Manatee County
SR 684 (Cortez Road) Water and Force Main Intracoastal Crossing Drill Report

Prepared for:
Manatee County
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FOR INFORMATION ONLY

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Executive Summary

On September 8, 2021, Manatee County authorized Kimley-Horn to provide utility engineering design services for the SR 684 (Cortez Road) water main and force main intracoastal crossing project. The Cortez Road water main and force main intracoastal crossing project consists of relocating the 24-inch water main and 20-inch force main to the south side of the existing Cortez Bridge, outside of the proposed bridge alignment. Kimley-Horn used Vermeer BoreAid version 5.0 (BoreAid) software to aid in the design of the directional drill bore path. Given the soil parameters collected in the Geotechnical Report, Kimley-Horn analyzed the 24-inch water main and the 20-inch force main bore paths to determine if they are reasonable for a drilling contractor to implement. The results of the calculations show that a Contractor could reasonably construct the proposed 24-inch water main and 20-inch force main via a horizontal directional drill.

The proposed 24-inch water main length is approximately 3,120 feet and has a minimum depth of 50 feet. The radius of the proposed bore path is approximately 5,000 feet on the west side of the drill (entrance) and 4,000 feet on the east side of the drill (exit), with inclination angles of 10 degrees.

The proposed 20-inch force main length is approximately 3,250 feet and has a minimum depth of 60 feet. The radius of the proposed bore path is approximately 5,000 feet on the west side of the drill (entrance) and 4,000 feet on the east side of the drill (exit), with inclination angles of 10 degrees.

The proposed bore paths for both the force main and water main will assume a minimum pilot bore diameter of 13 inches and have a drill rod progression time of 15 min/rod. Figure 1 and Figure 2 show both the maximum allowable bore pressure graphs of the force main and water main. The shown Hydrofracture locations are isolated to the entrance and exit pits.

The deepest drill proposed is for the force main at a minimum 60-foot depth. The maximum allowable bore pressure (average) for the force main is approximately 101.786 pounds per square inch (PSI). The maximum circulating pressure for the force main, which is the pressure generated from static and friction losses, is approximately 56.99 PSI. The remaining estimated Factor of Safety between the allowable bore pressure and the circulating pressure is 44.80 PSI.

The water main drill is approximately 50 feet deep. The maximum allowable bore pressure (average) for the water main is approximately 92.15 PSI. The maximum circulating pressure for the force main, which is the pressure generated from static and friction losses, is approximately 49.53 PSI. The remaining estimated Factor of Safety between the allowable bore pressure and the circulating pressure is 42.62 PSI.

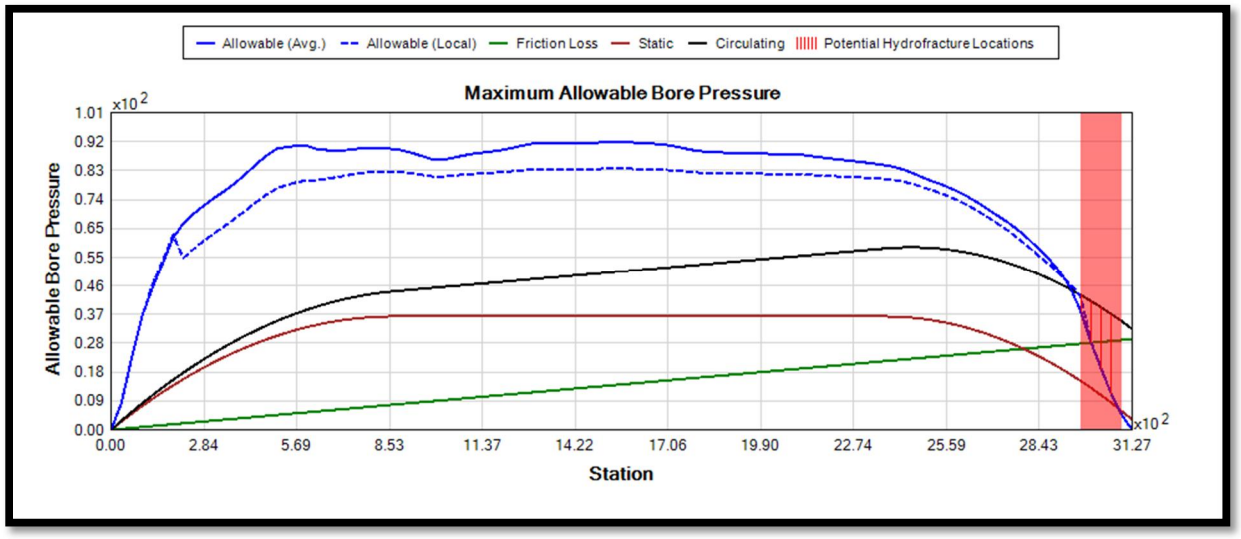

Figure 1: Water Main Maximum Allowable Bore Pressure Graph

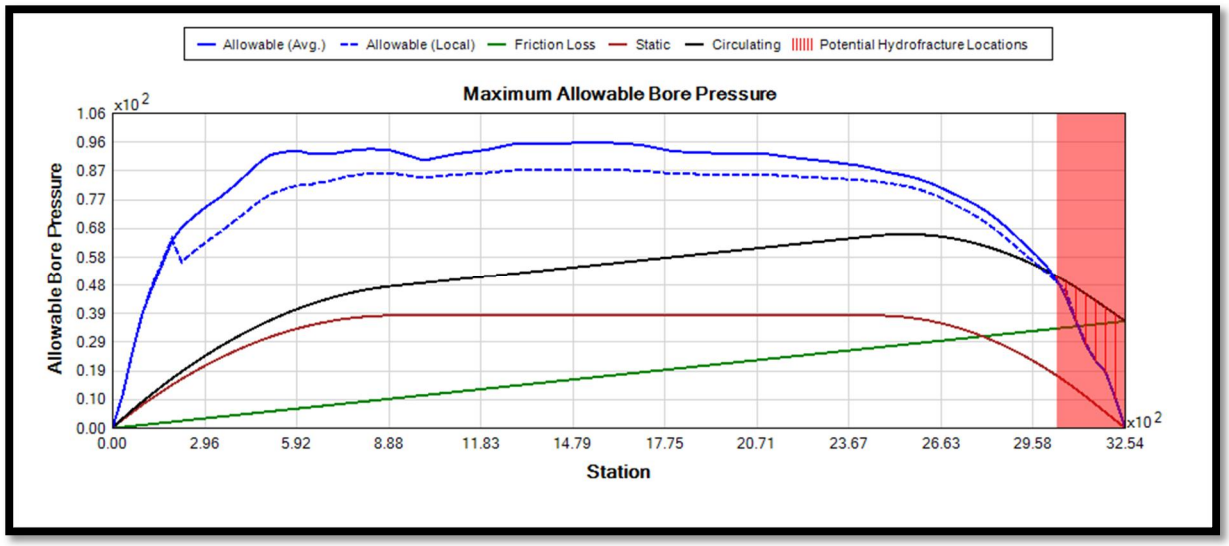

Figure 2: Force Main Maximum Allowable Bore Pressure Graph

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Introduction

On September 8, 2021, Manatee County authorized Kimley-Horn to provide utility engineering design services for the SR 684 (Cortez Road) water main and force main intracoastal crossing project. Cortez Road water main and force main intracoastal crossing project consists of relocating the 24-inch water main and 20-inch force main to the south side of the existing Cortez Bridge, outside of the proposed bridge alignment. To aid in the design of the directional drill bore path, Vermeer BoreAid version 5.0 (BoreAid) software was used to construct detailed plans with aspects such as load calculations, drilling fluids estimates, and requirements based on industry and Manatee County standards. Given the soil and environmental parameters, the 24-inch water main and the 20-inch force main were analyzed in BoreAid and provided a drill bore path that is reasonable for the drilling contractor to implement. The results of the calculations show that a Contractor could reasonably construct the proposed 24-inch water main and 20-inch force main via horizontal directional drill.

INPUT PARAMETERS

BoreAid was used to verify the Horizontal Directional Drill (HDD) bore path proposed for the 24-inch and 20-inch drills along Cortez Bridge. BoreAid requires several input parameters to be entered into the software to provide accurate results. The results include limiting pressures, evaluations of loads, and approximate frack-out areas. Multiple input parameters sections such as general information, surface topography, soil description, site specifications, and bore path configuration are required input parameters to yield bore path results. The 24-inch water main and the 20-inch force main were each analyzed separately.

General

The general parameter inputs in BoreAid include three sections, targets, pipe specifications, and drill rig. See Figure 3 and Figure 4 for the water main and force main general input parameters. The targets section includes the rig station, exit station, rig elevation, and exit elevation information. The difference in rig station and exit station equals the length of the drill, which is approximately 3,120 feet for the 24-inch water main and 3230 feet for the 20-inch force main. The rig elevation and the exit elevation are the surface elevations at the entrance and exit pit of the drills. The rig elevation for the water main is 5.61 feet, and the exit elevation is 4.3 feet. The rig elevation for the force main is 4.47 feet and the exit elevation is 4.2 feet.

