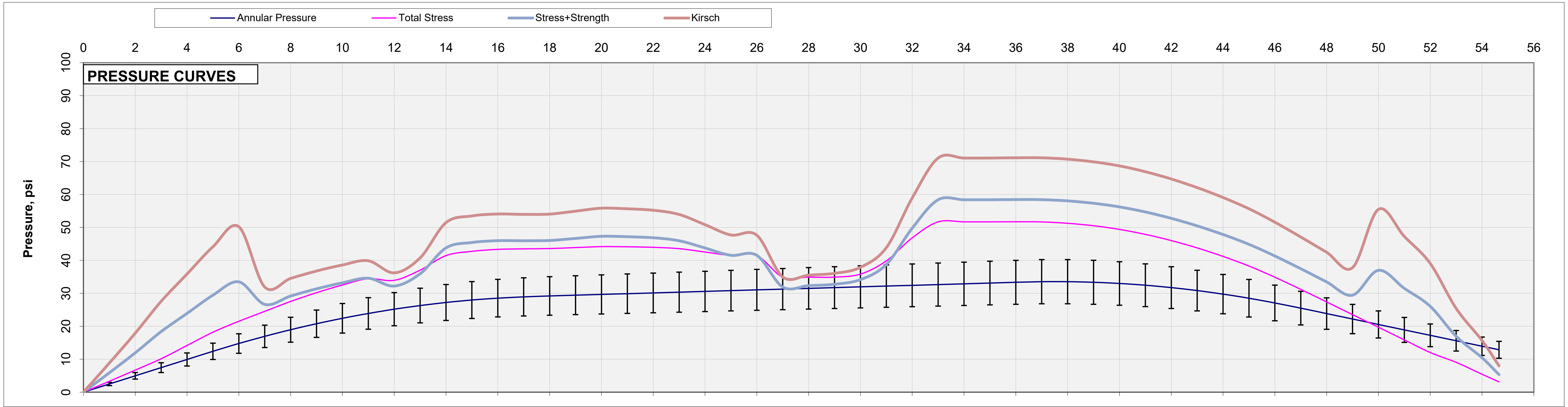
Example from Table T5, σ_i = 339 psi

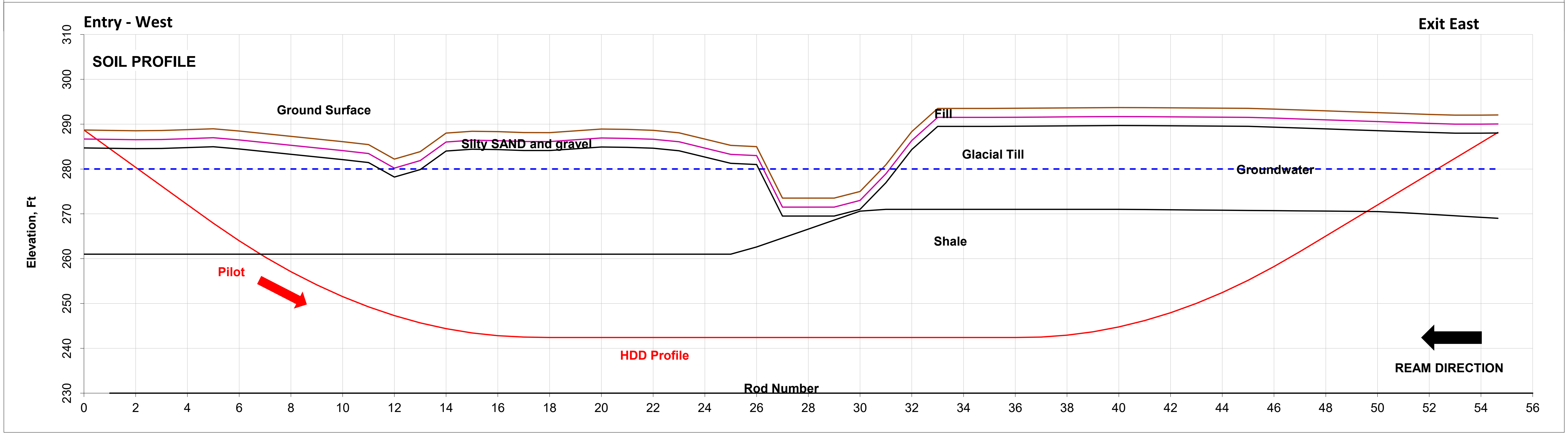
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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
400 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore logs

B190.0-1
K190.0
B190.1-1
KB-190.2

Print Date ; 3/6/2023 14:02

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 84 Conduit #2
New Scotland Rd

Revision 1

FIGURE 1

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#84 CIR #2_APC_20221023.xlsb]T4 Formation Pressure

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 84A Conduit #1**
New Scotland South Road

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: 14-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/14/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	10+28.09	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	651688.1418	1380027.0879	276.70 ft
Horizontal Curve PI	651964.0706	1379436.3908	
Exit	652150.1650	1379109.4328	280.70 ft
Depth to Mudline	1.70 ft	Clearance Depth =	43.00 ft
Measured Plan Length at ties =	1028.0875 ft		
Coordinate Length =	1028.0875 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	276.70 ft
Mudline Elev.*	275.00 ft
Lowest centerline Elev.	232.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	651688.1418	1380027.0879	5+71.48	651930.0086	1379509.3094	E 154.96159 N	571.48		
Curve	5+71.48	651930.0086	1379509.3094	7+32.36	652003.8816	1379366.4449	E 150.35280 N	160.88	2000.00	-4.609 deg.
Tangent	7+32.36	652003.8816	1379366.4449	10+28.09	652150.1650	1379109.4328	E 150.35280 N	295.73		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	571.48	Input Radius, ft.	2000.00	Plan Length, ft.	295.73	
Entry Azimuth, deg.^{5}	N 154.96159 E	Curve, deg	-4.609 deg.	Exit Azimuth, deg.^{5}	N 150.35280 E	
Entry Azimuth, rad.^{5}	2.70459	Curve, rad	-0.08044	Exit Azimuth, rad.^{5}	2.62415	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	160.83	Easting	652150.1650	***Check***
PCH Easting	651930.0086	Arc Length, ft.	160.88	Northing	1379109.4328	***Delta***
PCH Northing	1379509.3094	Chord Azimuth, deg	152.6572			**0.0000**
		PI Easting =	651964.0706			**0.0000**
		PI Northing =	1379436.3908			**OK CALC**
		PTH Easting =	652003.8816			
		PTH Northing =	1379366.4449			**Exit Station**
						10+28.09
Cum Plan Length	571.48	Cum Plan Length	732.36	Cum Plan Length	1028.087543	**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	280.70 ft	250.23 ft	-10.00 deg	-10.00 deg	0.00 deg	175.47 ft	0.00 ft
Entry Curve	250.23 ft	232.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	232.00 ft	232.00 ft	0.00 deg	0.00 deg	0.00 deg	310.49 ft	0.00 ft
Exit Curve	232.00 ft	258.22 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	258.22 ft	276.70 ft	12.00 deg	12.00 deg	0.00 deg	88.87 ft	0.00 ft
					Total Check =	1035.59 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	336.42	571.48	No, Horiz > Entry V(Tan+Curve)
Exit	381.18	295.73	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	1200.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	280.70	
		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	86.928 ft	Plan Length	249.494 ft	Plan Length	310.48767 ft	Plan Length	208.378 ft	Plan Length	172.800 ft	1,028.088 ft
Rod Length	88.870 ft	Arc Rod Length	251.327 ft	Rod Length	310.48767 ft	Arc Rod Length	209.440 ft	Rod Length	175.466 ft	1,035.590 ft
Vertical Depth	-18.477 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	30.469 ft	4.000 ft
		Lowest Elevation	232.000 ft			Lowest Elevation	232.000 ft	CK Total Cum Depth	4.000 ft	
Start Elevation	276.700 ft	Start Elevation	258.223 ft	Start Elevation	232.000 ft	Start Elevation	232.000 ft	Start Elevation	250.231 ft	
End Elevation	258.223 ft	End Elevation	232.000 ft	End Elevation	232.000 ft	End Elevation	250.231 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***	***1028.087543***	

SUMMARY VERTICLE CURVE CALCULATIONS

										Stationing Check
Start Station	0+00.00	Start Station	0+86.93	Start Station	3+36.42	Start Station	6+46.91	Start Station	8+55.29	**OK STATIONING**
PVC Station	0+86.93	PTV Station	3+36.42	PCV Station	6+46.91	PTV Station	8+55.29	Exit Station	10+28.088	**Plan Length Check**
Cum Plan Length	86.93	Cum Plan Length	336.42	Cum Plan Length	646.91 ft	Cum Plan Length	855.29	Cum Plan Length	1028.09	**OK CALCULATION**
Cum Rod Length	88.87	Cum Rod Length	340.20	Cum Rod Length	650.69 ft	Cum Rod Length	860.12	Cum Rod Length	1035.59	**Elevation Change Check**
Cum Depth	-18.48	Cum Depth	-44.70	Cum Depth	-44.70 ft	Cum Depth	-26.4693	Cum Depth	4.00	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**4.00 ft**
Minimum Design Elevation =	**232.00 ft**
Invert Depth below exit =	**48.70 ft**
Invert Depth below entry =	**44.70 ft**
Path Length =	**1,035.59 ft**
Plan Length =	**1,028.09 ft**
Minimum Plan Length (No Tangent) =	**717.60 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**1,029 ft**

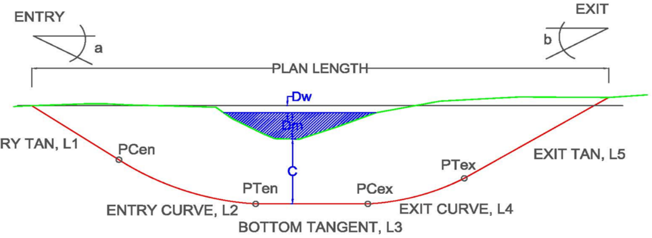
NOTES:

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. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 84A Conduit #1
New Scotland South Road

Revision 1 TBD

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Pull Geometry

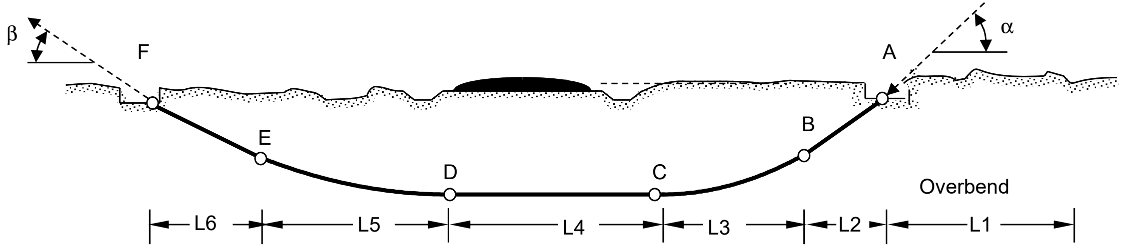
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	175.5 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	310.5 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	88.9 ft	β =	12.0 °	0.2094	
LT =	1135.6 ft				

Pipe Entry Location - Drill **EXIT**

(schematic, to show definition of variables only)

Pipe Exit El = 276.70 ft

Pipe Entry El = 280.70 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 =	276.70 ft	
Ballast Water El., H_W =	276.70 ft	
Lowest Invert El., El_m =	232.00 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 =	0.85 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	Ballast
A	2,006 lb	179 psi	OK	2,006 lb	179 psi	OK	OK	OK
B	3,489 lb	88 psi	OK	3,771 lb	95 psi	OK	OK	OK
C	5,170 lb	163 psi	OK	4,563 lb	147 psi	OK	OK	OK
D	6,023 lb	152 psi	OK	5,416 lb	137 psi	OK	OK	OK
E	11,008 lb	310 psi	OK	7,990 lb	234 psi	OK	OK	OK
F	12,908 lb	326 psi	OK	8,867 lb	224 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 98.77 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.923268486	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.141564048	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	326 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	4.84	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	24.21	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. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 84A Conduit #1
New Scotland South Road

Revision 1

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 84A Conduit #1

New Scotland South Road

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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	4710 HDPE	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

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HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY
HDD 84A Conduit #1
New Scotland South Road

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	48.70 ft	Ballast depth to invert, H_B	44.70 ft	Drill Fluid depth to invert, H_{DF}	44.70 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	19.43 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	24.29 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	24.91 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	19.43 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 = $(P_A+P_a)-P_{DF1}$	82.68 psi	8.62 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	82.06 psi	8.00 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.12 psi	28.06 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.49 psi	27.43 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 = $(P_A+P_a)-P_W$	87.54 psi	13.48 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

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

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

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

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TABLE 4
HDPE PROPERTIES
Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY

HDD 84A Conduit #1

New Scotland South Road

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 5,321 lb **Useing SSAS = 4,371 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.
AFE PULL STRENTH, SPS = 5,321 lb
Ultimate Pull Strength, UPS = 13,303 lb
Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
$fr = ((5.57-(r+1.09)^2)^.5)-1.09$ = 0.92327
$r = \sigma_i/2*(SSAS)$ = 0.14156
P_{CRR} = 246.9 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 123.5 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 118.60 psi Pull Back Condition - Optio **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 117.98 psi Pull Back Condition - Optio **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 326 psi

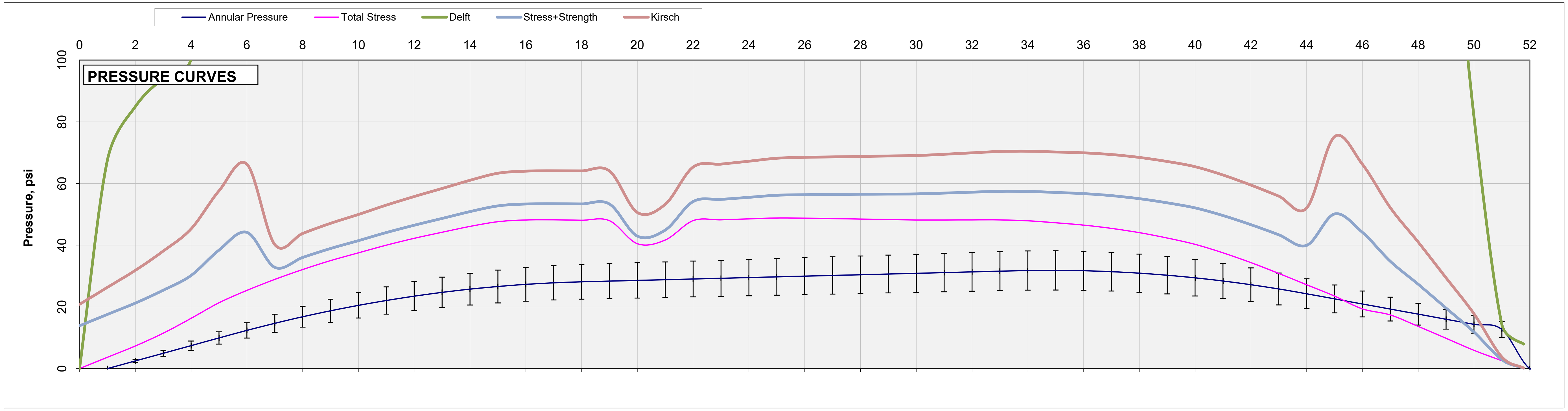
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

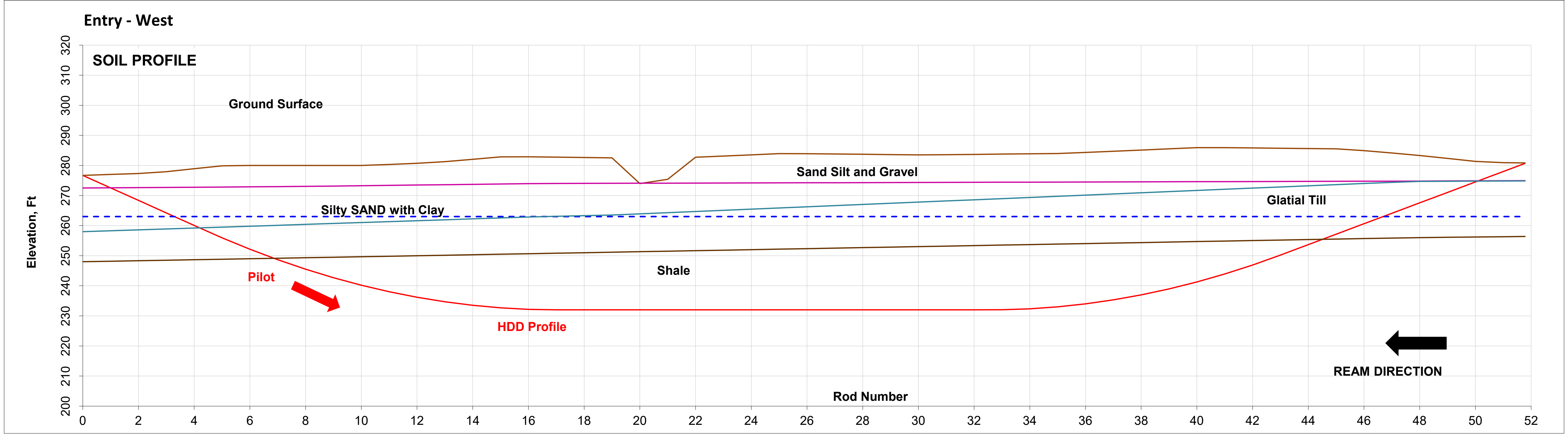
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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





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.

ISSUED: Issued for Construction

Basis of annulur pressure calculations

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

Bore Logs
KB190.8
KB190.9
B190.8-1

Print Date ; 3/14/2023 9:14

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 84A Conduit #1
New Scotland South Road

Revision 1

FIGURE 1

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 84A Conduit #2**

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: 14-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/14/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	10+26.80	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	651702.1367	1380033.7357	276.30 ft
Horizontal Curve PI	651932.9187	1379575.1303	
Exit	652163.7007	1379116.5249	279.70 ft
Depth to Mudline	0.30 ft	Clearance Depth =	44.00 ft
Measured Plan Length at ties =	1026.7994 ft		
Coordinate Length =	1026.7994 ft		
OK - NO HORIZONTAL CURVE TANGENT			

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

Water Surface Elev.*	276.00 ft
Mudline Elev.*	276.00 ft
Lowest centerline Elev.	232.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	651702.1367	1380033.7357	5+13.40	651932.9187	1379575.1303	E 153.28729 N	513.40		
Curve	5+13.40	651932.9187	1379575.1303	5+13.40	651932.9187	1379575.1303	E 153.28729 N	0.00	0.00	0.000 deg.
Tangent	5+13.40	651932.9187	1379575.1303	10+26.80	652163.7007	1379116.5249	E 153.28729 N	513.40		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	513.40	Input Radius, ft.	0.00	Plan Length, ft.	513.40	
Entry Azimuth, deg.^{5}	N 153.28729 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 153.28729 E	
Entry Azimuth, rad.^{5}	2.67537	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.67537	
		Calculate PTH		**Calculate Exit**		
Calculate PCH `		Chord Length, ft.	0.00	Easting	652163.7007	***Check***
PCH Easting	651932.9187	Arc Length, ft.	0.00	Northing	1379116.5249	***Delta***
PCH Northing	1379575.1303	Chord Azimuth, deg	153.2873			**0.0000**
		PI Easting =	651932.9187			**0.0000**
		PI Northing =	1379575.1303			**OK CALC**
		PTH Easting =	651932.9187			
		PTH Northing =	1379575.1303			**Exit Station**
						10+26.80
Cum Plan Length	513.40	Cum Plan Length	513.40	Cum Plan Length	1026.799385	**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	279.70 ft	250.23 ft	-10.00 deg	-10.00 deg	0.00 deg	169.71 ft	0.00 ft
Entry Curve	250.23 ft	232.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	232.00 ft	232.00 ft	0.00 deg	0.00 deg	0.00 deg	316.75 ft	0.00 ft
Exit Curve	232.00 ft	258.22 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	258.22 ft	276.30 ft	12.00 deg	12.00 deg	0.00 deg	86.95 ft	0.00 ft
					Total Check =	**1034.17 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	279.70	
		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	85.046 ft	Plan Length	249.494 ft	Plan Length	316.75265 ft	Plan Length	208.378 ft	Plan Length	167.129 ft	1,026.799 ft
Rod Length	86.946 ft	Arc Rod Length	251.327 ft	Rod Length	316.75265 ft	Arc Rod Length	209.440 ft	Rod Length	169.707 ft	1,034.173 ft
Vertical Depth	-18.077 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	29.469 ft	3.400 ft
		Lowest Elevation	232.000 ft			Lowest Elevation	232.000 ft	CK Total Cum Depth	3.400 ft	
Start Elevation	276.300 ft	Start Elevation	258.223 ft	Start Elevation	232.000 ft	Start Elevation	232.000 ft	Start Elevation	250.231 ft	
End Elevation	258.223 ft	End Elevation	232.000 ft	End Elevation	232.000 ft	End Elevation	250.231 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***	***1026.799385***	
SUMMARY VERTICLE CURVE CALCULATIONS										**Stationing Check**
Start Station	0+00.00	Start Station	0+85.05	Start Station	3+34.54	Start Station	6+51.29	Start Station	8+59.67	**OK STATIONING**
PVC Station	0+85.05	PTV Station	3+34.54	PCV Station	6+51.29	PTV Station	8+59.67	Exit Station	10+26.799	**Plan Length Check**
Cum Plan Length	85.05	Cum Plan Length	334.54	Cum Plan Length	651.29 ft	Cum Plan Length	859.67	Cum Plan Length	1026.80	**OK CALCULATION**
Cum Rod Length	86.95	Cum Rod Length	338.27	Cum Rod Length	655.03 ft	Cum Rod Length	864.47	Cum Rod Length	1034.17	**Elevation Change Check**
Cum Depth	-18.08	Cum Depth	-44.30	Cum Depth	-44.30 ft	Cum Depth	-26.0693	Cum Depth	3.40	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.40 ft**
Minimum Design Elevation =	**232.00 ft**
Invert Depth below exit =	**47.70 ft**
Invert Depth below entry =	**44.30 ft**
Path Length =	**1,034.17 ft**
Plan Length =	**1,026.80 ft**
Minimum Plan Length (No Tangent) =	**710.05 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

