Structure Foundation Exploration Report – FINAL, Rev #1
BEL-National Road Tunnel
St. Clairsville, Belmont County, Ohio
S&ME Project No. 210435B

PREPARED FOR:

ms consultants, inc.
425 Literary Road, Suite 100
Cleveland, OH 44113-4506

PREPARED BY:

S&ME, Inc.
6190 Enterprise Court
Dublin, OH 43016

July 25, 2023

July 25, 2023

ms consultants, inc.
425 Literary Road, Suite 100
Cleveland, OH 44113-4506

Attention: Mr. Jonathan Hren, P.E.

Reference: **Structure Foundation Exploration Report – FINAL, Rev #1**
BEL-National Road Tunnel (PID 108774)
St. Clairsville, Belmont County, Ohio
S&ME Project No. 210435B

Dear Mr. Hren:

In accordance with our revised proposal dated February 18, 2022, which was authorized by ms consultants, inc. (ms) on April 14, 2022, S&ME, Inc. (S&ME) has completed a Structure Foundation Exploration for proposed improvements at both ends of the existing tunnel carrying the National Road Bikeway trail beneath the National Road in St. Clairsville, Ohio. Also included in this project is the repair/replacement of a failing retaining wall at the northwest corner of the pedestrian trestle bridge carrying the trail over SR 9 approximately 0.75 miles north of the tunnel (see Vicinity Map, Plate 1 of the Appendix).

In accordance with Section 701 of the ODOT *Specifications for Geotechnical Explorations* (*SGE*), S&ME submitted a revised "draft" version of this report dated October 27, 2022. Review comments from ODOT D11 based on their review of the Stage 2 plans and dated April 4, 2023, were provided by ms to S&ME on April 11, 2023. This revised final report incorporates changes to address the Stage 2 comments provided by ODOT.

We appreciate being given the opportunity to be of service. Please do not hesitate to contact our office if you have any questions concerning our report.

Sincerely,

S&ME, Inc.

STATE OF OHIO
BRIAN KEITH SEARS
74693
REGISTERED
PROFESSIONAL ENGINEER

Brian K. Sears, P.E.
Senior Engineer | Project Manager

Richard S. Weigand, P.E.
Principal Engineer | Senior Reviewer

Attachments: Appendices I through V
Submitted: Electronic copy via email to Jonathan Hren (jhren@msconsultants.com), ms consultants

Table of Contents

Page

Table of Appendices

Appendix I — Plate No.

Appendix II

Appendix III

Appendix IV

Appendix V

1.0 Executive Summary

The BEL-National Road Tunnel project includes the construction of multiple retaining structures (soldier pile with lagging walls, an arched tunnel section, and modular block walls) to improve the safety and accessibility of the existing bikeway tunnel beneath National Road and at the existing trestle pedestrian bridge carrying the bikeway over SR 9 to the north of the tunnel. In total, approximately 370 linear feet of soldier pile with lagging retaining wall, 90 feet of arched tunnel and 80 feet of modular block walls are planned. The project is located in St. Clairsville, Belmont County, Ohio.

A geotechnical exploration consisting of 10 soil borings and six Wildcat Dynamic Cone Penetrometers (DCP's) were performed in multiple phases between June 13, 2022, and September 29, 2022. Beneath 4 to 17 inches of asphalt or 2 to 14 inches of topsoil, the borings encountered 1.7 to 11.1 feet of existing fill in six (6) of the borings to depths ranging from 2.0 to 12.5 feet below the existing grade. In borings performed above the trail, the fill was composed of stiff to hard SILT AND CLAY (A-6a) or medium-stiff to stiff CLAY (A-7-6). Medium-dense GRAVEL WITH SAND (A-1-b) was encountered in the borings drilled through the trail near the tunnel. A larger amount of fill was encountered near the trestle bridge with discontinuous layers of medium-dense GRAVEL (A-1-a) and COARSE AND FINE SAND (A-3a) and very-stiff SILT AND CLAY (A-6a) and CLAY (A-7-6).

Natural soil was encountered in each boring to depths ranging from 3.5 to 33 feet where shale bedrock was then encountered, except in Boring B-010-0-22, which was terminated at a depth of 15 feet without encountering bedrock. These natural soils consisted predominantly of cohesive materials including hard SANDY SILT (A-4a), stiff to hard SILT AND CLAY (A-6a), medium-stiff to hard SILTY CLAY (A-6b), very-stiff to hard ELASTIC CLAY (A-7-5) and stiff to hard CLAY (A-7-6). Discontinuous layers of GRAVEL WITH SAND AND SILT (A-2-4), dense COARSE AND FINE SAND (A-3a), and medium-dense GRAVEL WITH SAND, SILT AND CLAY (A-2-6) were encountered within these soils in Borings B-006, B-002 and B-008, respectively. In five of the borings, a layer of hard SANDY SILT (A-4a), SILT AND CLAY (A-6a), SILTY CLAY (A-6b) and CLAY (A-7-6) with the appearance of severely weathered or decomposed shale was encountered immediately above bedrock.