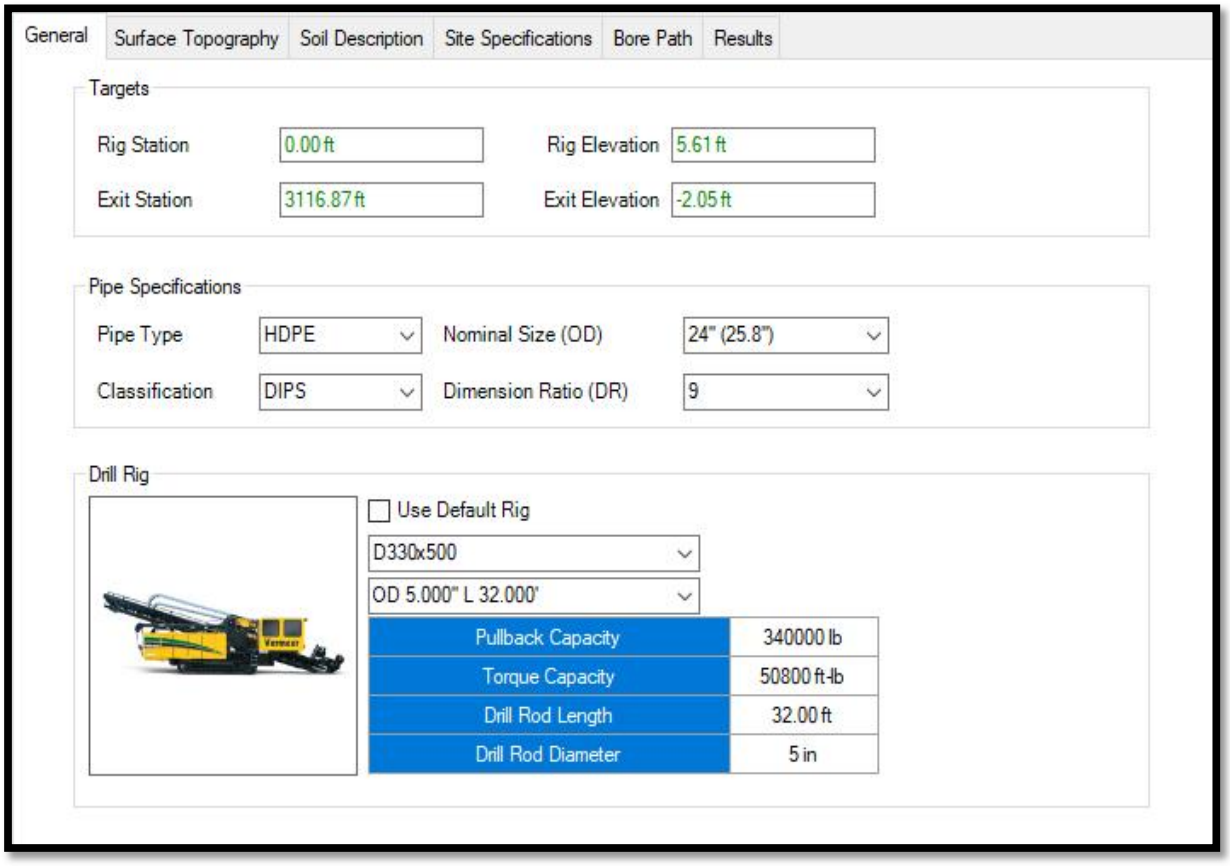


Figure 3: General Input Parameters for the 24-inch Water Main

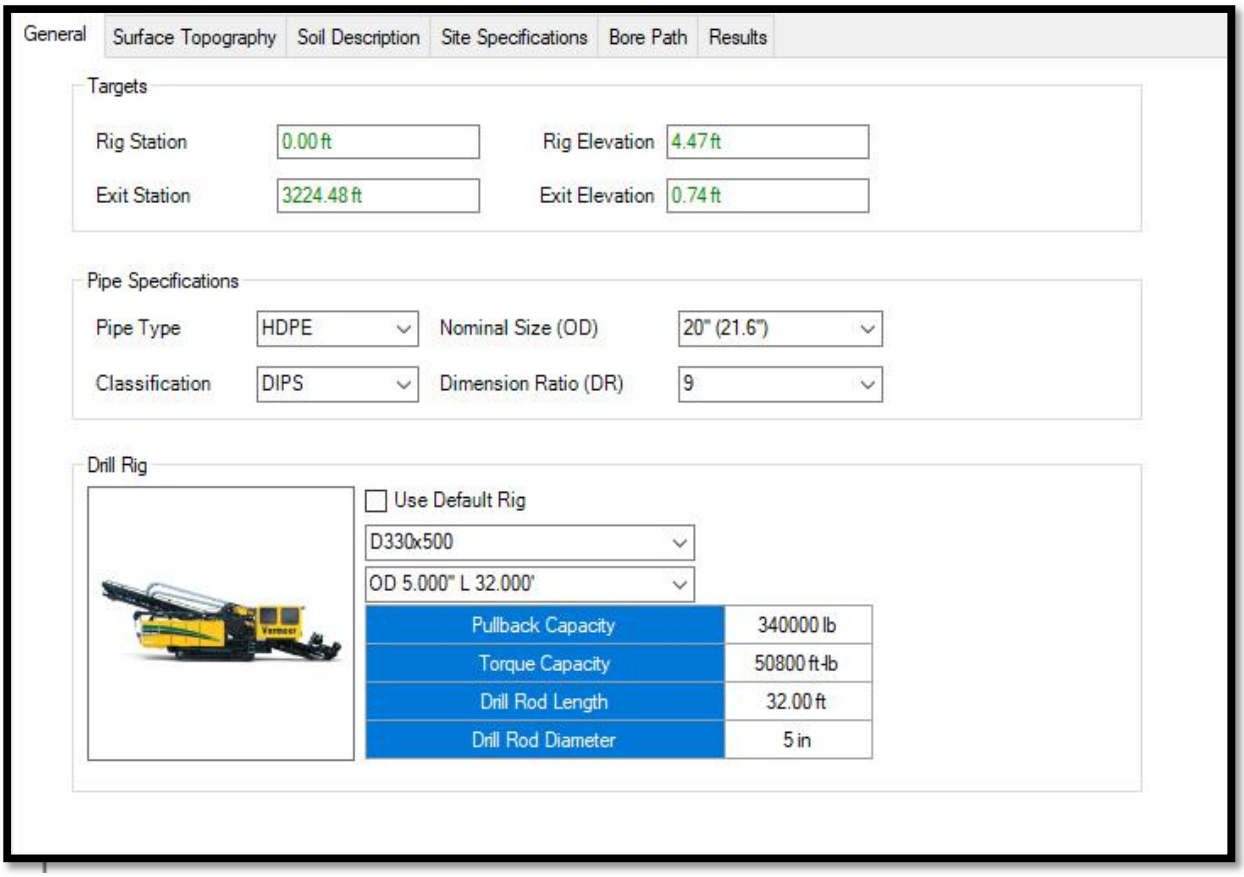


Figure 4: General Input Parameters for the 20-inch Force Main

The pipe specifications section includes the pipe type, classification, nominal size (outside diameter), and dimension ratio. The 24-inch water main drill uses High-Density Polyethylene (HDPE) pipe, has a nominal size (outside diameter) of 24 inches, a dimension ratio of nine (9), and is classified as ductile iron pipe (DIP). The 20-inch force main drill uses HDPE pipe, has a nominal size (outside diameter) of 20 inches, a dimension ratio of nine (9), and is classified as ductile iron pipe (DIP).

Both the 24-inch water main and 20-inch force main will utilize the D330x500 drill rig. The D330x500 drill rig has a drill rod diameter of five (5) inches and a drill rod length of 32 feet. The D330x500 drill rig has a 486hp/363kW Caterpillar C-15 Tier three (3) diesel engine which gives a ground-penetrating 50,000 ft-lb/67,800 Nm of rotational torque and 330,000 lbs/1,468 kN of thrust/pullback.

Surface Topography

BoreAid Topography Assistant was used to generate an accurate surface of the project. Figure 5 shows the surface topography, for the water main and force main, generated from distance and elevations points within the project's AutoCAD surface file. In AutoCAD, points were generated using the project's stations and elevations of the force main and water main alignments. BoreAid allows the station and depth points to regenerate the surface topography.