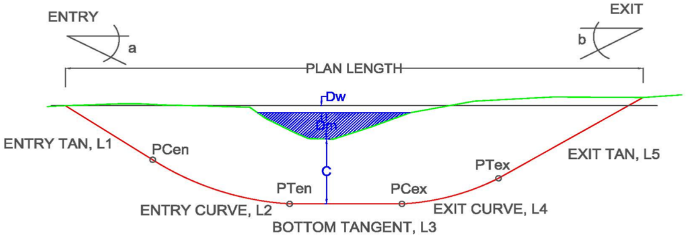
NOTES:

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 84A Conduit #2

Revision 1 TBD

Pull Geometry

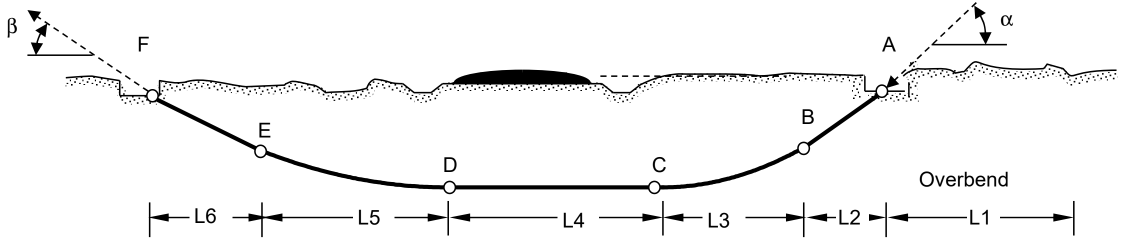
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	169.7 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	316.8 ft	χ =	0.0 ˚	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	86.9 ft	β =	12.0 ˚	0.2094	
LT =	1134.2 ft				

Pipe Entry Location - Drill EXIT

(schematic, to show definition of variables only)

Pipe Exit El = 276.30 ft

Pipe Entry El = 279.70 ft



INPUT: Assumed Friction Factors

μ_G = 0.10 dry + rollers

μ_b = 0.25 drill fluid in hole

μ_c = 0.30 in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f = 0.005 psi Drill Fluid Shear Stress

INPUT: Pipe Properties

Material	HDPE	IPS	
Safe Pull Max. Stress, σ_{PM}	1,150 psi	PPI Table 1 12hr @ 73Deg F	
Pile/Bundle Diam. 10.75	PIPE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	10.75	Pipe or Bundle	
Pipe Dry Weight, W_P =	15.70 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	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 =	1,000 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 =	276.00 ft		
Ballast Water El., H_W =	276.00 ft		
Lowest Invert El., El_m =	232.00 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 =	0.63 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	Max Tensile	ASSESS	Pull Force, F_B	Max Tensile	ASSESS	ASSESS	
							F_x < SPS	
	No Ballast	Stress, σ_T	$\sigma_T < \sigma_{PM}$	Ballasted Pipe	Stress, σ_T	$\sigma_T < \sigma_{PM}$	Air	Ballast
A	1,812 lb	148 psi	OK	1,812 lb	148 psi	OK	OK	OK
B	3,170 lb	88 psi	OK	3,417 lb	95 psi	OK	OK	OK
C	4,602 lb	153 psi	OK	4,046 lb	137 psi	OK	OK	OK
D	5,406 lb	151 psi	OK	4,850 lb	135 psi	OK	OK	OK
E	9,805 lb	298 psi	OK	7,069 lb	221 psi	OK	OK	OK
F	11,428 lb	319 psi	OK	7,802 lb	218 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 98.96 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	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 =	0.925072785	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.13860965	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	319 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	4.77	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	23.83	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 18

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

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 84A Conduit #2

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

Revision 1

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#84A CIR #2_APC_20230313.xlsb]F1A APCL

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express
Segment 8 (Pkg. 5A) - CSX: Roterdam to Bethlehem
Schenectady County, NY
HDD 84A Conduit #2

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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	4710 HDPE		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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	BG-W_{D2}

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 84A Conduit #2

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	47.70 ft	Ballast depth to invert, H_B	44.30 ft	Drill Fluid depth to invert, H_{DF}	44.30 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}^*(H_B+D_o/24)/144$	19.39 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}^*(H_{MDF}+D_o/24)/144$	24.24 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}^*(H_{MDF}+D_o/24)/144$	24.86 psi
Water, $P_W = \gamma_{INT}^*(H_{DF}+D_o/24)/144$	19.39 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 = $(P_A+P_a)-P_{DF1}$	82.74 psi	8.68 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	82.11 psi	8.06 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	102.13 psi	28.07 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.51 psi	27.45 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 = $(P_A+P_a)-P_W$	87.58 psi	13.52 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 84A Conduit #2

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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
FE PULL STRENTH, SPS = 50,200 lb
Temperature factor, f_{temp} = 1
ltimate 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 = 0.92507
$r = \sigma_i/2*(SSAS)$ = 0.13861
Example from Table T5, σ_i = 319 psi
P_{CRR} = 247.4 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 123.7 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 118.85 psi Pull Back Condition - Optio **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 118.23 psi Pull Back Condition - Optio **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

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

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

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

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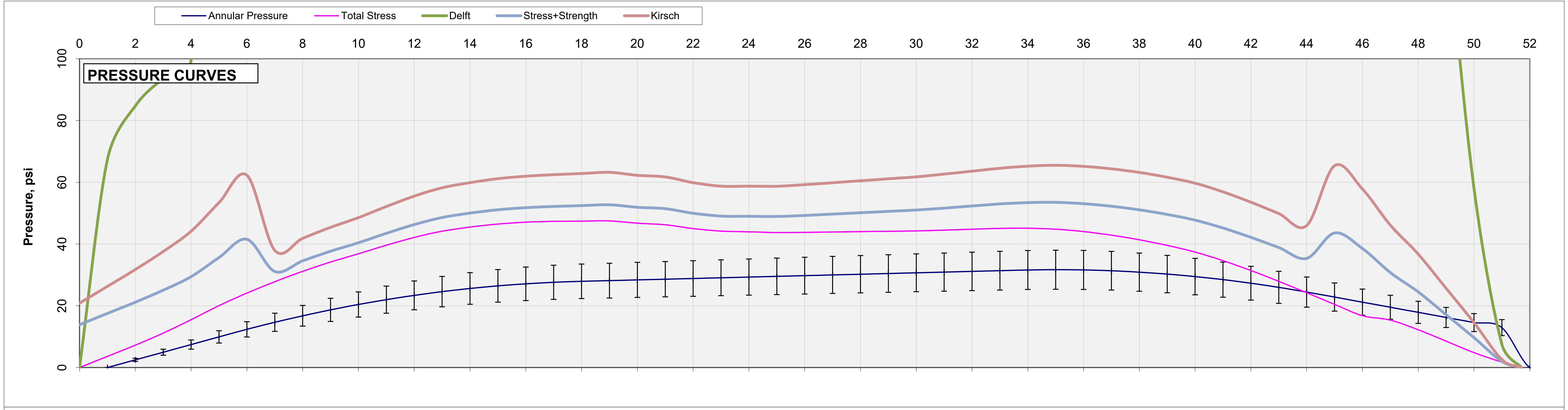

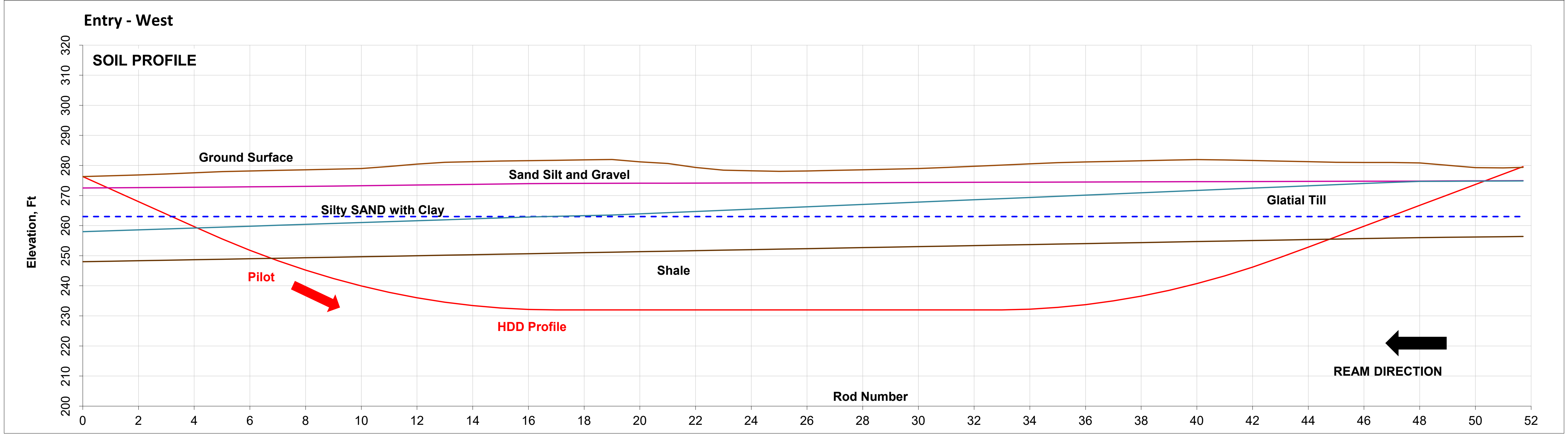

ISSUED: Issued for Construction

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
400 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs

KB190.8
KB190.9
B190.8-1

Print Date ; 3/14/2023 9:17

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 84A Conduit #2

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 84B Circuit #1**
Game Farm Road

ISSUE: **Design Submittal**

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: 13-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	10+32.30	FT

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

	East	North	Elevation
Entry	654006.9387	1375752.9205	256.10 ft
Horizontal Curve PI	654269.7018	1375308.6589	
Exit	654532.4649	1374864.3972	250.00 ft

Depth to Mudline	6.10 ft	Clearance Depth =	54.90 ft
Measured Plan Length at ties =	1032.3039 ft		
Coordinate Length =	1032.3039 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	225.00 ft
Mudline Elev.*	250.00 ft
Lowest centerline Elev.	195.10 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	654006.9387	1375752.9205	5+16.15	654269.7018	1375308.6589	E 149.39737 N	516.15		
Curve	5+16.15	654269.7018	1375308.6589	5+16.15	654269.7018	1375308.6589	E 149.39738 N	0.00	0.00	0.000 deg.
Tangent	5+16.15	654269.7018	1375308.6589	10+32.30	654532.4649	1374864.3972	E 149.39738 N	516.15		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	516.15	Input Radius, ft.	0.00	Plan Length, ft.	516.15	
Entry Azimuth, deg.^{5}	N 149.39737 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 149.39738 E	
Entry Azimuth, rad.^{5}	2.60748	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.60748	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	654532.4649	**Check**
PCH Easting	654269.7018	Arc Length, ft.	0.00	Northing	1374864.3972	**Delta**
PCH Northing	1375308.6589	Chord Azimuth, deg	149.3974			**0.0000**
		PI Easting =	654269.7018			**0.0000**
		PI Northing =	1375308.6589			**OK CALC**
		PTH Easting =	654269.7018			
		PTH Northing =	1375308.6589			**Exit Station**
						10+32.30
Cum Plan Length	516.15	Cum Plan Length	516.15	Cum Plan Length	1032.303948	**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	250.00 ft	210.29 ft	-10.00 deg	-10.00 deg	0.00 deg	228.67 ft	0.00 ft
Entry Curve	210.29 ft	195.10 ft	-10.00 deg	0.00 deg	10.00 deg	174.53 ft	1000.00 ft
Bottom Tangent	195.10 ft	195.10 ft	0.00 deg	0.00 deg	0.00 deg	220.35 ft	0.00 ft
Exit Curve	195.10 ft	221.32 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	221.32 ft	256.10 ft	12.00 deg	12.00 deg	0.00 deg	167.27 ft	0.00 ft
					Total Check =	**1042.15 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	1000.00	Exit Elevation	250.00	
		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	163.613 ft	Plan Length	249.494 ft	Plan Length	220.35439 ft	Plan Length	173.648 ft	Plan Length	225.194 ft	1,032.304 ft
Rod Length	167.269 ft	Arc Rod Length	251.327 ft	Rod Length	220.35439 ft	Arc Rod Length	174.533 ft	Rod Length	228.668 ft	1,042.151 ft
Vertical Depth	-34.777 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	39.708 ft	-6.100 ft
		Lowest Elevation	195.100 ft			Lowest Elevation	195.100 ft	CK Total Cum Depth	-6.100 ft	
Start Elevation	256.100 ft	Start Elevation	221.323 ft	Start Elevation	195.100 ft	Start Elevation	195.100 ft	Start Elevation	210.292 ft	
End Elevation	221.323 ft	End Elevation	195.100 ft	End Elevation	195.100 ft	End Elevation	210.292 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***	**1032.303948**	

SUMMARY VERTICLE CURVE CALCULATIONS										**Stationing Check**
Start Station	0+00.00	Start Station	1+63.61	Start Station	4+13.11	Start Station	6+33.46	Start Station	8+07.11	**OK STATIONING**
PVC Station	1+63.61	PTV Station	4+13.11	PCV Station	6+33.46	PTV Station	8+07.11	Exit Station	10+32.304	**Plan Length Check**
Cum Plan Length	163.61	Cum Plan Length	413.11	Cum Plan Length	633.46 ft	Cum Plan Length	807.11	Cum Plan Length	1032.30	**OK CALCULATION**
Cum Rod Length	167.27	Cum Rod Length	418.60	Cum Rod Length	638.95 ft	Cum Rod Length	813.48	Cum Rod Length	1042.15	**Elevation Change Check**
Cum Depth	-34.78	Cum Depth	-61.00	Cum Depth	-61.00 ft	Cum Depth	-45.8078	Cum Depth	-6.10	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-6.10 ft**
Minimum Design Elevation =	**195.10 ft**
Invert Depth below exit =	**54.90 ft**
Invert Depth below entry =	**61.00 ft**
Path Length =	**1,042.15 ft**
Plan Length =	**1,032.30 ft**
Minimum Plan Length (No Tangent) =	**811.95 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

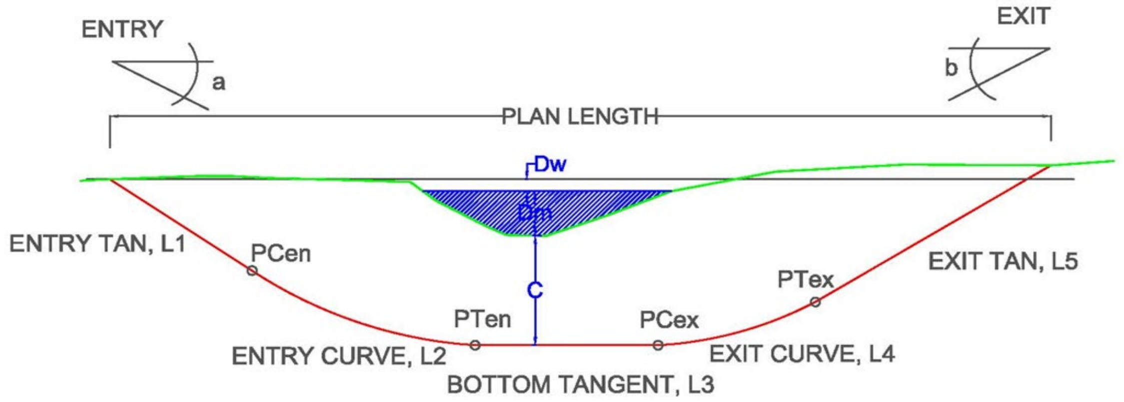
NOTES:

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

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Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 84B Circuit #1
Game Farm Road

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#84B CIR #1_APC_20221025.xlsb]T3 Plastic Pull

Pull Geometry

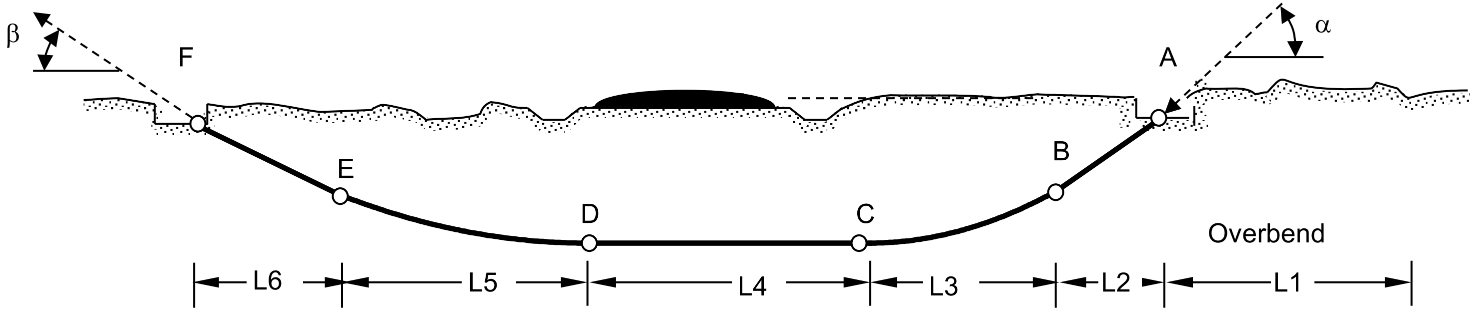
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	228.7 ft	α =	-10.0 °	-0.1745	
L3 =	174.5 ft				1,000.0 ft
L4 =	220.4 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	167.3 ft	β =	12.0 °	0.2094	
LT =	1142.2 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 256.10 ft

Pipe Entry El = 250.00 ft



INPUT: Assumed Friction Factors

μ_G = 0.10 dry + rollers

μ_b = 0.25 drill fluid in hole

μ_c = 0.30 in hole no fluid

INPUT: Assumed Hydrokinetic Drag

τ_f = 0.005 psi Drill Fluid Shear Stress

INPUT: Pipe Properties

Material HDPE IPS

Safe Pull Max. Stress, σ_{PM} 1,150 psi PPI Table 1 12hr @ 73Deg F

Pile/Bundle Diam. 14.25 BUNDLE PIPE/BUNDLE

Material Density, γ 59.28 pcf

Outside Diameter, D_{OD} 14.25 Pipe or Bundle

Pipe Dry Weight, W_P = 17.36 lb/ft Pipe or Bundle

Min. Wall Thickness, t_m 1.194 in For design installation pull stress

DR = D_O/t_{min} = 9 D_{OD} Stress 10.75 inches

Avg. Inside Diameter, D_{IA} BUNDLE Bundle Multiplier F_D 0.9042

12 Hr Pullback Modulus, E_T = 65,000 psi @T = 73 deg F

Poisson Ratio, μ = 0.45

Ovality Factor, f_o = 0.84 2%

Buckling Safety, N = 2.5

Hydrostatic Design Stress, HDS = 1,008 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 = 250.00 ft

Ballast Water El., H_W = 250.00 ft

Lowest Invert El., El_m = 195.10 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 = 0.85 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	 Ballast
A	2,018 lb	128 psi	OK	2,018 lb	128 psi	OK	OK	OK
B	4,054 lb	102 psi	OK	4,476 lb	113 psi	OK	OK	OK
C	5,506 lb	177 psi	OK	5,196 lb	170 psi	OK	OK	OK
D	5,744 lb	145 psi	OK	5,434 lb	137 psi	OK	OK	OK
E	10,715 lb	302 psi	OK	8,009 lb	234 psi	OK	OK	OK
F	13,764 lb	347 psi	OK	9,471 lb	239 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, P_{PA} > ΔP invert **$P_{PA} = P_AF_R$ =** 98.15 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 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 = 0.917498868 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.150946532 r = $\sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 347 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 5.95 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 29.74 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 84B Circuit #1
Game Farm Road

Revision 1

TABLE 4 **Pg 1 of 3**

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HDPE PROPERTIES

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

HDD 84B Circuit #1

Game Farm Road

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	PE4710		INPUT RESIN MATERIAL: PE3408, PE3608, PE4710
ASTM D3350 Cell Classification	445574C		Design resin with minimum PENT test of 10,000 hours
Standard Dimension	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 =	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

TABLE 4
HDPE PROPERTIES

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

HDD 84B Circuit #1

Game Farm Road

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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, ^{o}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, ^{o}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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	61.00 ft	Ballast depth to invert, H_B	54.90 ft	Drill Fluid depth to invert, H_{DF}	54.90 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	23.85 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	29.82 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	30.58 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	23.85 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 = $(P_A+P_a)-P_{DF1}$	77.16 psi	16.27 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	76.39 psi	15.50 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.01 psi	40.12 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.25 psi	39.35 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	83.12 psi	22.23 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.