Bedrock at the site consisted of predominantly gray SHALE, which was slightly to highly weathered and very weak to moderately strong. Interbedded SHALE and SANDSTONE or SANDSTONE bedrock were encountered in three borings, and several limestone seams were encountered in Boring B-004-0-22. Zones of carbonaceous shale or coal were encountered in three borings.

Based on the results of the borings, the subsurface conditions appear generally suitable for supporting the currently planned retaining structures. Recommended design parameters for axial and lateral design of drilled shaft foundations to support the soldier pile and lagging walls are presented in Section 6.1. Factored bearing resistance values for shallow spread footings planned to support the arched tunnel extension structure and the modular block walls are included in Section 6.2. The results of stability analyses performed on representative cross sections and recommendations for slope regrading are discussed in Section 6.3. Recommendations regarding embankment construction and the placement of fill are summarized in Section 6.4.

2.0 Introduction

The National Road Bikeway serves as a key recreational benefit to the City of St. Clairsville, extending from the southern terminus at TR 278 (near the intersection with SR 9) and winding its way approximately 2.5 miles north, crossing under IR 70 and National Road (US 40), and then over SR 9, terminating at the St. Clairsville Junior Sports Fields. A former railroad tunnel currently carries the bikeway beneath US 40. At both ends of the old railway tunnel, over-steepened slopes are present on both sides of the path. These slopes have previously experienced numerous slope failures of varying size and severity, resulting in vegetation (trees, shrubs, etc.), soil, and rock fragments falling on the existing path. These conditions create a safety hazard and impact the safe use of the tunnel and bike path.

S&ME is pleased to work with ms and the City on this project to improve conditions at the tunnel termini and at the SR 9 bridge. Currently, it is proposed to provide retaining structures and/or regrading of soil/rock slopes at both ends of the existing tunnel to protect the trail from future slope failure. Based on a retaining wall type study prepared by ms (dated September 2, 2022) and follow-up discussions between ms, ODOT District 11, and the City of St. Clairsville, we understand the preferred remediation will include soldier pile with lagging walls along the trail at the north end of the tunnel and extending the tunnel with a cast-in-place arch concrete tunnel and soldier pile wingwalls on the south end. Improvements planned at the trestle bridge carrying the trail over SR 9 approximately 0.75 miles north of the National Road Tunnel include the replacement of a failing retaining wall at the northwest corner of the bridge.

To assess conditions at the project site, S&ME performed a total of 10 borings (nine (9) in the vicinity of the tunnel and one (1) at the north abutment of the trestle bridge) and six (6) Wildcat Dynamic Cone Penetrometer (DCP) explorations (five (5) in the vicinity of the tunnel and one (1) below the retaining wall at the northwest corner of the trestle bridge). This Geotechnical Exploration has been performed in general accordance with the January 2022 update of the ODOT *Specifications for Geotechnical Investigations* (*SGE*). However, at the request of ms and ODOT District 11, preparation of Soil Profile – Structure sheets are <u>not</u> required.

3.0 Geology and Observations of the Project

3.1 Site Geology

The site lies within the Appalachian Plateaus Province and more specifically the Little Switzerland Plateau physiographic region of the Allegheny (Kanawha) Plateau section. This region is composed of highly dissected and high-relief plateaus which typically consist of Pleistocene-age silty clay loam colluvium Pennsylvanian-age Upper Conemaugh Group through Permian-age Dunkard Group red and gray shales, siltstones, limestones, sandstones, and coal. Additionally, landslides are common throughout this region.

Topographic mapping indicates the ground surface along the project alignment at the existing US 40 tunnel ranges from approximate El. 1240 on National Road to El. 1145 on the trail. Bedrock outcrops are visible above the trail at both ends of the tunnel to roughly the same elevation as the top of the existing tunnel, near El. 1175. The top of bedrock elevations encountered in the borings performed above the trail varied from El. 1200.7 near the tunnel, to El. 1161.2 where bedrock had been previously excavated to construct the rail line.