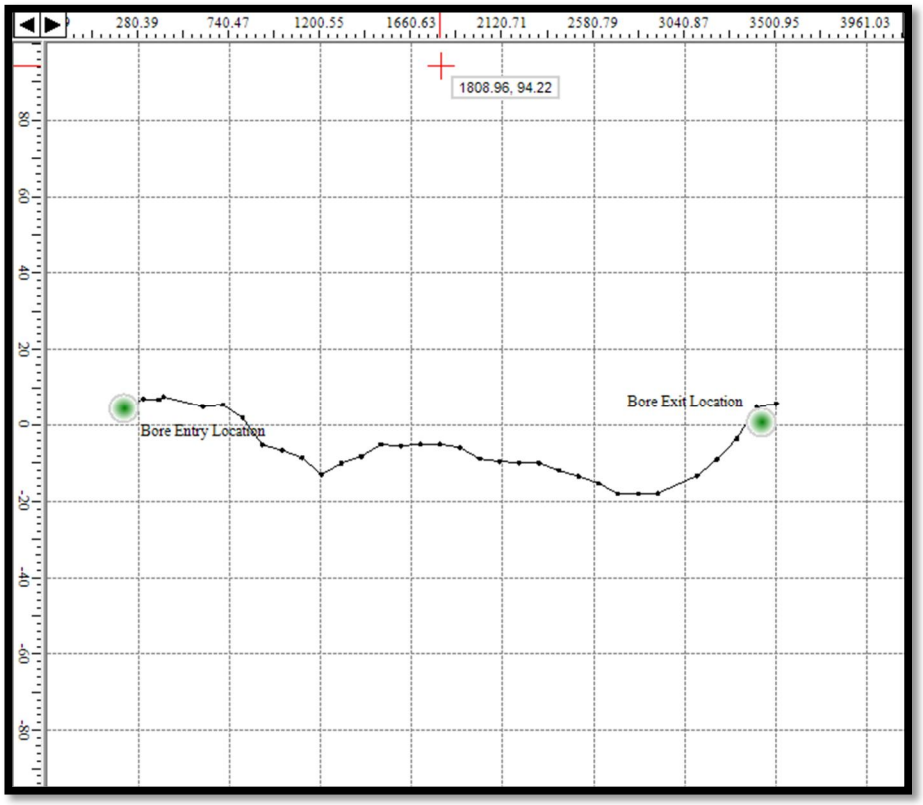


Figure 5: BoreAid Topography Assistant

Soil Description

The Soil Description section referenced the Ardaman & Associates, Inc. geotechnical report for the water main and force main intracoastal crossing along Cortez Road. BoreAid allows for one soil classification layer at a specific depth. The soil classifications used were the most conservative soil values per every ten (10) feet across each bore with the internal friction angle generated in the geotechnical report. Figure 6 shows the soil classification layers and depths with the proposed drill.

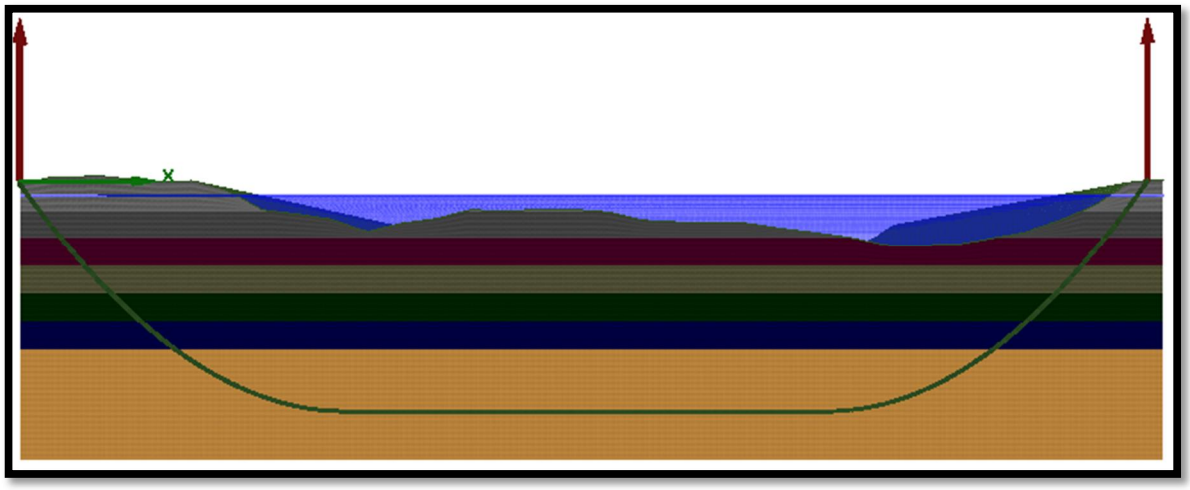


Figure 6: BoreAid Soil Description Section

Bore Path

The bore path section in BoreAid requires the depth of cover, entrance and exit angles, and bending radius for both the water main and force main drills. The 24-inch water main has a minimum cover of 50 feet, and the 20-inch force main has a minimum cover of 60 feet. Both the 20-inch force main and 24-inch water main have 10-degree inclination angles at the entrance and exit pit of the drill. The bending radius is approximately 5000 feet for west side (entrance) of the bore and approximately 4000 feet for the east side (exit) of the bore, for both the water main and force main. Figure 7 and Figure 8 show the 20-inch force main and 24-inch water main bore paths in BoreAid.

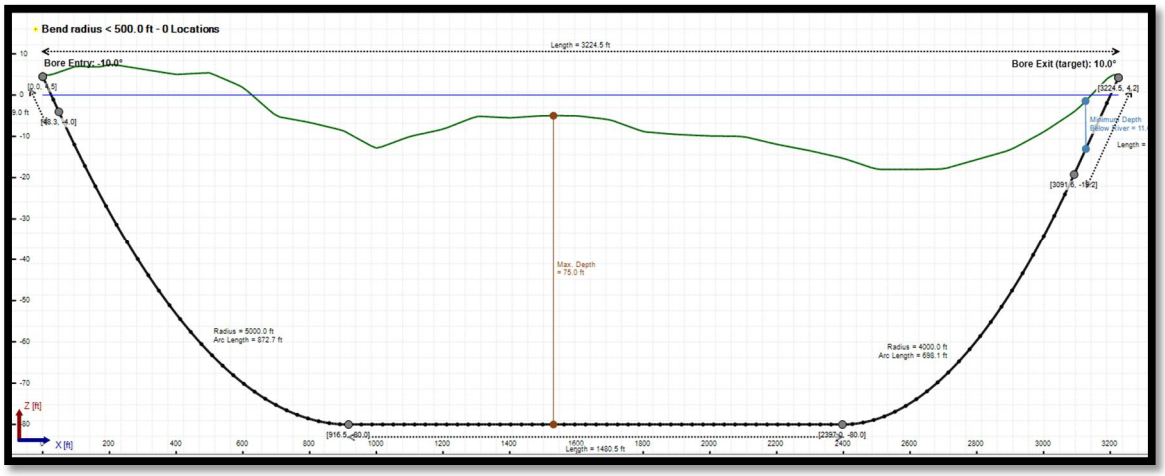


Figure 7: 20-Inch Force Main Bore Path

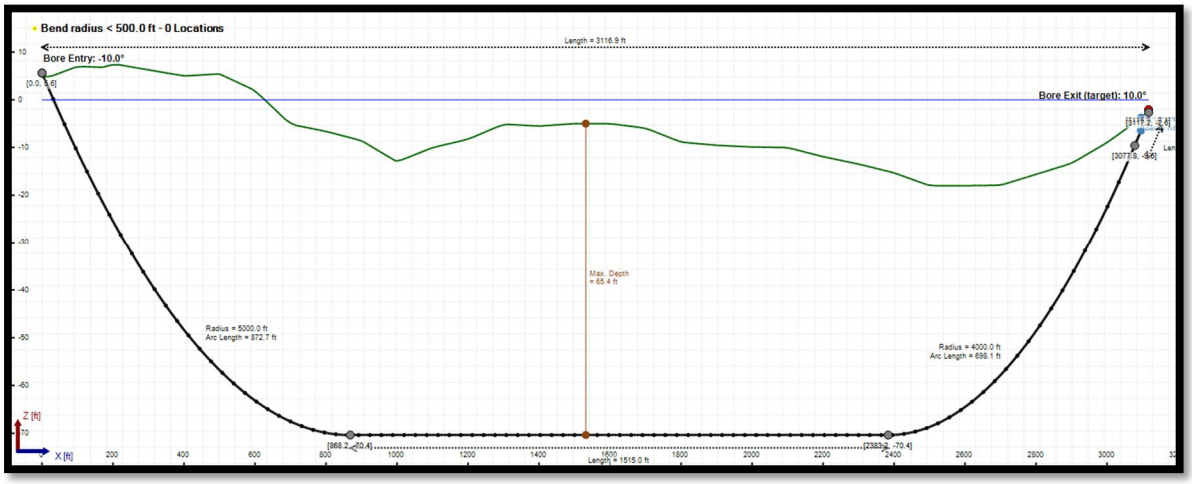


Figure 8: 24-Inch Water Main Bore Path

EVALUATION OF LOADS

Information

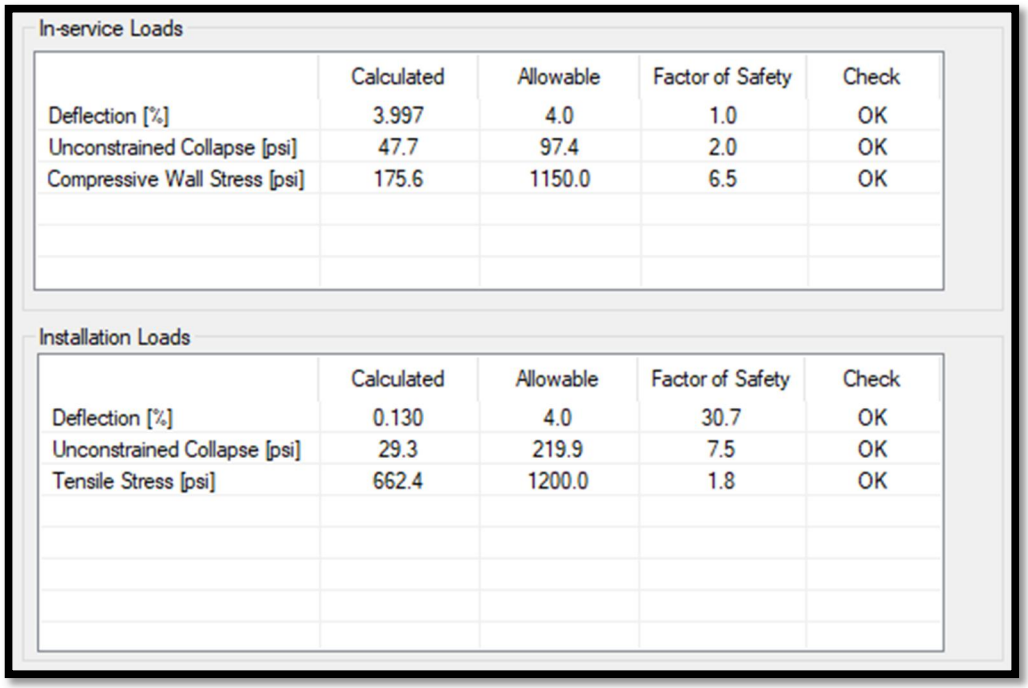
The load verifier section in BoreAid evaluates the in-service loads and installation loads for both the proposed HDD path of the force main and water main. The information provided from the loads and the installation parameters set in the bore tool section provide the evaluation of each drill as it pertains to the in-service loads and installation loads.