HDPE PROPERTIES

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

HDD 84B Circuit #1

Game Farm Road

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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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
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**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.
FE PULL STRENTH, SPS = 5,321 lb
ltimate Pull Strength, UPS = 13,303 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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.91750
$r = \sigma_i/2*(SSAS)$ = 0.15095
P_{CRR} = 245.4 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 122.7 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 116.72 psi Pull Back Condition - C **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 115.96 psi Pull Back Condition - C **OK as >0**

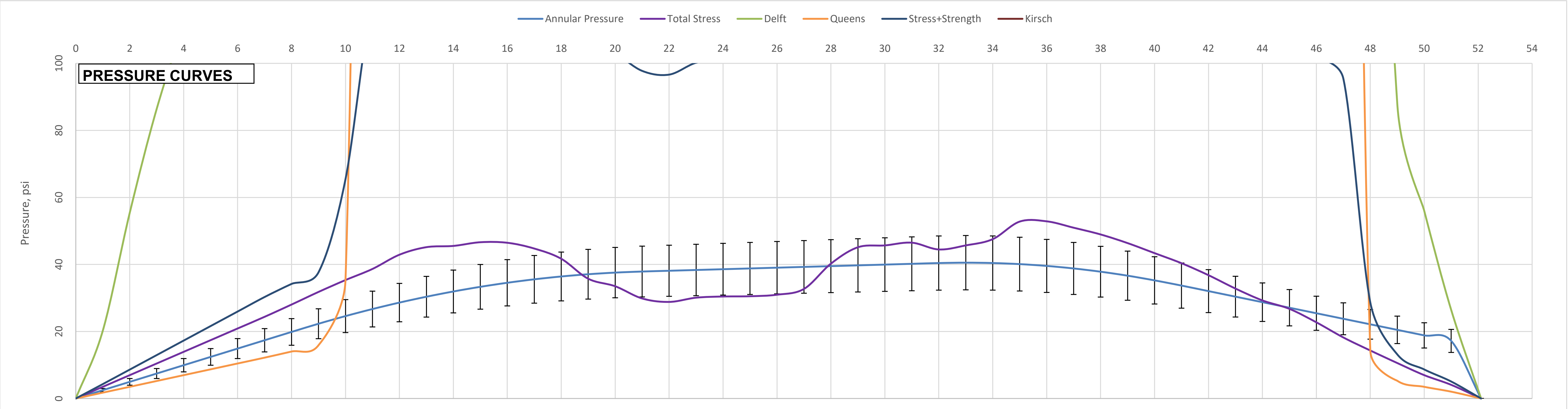
Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Example from Table T5, σ_i = 347 psi

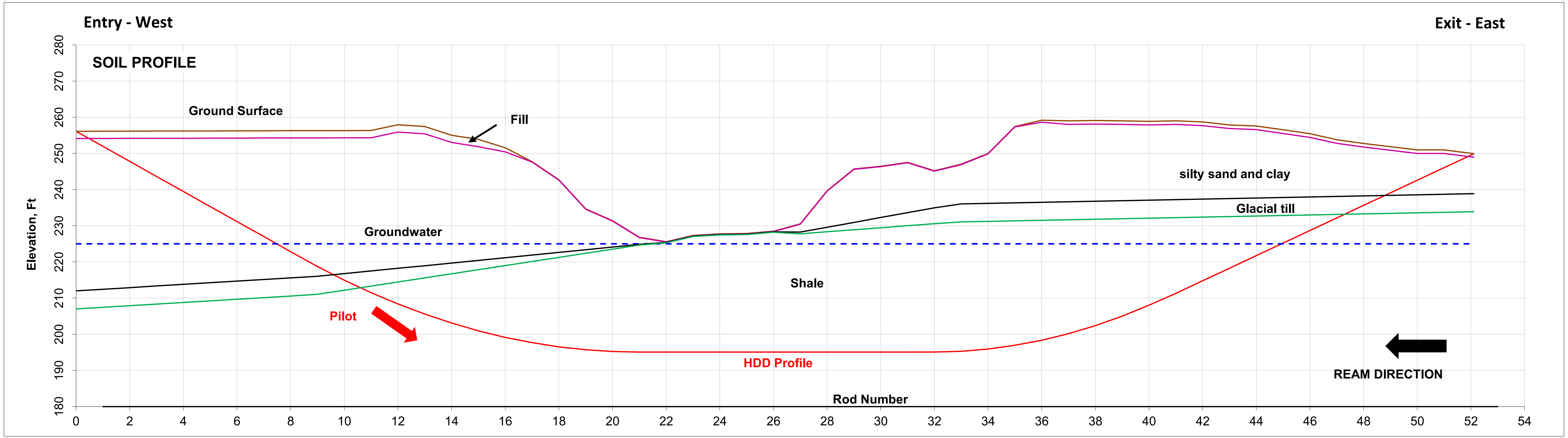
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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





ISSUED: Issued for Construction (IFC)

Notes:

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

Basis of annular pressure calculations

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

Print Date ; 3/13/2023 14:27

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 84B Circuit #1
Game Farm Road

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#84B CIR #1_APC_20221025.xlsb]T3 Plastic Pull

HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 84B Circuit #2**
Game Farm Road

ISSUE: **Design Submittal**

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: 13-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	10+32.30	FT

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

	East	North	Elevation
Entry	654019.8493	1375760.5568	256.60 ft
Horizontal Curve PI	654282.6638	1375316.2084	
Exit	654545.3757	1374872.0335	249.80 ft

Depth to Mudline	6.80 ft	Clearance Depth =	55.10 ft
Measured Plan Length at ties =	1032.3041 ft		
Coordinate Length =	1032.3041 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	225.00 ft
Mudline Elev.*	249.80 ft
Lowest centerline Elev.	194.70 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	654019.8493	1375760.5568	5+16.25	654282.6638	1375316.2084	E 149.39736 N	516.25		
Curve	5+16.25	654282.6638	1375316.2084	5+16.25	654282.6638	1375316.2084	E 149.39736 N	0.00	0.00	0.000 deg.
Tangent	5+16.25	654282.6638	1375316.2084	10+32.30	654545.3757	1374872.0335	E 149.39736 N	516.05		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	516.25	Input Radius, ft.	0.00	Plan Length, ft.	516.05	
Entry Azimuth, deg.^{5}	N 149.39736 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 149.39736 E	
Entry Azimuth, rad.^{5}	2.60748	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	2.60748	
		Calculate PTH		**Calculate Exit**		
Calculate PCH `		Chord Length, ft.	0.00	Easting	654545.3757	**Check**
PCH Easting	654282.6638	Arc Length, ft.	0.00	Northing	1374872.0335	**Delta**
PCH Northing	1375316.2084	Chord Azimuth, deg	149.3974			**0.0000**
		PI Easting =	654282.6638			**0.0000**
		PI Northing =	1375316.2084			**OK CALC**
		PTH Easting =	654282.6638			
		PTH Northing =	1375316.2084			**Exit Station**
						10+32.30
Cum Plan Length	516.25	Cum Plan Length	516.25	Cum Plan Length	1032.30405	**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	249.80 ft	209.89 ft	-10.00 deg	-10.00 deg	0.00 deg	229.82 ft	0.00 ft
Entry Curve	209.89 ft	194.70 ft	-10.00 deg	0.00 deg	10.00 deg	174.53 ft	1000.00 ft
Bottom Tangent	194.70 ft	194.70 ft	0.00 deg	0.00 deg	0.00 deg	214.99 ft	0.00 ft
Exit Curve	194.70 ft	220.92 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	220.92 ft	256.60 ft	12.00 deg	12.00 deg	0.00 deg	171.60 ft	0.00 ft
					Total Check =	**1042.26 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	1000.00	Exit Elevation	249.80	
		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	167.848 ft	Plan Length	249.494 ft	Plan Length	214.98607 ft	Plan Length	173.648 ft	Plan Length	226.328 ft	1,032.304 ft
Rod Length	171.597 ft	Arc Rod Length	251.327 ft	Rod Length	214.98607 ft	Arc Rod Length	174.533 ft	Rod Length	229.820 ft	1,042.263 ft
Vertical Depth	-35.677 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	39.908 ft	-6.800 ft
		Lowest Elevation	194.700 ft			Lowest Elevation	194.700 ft	CK Total Cum Depth	-6.800 ft	
Start Elevation	256.600 ft	Start Elevation	220.923 ft	Start Elevation	194.700 ft	Start Elevation	194.700 ft	Start Elevation	209.892 ft	
End Elevation	220.923 ft	End Elevation	194.700 ft	End Elevation	194.700 ft	End Elevation	209.892 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*	1032.30405	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+67.85	Start Station	4+17.34	Start Station	6+32.33	Start Station	8+05.98	**Stationing Check**
PVC Station	1+67.85	PTV Station	4+17.34	PCV Station	6+32.33	PTV Station	8+05.98	Exit Station	10+32.304	**OK STATIONING**
Cum Plan Length	167.85	Cum Plan Length	417.34	Cum Plan Length	632.33	Cum Plan Length	805.98	Cum Plan Length	1032.30	**Plan Length Check**
Cum Rod Length	171.60	Cum Rod Length	422.92	Cum Rod Length	637.91	Cum Rod Length	812.44	Cum Rod Length	1042.26	**OK CALCULATION**
Cum Depth	-35.68	Cum Depth	-61.90	Cum Depth	-61.90	Cum Depth	-46.7078	Cum Depth	-6.80	**Elevation Change Check** **OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**-6.80 ft**
Minimum Design Elevation =	**194.70 ft**
Invert Depth below exit =	**55.10 ft**
Invert Depth below entry =	**61.90 ft**
Path Length =	**1,042.26 ft**
Plan Length =	**1,032.30 ft**
Minimum Plan Length (No Tangent) =	**817.32 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

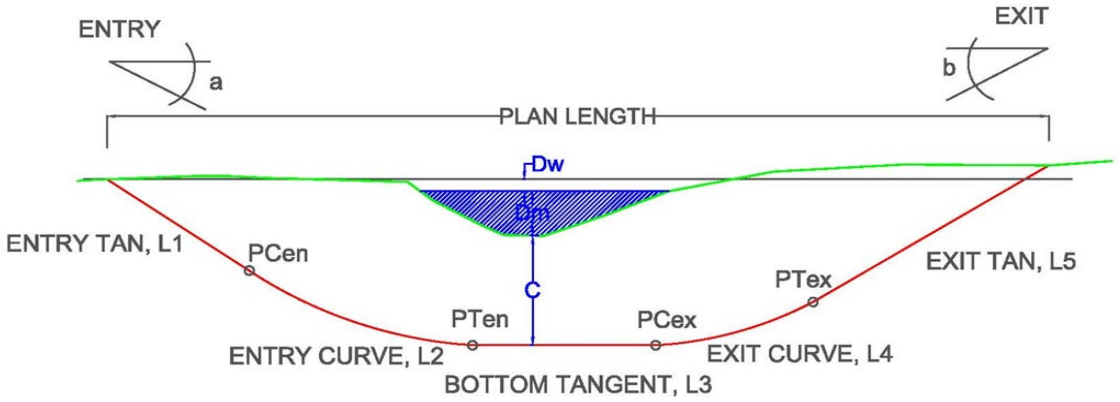
NOTES:

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

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 84B Circuit #2
Game Farm Road

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#84B CIR #2_APC_20221025.xlsb]T3 Plastic Pull

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	229.8 ft	α =	-10.0 °	-0.1745	
L3 =	174.5 ft				1,000.0 ft
L4 =	215.0 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	171.6 ft	β =	12.0 °	0.2094	
LT =	1142.3 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} 14.25 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} 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 = 256.60 ft

Ballast Water El., H_W = 256.60 ft

Lowest Invert El., El_m = 194.70 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 = 0.85 lb/ft Comparison Only @ 8psi

Calculated Buoyant Forces

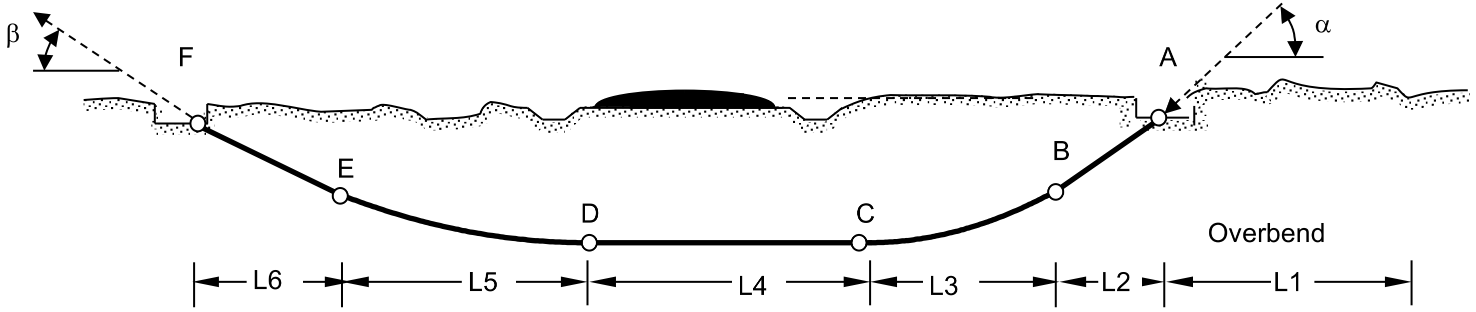
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 256.60 ft

Pipe Entry El = 249.80 ft



Calculated Pull Force							ASSESS	
POINT	Pull Force, F_D	Max Tensile	**ASSESS**	Pull Force, F_B	Max Tensile	**ASSESS**	**F_x < SPS**	
	No Ballast	Stress, σ_T	**$\sigma_T < \sigma_{PM}$**	Ballasted Pipe	Stress, σ_T	**$\sigma_T < \sigma_{PM}$**	Air	Ballast
A	1,825 lb	128 psi	OK	1,825 lb	128 psi	OK	OK	OK
B	3,618 lb	101 psi	OK	4,001 lb	112 psi	OK	OK	OK
C	4,975 lb	177 psi	OK	4,697 lb	170 psi	OK	OK	OK
D	5,157 lb	144 psi	OK	4,879 lb	136 psi	OK	OK	OK
E	9,718 lb	303 psi	OK	7,274 lb	235 psi	OK	OK	OK
F	13,078 lb	365 psi	OK	8,850 lb	247 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, P_{PA} > ΔP invert **$P_{PA} = P_AF_R$ =** 97.64 psi

Ballasted	OK
No Ballast	OK

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

PPI Ch 12 Eq 16

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.912727364 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.158632495 r = $\sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 365 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 6.71 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 33.53 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 84B Circuit #2
Game Farm Road

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

Revision 1

TABLE 4 **Pg 1 of 3**

BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

HDPE PROPERTIES

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

HDD 84B Circuit #2

Game Farm Road

INPUTS

Pipe Material Properties

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

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

Design Working Pressure, P_{WORK}	250 psi		
Quantity of Pipes in Hole, Q =	1		
Pipe Material	4710 HDPE	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 =	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 =	15.70	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	BG-W_{D2}

TABLE 4 **Pg 2 of 3**

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDPE PROPERTIES

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

HDD 84B Circuit #2

Game Farm Road

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	61.90 ft	Ballast depth to invert, H_B	55.10 ft	Drill Fluid depth to invert, H_{DF}	55.10 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	24.07 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	30.09 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	30.86 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	24.07 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 = $(P_A+P_a)-P_{DF1}$	76.89 psi	2.83 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	76.11 psi	2.06 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	100.96 psi	26.90 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.19 psi	26.13 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 = $(P_A+P_a)-P_W$	82.90 psi	8.84 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 **Pg 3 of 3**

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 84B Circuit #2

Game Farm Road

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
FE PULL STRENTH, SPS = **50,200 lb**
Temperature factor, f_{temp} = 1
ltimate Pull Strength, UPS = ########
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)

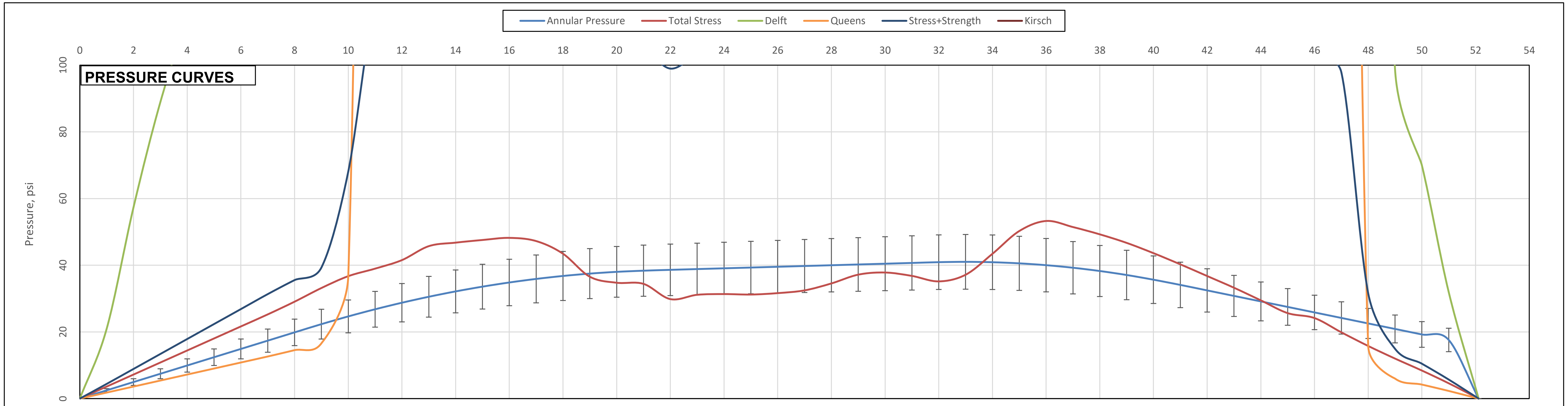
Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 1,400 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.91273
$r = \sigma_i/2*(SSAS)$ = 0.15863
Example from Table T5, σ_i = 365 psi
P_{CRR} = 244.1 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 122.0 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 116.03 psi Pull Back Condition - C **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 115.26 psi Pull Back Condition - C **OK as >0**