The "Ohio Karst Areas" map published by ODNR shows that the project site lies in an area known to not contain karst features. A review of ODNR's "Landslides in Ohio" shows the site is located within an area that is subject to severe slope failure. The "Abandoned Underground Mine Maps" published by ODNR indicate a significant presence of abandoned underground coal mines in and surrounding St. Clairsville, with some mapped mines overlapping with the current project limits. On the south side of National Road, an abandoned coal mine (Willow Grove No. 10) overlaps with a portion of our project limits with a coal elevation of El. 886 (approximately 260 feet below the level of the path). On the north side of the National Road, another abandoned coal mine (Colliery No. 1) overlaps with a portion of our project limits with a reported coal seam elevation of El. 890. This same mine (Colliery No. 1) extends north to completely encompass the site of the trestle bridge.

3.2 Site Reconnaissance

S&ME visited the site on multiple occasions between October 25, 2021, to September 29, 2022, to observe the site conditions, mark boring locations, and perform the field explorations. Bedrock outcrops, as previously mentioned, were observed at both ends of the tunnel. Steep rock slopes with varying amounts of talus (eroded rock/soil) at the trail level rise above the trail transitioning to moderate to steep soil slopes. Heavy vegetation (trees, brush, etc.) is present around the rim of the cut down to the trail and multiple instances of exposed root systems were observed. Some areas of undermining where weaker and more degraded rock is present beneath a stronger and more resistant rock layer were observed in the bedrock outcrops at both ends of the tunnel. These undermined layers were more prevalent at the south end of the tunnel. The timber retaining walls along the access path down to the trail at the north end of the tunnel are in varying states of failure, with numerous instances of bulging or rot observed.

At the trestle bridge, the north abutment is positioned at the top a steep soil slope. No bedrock outcrops were observed in this slope. The retaining wall at the northwest quadrant of the bridge is showing similar signs of bulging and rot.

4.0 Exploration

4.1 Field Investigation

S&ME visited the site on April 22, 2022, to mark the locations of the proposed borings and DCPs to be performed. The borings were completed in two phases. The first phase included Borings B-001-0-22, B-002-0-22, B-004-0-22, B-008-0-22, and B-010-0-22 and was performed between June 13 and 16, 2022. The second phase of the exploration program included Borings B-003-0-22, B-005-0-22, B-006-0-22, B-007-0-22 and B-009-0-22, and this phase was performed between July 18 and 21, 2022. All boring numbers will hereafter be referred to without their offset and year designations (e.g., B-001, B-002, etc.). These soil borings were drilled to depths ranging from 15 to 76 feet.

A total of six (6) Wildcat DCPs (D-006-1-22, D-006-2-22, D-006-3-22, D-008-1-22, D-008-2-22 and D-010-1-22) were also performed for this project during the period of July 22 and September 29, 2022. As with the borings, the DCPs will hereafter be referred to without their year designations (e.g., D-006-1, D-008-1, etc.).

The borings were advanced by truck and ATV-mounted drill rigs using a 3¼-inch hollow-stem auger. Disturbed, but representative, soil samples were attempted by lowering a 2-inch O.D. split-barrel sampler through the auger stem to the bottom of the boring and then driving the sampler into the soil with blows from a 140-pound hammer freely falling 30 inches (AASHTO T206 – Standard Penetration Test, SPT). Recovered SPT samples were examined immediately after recovery and representative portions were preserved in airtight glass jars. In accordance with ODOT specifications, the hammer systems on the drilling rigs were calibrated (ASTM D4633) to determine the drill rod energy ratio. The truck rig used to perform borings in the first phase was calibrated on November 25, 2020, with a drill rod energy ratio of 98.6% which has been limited to 90% in accordance with the ODOT *SGE*. The ATV rig used to perform borings in the second phase was calibrated on June 7, 2022, with a drill rod energy ratio of 69.8%.

All soil samples were examined in the field and representative portions were preserved in airtight glass jars. Rock core samples were stored in compartmented cardboard or wood boxes. Following the completion of drilling, the borings were backfilled with cuttings mixed with bentonite or sealed with a bentonite-cement grout, and a plastic hole plug was placed in the borehole a few feet below the surface. At Borings B-002, B-008 and B-010, the existing trail pavement was patched with an equivalent thickness of cold patch asphalt.

Soil samples were delivered to S&ME's lab for further examination and testing. Coordinates were obtained by S&ME using a handheld GPS and were provided to ms consultants who provided stations, offsets, and ground surface elevations at the boring/DCP locations.

In the field, experienced personnel from S&ME observed the drilling procedures and performed the following specific duties: preserved all recovered samples; prepared a log of each boring; made seepage and groundwater observations in the borings; obtained hand-penetrometer measurements in soil samples exhibiting cohesion; and, provided liaison between the fieldwork and the Project Manager so that the program of exploration could be modified, if necessary, because of unanticipated conditions.