In-Service Loads

The in-service load section uses categories such as deflection, unconstrained collapse, and compressive wall stress to provide results in calculated load, allowable load, factor of safety, and load check for each drill. The in-service loads are the actual loads that will be assumed to act on the pipe when the pipe is in service.

Installation Loads

The installation load section also displays the three categories (deflection, unconstrained collapse, and compressive wall stress) to provide its own calculated load, allowable load, factor of safety, and check load. The installation load includes the weight of the pipe proper, the content that the pipe carries as it is being installed, with all the pipe fittings attached to the pipe, and the pipe covering or lining. The installation load also considers, in the calculation, the additional features, such as the ballast and rollers needed to help offset friction pressure when installing the pipes. Figure 9 and Figure 10 show the load categories and results for the 20-inch force main and 24-water main drills.



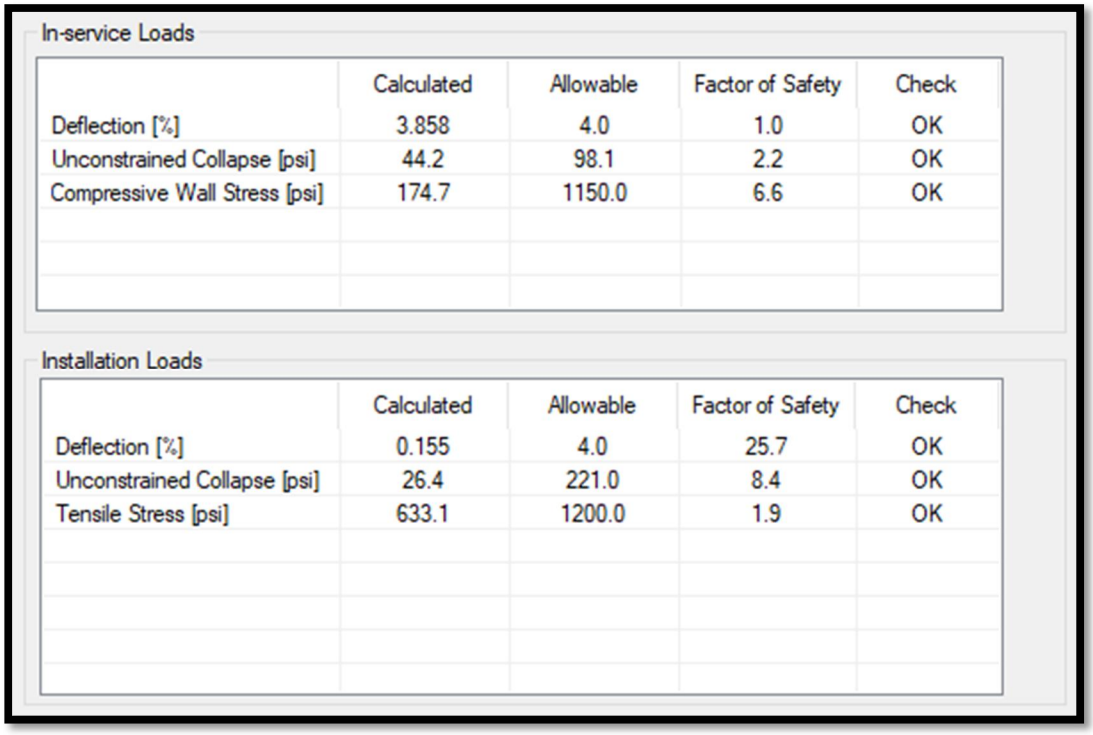
In-service Loads

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	3.997	4.0	1.0	OK
Unconstrained Collapse [psi]	47.7	97.4	2.0	OK
Compressive Wall Stress [psi]	175.6	1150.0	6.5	OK

Installation Loads

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	0.130	4.0	30.7	OK
Unconstrained Collapse [psi]	29.3	219.9	7.5	OK
Tensile Stress [psi]	662.4	1200.0	1.8	OK

Figure 9: In-service and Installation Load Results for the 20-Inch Force Main Drill



In-service Loads

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	3.858	4.0	1.0	OK
Unconstrained Collapse [psi]	44.2	98.1	2.2	OK
Compressive Wall Stress [psi]	174.7	1150.0	6.6	OK

Installation Loads

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	0.155	4.0	25.7	OK
Unconstrained Collapse [psi]	26.4	221.0	8.4	OK
Tensile Stress [psi]	633.1	1200.0	1.9	OK

Figure 10: In-service and Installation Load Results for the 24-Inch Water Main Drill

DRILL SEQUENCE EVALUATIONS

Drill Sequence

The drill sequence section in BoreAid is comprised of the pilot bore diameter and drill time information. Both the 20-inch force main and 24-inch water main use a 13-inch pilot bore diameter. The main purpose of the pilot bore is to map the predetermined path of the pipe installation. Having a larger pilot bore diameter will allow the initial horizontal hole drilled along the intended route to reduce frack out in the exit pit area. The pilot bore diameter and drill time also factor in determining the deflection and unconstrained collapse values within the load verifier section. Figure 11 shows the ream sequence and the input parameters.

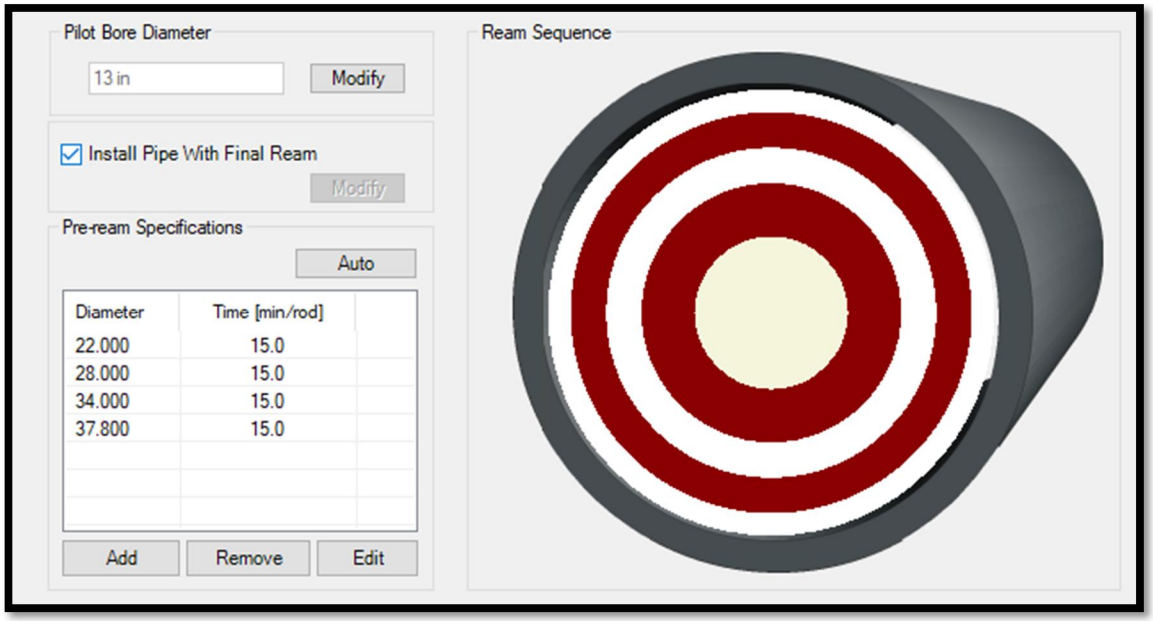


Figure 11: Drill Sequence section in BoreAid

Drill Time

The drill sequence drill time for both the 24-inch water main and 20-inch force main is 15 min/rod. The drill time is time required in rotary drilling for the bit to penetrate a specified thickness (usually 1 foot) of rock. The 15 min/rod drill time directly impacts the frack out area. The longer the drill time, the less frack out are at the exit pit.

Pressure Analysis

Maximum Allowable Bore Pressure

In the Limiting Pressure section of BoreAid, the maximum allowable bore pressure, friction loss, static pressure, and circulating pressure are calculated and converted into a graph measuring the allowable bore pressure versus the bore path stationing. The maximum allowable bore pressure is calculated using average and local soil strength parameters in the case of multiple soil layers. The average value estimates the maximum allowable bore pressure using depth-weighted average soil strength parameters and the 'Local' value estimates the maximum allowable bore pressure using the strength parameters of the soil at the given depth of the bore.