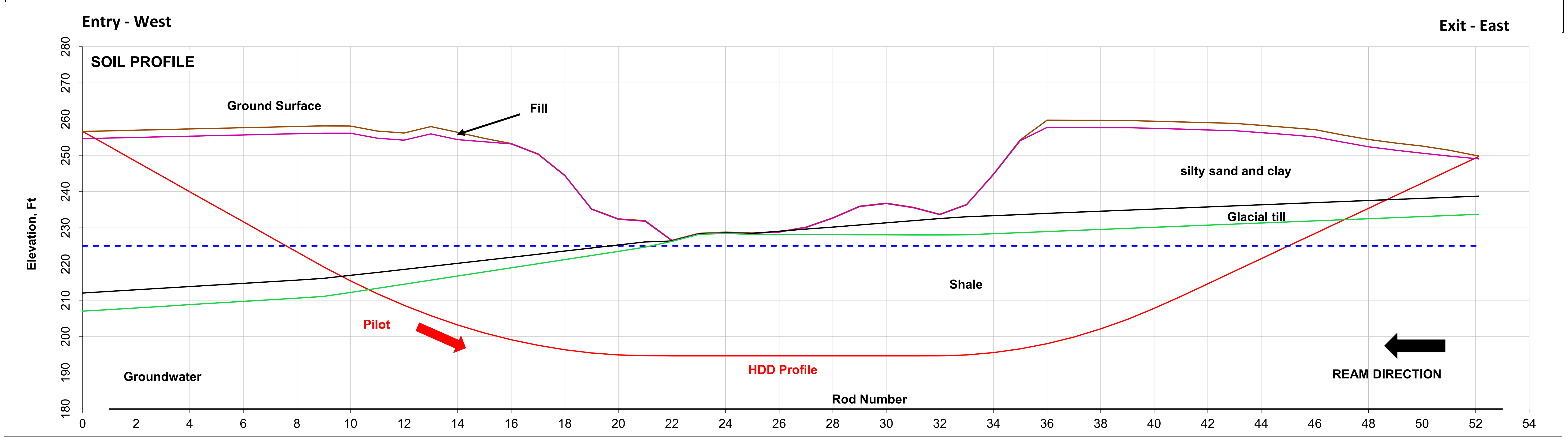
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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
400 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 3/13/2023 15:09

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 84B Circuit #2
Game Farm Road

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#84B CIR #2_APC_20221025.xlsb]T3 Plastic Pull

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL CONCEPTUAL DRILL DESIGN

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

CROSSING: **HDD 85 Conduit #1**
Delaware Turnpike

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: 14-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/14/2023	1	Issued for Construction (IFC)	ABL

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#85 CIR #2_APC_20230314.xlsb]F1A APCL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	15+54.66	FT

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

	East	North	Elevation
Entry	655621.1198	1373171.7068	239.70 ft
Horizontal Curve PI	655874.5022	1372877.0077	
Exit	656524.0478	1371908.4651	242.70 ft

Depth to Mudline 0.70 ft Clearance Depth = 60.20 ft

Measured Plan Length at ties = 1554.6649 ft

Coordinate Length = 1554.6649 ft

OK-HORIZONTAL CURVE

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

Water Surface Elev.*	239.00 ft
Mudline Elev.*	239.00 ft
Lowest centerline Elev.	178.80 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	655621.1198	1373171.7068	3+16.92	655827.7383	1372931.3970	E 139.31104 N	316.92		
Curve	3+16.92	655827.7383	1372931.3970	4+60.21	655914.4541	1372817.4350	E 146.15252 N	143.29	1200.00	6.841 deg.
Tangent	4+60.21	655914.4541	1372817.4350	15+54.66	656524.0478	1371908.4651	E 146.15252 N	1094.45		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	316.92	Input Radius, ft.	1200.00	Plan Length, ft.	1094.45	
Entry Azimuth, deg.[5]	N 139.31104 E	Curve, deg	6.841 deg.	Exit Azimuth, deg.[5]	N 146.15252 E	
Entry Azimuth, rad.[5]	2.43144	Curve, rad	0.11941	Exit Azimuth, rad.[5]	2.55084	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	143.20	Easting	656524.0478	**Check**
PCH Easting	655827.7383	Arc Length, ft.	143.29	Northing	1371908.4651	**Delta**
PCH Northing	1372931.3970	Chord Azimuth, deg	142.7318			**0.0000**
		PI Easting =	655874.5022			**0.0000**
		PI Northing =	1372877.0077			**OK CALC**
		PTH Easting =	655914.4541			
		PTH Northing =	1372817.4350			**Exit Station**
						15+54.66
Cum Plan Length	316.92	Cum Plan Length	460.21	Cum Plan Length	1554.664909	**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	242.70 ft	193.99 ft	-10.00 deg	-10.00 deg	0.00 deg	280.50 ft	0.00 ft
Entry Curve	193.99 ft	178.80 ft	-10.00 deg	0.00 deg	10.00 deg	174.53 ft	1000.00 ft
Bottom Tangent	178.80 ft	178.80 ft	0.00 deg	0.00 deg	0.00 deg	692.14 ft	0.00 ft
Exit Curve	178.80 ft	205.02 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	205.02 ft	239.70 ft	12.00 deg	12.00 deg	0.00 deg	166.79 ft	0.00 ft
					Total Check =	**1565.29 ft**	**OK**

Compound Curve Assessment

Start	**Vert. Plan**	**Horiz. Plan**	
Entry	412.64	316.92	Yes, Horiz < Exit V(Tan+Curve
Exit	449.88	1094.45	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	1000.00	Exit Elevation	242.70	
		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	163.143 ft	Plan Length	249.494 ft	Plan Length	692.14428 ft	Plan Length	173.648 ft	Plan Length	276.235 ft	1,554.665 ft
Rod Length	166.788 ft	Arc Rod Length	251.327 ft	Rod Length	692.14428 ft	Arc Rod Length	174.533 ft	Rod Length	280.497 ft	1,565.289 ft
Vertical Depth	-34.677 ft	Curve Δ Vert Depth	-26.223 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	15.192 ft	Vertical Depth	48.708 ft	3.000 ft
		Lowest Elevation	178.800 ft			Lowest Elevation	178.800 ft	CK Total Cum Depth	3.000 ft	
Start Elevation	239.700 ft	Start Elevation	205.023 ft	Start Elevation	178.800 ft	Start Elevation	178.800 ft	Start Elevation	193.992 ft	
End Elevation	205.023 ft	End Elevation	178.800 ft	End Elevation	178.800 ft	End Elevation	193.992 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*	*1554.664909*	
SUMMARY VERTICLE CURVE CALCULATIONS										
Start Station	0+00.00	Start Station	1+63.14	Start Station	4+12.64	Start Station	11+04.78	Start Station	12+78.43	**Stationing Check**
PVC Station	1+63.14	PTV Station	4+12.64	PCV Station	11+04.78	PTV Station	12+78.43	Exit Station	15+54.665	**OK STATIONING**
Cum Plan Length	163.14	Cum Plan Length	412.64	Cum Plan Length	1104.78 ft	Cum Plan Length	1278.43	Cum Plan Length	1554.66	**Plan Length Check**
Cum Rod Length	166.79	Cum Rod Length	418.12	Cum Rod Length	1110.26 ft	Cum Rod Length	1284.79	Cum Rod Length	1565.29	**OK CALCULATION**
Cum Depth	-34.68	Cum Depth	-60.90	Cum Depth	-60.90 ft	Cum Depth	-45.7078	Cum Depth	3.00	**Elevation Change Check** **OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.00 ft**
Minimum Design Elevation =	**178.80 ft**
Invert Depth below exit =	**63.90 ft**
Invert Depth below entry =	**60.90 ft**
Path Length =	**1,565.29 ft**
Plan Length =	**1,554.66 ft**
Minimum Plan Length (No Tangent) =	**862.52 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**849 ft**
Compound Curve at Exit =	**NO**

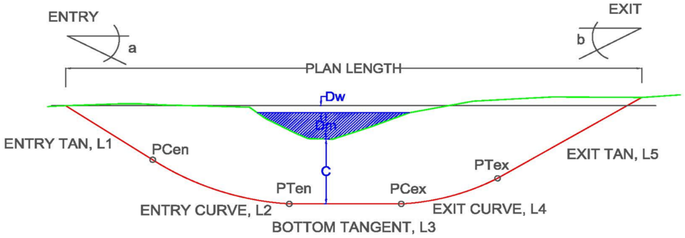
NOTES:

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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"Creating Space Underground"

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 85 Conduit #1
Delaware Turnpike

Revision 1 TBD

Pull Geometry

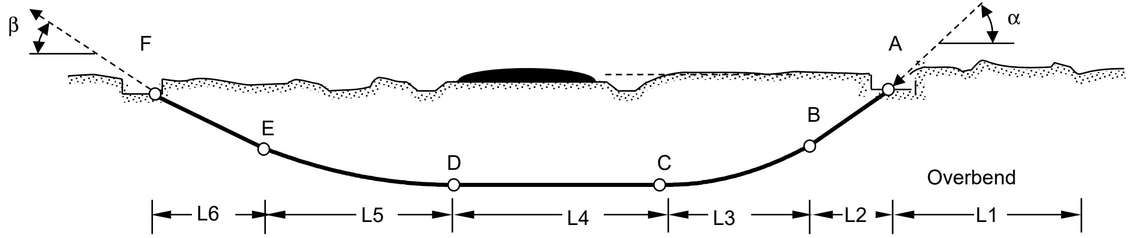
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	280.5 ft	α =	-10.0 ˚	-0.1745	
L3 =	174.5 ft				1,000.0 ft
L4 =	692.1 ft	χ =	0.0 ˚	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	166.8 ft	β =	12.0 ˚	0.2094	
LT =	1665.3 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 239.70 ft

Pipe Entry El = 242.70 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 =	239.70 ft		
Ballast Water El., H_W =	239.70 ft		
Lowest Invert El., El_m =	178.80 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	 Ballast
A	2,942 lb	203 psi	OK	2,942 lb	203 psi	OK	OK	OK
B	5,376 lb	136 psi	OK	5,862 lb	148 psi	OK	OK	OK
C	6,887 lb	212 psi	OK	6,644 lb	206 psi	OK	OK	OK
D	9,612 lb	242 psi	OK	9,369 lb	236 psi	OK	OK	OK
E	14,791 lb	405 psi	OK	12,156 lb	339 psi	OK	OK	OK
F	18,357 lb	463 psi	OK	13,802 lb	348 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 94.72 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.885474979	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.201316618	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	463 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	6.60	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	32.99	psi (-) indicates pipe is pressurized

Calculated Drill Hole Diameter Assumed for Calculations

D_H = 22

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

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	44.77 in	
Wall Section Area, A_W	41.68747289	
Volume Outside, V_{DO}	0.697 cf/LF	
Volume Inside, V_{DI}	0.408 cf/LF	
q_d =	2.69 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.56 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

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

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

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BRIERLEY ASSOCIATES
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 85 Conduit #1
Delaware Turnpike

Revision 1 TBD

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

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

BRIERLEY ASSOCIATES
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HDD 85 Conduit #1
Delaware Turnpike

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

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

https://brierleyassoc-my.sharepoint.com/personal/blindelof_brierleyassociates_com/Documents/Desktop/Projects/CHPE/Engineering/Spring 2023 Submittal/[HDD#85 CIR #2_APC_20230314.xlsb]F1A APCL

TABLE 4 **Pg 2 of 3**

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDPE PROPERTIES

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

HDD 85 Conduit #1
Delaware Turnpike

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	63.90 ft	Ballast depth to invert, H_B	60.90 ft	Drill Fluid depth to invert, H_{DF}	60.90 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	26.45 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	33.07 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	33.91 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	26.45 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 = $(P_A+P_a)-P_{DF1}$	73.91 psi	13.02 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	73.06 psi	12.17 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	100.36 psi	39.47 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	99.51 psi	38.62 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	80.52 psi	19.63 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 **Pg 3 of 3**

BRIERLEY ASSOCIATES
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HDPE PROPERTIES

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

HDD 85 Conduit #1
Delaware Turnpike

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

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

Designed Pull Duration Time =	12 hr		Quantity of pipes, Q =	1
Yield Strength Factor, f_Y =	0.4	Recommended (FS = 2.5)	Pull Temperature, F =	73 deg.
Pull Time factor, f_T =	1	Plexco Engineering Manual Table 3.7		
Design Factor, DF = f_T*f_Y	0.4	**SAFE PULL STRENTH, SPS =**	**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 =	0.88547			
r = σ_i/2*(SSAS) =	0.20132		Example from Table T5, σ_i =	463 psi
P_{CRR} =	236.8 psi			
FS =	2.0			
P_{ACRR} = P_{CRR}/FS =	118.4 psi	Allowable Reduced Short Term Buckling pressure during pull		
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1}	85.34 psi	Pull Back Condition - Option 3	**OK as >0**	
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2}	84.49 psi	Pull Back Condition - Option 4	**OK as >0**	

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

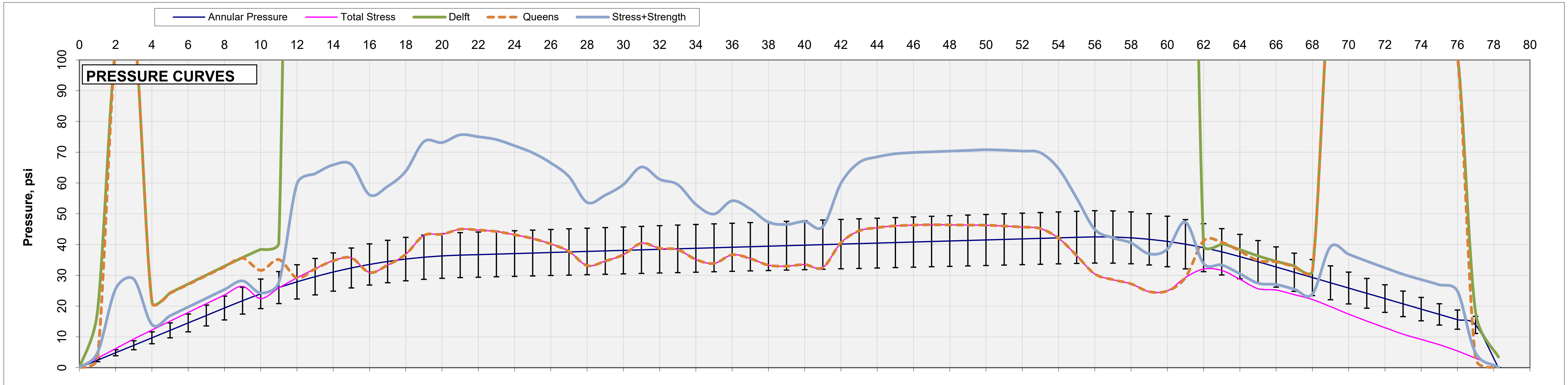
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

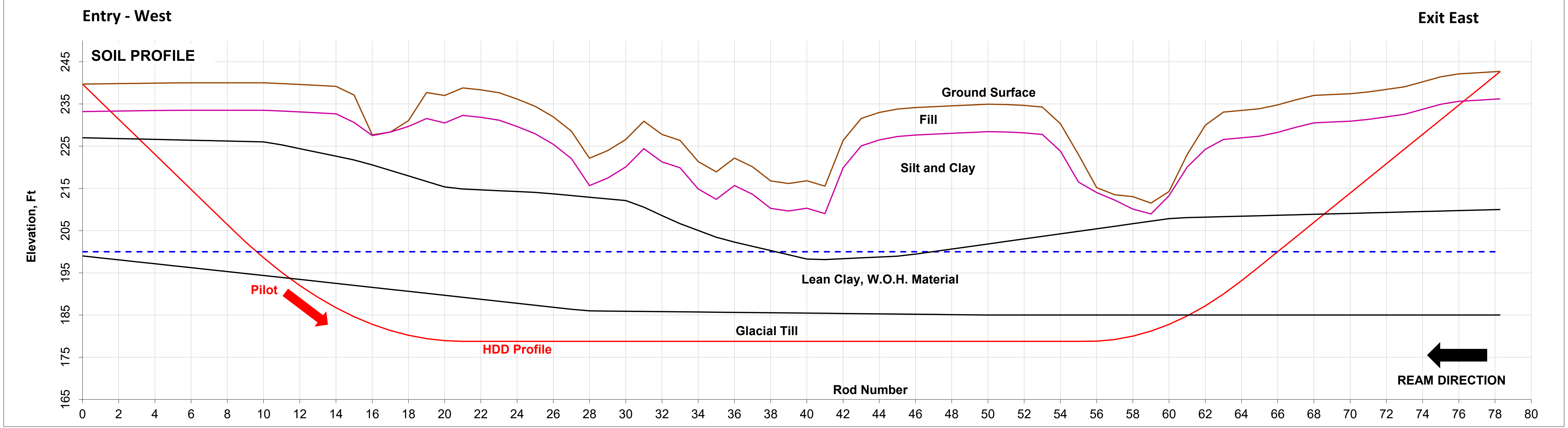
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB

CHAPTER 6 - TABLE 1-2

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

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





ISSUED: Issued for Construction

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs

K192.3
B192.4
KB192.4-14
RS9

Print Date ; 3/14/2023 15:49

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 85 Conduit #1
Delaware Turnpike

Revision 1

FIGURE 1

BRIERLEY ASSOCIATES
Creating Space Underground

HORIZONTAL DIRECTIONAL CONCEPTUAL DRILL DESIGN

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

CROSSING: **HDD 85 Conduit #2**
Delaware Turnpike

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: 14-Mar-2023

DATE	REV	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/14/2023	1	Issued for Construction (IFC)	ABL

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	15+54.60	FT

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

	East	North	Elevation
Entry	655632.3290	1373180.8678	239.70 ft
Horizontal Curve PI	655942.2900	1372822.3546	
Exit	656535.1519	1371918.5498	242.70 ft
Depth to Mudline	0.70 ft	Clearance Depth =	60.20 ft
Measured Plan Length at ties =	1554.5972 ft		
Coordinate Length =	1554.5972 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	239.00 ft
Mudline Elev.*	239.00 ft
Lowest centerline Elev.	178.80 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	655632.3290	1373180.8678	3+94.41	655890.2823	1372882.5088	E 139.15418 N	394.41		
Curve	3+94.41	655890.2823	1372882.5088	5+53.21	655985.9055	1372755.8638	E 146.73663 N	158.81	1200.00	7.582 deg.
Tangent	5+53.21	655985.9055	1372755.8638	15+54.60	656535.1519	1371918.5498	E 146.73663 N	1001.38		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment

Plan Length, ft.	394.41
Entry Azimuth, deg.[5]	N 139.15418 E
Entry Azimuth, rad.[5]	2.42870
Calculate PCH	`
PCH Easting	655890.2823
PCH Northing	1372882.5088
Cum Plan Length	394.41

Horizontal Curve Segment

Input Radius, ft.	1200.00
Curve, deg	7.582 deg.
Curve, rad	0.13234
Calculate PTH	
Chord Length, ft.	158.69
Arc Length, ft.	158.81
Chord Azimuth, deg	142.9454
PI Easting =	655942.2900
PI Northing =	1372822.3546
PTH Easting =	655985.9055
PTH Northing =	1372755.8638
Cum Plan Length	553.21

Exit Tangent Segment

Plan Length, ft.	1001.38
Exit Azimuth, deg.[5]	N 146.73663 E
Exit Azimuth, rad.[5]	2.56104
Calculate Exit	
Easting	656535.1519
Northing	1371918.5498
Cum Plan Length	1554.597233

Check Delta
0.0000
0.0000
OK CALC

Exit Station
15+54.60
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	242.70 ft	193.99 ft	-10.00 deg	-10.00 deg	0.00 deg	280.50 ft	0.00 ft
Entry Curve	193.99 ft	178.80 ft	-10.00 deg	0.00 deg	10.00 deg	174.53 ft	1000.00 ft
Bottom Tangent	178.80 ft	178.80 ft	0.00 deg	0.00 deg	0.00 deg	692.08 ft	0.00 ft
Exit Curve	178.80 ft	205.02 ft	0.00 deg	12.00 deg	12.00 deg	251.33 ft	1200.00 ft
Exit Tangent	205.02 ft	239.70 ft	12.00 deg	12.00 deg	0.00 deg	166.79 ft	0.00 ft
					Total Check =	1565.22 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	412.64	394.41	Yes, Horiz < Exit V(Tan+Curve
Exit	449.88	1001.38	No, Horiz > Entry V(Tan+Curve)

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1

Entry Angle	-12.000 deg.
Calculate Vertical PCV	
Plan Length	163.143 ft
Rod Length	166.788 ft
Vertical Depth	-34.677 ft
Start Elevation	239.700 ft
End Elevation	205.023 ft
End Vert Angle	-12.000 deg

Entry Vert. Curve Segment 2

Vertical Radius	1200.00
Vert. Curve, deg.	12.000 deg.
Calculate Vertical PTV	
Plan Length	249.494 ft
Arc Rod Length	251.327 ft
Curve Δ Vert Depth	-26.223 ft
Lowest Elevation	178.800 ft
Start Elevation	205.023 ft
End Elevation	178.800 ft
End Vert Angle	0.000 deg