Estimated Bore Pressure

The estimated bore pressure uses the automated calculated flow rate (Q) of 280 US Gallon/minute and drill fluid density of 0.03974 lb/in3. These values factor into the maximum allowable bore pressure graph showing the allowable average, allowable local, friction loss, static and circulating pressures. Figure 12 and Figure 13 show the graph of the maximum allowable bore pressure for the force main and water main.

The deepest drill proposed is for the force main at a minimum 60-foot depth. The maximum allowable bore pressure (average) for the force main is approximately 101.786 pounds per square inch (PSI). The maximum circulating pressure for the force main, which is the pressure generated from static and friction losses, is approximately 56.99 PSI. The remaining estimated Factor of Safety between the allowable bore pressure and the circulating pressure is 44.80 PSI.

The water main drill is approximately 50 feet deep. The maximum allowable bore pressure (average) for the water main is approximately 92.15 PSI. The maximum circulating pressure for the force main, which is the pressure generated from static and friction losses, is approximately 49.53 PSI. The remaining estimated Factor of Safety between the allowable bore pressure and the circulating pressure is 42.62 PSI.

The shaded red area shows the area of frac-out at the drill entrance and exit pit. The frac-out area will extend further along the exit pit due to the pressure within the borehole (annular pressure) exceeds what the formation can withstand.

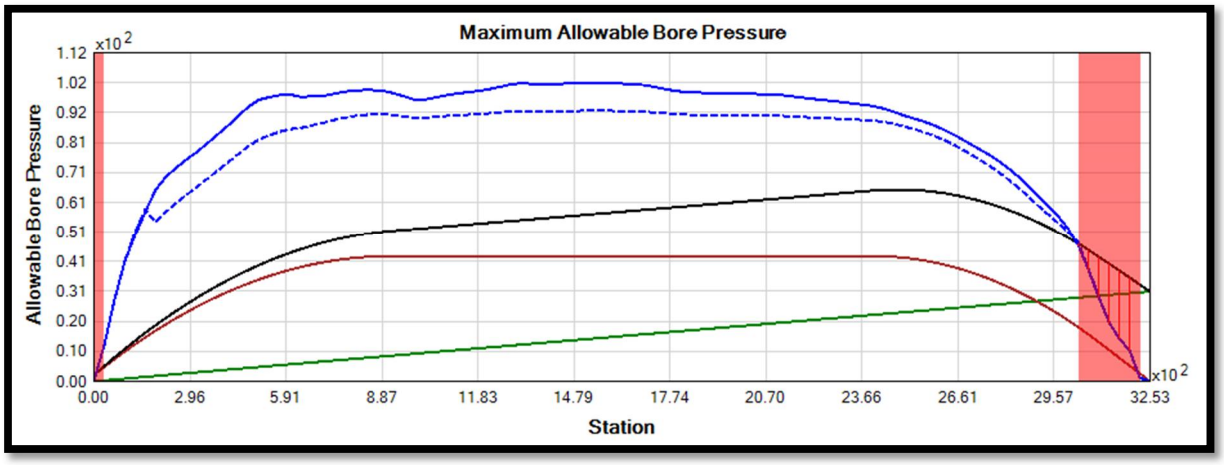


Figure 12: Force Main Maximum Allowable Bore Pressure Graph

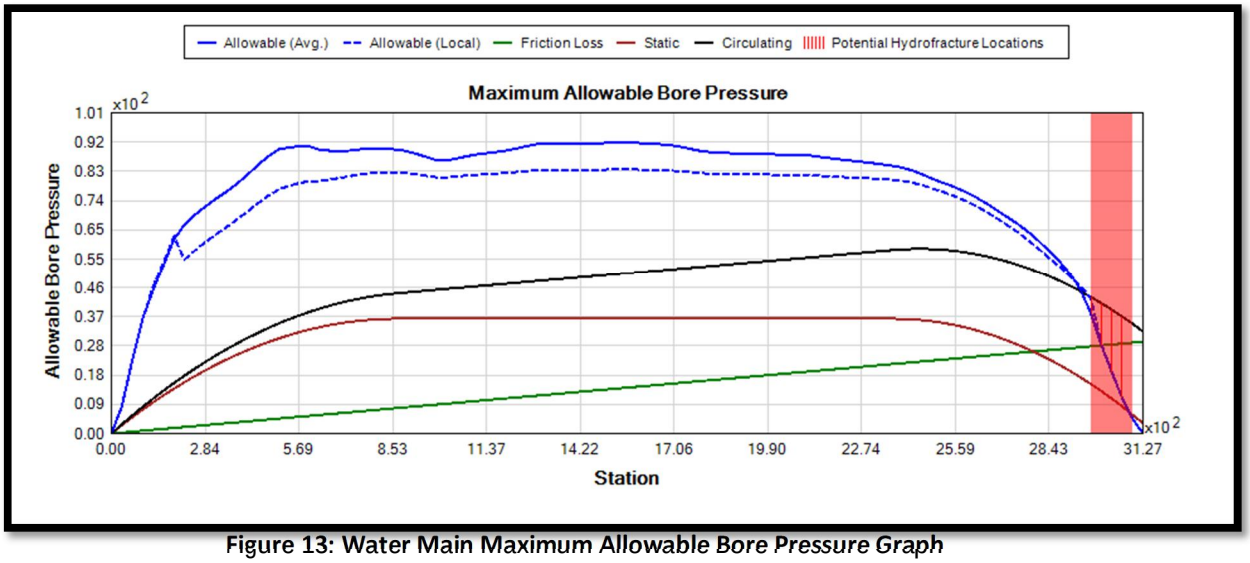


Figure 13: Water Main Maximum Allowable Bore Pressure Graph

Summary

BoreAid was used to assess the 20-inch force main and 24-inch water main drill along the Cortez bridge. With the geotechnical report and input parameters based on the surrounding environment, both drills should have structural integrity while drilling across the intracoastal waterway.

According to the input parameters and load evaluation, both drills require at least a 12-inch pilot bore diameter, with the drill time averaging 15 rod/ min. The drills for both the 20-inch force main and the 24-inch water main maintain a radius of approximately 5,000 feet on the west side of the drill (entrance) and 4,000 feet on the east side of the drill (exit). The minimum drill depth of the water main is 50 feet, and the minimum depth of the force main is 60 feet. These inputs yield a reasonable maximum allowable pressure and maximum allowable bore pressure. The maximum allowable pressure, friction loss, and circulating pressure are directly related to the drill sequence inputs provided and, therefore, directly correlate to the frack-out area in the exit pit area. Appendix A provides the full report of the BoreAid results.

References

1. Vermeer. (n.d.). Version (5.0). *Vermeer BoreAid*. Retrieved January 30, 2023, from https://store.vermeer.com/navigation-items/products/vermeer-boreaid%C2%AE-design-tool.

2. Autodesk. (2022). Autodesk Autocad Civil 3D 2022. computer software, San Rafael (Calif.).

Generated Output

WARNING: The accuracy of the data obtained by the BoreAid® system is highly dependent upon accurate data gathering, data input and proper use of the software. Vermeer is not responsible for that information. BoreAid® data is not intended to replace the need for future on-site utility locating, measuring and verification procedures, which are essential for accurate placement of new underground installations and avoidance of existing utilities.

CALL YOUR ONE-CALL SYSTEM FIRST

WARNING: Always contact your local One-Call system before the start of your digging project. The BoreAid® system is intended to be used with other utility locating methods, such as the use of the One-Call system and the exposing of existing utilities by potholing.

Locate utilities before drilling. Call 811 (U.S. only) or 1-888-258-0808 (U.S. or Canada) or local utility companies or national regulating authority.

Before you start any digging project, do not forget to call the local One-Call system in your area and any utility company that does not subscribe to the One-Call system. For areas not represented by One-Call Systems International, contact the appropriate utility companies or national regulating authority to locate and mark the underground installations. If you do not call, you may have an accident or suffer injuries; cause interruption of services; damage the environment; or experience job delays.

OSHA CFR 29 1926.651 requires that the estimated location of underground utilities be determined before beginning the excavation or underground drilling operation. When the actual excavation or bore approaches an estimated utility location, the exact location of the underground installation must be determined by a safe, acceptable and dependable method. If the utility cannot be precisely located, it must be shut off by the utility company.

Project Summary

General:	CORTEZ BRIDGE WM AND FM CROSSING Start Date: 03-19-2024 End Date: 01-27-2023
Designer:	
Description:	WATER MAIN DRILL FOR THE CORTEZ BRIDGE CROSSING

Input Summary

Start Coordinate	(0.00, 0.00, 5.61) ft
End Coordinate	(3116.87, 0.00, 4.30) ft
Project Length	3116.87 ft
Pipe Type	HDPE
OD Classification	DIPS
Pipe OD	25.800 in
Pipe DR	9.0
Pipe Thickness	2.87 in
Rod Length	32.00 ft
Rod Diameter	5 in
Drill Rig Location	(0.00, 0.00, 0.00) ft

Soil Summary

Number of Layers: 10

Soil Layer #1 USCS, Sand (S), SP
Depth: 10.00 ft
Unit Weight: 0.0634 (dry), 0.0610 (sat) [lb/in3]
Phi: 27.00, S.M.: 145.00, Coh: 0.00 [psi]

Soil Layer #2 USCS, Sand (S), SP
Depth: 10.00 ft
Unit Weight: 0.0634 (dry), 0.0625 (sat) [lb/in3]
Phi: 27.00, S.M.: 145.00, Coh: 0.00 [psi]

Soil Layer #3 USCS, Sand (S), SP
Depth: 10.00 ft
Unit Weight: 0.0634 (dry), 0.0665 (sat) [lb/in3]
Phi: 28.00, S.M.: 145.00, Coh: 0.00 [psi]

Soil Layer #4 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0610 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #5 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0610 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #6 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0723 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #7 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0735 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #8 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0752 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #9 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0763 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #10 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0769 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Bore Path Info

Section No.

Curve in Section View - Straight in Plan View
Start Location: (,,) ft
End Location: (,,) ft
Inclination Angle: (Start = Deg., End = Deg.)
Azimuth Angle: (Start = Deg., End = Deg.)
Bend Radius = ft
Number of drill rods in segement =

Section No.

Straight in Section View - Straight in Plan View
Start Location: (,,) ft
End Location: (,,) ft
Inclination Angle: (Start = Deg., End = Deg.)
Azimuth Angle: (Start = Deg., End = Deg.)
Number of drill rods in segement =

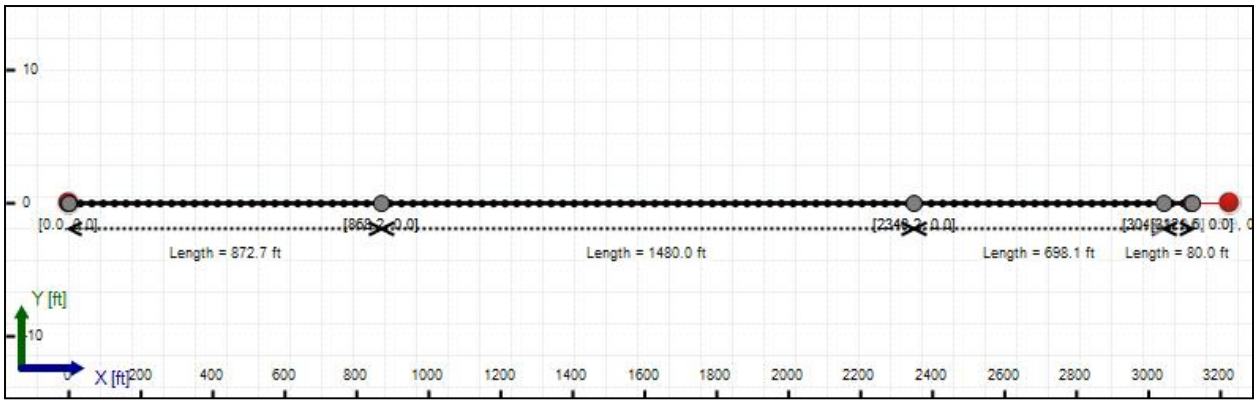
Section No.

Curve in Section View - Straight in Plan View
Start Location: (,,) ft
End Location: (,,) ft
Inclination Angle: (Start = Deg., End = Deg.)
Azimuth Angle: (Start = Deg., End = Deg.)
Bend Radius = ft
Number of drill rods in segement =

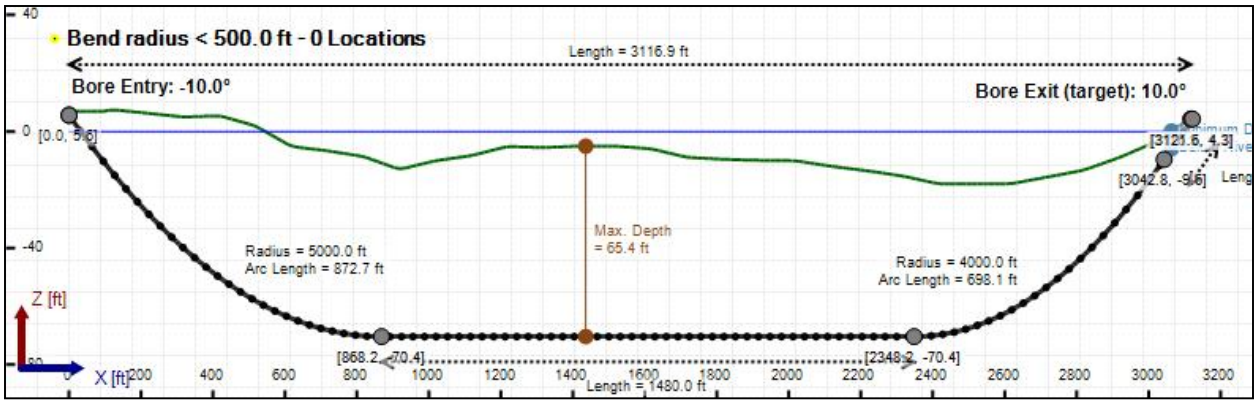
Section No.

Straight in Section View - Straight in Plan View
Start Location: (,,) ft
End Location: (,,) ft
Inclination Angle: (Start = Deg., End = Deg.)
Azimuth Angle: (Start = Deg., End = Deg.)
Number of drill rods in segement =

Bore Plan View



Bore Cross-Section View



Load Verifier Input Summary:

Pipe Application: Sewer
Pipe Type: HDPE
Classification: DIPS
Pipe OD: 24" (25.8")
Pipe DR: 9
Pipe Length: 3136.00 ft
Internal Pressure: 5 psi
Borehole Diameter: 3.15000025431315 ft
Silo Width: 3.15000025431315 ft
Surface Surcharge: 0 psi
Short Term Modulus: 57500 psi
Long Term Modulus: 28200 psi
Short Term Poisson Ratio: 0.35
Long Term Poisson Ratio: 0.45
Pipe Unit Weight: 0.03432 lb/in3
Allowable Tensile Stress (Short Term): 1200 psi
Allowable Tensile Stress (Long Term): 1100 psi
Allowable Compressive Stress (Short Term): 1150 psi
Allowable Compressive Stress (Long Term): 1150 psi
Surface-pipe friction coefficient at entrance: 0.1
Surface-pipe friction coefficient in borehole: 0.3
Pipe-soil friction angle: 30
Slurry Unit Weight: 0.05419 lb/in3
Hydrokinetic Pressure: 10 psi
Ballast Unit Weight: 0.03613 lb/in3

In-service Load Summary:

Pressure [psi]	Deformed	Collapsed
Earth Pressure	12.9	24.2
Water Pressure	30.4	30.5
Surface Surcharge	0.0	0.0
Internal Pressure	5.0	5.0
Net Pressure	38.3	49.7
Deflection		
Earth Load Deflection	3.541	6.593
Bouyant Deflection	0.317	0.317
Reissner Effect	0	0
Net Deflection	3.858	6.910
Compressive Stress [psi]		
Compressive Wall Stress	174.7	226.2

Installation Load Summary:

Forces/Stresses	@Maximum Force	Absolute Maximum
Pullback Force [lb]	128846.1	128846.1
Pullback Stress [psi]	623.8	623.8
Pullback Strain	1.085E-2	1.085E-2
Bending Stress [psi]	12.4	15.5
Bending Strain	2.150E-4	2.688E-4
Tensile Stress [psi]	636.2	636.2
Tensile Strain	1.128E-2	1.128E-2

Net External Pressure = 10.0 [psi]

Bouyant Deflection = 0.2

Hydrokinetic Force = 2997.1 lb

In-service Analysis

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	3.858	4.0	1.0	OK
Unconstrained Collapse [psi]	44.2	98.1	2.2	OK
Compressive Wall Stress [psi]	174.7	1150.0	6.6	OK

Installation Analysis

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	0.155	4.0	25.7	OK
Unconstrained Collapse [psi]	26.4	221.0	8.4	OK
Tensile Stress [psi]	633.1	1200.0	1.9	OK

Drill Planner Input Summary:

Bore Length: 3136.00 ft
Pipe Diameter: 24" (25.8")
Overcut Ratio: 1.50
Maximum Reamer Size: 3.15 ft
Drill Rod Length: 32.00 ft
Drill Fluid / Soil Ratio: 2.5
Specified Maximum Pump Rate: 350.00 US (liquid) gallon/min
Pump Efficiency: 80.00 %
Drill Fluid Tank Volume: 1750.00 US (liquid) gallon

Reaming Sequence Summary:

Pilot Bore: 13.000 in @ 5.00 min/rod
Reamer Pass #1: 22.000 in @ 15.00 min/rod
Reamer Pass #2: 28.000 in @ 15.00 min/rod
Reamer Pass #3: 34.000 in @ 15.00 min/rod
Reamer Pass #4: 37.800 in @ 15.00 min/rod

Drill Planner Results Summary

Ream	Diameter [in]	Soil Volume [US (liquid) gallon]	Fluid Volume [US (liquid) gallon]	Time/Rod [min/rod]
Pilot Bore	13	220.6	551.6	5.0
1	22	411.3	1028.2	15.0
2	28	391.7	979.2	15.0
3	34	485.7	1214.2	15.0
4	37.7999992370605	356.2	890.5	15.0

Ream	Fluid Rate [US (liquid) gallon/min]	# Tanks	Drill Time [hr]	Check
Pilot Bore	110.3	30.9	8.2	OK
1	68.5	57.6	24.5	OK
2	65.3	54.8	24.5	OK
3	80.9	68.0	24.5	OK
4	59.4	49.9	24.5	OK

Total Drill Time: 106.2 hr

Total Volume of Drill Fluid: 457044.8 US (liquid) gallon

Total Number of Tanks: 261.2

Maximum Allowable Bore Pressure Summary

Ream Number	Initial Diameter	Final Diameter	Estimated Maximum Pressure (Avg.)	Estimated Maximum Pressure (Local)
Pilot Bore	0.00 in	13.00 in	92.150 psi	83.806 psi
1	13.00 in	22.00 in	92.091 psi	83.732 psi
2	22.00 in	28.00 in	92.035 psi	83.663 psi
3	28.00 in	34.00 in	91.966 psi	83.578 psi
4	34.00 in	37.80 in	91.916 psi	83.516 psi

Note: The maximum bore pressures presented in this table are the maximum values along the length of the bore and not the maximum allowable at any point. The estimated maximum pressures should be compared to the estimated circulating pressures along the bore to determine potential locations of inadvertant returns.