Middle Tangent Segment 3

End Vert Angle	0.000 deg.
Inclined Bottom Tan	NO
Calculate Vertical PCV	
Plan Length	692.07661 ft
Rod Length	692.07661 ft
Vertical Depth	0.00000 ft
Start Elevation	178.800 ft
End Elevation	178.800 ft
End Vert Angle	0.000 deg

Exit Vert. Curve Segment 4

Radius	1000.00
Angle Change	10.000 deg.
Calculate Vertical PTV	
Plan Length	173.648 ft
Arc Rod Length	174.533 ft
Curve Δ Vert Depth	15.192 ft
Lowest Elevation	178.800 ft
Start Elevation	178.800 ft
End Elevation	193.992 ft
End Vert Angle	10.000 deg

Exit Tangent Segment 5

Exit Elevation	242.70
Design Exit Angle	10.00 deg
Calculate Exit	
Plan Length	276.235 ft
Rod Length	280.497 ft
Vertical Depth	48.708 ft
CK Total Cum Depth	3.000 ft
Start Elevation	193.992 ft
Ck Exit Elevation	
Prop. Plan Length	***1554.597233***

SUMS
1,554.597 ft
1,565.221 ft
3.000 ft

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+63.14	Start Station	4+12.64	Start Station	11+04.71	Start Station	12+78.36
PVC Station	1+63.14	PTV Station	4+12.64	PCV Station	11+04.71	PTV Station	12+78.36	Exit Station	15+54.597
Cum Plan Length	163.14	Cum Plan Length	412.64	Cum Plan Length	1104.71 ft	Cum Plan Length	1278.36	Cum Plan Length	1554.60
Cum Rod Length	166.79	Cum Rod Length	418.12	Cum Rod Length	1110.19 ft	Cum Rod Length	1284.72	Cum Rod Length	1565.22
Cum Depth	-34.68	Cum Depth	-60.90	Cum Depth	-60.90 ft	Cum Depth	-45.7078	Cum Depth	3.00

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.00 ft**
Minimum Design Elevation =	**178.80 ft**
Invert Depth below exit =	**63.90 ft**
Invert Depth below entry =	**60.90 ft**
Path Length =	**1,565.22 ft**
Plan Length =	**1,554.60 ft**
Minimum Plan Length (No Tangent) =	**862.52 ft**
Entry Angle =	**-12.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**849 ft**
Compound Curve at Exit =	**NO**

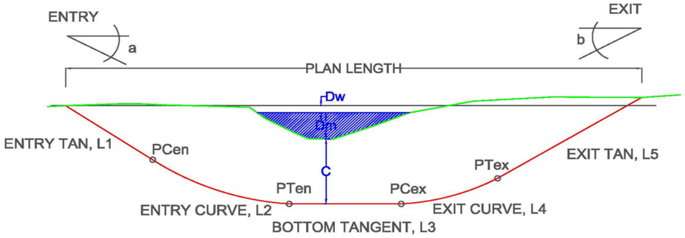
NOTES:

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:	Issued for Construction

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

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

TABLE 2
DRILL PATH DESIGN CALCULATIONS
HDD 85 Conduit #2
Delaware Turnpike

Revision 1 TBD

Pull Geometry

Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	300.0 ft
L2 =	280.5 ft	α =	-10.0 °	-0.1745	
L3 =	174.5 ft				1,000.0 ft
L4 =	692.1 ft	χ =	0.0 °	0.0000	
L5 =	251.3 ft				1,200.0 ft
L6 =	166.8 ft	β =	12.0 °	0.2094	
LT =	1665.2 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. 10.75	PIPE	PIPE/BUNDLE	
Material Density, γ	59.28 pcf		
Outside Diameter, D_{OD}	10.75	Pipe or Bundle	
Pipe Dry Weight, W_P =	15.70 lb/ft	Pipe or Bundle	
Min. Wall Thickness, t_m	1.194 in	For design installation pull stress	
DR = D_O/t_{min} =	9	D_{OD} Stress 10.75	inches
Avg. Inside Diameter, D_{IA}	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 =	1,000 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 =	239.70 ft		
Ballast Water El., H_W =	239.70 ft		
Lowest Invert El., El_m =	178.80 ft		

Calculated Pipe and Fluid Properties

Pressure Pipe:	YES	
OD Perimeter Length, P	33.77 in	
Wall Section Area, A_W	37.70738915	
Volume Outside, V_{DO}	0.630 cf/LF	
Volume Inside, V_{DI}	0.368 cf/LF	
q_d =	2.03 lb/ft	Drill Fluid (unit drag)
ASTM EQ 18: Hydrokinetic, ΔT =	0.42 lb/ft	Comparison Only @ 8psi

Calculated Buoyant Forces

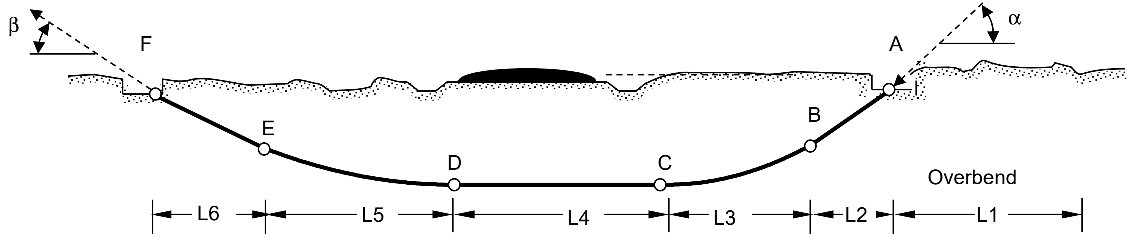
	Pipe	Air Filled	Ballasted
On Ground, w_a/w_{af} =		15.70 Lb/LF	38.69 Lb/LF
In Hole with Drill Fluid, w_b/w_{bf} =		-33.46 Lb/LF	-10.47 Lb/LF

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 239.70 ft

Pipe Entry El = 242.70 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	Ballast
A	2,660 lb	171 psi	OK	2,660 lb	171 psi	OK	OK	OK
B	4,968 lb	139 psi	OK	5,407 lb	151 psi	OK	OK	OK
C	6,266 lb	204 psi	OK	6,046 lb	198 psi	OK	OK	OK
D	8,730 lb	244 psi	OK	8,510 lb	237 psi	OK	OK	OK
E	13,308 lb	396 psi	OK	10,926 lb	329 psi	OK	OK	OK
F	16,464 lb	459 psi	OK	12,347 lb	344 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $\mathbf{P_{PA} > \Delta P}$ **invert** $\mathbf{P_{PA} = P_AF_R}$ = 94.84 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	41,235 lb	SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.886529444	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.199702042	r = σ_T/2SPS
Maximum applied pull Stress, σ_T =	459 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_B}$ **invert** =	6.60	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, $\mathbf{\Delta P_U}$ **invert** =	32.99	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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Bedford, NH 03110

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 85 Conduit #2
Delaware Turnpike

Revision 1 TBD

TABLE 4 Pg 1 of 3

HDPE PROPERTIES

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

HDD 85 Conduit #2
Delaware Turnpike

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 =	15.7	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-33.46 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

TABLE 4 **Pg 2 of 3**

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HDPE PROPERTIES

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

HDD 85 Conduit #2
Delaware Turnpike

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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 63.90 ft Ballast depth to invert, H_B 60.90 ft Drill Fluid depth to invert, H_{DF} 60.90 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A 0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$ 26.58 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$ 33.23 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$ 34.08 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$ 26.58 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 = $(P_A+P_a)-P_{DF1}$	73.74 psi	12.85 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	72.89 psi	12.00 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	100.33 psi	39.44 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	99.48 psi	38.58 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	80.39 psi	19.50 psi	Operational Dewatering NO SOIL LOADS

ASSESSMENT UNCONSTRAINED BUCKLING ALONG DRILL PATH BY DIFFERENTIAL PRESSURE

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

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

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

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HDPE PROPERTIES

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

HDD 85 Conduit #2
Delaware Turnpike

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
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, $DF = f_T*f_Y$ = 0.4
Temperature factor, f_{temp} = 1
Temp Corr Tensile Yield, $Ty*f_{temp}$ = 3,500 psi
Safe Allowable Stress, SAS = 1,400 psi $SAS = Ty*f_{temp}*DF$
Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

Quantity of pipes, Q = 1
Pull Temperature, F = 73 deg.

SAFE PULL STRENTH, SPS = 50,200 lb
Ultimate Pull Strength, UPS = 125,499 lb

Suggested SSAS = 1,150 psi

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
SAS = 1,400 psi
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.88653
$r = \sigma_i/2*(SSAS)$ = 0.19970
P_{CRR} = 237.1 psi
FS = 2.0
$P_{ACRR} = P_{CRR}/FS$ = 118.5 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$ 85.32 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 84.46 psi Pull Back Condition - Option 4 **OK as >0**

Pcr = 267.4 psi
Design Depth in DF, H_{MDF} = 0.0 ft

Example from Table T5, σ_i = 459 psi

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

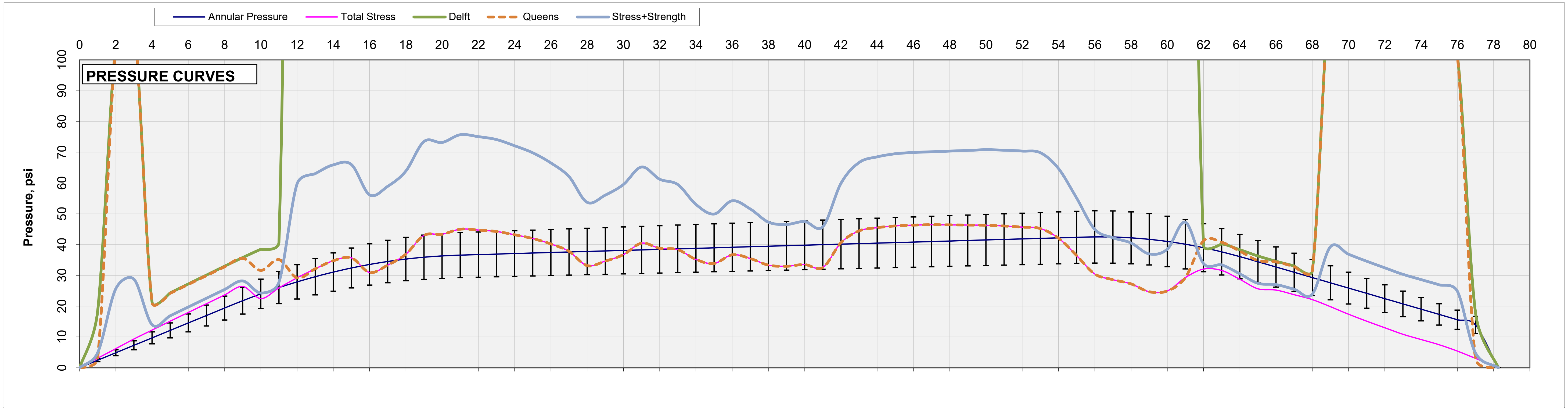
ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

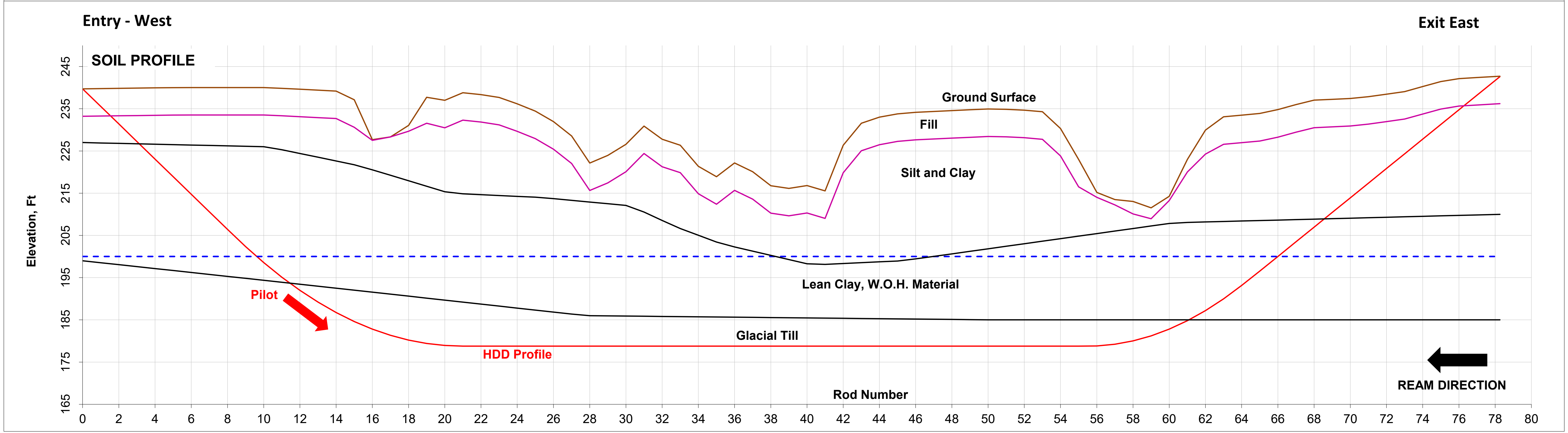
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Bore Logs

K192.3
B192.4
KB192.4-14
RS9

Print Date ; 3/14/2023 15:52

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Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

Champlain Hudson Power Express
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ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 85 Conduit #2
Delaware Turnpike

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 87 Circuit #1**
CSX RR

ISSUE: **Design Submittal**

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: 17-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/17/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	12+15.77	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	657417.2675	1370253.2636	244.70 ft
Horizontal Curve PI	657181.5439	1370609.4231	
Exit	656963.9491	1371370.2384	248.40 ft
Depth to Mudline	0.00 ft	Clearance Depth =	50.70 ft
Measured Plan Length at ties =	1215.7672 ft		
Coordinate Length =	1215.7672 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	215.00 ft
Mudline Elev.*	244.70 ft
Lowest centerline Elev.	194.00 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	657417.2675	1370253.2636	2+57.42	657275.1920	1370467.9283	E 326.50148 N	257.42		
Curve	2+57.42	657275.1920	1370467.9283	5+94.13	657134.8862	1370772.5606	E 344.03936 N	336.70	1100.00	17.538 deg.
Tangent	5+94.13	657134.8862	1370772.5606	12+15.77	656963.9491	1371370.2384	E 344.03936 N	621.64		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	257.42	Input Radius, ft.	1100.00	Plan Length, ft.	621.64	
Entry Azimuth, deg.[5]	N 326.50148 E	Curve, deg	17.538 deg.	Exit Azimuth, deg.[5]	N 344.03936 E	
Entry Azimuth, rad.[5]	5.69853	Curve, rad	0.30609	Exit Azimuth, rad.[5]	6.00462	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	335.39	Easting	656963.9491	***Check***
PCH Easting	657275.1920	Arc Length, ft.	336.70	Northing	1371370.2384	***Delta***
PCH Northing	1370467.9283	Chord Azimuth, deg	335.2704			**0.0000**
		PI Easting =	657181.5439			**0.0000**
		PI Northing =	1370609.4231			**OK CALC**
		PTH Easting =	657134.8862			
		PTH Northing =	1370772.5606			**Exit Station**
						12+15.77
Cum Plan Length	257.42	Cum Plan Length	594.13	Cum Plan Length	1215.767208	**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	248.40 ft	212.23 ft	-10.00 deg	-10.00 deg	0.00 deg	208.29 ft	0.00 ft
Entry Curve	212.23 ft	194.00 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	194.00 ft	194.00 ft	0.00 deg	0.00 deg	0.00 deg	435.52 ft	0.00 ft
Exit Curve	194.00 ft	214.21 ft	0.00 deg	11.00 deg	11.00 deg	211.18 ft	1100.00 ft
Exit Tangent	214.21 ft	244.70 ft	11.00 deg	11.00 deg	0.00 deg	159.79 ft	0.00 ft
					Total Check =	1224.22 ft	OK

Compound Curve Assessment

Start	Vert. Plan	Horiz. Plan	
Entry	366.75	257.42	Yes, Horiz < Exit V(Tan+Curve
Exit	413.50	621.64	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	-11.000 deg.	Vertical Radius	1100.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	248.40	
		Vert. Curve, deg.	11.000 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	156.857 ft	Plan Length	209.890 ft	Plan Length	435.51624 ft	Plan Length	208.378 ft	Plan Length	205.126 ft	1,215.767 ft
Rod Length	159.793 ft	Arc Rod Length	211.185 ft	Rod Length	435.51624 ft	Arc Rod Length	209.440 ft	Rod Length	208.291 ft	1,224.224 ft
Vertical Depth	-30.490 ft	Curve Δ Vert Depth	-20.210 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	36.169 ft	3.700 ft
		Lowest Elevation	194.000 ft			Lowest Elevation	194.000 ft	CK Total Cum Depth	3.700 ft	
Start Elevation	244.700 ft	Start Elevation	214.210 ft	Start Elevation	194.000 ft	Start Elevation	194.000 ft	Start Elevation	212.231 ft	
End Elevation	214.210 ft	End Elevation	194.000 ft	End Elevation	194.000 ft	End Elevation	212.231 ft	Ck Exit Elevation		
End Vert Angle	-11.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	*Prop. Plan Length*	*1215.767208*	

SUMMARY VERTICLE CURVE CALCULATIONS										
										Stationing Check
Start Station	0+00.00	Start Station	1+56.86	Start Station	3+66.75	Start Station	8+02.26	Start Station	10+10.64	**OK STATIONING**
PVC Station	1+56.86	PTV Station	3+66.75	PCV Station	8+02.26	PTV Station	10+10.64	Exit Station	12+15.767	**Plan Length Check**
Cum Plan Length	156.86	Cum Plan Length	366.75	Cum Plan Length	802.26 ft	Cum Plan Length	1010.64	Cum Plan Length	1215.77	**OK CALCULATION**
Cum Rod Length	159.79	Cum Rod Length	370.98	Cum Rod Length	806.49 ft	Cum Rod Length	1015.93	Cum Rod Length	1224.22	**Elevation Change Check**
Cum Depth	-30.49	Cum Depth	-50.70	Cum Depth	-50.70 ft	Cum Depth	-32.4693	Cum Depth	3.70	**OK CALCULATION**

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.70 ft**
Minimum Design Elevation =	**194.00 ft**
Invert Depth below exit =	**54.40 ft**
Invert Depth below entry =	**50.70 ft**
Path Length =	**1,224.22 ft**
Plan Length =	**1,215.77 ft**
Minimum Plan Length (No Tangent) =	**780.25 ft**
Entry Angle =	**-11.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**778 ft**
Compound Curve at Exit =	**NO**

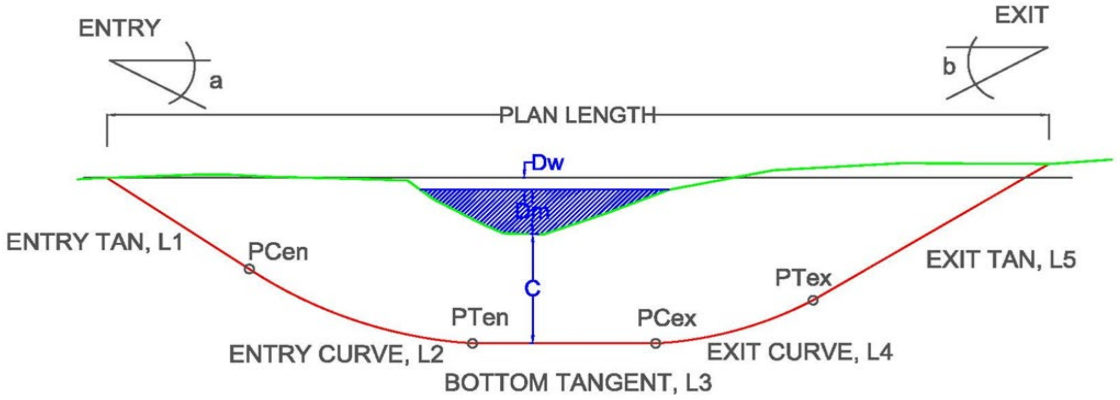
NOTES:

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:	**Issued for Construction (IFC)**

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 87 Circuit #1
CSX RR

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87 CIR #1_APC_20221025_PH.xlsb]T3 Plastic Pull