Estimated Circulating Pressure Summary

Active	Shear Rate [rpm]	Shear Stress [Fann Degrees]
No	600	37
No	300	32
No	200	29
Yes	100	25
Yes	6	17
No	3	15

Flow Rate (Q): 280.00 US (liquid) gallon/min

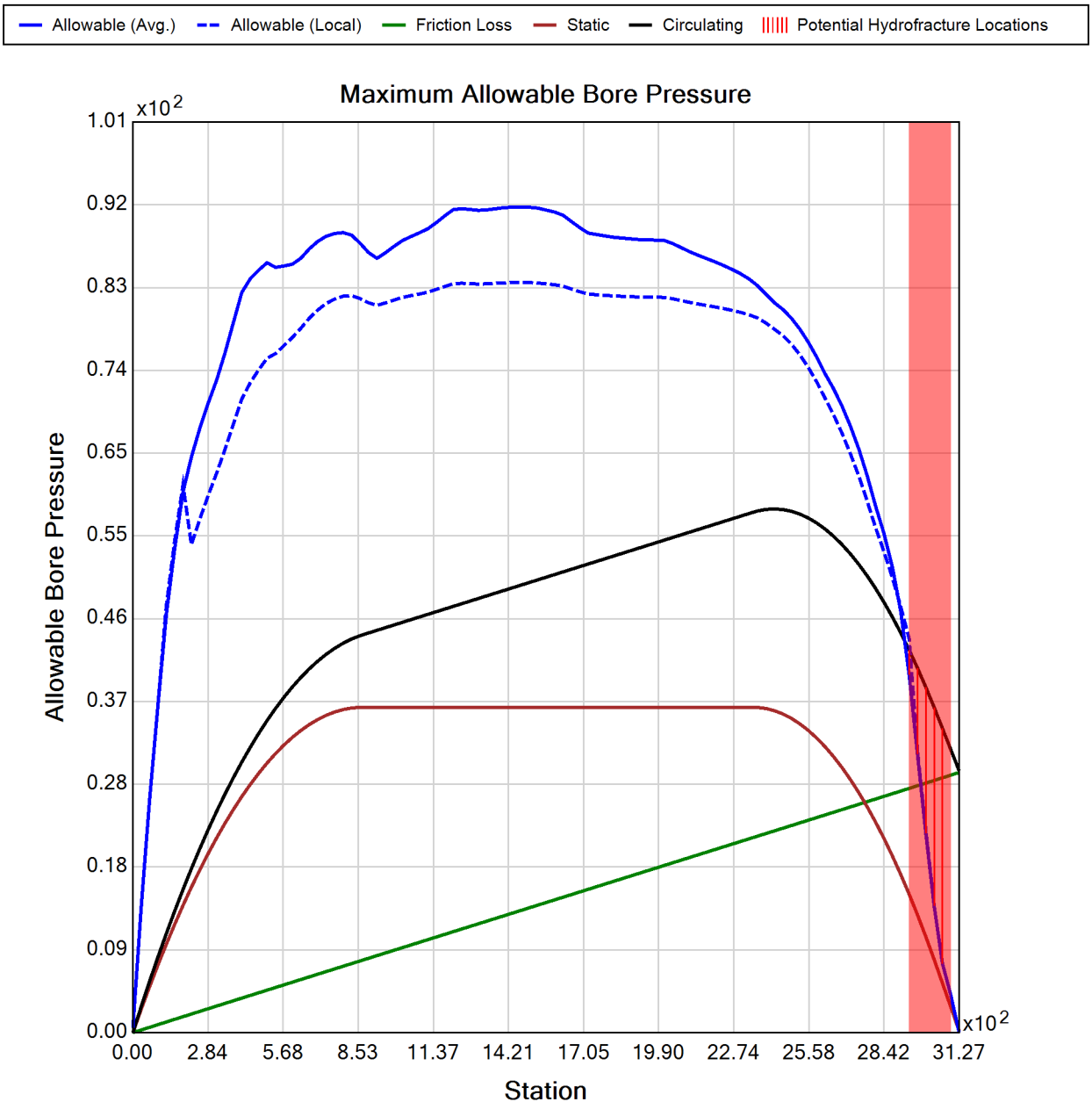
Drill Fluid Density: 0.040 lb/in3

Rheological model: Power-Law

Fluid Consistency Index (K): 63.17

Power Law Exponent (n): 0.14

Effective Viscosity (cP): 636.9



Generated Output

WARNING: The accuracy of the data obtained by the BoreAid® system is highly dependent upon accurate data gathering, data input and proper use of the software. Vermeer is not responsible for that information. BoreAid® data is not intended to replace the need for future on-site utility locating, measuring and verification procedures, which are essential for accurate placement of new underground installations and avoidance of existing utilities.

CALL YOUR ONE-CALL SYSTEM FIRST

WARNING: Always contact your local One-Call system before the start of your digging project. The BoreAid® system is intended to be used with other utility locating methods, such as the use of the One-Call system and the exposing of existing utilities by potholing.

Locate utilities before drilling. Call 811 (U.S. only) or 1-888-258-0808 (U.S. or Canada) or local utility companies or national regulating authority.

Before you start any digging project, do not forget to call the local One-Call system in your area and any utility company that does not subscribe to the One-Call system. For areas not represented by One-Call Systems International, contact the appropriate utility companies or national regulating authority to locate and mark the underground installations. If you do not call, you may have an accident or suffer injuries; cause interruption of services; damage the environment; or experience job delays.

OSHA CFR 29 1926.651 requires that the estimated location of underground utilities be determined before beginning the excavation or underground drilling operation. When the actual excavation or bore approaches an estimated utility location, the exact location of the underground installation must be determined by a safe, acceptable and dependable method. If the utility cannot be precisely located, it must be shut off by the utility company.

Project Summary

General:	CORTEZ BRIDGE WM AND FM CROSSING Start Date: 03-27-2023 End Date: 01-27-2023
Designer:	
Description:	CORTEZ BRIDGE FM CROSSING

Input Summary

Start Coordinate	(0.00, 0.00, 4.47) ft
End Coordinate	(3224.48, 0.00, 4.20) ft
Project Length	3224.48 ft
Pipe Type	HDPE
OD Classification	DIPS
Pipe OD	21.600 in
Pipe DR	9.0
Pipe Thickness	2.40 in
Rod Length	32.00 ft
Rod Diameter	5 in
Drill Rig Location	(0.00, 0.00, 0.00) ft

Soil Summary

Number of Layers: 10

Soil Layer #1 USCS, Sand (S), SP
Depth: 10.00 ft
Unit Weight: 0.0634 (dry), 0.0610 (sat) [lb/in3]
Phi: 27.00, S.M.: 145.00, Coh: 0.00 [psi]

Soil Layer #2 USCS, Sand (S), SP
Depth: 10.00 ft
Unit Weight: 0.0634 (dry), 0.0625 (sat) [lb/in3]
Phi: 27.00, S.M.: 145.00, Coh: 0.00 [psi]

Soil Layer #3 USCS, Sand (S), SP
Depth: 10.00 ft
Unit Weight: 0.0634 (dry), 0.0665 (sat) [lb/in3]
Phi: 28.00, S.M.: 145.00, Coh: 0.00 [psi]

Soil Layer #4 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0610 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #5 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0610 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #6 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0723 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #7 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0735 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #8 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0752 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #9 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0763 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Soil Layer #10 USCS, Clay (C), CL
Depth: 10.00 ft
Unit Weight: 0.0620 (dry), 0.0769 (sat) [lb/in3]
Phi: 0.00, S.M.: 145.00, Coh: 7.30 [psi]

Bore Path Info

Section No.

Straight in Section View - Straight in Plan View

Start Location: (,,) ft

End Location: (,,) ft

Inclination Angle: (Start = Deg., End = Deg.)

Azimuth Angle: (Start = Deg., End = Deg.)

Number of drill rods in segement =

Section No.

Curve in Section View - Straight in Plan View

Start Location: (,,) ft

End Location: (,,) ft

Inclination Angle: (Start = Deg., End = Deg.)

Azimuth Angle: (Start = Deg., End = Deg.)

Bend Radius = ft

Number of drill rods in segement =

Section No.

Straight in Section View - Straight in Plan View

Start Location: (,,) ft

End Location: (,,) ft

Inclination Angle: (Start = Deg., End = Deg.)

Azimuth Angle: (Start = Deg., End = Deg.)

Number of drill rods in segement =

Section No.