Pull Geometry

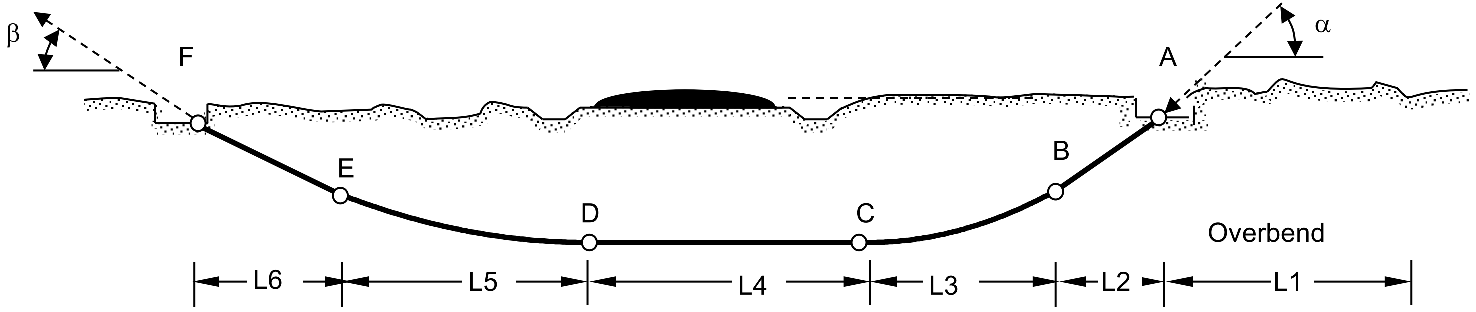
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	208.3 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	435.5 ft	χ =	0.0 °	0.0000	
L5 =	211.2 ft				1,100.0 ft
L6 =	159.8 ft	β =	11.0 °	0.1920	
LT =	1324.2 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 244.70 ft

Pipe Entry El = 248.40 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 = 244.70 ft

Ballast Water El., H_W = 244.70 ft

Lowest Invert El., El_m = 194.00 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 = 0.72 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	2,339 lb	136 psi	OK	2,339 lb	136 psi	OK	OK	OK
B	4,118 lb	104 psi	OK	4,463 lb	113 psi	OK	OK	OK
C	5,827 lb	179 psi	OK	5,287 lb	166 psi	OK	OK	OK
D	7,284 lb	184 psi	OK	6,743 lb	170 psi	OK	OK	OK
E	11,473 lb	324 psi	OK	8,963 lb	261 psi	OK	OK	OK
F	14,791 lb	373 psi	OK	10,509 lb	265 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 97.40 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 45,606 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$

Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$

Maximum 12 hour Pull Stress Reduction, F_R = 0.910487945 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.162217227 r = $\sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 373 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 5.49 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 27.46 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. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87 Circuit #1
CSX RR

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

Revision 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87 CIR #1_APC_20221025_PH.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 87 Circuit #1

CSX RR

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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 =	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 =	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	$BG-W_{D2}$

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87 CIR #1_APC_20221025_PH.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

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HDPE PROPERTIES

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

HDD 87 Circuit #1

CSX RR

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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	54.40 ft	Ballast depth to invert, H_B	50.70 ft	Drill Fluid depth to invert, H_{DF}	50.70 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}^*(H_B+D_o/24)/144$	22.03 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}^*(H_{MDF}+D_o/24)/144$	27.54 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}^*(H_{MDF}+D_o/24)/144$	28.25 psi
Water, $P_W = \gamma_{INT}^*(H_{DF}+D_o/24)/144$	22.03 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 = $(P_A+P_a)-P_{DF1}$	79.43 psi	18.54 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	78.73 psi	17.83 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.47 psi	40.57 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	100.76 psi	39.87 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	84.94 psi	24.05 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 87 Circuit #1

CSX RR

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	**FE PULL STRENTH, SPS =**	**5,321 lb**	
Temperature factor, f_{temp} =	1	ltimate 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)

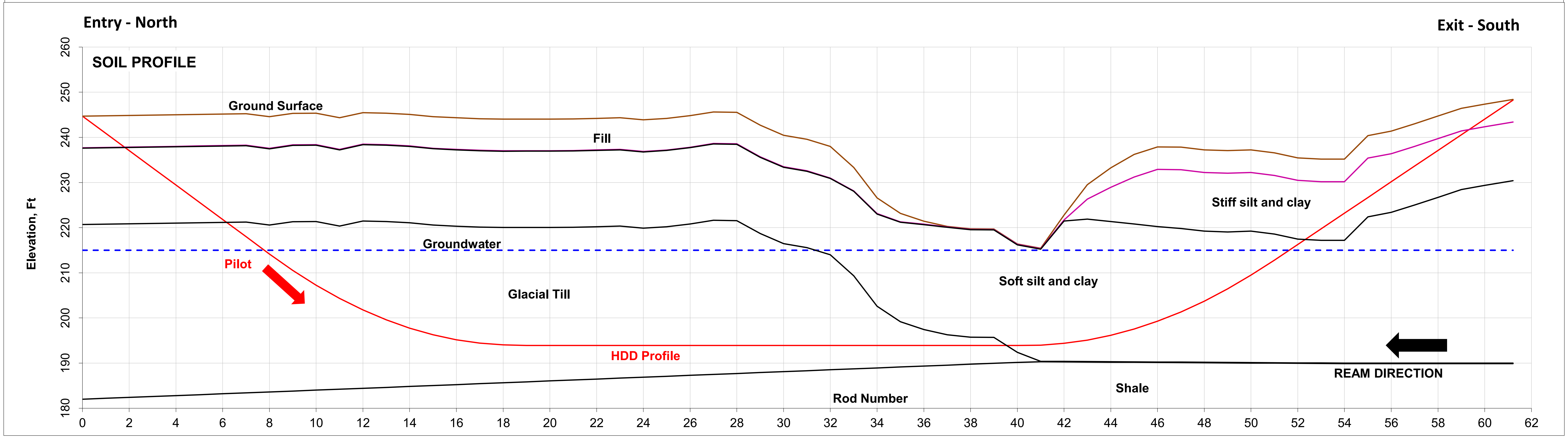
Pull Duration Time =	12 Hr	Pcr =	267.4 psi
SAS =	1,400 psi	Design Depth in DF, H_{MDF} =	0.0 ft
Estimated Maximum Pull Stress, σ_i =	1,150 psi	Design Assumption as Maximum	
fr = ((5.57-(r+1.09)^2)^.5)-1.09 =	0.91049		
$r = \sigma_i/2*(SSAS)$ =	0.16222	Example from Table T5, σ_i =	373 psi
P_{CRR} =	243.5 psi		
FS =	2.0		
$P_{ACRR} = P_{CRR}/FS$ =	121.7 psi	Allowable Reduced Short Term Buckling pressure during pull	
Internal Ballasted and External Fluid 1 = $(P_B+P_{ACRR})-P_{DF1}$	116.24 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



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.

ISSUED: Issued for Construction (IFC)

Basis of annular pressure calculations

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

Print Date ; 3/17/2023 9:18

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87 Circuit #1
CSX RR

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 87 Circuit #2**
CSX RR

ISSUE: **Design Submittal**

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: 17-Mar-2023

Revision	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/17/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	12+09.00	FT

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

	East	North	Elevation
Entry	657434.0448	1370264.3871	245.30 ft
Horizontal Curve PI	657193.9793	1370639.1389	
Exit	656981.7410	1371375.3335	251.50 ft
Depth to Mudline	0.00 ft	Clearance Depth =	45.83 ft
Measured Plan Length at ties =	1208.9956 ft		
Coordinate Length =	1208.9956 ft		
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	215.00 ft
Mudline Elev.*	245.30 ft
Lowest centerline Elev.	199.47 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	657434.0448	1370264.3871	2+84.95	657280.3379	1370504.3297	E 327.35643 N	284.95		
Curve	2+84.95	657280.3379	1370504.3297	6+02.92	657149.6307	1370792.9717	E 343.91820 N	317.96	1100.00	16.562 deg.
Tangent	6+02.92	657149.6307	1370792.9717	12+09.00	656981.7410	1371375.3335	E 343.91820 N	606.08		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	284.95	Input Radius, ft.	1100.00	Plan Length, ft.	606.08	
Entry Azimuth, deg.^{5}	N 327.35643 E	Curve, deg	16.562 deg.	Exit Azimuth, deg.^{5}	N 343.91820 E	
Entry Azimuth, rad.^{5}	5.71345	Curve, rad	0.28906	Exit Azimuth, rad.^{5}	6.00250	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	316.86	Easting	656981.7410	**Check**
PCH Easting	657280.3379	Arc Length, ft.	317.96	Northing	1371375.3335	**Delta**
PCH Northing	1370504.3297	Chord Azimuth, deg	335.6373			**0.0000**
		PI Easting =	657193.9793			**0.0000**
		PI Northing =	1370639.1389			**OK CALC**
		PTH Easting =	657149.6307			
		PTH Northing =	1370792.9717			**Exit Station**
						12+09.00
Cum Plan Length	284.95	Cum Plan Length	602.92	Cum Plan Length	1208.995626	**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	251.50 ft	217.70 ft	-10.00 deg	-10.00 deg	0.00 deg	194.64 ft	0.00 ft
Entry Curve	217.70 ft	199.47 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	199.47 ft	199.47 ft	0.00 deg	0.00 deg	0.00 deg	467.24 ft	0.00 ft
Exit Curve	199.47 ft	219.68 ft	0.00 deg	11.00 deg	11.00 deg	211.18 ft	1100.00 ft
Exit Tangent	219.68 ft	245.30 ft	11.00 deg	11.00 deg	0.00 deg	134.27 ft	0.00 ft
					Total Check =	**1216.78 ft**	**OK**

Compound Curve Assessment

Start	**Vert. Plan**	**Horiz. Plan**	
Entry	341.69	284.95	Yes, Horiz < Exit V(Tan+Curve
Exit	400.06	606.08	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	-11.000 deg.	Vertical Radius	1100.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	251.50	
		Vert. Curve, deg.	11.000 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	131.803 ft	Plan Length	209.890 ft	Plan Length	467.23957 ft	Plan Length	208.378 ft	Plan Length	191.685 ft	1,208.996 ft
Rod Length	134.270 ft	Arc Rod Length	211.185 ft	Rod Length	467.23957 ft	Arc Rod Length	209.440 ft	Rod Length	194.642 ft	1,216.776 ft
Vertical Depth	-25.620 ft	Curve Δ Vert Depth	-20.210 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	33.799 ft	6.200 ft
		Lowest Elevation	199.470 ft			Lowest Elevation	199.470 ft	CK Total Cum Depth	6.200 ft	
Start Elevation	245.300 ft	Start Elevation	219.680 ft	Start Elevation	199.470 ft	Start Elevation	199.470 ft	Start Elevation	217.701 ft	
End Elevation	219.680 ft	End Elevation	199.470 ft	End Elevation	199.470 ft	End Elevation	217.701 ft	Ck Exit Elevation		
End Vert Angle	-11.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***1208.995626***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	1+31.80	Start Station	3+41.69	Start Station	8+08.93	Start Station	10+17.31	**OK STATIONING**
PVC Station	1+31.80	PTV Station	3+41.69	PCV Station	8+08.93	PTV Station	10+17.31	Exit Station	12+08.996	**Plan Length Check**
Cum Plan Length	131.80	Cum Plan Length	341.69	Cum Plan Length	808.93 ft	Cum Plan Length	1017.31	Cum Plan Length	1209.00	**OK CALCULATION**
Cum Rod Length	134.27	Cum Rod Length	345.45	Cum Rod Length	812.69 ft	Cum Rod Length	1022.13	Cum Rod Length	1216.78	**Elevation Change Check**
Cum Depth	-25.62	Cum Depth	-45.83	Cum Depth	-45.83 ft	Cum Depth	-27.5993	Cum Depth	6.20	**OK CALCULATION**

Stationing Check

Summary of Drill Calculations

Entry to Exit Elevation Change =	**6.20 ft**
Minimum Design Elevation =	**199.47 ft**
Invert Depth below exit =	**52.03 ft**
Invert Depth below entry =	**45.83 ft**
Path Length =	**1,216.78 ft**
Plan Length =	**1,209.00 ft**
Minimum Plan Length (No Tangent) =	**741.76 ft**
Entry Angle =	**-11.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**778 ft**
Compound Curve at Exit =	**NO**

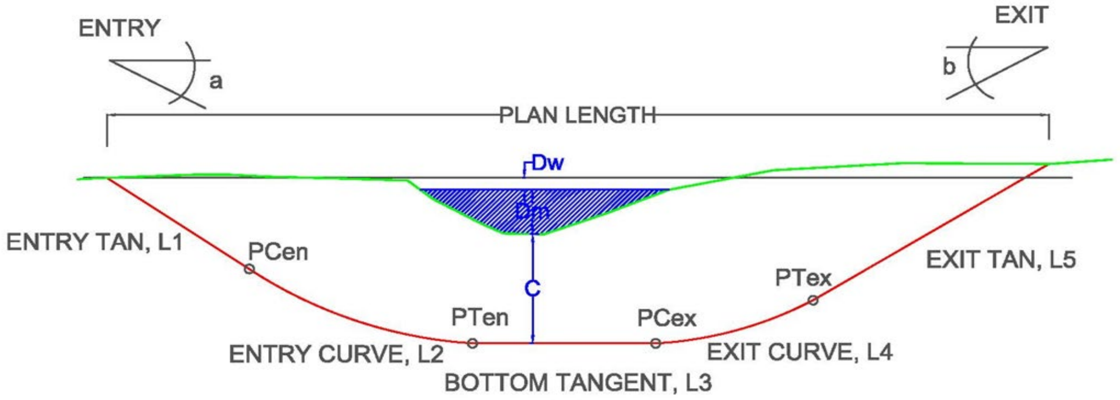
NOTES:

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 87 Circuit #2
CSX RR

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87 CIR #2_APC_20230317.xlsb]T3 Plastic Pull

Pull Geometry

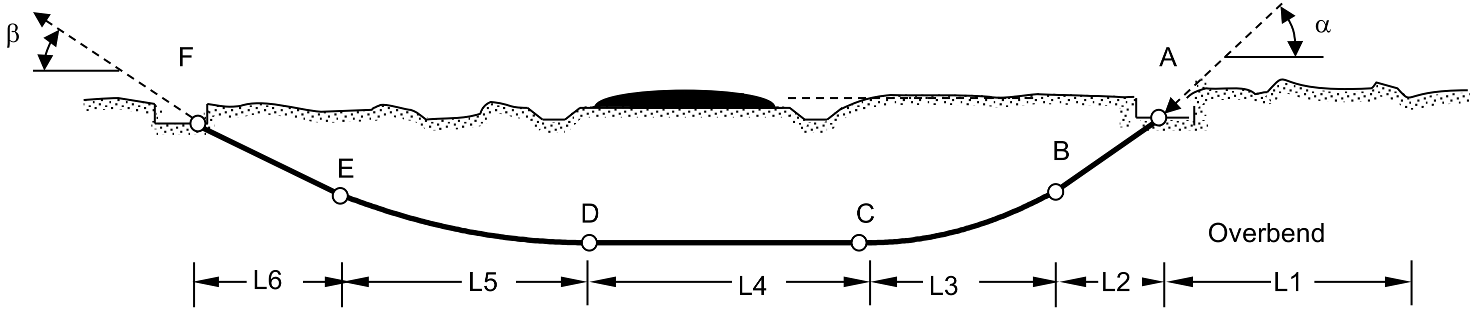
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	194.6 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	467.2 ft	χ =	0.0 °	0.0000	
L5 =	211.2 ft				1,100.0 ft
L6 =	134.3 ft	β =	11.0 °	0.1920	
LT =	1316.8 ft				

Pipe Entry Location - Drill **Exit**

(schematic, to show definition of variables only)

Pipe Exit El = 245.30 ft

Pipe Entry El = 251.50 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} 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$_T$A$_F$/(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 = 245.30 ft

Ballast Water El., H_W = 245.30 ft

Lowest Invert El., El_m = 199.47 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 = 0.54 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	Ballast
A	2,104 lb	117 psi	OK	2,104 lb	117 psi	OK	OK	OK
B	3,627 lb	101 psi	OK	3,892 lb	109 psi	OK	OK	OK
C	5,080 lb	166 psi	OK	4,543 lb	151 psi	OK	OK	OK
D	6,590 lb	184 psi	OK	6,052 lb	169 psi	OK	OK	OK
E	10,288 lb	313 psi	OK	7,968 lb	249 psi	OK	OK	OK
F	12,755 lb	356 psi	OK	9,089 lb	254 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, **P_{PA} > ΔP invert** **$P_{PA} = P_A F_R$ =** 97.90 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 = 0.915165074 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$

r = 0.154714033 $r = \sigma_T/2SPS$

Maximum applied pull Stress, σ_T = 356 psi From Pull Force Calculations

Ballasted Max. Differential Pressure on Pipe, **ΔP_B invert** = 4.96 psi (-) indicates pipe is pressurized

Unballasted Max. Differential Pressure on Pipe, **ΔP_U invert** = 24.82 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
Limited Liability Company
"Creating Space Underground"

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

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87 Circuit #2
CSX RR

Revision 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87 CIR #2_APC_20230317.xlsb]T3 Plastic Pull

TABLE 4 **Pg 1 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 87 Circuit #2

CSX RR

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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 =	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 =	15.70	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	0.84	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	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-34.72 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	38.69 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-10.47 lb/ft	$BG-W_{D1}$
Buoyant Ballasted in Fluid 2, B_{BB2} =	-11.73 lb/ft	$BG-W_{D2}$

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87 CIR #2_APC_20230317.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 87 Circuit #2

CSX RR

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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 =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 psi

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

Critical unconstrained buckling pressure is at the pipe invert

Max. Depth to Invert	52.03 ft	Ballast depth to invert, H_B	45.83 ft	Drill Fluid depth to invert, H_{DF}	45.83 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	20.05 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	25.07 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	25.71 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	20.05 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 = $(P_A+P_a)-P_{DF1}$	81.91 psi	21.01 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	81.26 psi	20.37 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	101.96 psi	41.07 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	101.32 psi	40.43 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	86.92 psi	26.03 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 **Pg 3 of 3**

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HDPE PROPERTIES

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

HDD 87 Circuit #2

CSX RR

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
FE PULL STRENTH, SPS = 50,200 lb
Temperature factor, f_{temp} = 1
ltimate Pull Strength, UPS = ########
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 = 0.91517
$r = \sigma_i/2*(SSAS)$ = 0.15471
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 = $(P_B+P_{ACRR})-P_{DF1}$ 117.36 psi Pull Back Condition - C **OK as >0**
Internal Ballasted and External Fluid 2 = $(P_B+P_{ACRR})-P_{DF2}$ 116.72 psi Pull Back Condition - C **OK as >0**

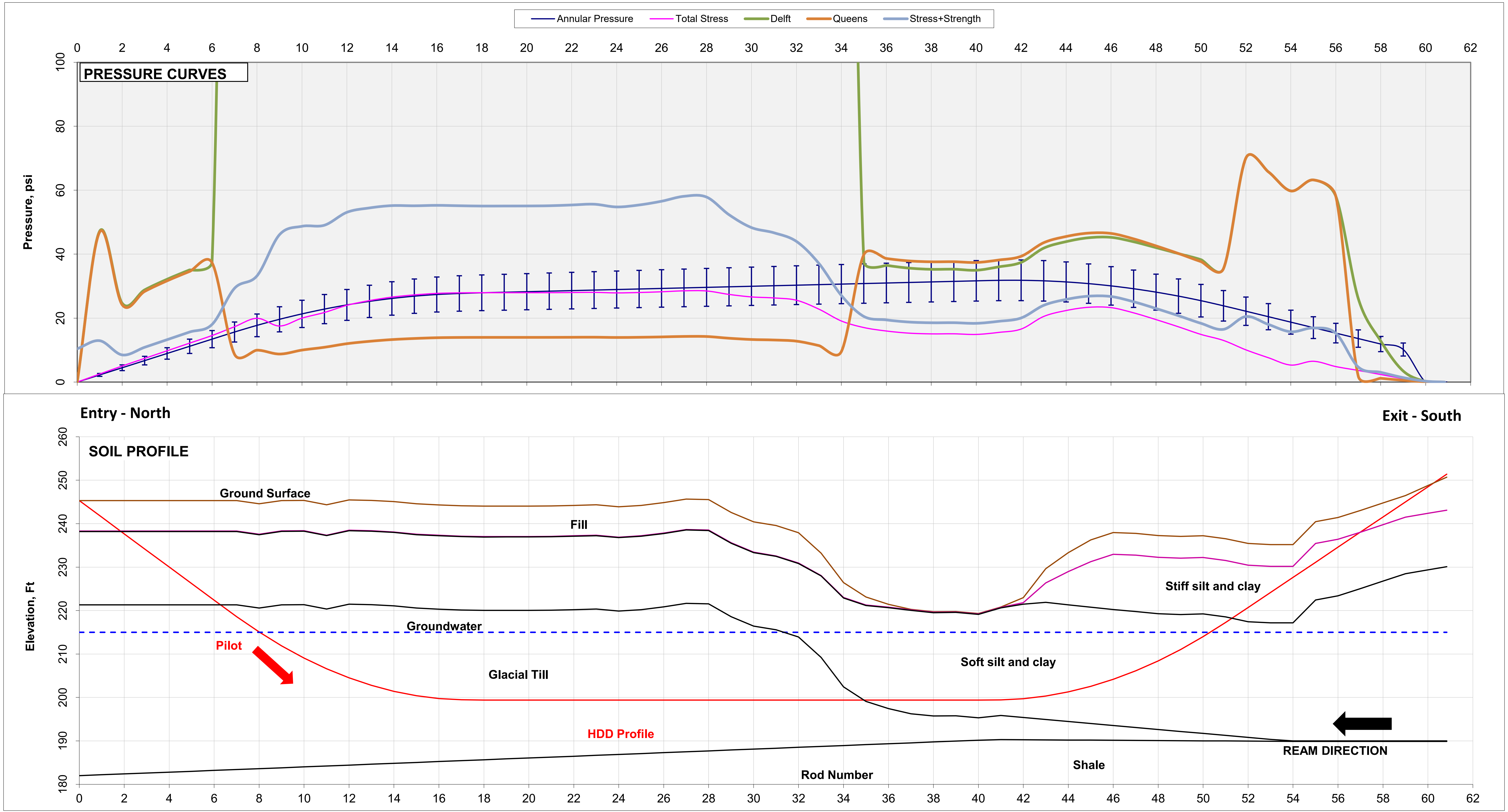
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