Curve in Section View - Straight in Plan View

Start Location: (,,) ft

End Location: (,,) ft

Inclination Angle: (Start = Deg., End = Deg.)

Azimuth Angle: (Start = Deg., End = Deg.)

Bend Radius = ft

Number of drill rods in segement =

Section No.

Straight in Section View - Straight in Plan View

Start Location: (,,) ft

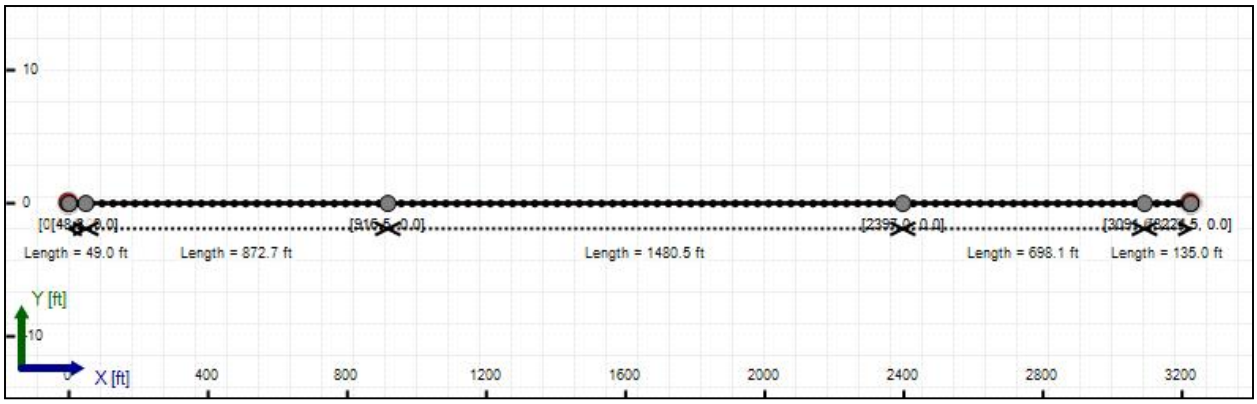
End Location: (,,) ft

Inclination Angle: (Start = Deg., End = Deg.)

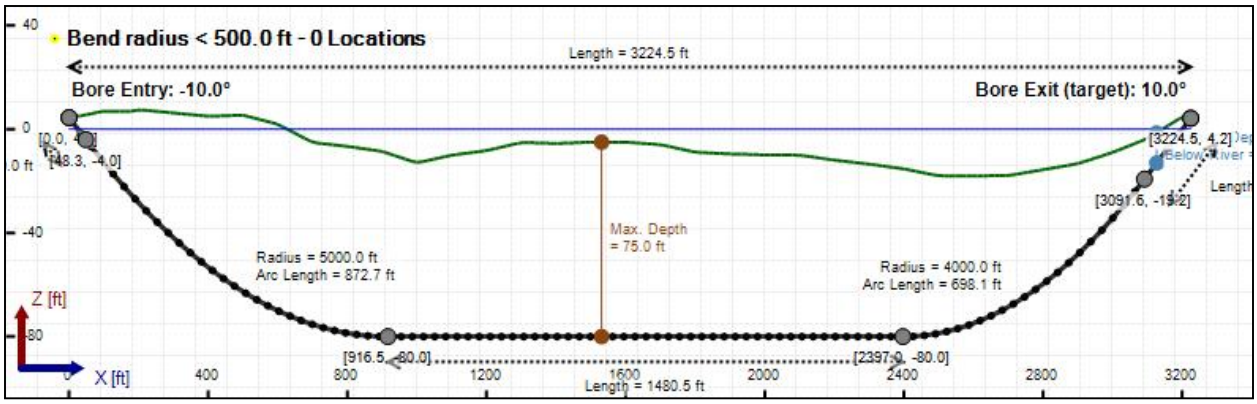
Azimuth Angle: (Start = Deg., End = Deg.)

Number of drill rods in segement =

Bore Plan View



Bore Cross-Section View



Load Verifier Input Summary:

Pipe Application: Sewer
Pipe Type: HDPE
Classification: DIPS
Pipe OD: 20" (21.6")
Pipe DR: 9
Pipe Length: 3264.00 ft
Internal Pressure: 10 psi
Borehole Diameter: 2.70000012715658 ft
Silo Width: 2.70000012715658 ft
Surface Surcharge: 0 psi
Short Term Modulus: 57500 psi
Long Term Modulus: 28200 psi
Short Term Poisson Ratio: 0.35
Long Term Poisson Ratio: 0.45
Pipe Unit Weight: 0.03432 lb/in3
Allowable Tensile Stress (Short Term): 1200 psi
Allowable Tensile Stress (Long Term): 1100 psi
Allowable Compressive Stress (Short Term): 1150 psi
Allowable Compressive Stress (Long Term): 1150 psi
Surface-pipe friction coefficient at entrance: 0.1
Surface-pipe friction coefficient in borehole: 0.3
Pipe-soil friction angle: 30
Slurry Unit Weight: 0.05419 lb/in3
Hydrokinetic Pressure: 10 psi
Ballast Unit Weight: 0.03613 lb/in3

In-service Load Summary:

Pressure [psi]	Deformed	Collapsed
Earth Pressure	13.7	28.6
Water Pressure	34.2	34.7
Surface Surcharge	0.0	0.0
Internal Pressure	10.0	10.0
Net Pressure	37.9	53.3
Deflection		
Earth Load Deflection	3.732	7.791
Bouyant Deflection	0.265	0.265
Reissner Effect	0	0
Net Deflection	3.997	8.057
Compressive Stress [psi]		
Compressive Wall Stress	175.6	244.8

Installation Load Summary:

Forces/Stresses	@Maximum Force	Absolute Maximum
Pullback Force [lb]	94963.0	94963.0
Pullback Stress [psi]	656.0	656.0
Pullback Strain	1.141E-2	1.141E-2
Bending Stress [psi]	0.0	12.9
Bending Strain	0	2.250E-4
Tensile Stress [psi]	656.0	662.4
Tensile Strain	1.141E-2	1.170E-2

Net External Pressure = 11.0 [psi]

Bouyant Deflection = 0.1

Hydrokinetic Force = 2290.2 lb

In-service Analysis

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	3.997	4.0	1.0	OK
Unconstrained Collapse [psi]	47.7	97.4	2.0	OK
Compressive Wall Stress [psi]	175.6	1150.0	6.5	OK

Installation Analysis

	Calculated	Allowable	Factor of Safety	Check
Deflection [%]	0.130	4.0	30.7	OK
Unconstrained Collapse [psi]	29.3	219.9	7.5	OK
Tensile Stress [psi]	662.4	1200.0	1.8	OK

Drill Planner Input Summary:

Bore Length: 3264.00 ft
Pipe Diameter: 20" (21.6")
Overcut Ratio: 1.50
Maximum Reamer Size: 2.70 ft
Drill Rod Length: 32.00 ft
Drill Fluid / Soil Ratio: 2.5
Specified Maximum Pump Rate: 350.00 US (liquid) gallon/min
Pump Efficiency: 80.00 %
Drill Fluid Tank Volume: 1750.00 US (liquid) gallon

Reaming Sequence Summary:

Pilot Bore: 13.000 in @ 15.00 min/rod
Reamer Pass #1: 22.000 in @ 15.00 min/rod
Reamer Pass #2: 28.000 in @ 15.00 min/rod
Reamer Pass #3: 32.400 in @ 15.00 min/rod

Drill Planner Results Summary

Ream	Diameter [in]	Soil Volume [US (liquid) gallon]	Fluid Volume [US (liquid) gallon]	Time/Rod [min/rod]
Pilot Bore	13	220.6	551.6	15.0
1	22	411.3	1028.2	15.0
2	28	391.7	979.2	15.0
3	32.4000015258789	347.0	867.4	15.0

Ream	Fluid Rate [US (liquid) gallon/min]	# Tanks	Drill Time [hr]	Check
Pilot Bore	36.8	32.2	25.5	OK
1	68.5	59.9	25.5	OK
2	65.3	57.1	25.5	OK
3	57.8	50.6	25.5	OK

Total Drill Time: 102.0 hr

Total Volume of Drill Fluid: 349493.7 US (liquid) gallon

Total Number of Tanks: 199.7

Maximum Allowable Bore Pressure Summary

Ream Number	Initial Diameter	Final Diameter	Estimated Maximum Pressure (Avg.)	Estimated Maximum Pressure (Local)
Pilot Bore	0.00 in	13.00 in	101.786 psi	92.400 psi
1	13.00 in	22.00 in	101.742 psi	92.344 psi
2	22.00 in	28.00 in	101.701 psi	92.291 psi
3	28.00 in	32.40 in	101.664 psi	92.245 psi

Note: The maximum bore pressures presented in this table are the maximum values along the length of the bore and not the maximum allowable at any point. The estimated maximum pressures should be compared to the estimated circulating pressures along the bore to determine potential locations of inadvertant returns.

Estimated Circulating Pressure Summary

Active	Shear Rate [rpm]	Shear Stress [Fann Degrees]
No	600	37
No	300	32
No	200	29
Yes	100	25
Yes	6	17
No	3	15

Flow Rate (Q): 280.00 US (liquid) gallon/min

Drill Fluid Density: 0.000 lb/in3

Rheological model: Power-Law

Fluid Consistency Index (K): 63.17

Power Law Exponent (n): 0.14

Effective Viscosity (cP): 636.9