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
200 gal/min	Pump Rate
3.50 in	Drill Rod Diameter
20	Ft per rod
20%	for APC curve

Print Date ; 3/17/2023 9:16

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87 Circuit #2
CSX RR

Revision 1

FIGURE 1

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 87A Conduit #1**
Box Culvert

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

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Table 3	ANTICIPATED PULLING FORCE - CONDUIT BUNDLE
Table 4	LONG TERM PLASTIC STRESS - 3-inch CONDUIT
Figure 1	APC AND FPC CURVES AND ASSUMED GEOLOGIC SECTION

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT	
Exit Station	6+49.09	FT	
Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)			
	East	North	Elevation
Entry	660651.3196	1365901.4838	209.40 ft
Horizontal Curve PI	660458.7244	1366162.7032	
Exit	660266.1291	1366423.9225	212.80 ft
Depth to Mudline	0.00 ft	Clearance Depth =	28.70 ft
Measured Plan Length at ties =		649.0870 ft	
Coordinate Length =		649.0870 ft	
	OK-HORIZONTAL CURVE		

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

Water Surface Elev.*	205.00 ft
Mudline Elev.*	209.40 ft
Lowest centerline Elev.	180.70 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	660651.3196	1365901.4838	3+24.54	660458.7244	1366162.7032	E 323.59891 N	324.54		
Curve	3+24.54	660458.7244	1366162.7032	3+24.54	660458.7244	1366162.7032	E 323.59889 N	0.00	0.00	0.000 deg.
Tangent	3+24.54	660458.7244	1366162.7032	6+49.09	660266.1291	1366423.9225	E 323.59889 N	324.54		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		***Horizontal Curve Segment***		***Exit Tangent Segment***		
Plan Length, ft.	324.54	Input Radius, ft.	0.00	Plan Length, ft.	324.54	
Entry Azimuth, deg.^{5}	N 323.59891 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 323.59889 E	
Entry Azimuth, rad.^{5}	5.64787	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	5.64787	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	660266.1291	**Check**
PCH Easting	660458.7244	Arc Length, ft.	0.00	Northing	1366423.9225	**Delta**
PCH Northing	1366162.7032	Chord Azimuth, deg	323.5989			**0.0000**
		PI Easting =	660458.7244			**0.0000**
		PI Northing =	1366162.7032			**OK CALC**
		PTH Easting =	660458.7244			
		PTH Northing =	1366162.7032			**Exit Station**
						6+49.09
Cum Plan Length	324.54	Cum Plan Length	324.54	Cum Plan Length	649.0869869	**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**	**∆ Angle**	**Length**	**Radius**
Entry Tangent	212.80 ft	198.93 ft	-10.00 deg	-10.00 deg	0.00 deg	79.87 ft	0.00 ft
Entry Curve	198.93 ft	180.70 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	180.70 ft	180.70 ft	0.00 deg	0.00 deg	0.00 deg	118.11 ft	0.00 ft
Exit Curve	180.70 ft	199.07 ft	0.00 deg	11.00 deg	11.00 deg	191.99 ft	1000.00 ft
Exit Tangent	199.07 ft	209.40 ft	11.00 deg	11.00 deg	0.00 deg	54.12 ft	0.00 ft
					Total Check =	**653.53 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	-11.000 deg.	Vertical Radius	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	212.80	
		Vert. Curve, deg.	11.000 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	53.129 ft	Plan Length	190.809 ft	Plan Length	118.11470 ft	Plan Length	208.378 ft	Plan Length	78.657 ft	649.087 ft
Rod Length	54.123 ft	Arc Rod Length	191.986 ft	Rod Length	118.11470 ft	Arc Rod Length	209.440 ft	Rod Length	79.870 ft	653.534 ft
Vertical Depth	-10.327 ft	Curve ∆ Vert Depth	-18.373 ft	Vertical Depth	0.00000 ft	Curve ∆ Vert Depth	18.231 ft	Vertical Depth	13.869 ft	3.400 ft
		Lowest Elevation	180.700 ft			Lowest Elevation	180.700 ft	CK Total Cum Depth	3.400 ft	
Start Elevation	209.400 ft	Start Elevation	199.073 ft	Start Elevation	180.700 ft	Start Elevation	180.700 ft	Start Elevation	198.931 ft	
End Elevation	199.073 ft	End Elevation	180.700 ft	End Elevation	180.700 ft	End Elevation	198.931 ft	Ck Exit Elevation		
End Vert Angle	-11.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	***649.0869869***	

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+53.13	Start Station	2+43.94	Start Station	3+62.05	Start Station	5+70.43	**Stationing Check** **OK STATIONING**
PVC Station	0+53.13	PTV Station	2+43.94	PCV Station	3+62.05	PTV Station	5+70.43	Exit Station	6+49.087	**Plan Length Check** **OK CALCULATION**
Cum Plan Length	53.13	Cum Plan Length	243.94	Cum Plan Length	362.05 ft	Cum Plan Length	570.43	Cum Plan Length	649.09	
Cum Rod Length	54.12	Cum Rod Length	246.11	Cum Rod Length	364.22 ft	Cum Rod Length	573.66	Cum Rod Length	653.53	**Elevation Change Check** **OK CALCULATION**
Cum Depth	-10.33	Cum Depth	-28.70	Cum Depth	-28.70 ft	Cum Depth	-10.4693	Cum Depth	3.40	

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.40 ft**
Minimum Design Elevation =	**180.70 ft**
Invert Depth below exit =	**32.10 ft**
Invert Depth below entry =	**28.70 ft**
Path Length =	**653.53 ft**
Plan Length =	**649.09 ft**
Minimum Plan Length (No Tangent) =	**530.97 ft**
Entry Angle =	**-11.00 deg**
Exit Angle =	**10.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**NO**

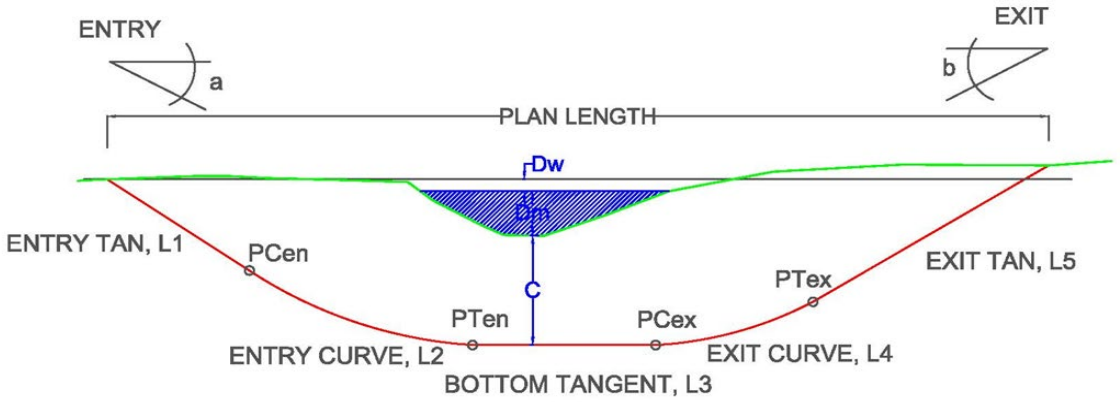
NOTES:

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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Limited Liability Company
"Creating Space Underground"

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

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 87A Conduit #1
Box Culvert

Revision 1　　TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87A CIR #1_APC_20220830.xlsb]T3 Plastic Pull

Pull Geometry

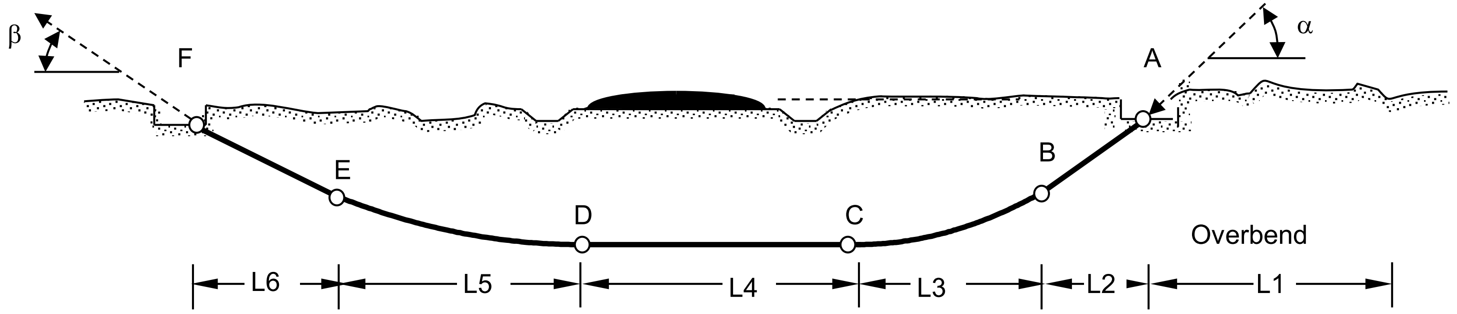
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	79.9 ft	α =	-10.0 °	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	118.1 ft	χ =	0.0 °	0.0000	
L5 =	192.0 ft				1,000.0 ft
L6 =	54.1 ft	β =	11.0 °	0.1920	
LT =	753.5 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 209.40 ft

Pipe Entry El = 212.80 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 =	800 psi	HDB/2	
Pressure Rating, $PR_{(80F)}$ =	200 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 =	209.40 ft	
Ballast Water El., H_W =	209.40 ft	
Lowest Invert El., El_m =	180.70 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 =	1.35 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	 Ballast
A	1,331 lb	111 psi	OK	1,331 lb	111 psi	OK	OK	OK
B	1,967 lb	50 psi	OK	2,078 lb	52 psi	OK	OK	OK
C	3,580 lb	122 psi	OK	2,795 lb	103 psi	OK	OK	OK
D	3,586 lb	90 psi	OK	2,801 lb	71 psi	OK	OK	OK
E	7,245 lb	221 psi	OK	4,656 lb	156 psi	OK	OK	OK
F	8,369 lb	211 psi	OK	5,179 lb	131 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 101.66 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS =	45,606 lb	$SSPS = \sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A =	106.97 psi	$P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R =	0.950306925	$F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r =	0.096232545	$r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T =	221 psi	From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** =	3.11	psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** =	15.55	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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Segment 8 (Pkg. 5A) - CSX: Roterdam to Selkirk
Schenectady County, NY

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87A Conduit #1
Box Culvert

Revision 1 TBD

TABLE 4 Pg 1 of 3
HDPE PROPERTIES

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

HDD 87A Conduit #1
Box Culvert

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INPUTS
Pipe Material Properties

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

Design Working Pressure, P_{WORK}	0 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 =	0.50		Based on PPI PE Handbook 2nd ED Chapter 5
Hydrostatic Design Stress, HDS =	800 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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

Buoyant Unballasted Fluid 1, B_{B1} =	-3.55 lb/ft	W_P-W_{D1}
Buoyant Unballasted Fluid 2, B_{B2} =	-3.69 lb/ft	W_P-W_{D2}
Ballasted on ground, B_G =	4.10 lb/ft	W_P+W_B
Buoyant Ballasted in Fluid 1, BB_{B1} =	-1.11 lb/ft	BG-W_{D1}
Buoyant Ballasted in Fluid 2, B_{BB2} =	-1.24 lb/ft	BG-W_{D2}

TABLE 4 **Pg 2 of 3**

HDPE PROPERTIES

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

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HDD 87A Conduit #1
Box Culvert

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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	$P_A = 2*HDB*f_t/(DR-1)$
	Long Term	**Design for operating conditions**
Design Temperature, ^oF =	73 deg F	
Pressure Rating, PR =	200 psi	$PR = 2*HDS*f_t*Af_e/(DR-1)$
Maximum Ocassional Surge, P_{OS} =	400 psi	$P_{OS} = 2*PR$
Maximum Reoccuring Surge, PRS =	300 psi	$P_{RS} = 1.5*PR$

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

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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	32.10 ft	Ballast depth to invert, H_B	28.70 ft	Drill Fluid depth to invert, H_{DF}	28.70 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B = \gamma_{INT}*(H_B+D_o/24)/144$	12.50 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	15.62 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	16.03 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	12.50 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 = $(P_A+P_a)-P_{DF1}$	91.35 psi	30.46 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	90.95 psi	30.06 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	103.85 psi	42.96 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.45 psi	42.56 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	94.48 psi	33.58 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 **Pg 3 of 3**

HDPE PROPERTIES

Champlain Hudson Power Express

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

Schenectady County, NY

HDD 87A Conduit #1

Box Culvert

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

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

Designed Pull Duration Time = 12 hr
Quantity of pipes, Q = 1
Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)
Pull Temperature, F = 73 deg.
Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7
Design Factor, DF = f_T*f_Y 0.4
SAFE PULL STRENTH, SPS = 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)

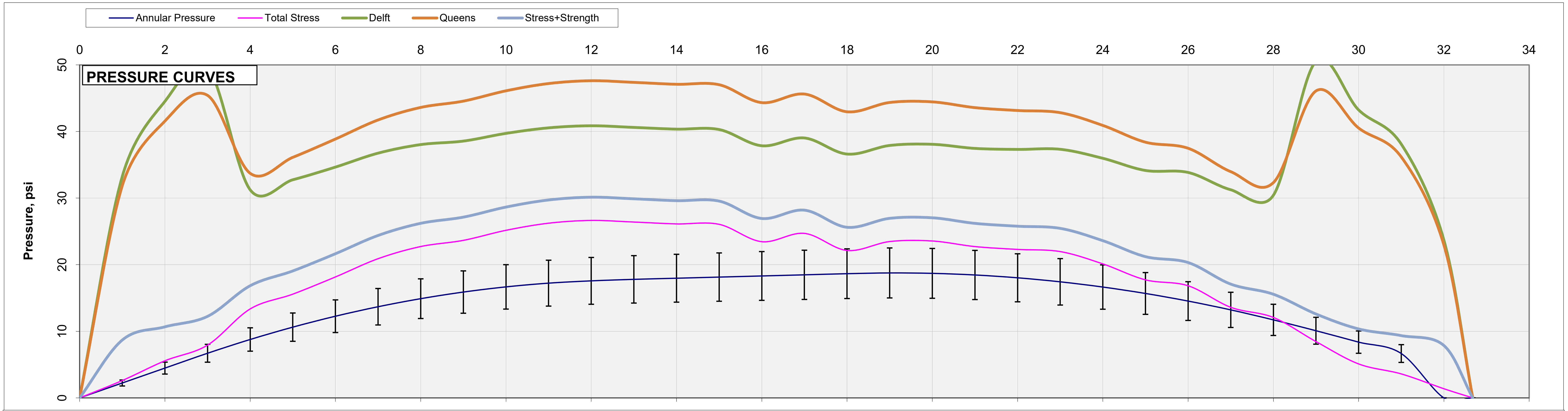
Pull Duration Time = 12 Hr
Pcr = 267.4 psi
SAS = 1,400 psi
Design Depth in DF, H_{MDF} = 0.0 ft
Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum
fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.95031
r = σ_i/2*(SSAS) = 0.09623
Example from Table T5, σ_i = 221 psi
P_{CRR} = 254.1 psi
FS = 2.0
P_{ACRR} = P_{CRR}/FS = 127.1 psi Allowable Reduced Short Term Buckling pressure during pull
Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 111.45 psi Pull Back Condition - Option 3 **OK as >0**
Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 111.05 psi Pull Back Condition - Option 4 **OK as >0**

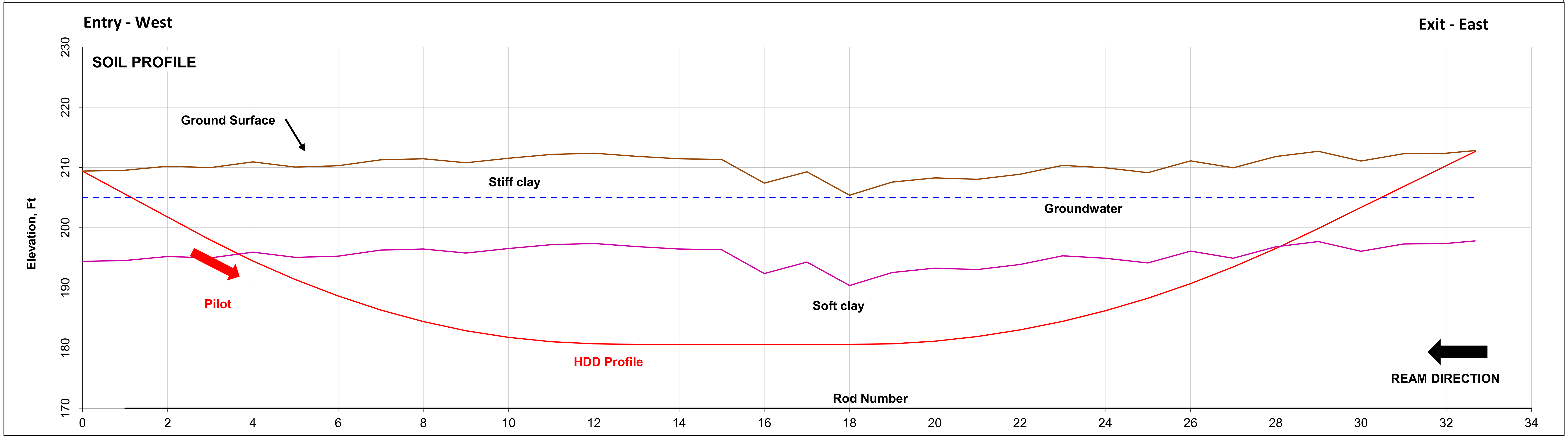
ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
REFERENCE 2 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition
Design Factor (fe) to apply to HDB
CHAPTER 6 - TABLE 1-2
REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7
Time factor for pull duration, f_T

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





ISSUED: Issued for Construction (IFC)

Notes:

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

Basis of annulur pressure calculations

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

Print Date ; 3/13/2023 8:52

BRIERLEY ASSOCIATES
Creating Space Underground

167 S. River Road, Suite 8
Bedford, NH 03110
603.206.5775 (O)

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

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87A Conduit #1
Box Culvert

Revision 1

FIGURE 1

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87A CIR #1_APC_20220830.xlsb]T3 Plastic Pull

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HORIZONTAL DIRECTIONAL DRILL DESIGN

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

CROSSING: **HDD 87A Conduit #2**
Box Culvert

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: 13-Mar-2023

Date	Rev	DESCRIPTION	BY
10/23/2022	0	Design Submittal	ABL
3/13/2023	1	Issued for Construction	KRF

DRILL PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	6+49.30	FT

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

	East	North	Elevation
Entry	660663.5583	1365910.1609	208.30 ft
Horizontal Curve PI	660470.8999	1366171.4660	
Exit	660278.2414	1366432.7711	211.70 ft
Depth to Mudline	0.00 ft	Clearance Depth =	26.70 ft

Measured Plan Length at ties = 649.3000 ft
Coordinate Length = 649.3000 ft
OK-HORIZONTAL CURVE

*If no water or mudline then use lower of entry or exit elevation
Water Surface Elev.* 205.00 ft
Mudline Elev.* 208.30 ft
Lowest centerline Elev. 181.60 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	660663.5583	1365910.1609	3+24.65	660470.8999	1366171.4660	E 323.59891 N	324.65		
Curve	3+24.65	660470.8999	1366171.4660	3+24.65	660470.8999	1366171.4660	E 323.59890 N	0.00	0.00	0.000 deg.
Tangent	3+24.65	660470.8999	1366171.4660	6+49.30	660278.2414	1366432.7711	E 323.59890 N	324.65		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	324.65	Input Radius, ft.	0.00	Plan Length, ft.	324.65	
Entry Azimuth, deg.^{5}	N 323.59891 E	Curve, deg	0.000 deg.	Exit Azimuth, deg.^{5}	N 323.59890 E	
Entry Azimuth, rad.^{5}	5.64787	Curve, rad	0.00000	Exit Azimuth, rad.^{5}	5.64787	
		Calculate PTH		**Calculate Exit**		
Calculate PCH	`	Chord Length, ft.	0.00	Easting	660278.2414	***Check***
PCH Easting	660470.8999	Arc Length, ft.	0.00	Northing	1366432.7711	***Delta***
PCH Northing	1366171.4660	Chord Azimuth, deg	323.5989			**0.0000**
		PI Easting =	660470.8999			**0.0000**
		PI Northing =	1366171.4660			**OK CALC**
		PTH Easting =	660470.8999			
		PTH Northing =	1366171.4660			**Exit Station**
						6+49.30
Cum Plan Length	324.65	Cum Plan Length	324.65	Cum Plan Length	649.3000343	**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	211.70 ft	199.83 ft	-10.00 deg	-10.00 deg	0.00 deg	68.35 ft	0.00 ft
Entry Curve	199.83 ft	181.60 ft	-10.00 deg	0.00 deg	10.00 deg	209.44 ft	1200.00 ft
Bottom Tangent	181.60 ft	181.60 ft	0.00 deg	0.00 deg	0.00 deg	139.96 ft	0.00 ft
Exit Curve	181.60 ft	199.97 ft	0.00 deg	11.00 deg	11.00 deg	191.99 ft	1000.00 ft
Exit Tangent	199.97 ft	208.30 ft	11.00 deg	11.00 deg	0.00 deg	43.64 ft	0.00 ft
					Total Check =	**653.38 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	-11.000 deg.	Vertical Radius	1000.00	End Vert Angle	0.000 deg.	Radius	1200.00	Exit Elevation	211.70
		Vert. Curve, deg.	11.000 deg.	Inclined Bottom Tan	NO	Angle Change	10.000 deg.	Design Exit Angle	10.00 deg
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	42.840 ft	Plan Length	190.809 ft	Plan Length	139.95941 ft	Plan Length	208.378 ft	Plan Length	67.314 ft
Rod Length	43.641 ft	Arc Rod Length	191.986 ft	Rod Length	139.95941 ft	Arc Rod Length	209.440 ft	Rod Length	68.353 ft
Vertical Depth	-8.327 ft	Curve Δ Vert Depth	-18.373 ft	Vertical Depth	0.00000 ft	Curve Δ Vert Depth	18.231 ft	Vertical Depth	11.869 ft
		Lowest Elevation	181.600 ft			Lowest Elevation	181.600 ft	CK Total Cum Depth	3.400 ft
Start Elevation	208.300 ft	Start Elevation	199.973 ft	Start Elevation	181.600 ft	Start Elevation	181.600 ft	Start Elevation	199.831 ft
End Elevation	199.973 ft	End Elevation	181.600 ft	End Elevation	181.600 ft	End Elevation	199.831 ft	Ck Exit Elevation	
End Vert Angle	-11.000 deg	End Vert Angle	0.000 deg	End Vert Angle	0.000 deg	End Vert Angle	10.000 deg	***Prop. Plan Length***	**649.3000343**

SUMS
649.300 ft
653.379 ft
3.400 ft

SUMMARY VERTICLE CURVE CALCULATIONS

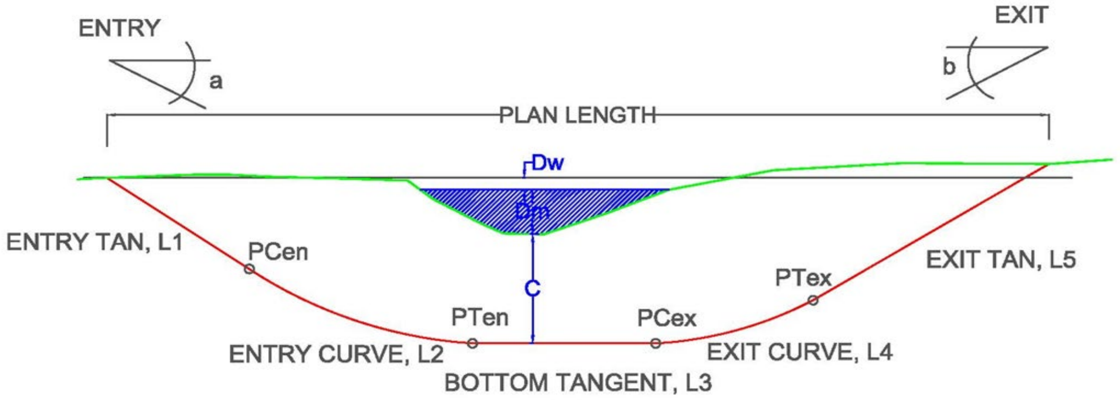
Start Station	0+00.00	Start Station	0+42.84	Start Station	2+33.65	Start Station	3+73.61	Start Station	5+81.99
PVC Station	0+42.84	PTV Station	2+33.65	PCV Station	3+73.61	PTV Station	5+81.99	Exit Station	6+49.300
Cum Plan Length	42.84	Cum Plan Length	233.65	Cum Plan Length	373.61 ft	Cum Plan Length	581.99	Cum Plan Length	649.30
Cum Rod Length	43.64	Cum Rod Length	235.63	Cum Rod Length	375.59 ft	Cum Rod Length	585.03	Cum Rod Length	653.38
Cum Depth	-8.33	Cum Depth	-26.70	Cum Depth	-26.70 ft	Cum Depth	-8.4693	Cum Depth	3.40

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

Summary of Drill Calculations

Entry to Exit Elevation Change =	**3.40 ft**
Minimum Design Elevation =	**181.60 ft**
Invert Depth below exit =	**30.10 ft**
Invert Depth below entry =	**26.70 ft**
Path Length =	**653.38 ft**
Plan Length =	**649.30 ft**
Minimum Plan Length (No Tangent) =	**509.34 ft**
Entry Angle =	**-11.00 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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Limited Liability Company
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Brierley Associates
167 S. River Road, Suite 8
Bedford, NH 03110

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

TABLE 2
DESIGN DRILL PATH CALCULATION
HDD 87A Conduit #2
Box Culvert

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87A CIR #2_APC_20221023.xlsb]T3 Plastic Pull

Pull Geometry

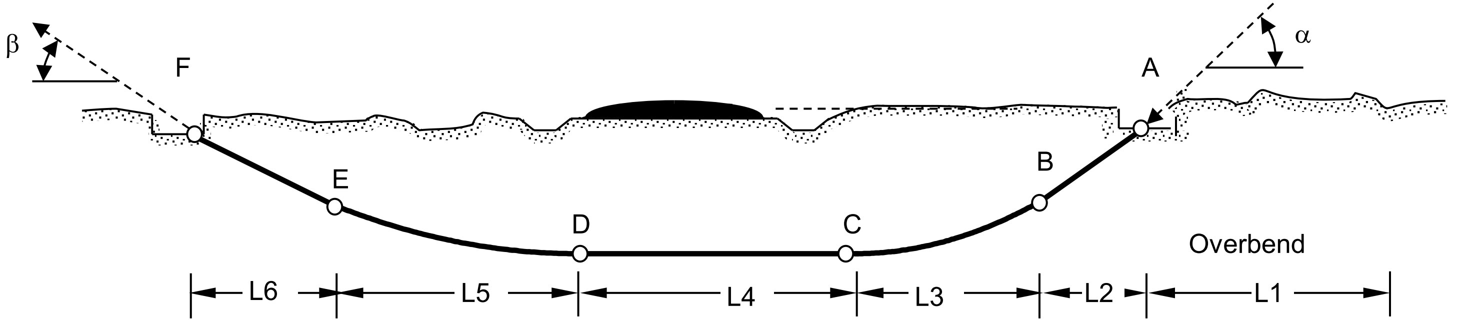
Lengths (Path)		Angles			Radius, R
L1 =	100.0 ft	Overbend	deg	radian	500.0 ft
L2 =	68.4 ft	α =	-10.0 ˚	-0.1745	
L3 =	209.4 ft				1,200.0 ft
L4 =	140.0 ft	χ =	0.0 ˚	0.0000	
L5 =	192.0 ft				1,000.0 ft
L6 =	43.6 ft	β =	11.0 ˚	0.1920	
LT =	753.4 ft				

Pipe Entry Location - Drill Exit

(schematic, to show definition of variables only)

Pipe Exit El = 208.30 ft

Pipe Entry El = 211.70 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} 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 = 208.30 ft
Ballast Water El., H_W = 208.30 ft
Lowest Invert El., El_m = 181.60 ft

POINT	**Calculated Pull Force**						**ASSESS**	
	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	Ballast
A	1,204 lb	92 psi	OK	1,204 lb	92 psi	OK	OK	OK
B	1,702 lb	47 psi	OK	1,784 lb	50 psi	OK	OK	OK
C	3,069 lb	110 psi	OK	2,340 lb	90 psi	OK	OK	OK
D	3,195 lb	89 psi	OK	2,466 lb	69 psi	OK	OK	OK
E	6,420 lb	208 psi	OK	4,059 lb	142 psi	OK	OK	OK
F	7,222 lb	201 psi	OK	4,423 lb	123 psi	OK	OK	OK

ASSESS Pull Restricted Buckling Capacity, $P_{PA} > \Delta P$ **invert** $P_{PA} = P_AF_R$ = 102.01 psi

Ballasted	OK
No Ballast	OK

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

Calculated Material Design Limits For Designed Drill Path

Safe Pull Strength, SPS = 41,235 lb SSPS = $\sigma_{PM}\pi D_{OD}^2((1/DR)-(1/DR^2))$
Allowable Short Term Unconstrained Buckling, P_A = 106.97 psi $P_A = (2E_T/(1-\mu^2))(1/(DR-1))^3(f_o/N)$
Maximum 12 hour Pull Stress Reduction, F_R = 0.953610178 $F_R = (5.57-(r+1.09)^2)^{1/2}-1.09$
r = 0.090532694 $r = \sigma_T/2SPS$
Maximum applied pull Stress, σ_T = 208 psi From Pull Force Calculations
Ballasted Max. Differential Pressure on Pipe, ΔP_B **invert** = 2.89 psi (-) indicates pipe is pressurized
Unballasted Max. Differential Pressure on Pipe, ΔP_U **invert** = 14.46 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 $D_H=D_O+12$"

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 = 1.00 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

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
Limited Liability Company
"Creating Space Underground"

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

TABLE 3 - PULL ASSESSMENT
ANTICIPATED PULLING FORCE - HDPE PULL
HDD 87A Conduit #2
Box Culvert

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

Revision 1 TBD

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87A CIR #2_APC_20221023.xlsb]T3 Plastic Pull

BRIERLEY ASSOCIATES
Limited Liability Company

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TABLE 4 Pg 1 of 3

HDPE PROPERTIES

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

HDD 87A Conduit #2
Box Culvert

INPUTS

Pipe Material Properties

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

Design Working Pressure, P_{WORK} 0 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 =	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 =	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	0.84	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 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	$W_{D2} = V_{Do}*\gamma_{EXT2}$

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

S:\Projects\2022 Projects\322004-000 Champlain Hudson Power Express\Engineering\[HDD#87A CIR #2_APC_20221023.xlsb]T3 Plastic Pull

TABLE 4 **Pg 2 of 3**

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"Creating Space Underground"

HDPE PROPERTIES

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

HDD 87A Conduit #2
Box Culvert

1. ASSESS PIPE PRESSURE RATING

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

Short Term (<10 hours)

Design Temperature, ^oF =	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, ^oF =	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	115.2 psi
$P_a = P_{CR}/FS$	107.0 psi	46.1 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	30.10 ft	Ballast depth to invert, H_B	26.70 ft	Drill Fluid depth to invert, H_{DF}	26.70 ft

Pipe Invert Internal Pressure, P_I

Air Ballast, P_A	0.00 psi
Full Ballast, $P_B=\gamma_{INT}*(H_B+D_o/24)/144$	11.76 psi

Pipe Invert External Pressure, P_E

Drill Fluid 1, $P_{DF1} = \gamma_{EXT1}*(H_{MDF}+D_o/24)/144$	14.71 psi
Drill Fluid 2, $P_{DF2} = \gamma_{EXT2}*(H_{MDF}+D_o/24)/144$	15.08 psi
Water, $P_W = \gamma_{INT}*(H_{DF}+D_o/24)/144$	11.76 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 = $(P_A+P_a)-P_{DF1}$	92.27 psi	31.38 psi	Pull Back Condition - Option 1
Internal Air and External Fluid 2 = $(P_A+P_a)-P_{DF2}$	91.89 psi	31.00 psi	Pull Back Condition - Option 2
Internal Ballasted and External Fluid 1 = $(P_B+P_a)-P_{DF1}$	104.03 psi	43.14 psi	Pull Back Condition - Option 3
Internal Ballasted and External Fluid 2 = $(P_B+P_a)-P_{DF2}$	103.66 psi	42.76 psi	Pull Back Condition - Option 4
Internal Ballasted and External Water = $(P_B+P_a)-P_W$	106.97 psi	46.08 psi	Long Term Operating Conditions
Internal Air and External Water = $(P_A+P_a)-P_W$	95.21 psi	34.32 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. 5A) - CSX: Roterdam to Selkirk

Schenectady County, NY

BRIERLEY ASSOCIATES
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"Creating Space Underground"

HDD 87A Conduit #2

Box Culvert

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

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

Designed Pull Duration Time = 12 hr

Quantity of pipes, Q = 1

Yield Strength Factor, f_Y = 0.4 Recommended (FS = 2.5)

Pull Temperature, F = 73 deg.

Pull Time factor, f_T = 1 Plexco Engineering Manual Table 3.7

Design Factor, DF = f_T*f_Y 0.4

SAFE PULL STRENTH, SPS = 50,200 lb

Temperature factor, f_{temp} = 1

Ultimate Pull Strength, UPS = 125,499 lb

Temp Corr Tensile Yield, Ty*f_{temp} = 3,500 psi

Safe Allowable Stress, SAS = 1,400 psi SAS = Ty*f_{temp}*DF

Suggested SSAS = 1,150 psi

Safe Pull Strength, SPS Pipe = 50,200 lb **Useing SSAS = 41,235 lb**

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

(ASTM F-1962 EQ. 22)

Pull Duration Time = 12 Hr

Pcr = 267.4 psi

SAS = 1,400 psi

Design Depth in DF, H_{MDF} = 0.0 ft

Estimated Maximum Pull Stress, σ_i = 1,150 psi Design Assumption as Maximum

fr = ((5.57-(r+1.09)^2)^.5)-1.09 = 0.95361

r = σ_i/2*(SSAS) = 0.09053

Example from Table T5, σ_i = 208 psi

P_{CRR} = 255.0 psi

FS = 2.0

P_{ACRR} = P_{CRR}/FS = 127.5 psi Allowable Reduced Short Term Buckling pressure during pull

Internal Ballasted and External Fluid 1 = (P_B+P_{ACRR})-P_{DF1} 112.81 psi Pull Back Condition - Option 3 **OK as >0**

Internal Ballasted and External Fluid 2 = (P_B+P_{ACRR})-P_{DF2} 112.43 psi Pull Back Condition - Option 4 **OK as >0**

ASSESSMENT OF SAFE PULL STRENGTH ON TENSION REDUCED BUCKLING CAPACITY

ACCEPTIBLE Acceptible if differential pressures > 0 for reduced buckling capacity

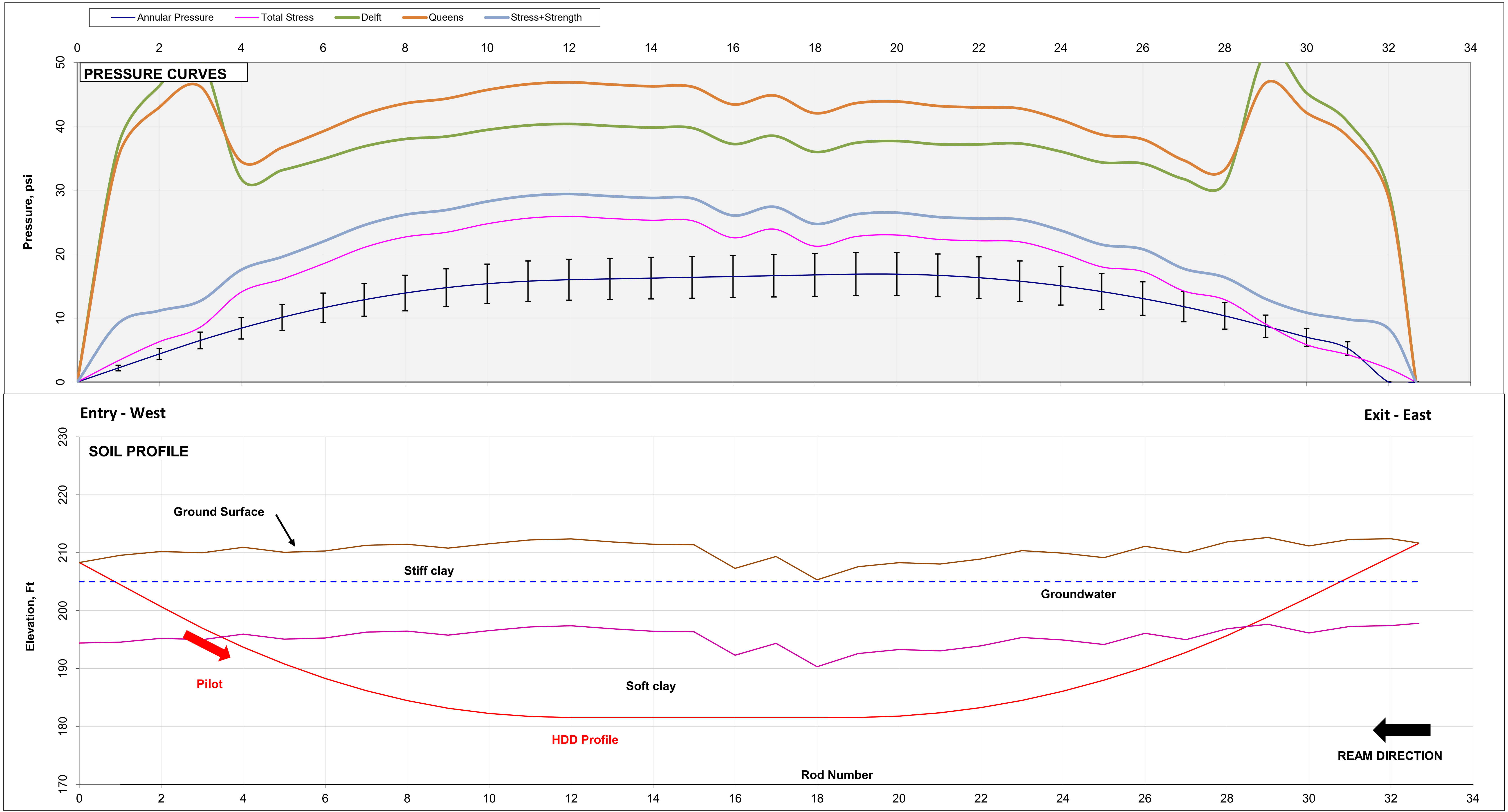
REFERENCE 1 - Plastic Pipe Institute - Handbook of PE Pipe 2nd Edition

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

REFERENCE 3 - Plexco Engineering Manual Book 3 Ch 3 Table 3.7

Time factor for pull duration, f_T

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



ISSUED: Issued for Construction (IFC)

Notes:

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

Basis of annular pressure calculations

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

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603.206.5775 (O)

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ANNULAR PRESSURE AND FORMATION PRESSURE CURVES
HDD 87A Conduit #2
Box Culvert

Revision 1

FIGURE 1