4.2 Laboratory Testing

In the laboratory, all soil samples were visually identified and tested for natural moisture content. Classification testing (liquid/plastic limit determinations and grain-size analyses) was also performed on selected representative specimens. In addition, ten (10) unconfined compressive strength tests and four (4) slake durability tests were performed on selected bedrock samples. Unit weight determinations were performed on a section of soil retrieved in the two (2) recovered Shelby tube samples. Results of these tests are recorded numerically on the boring logs, with photos of the recovered bedrock cores and the results of the bedrock testing included in Appendix II.

Based upon the results of the laboratory testing program, the field logs were modified, if necessary, and copies of the laboratory corrected boring logs are submitted as Plates 5 through 20 of Appendix I. Shown on these logs are: descriptions of the soil stratigraphy encountered; depths from which samples were preserved; sampling efforts (blow-counts) required to obtain the specimens in the borings; calculated N_{60} values; laboratory testing results; seepage and groundwater observations made at the time of drilling; values of hand-penetrometer measurements made in soil samples exhibiting cohesion; and, RQD (rock quality designation) and recovery percentages of rock core samples. For your reference, hand-penetrometer values are roughly equivalent to the unconfined compressive strength of the cohesive fraction of the soil sample.

Soils have been classified in general accordance with Section 603 of the ODOT *SGE* and described in general in accordance with Section 602. Bedrock has been classified and described in general accordance with Section 605 of the ODOT *SGE*. An explanation of the symbols and terms used on the boring logs, definitions of the special adjectives used to denote the minor soil components, description of rock, and information pertaining to sampling and identification are presented on Plate 3 and 4 of Appendix I. Group Indices determined from the results of the laboratory testing program are also provided on the boring logs.

5.0 Findings

Please refer to the individual boring logs (Plates 5 through 20 in Appendix I) for detailed descriptions of the pavement, soil, rock and groundwater/seepage conditions encountered at each boring location. Inferences should not be made regarding the subsurface conditions between or in areas away from the borings without performance of additional borings or other methods of field verification.

5.1 Surface Materials

The existing trail pavement was encountered in three borings and ranged from 4 to 6 inches thick near the tunnel entrances to 17 inches in Boring B-010 drilled at the trestle bridge. No definite aggregate base course was observed in any of the borings performed through the trail pavement; however, a granular fill material (sand and/or gravel) was present below the pavement. The remaining seven (7) borings encountered 2 to 14 inches of topsoil.

5.2 Fill Materials

Below the pavement section or topsoil, 1.7 to 11.1 feet of existing fill was visually identified in six (6) of the borings to depths ranging from 2.0 to 12.5 feet below the existing grade. Borings B-001, B-003 and B-005, performed above the trail, encountered existing fill composed of stiff to hard SILT AND CLAY (A-6a) or medium-stiff to stiff CLAY (A-7-6), with some wood fragments observed in Boring B-001. Medium-dense brownish gray or grayish black GRAVEL WITH SAND (A-1-b) was encountered in Borings B-002 and B-008 beneath the trail pavement near the tunnel. Boring B-010 near the trestle bridge encountered 11.1 feet of fill with discontinuous layers of medium-dense gray or black GRAVEL (A-1-a) and COARSE AND FINE SAND (A-3a), and very-stiff gray and/or brown SILT AND CLAY (A-6a) and CLAY (A-7-6).

5.3 Natural Soil

Natural soil was encountered in each boring to depths ranging from 3.5 to 33 feet, whereupon shale bedrock was encountered, except in Boring B-010, which was terminated at a depth of 15 feet before encountering bedrock.

Natural soils consisted predominantly of cohesive materials including hard gray SANDY SILT (A-4a), stiff to hard brown and/or gray SILT AND CLAY (A-6a), medium-stiff to hard brown and/or gray SILTY CLAY (A-6b), very-stiff to hard gray and black ELASTIC CLAY (A-7-5) and stiff to hard brown and/or gray CLAY (A-7-6). The SANDY SILT (A-4a) and SILT AND CLAY (A-6a) were only encountered on the north side of National Road. Discontinuous layers of GRAVEL WITH SAND AND SILT (A-2-4), dense COARSE AND FINE SAND (A-3a), and medium-dense GRAVEL WITH SAND, SILT AND CLAY (A-2-6) were encountered within these soils in Borings B-006, B-002 and B-008, respectively.

In Borings B-003, B-004, B-005, B-007 and B-009, a 3.0 to 13.5-foot-thick layer of hard gray with some brown SANDY SILT (A-4a), SILT AND CLAY (A-6a), SILTY CLAY (A-6b) and CLAY (A-7-6) was encountered immediately above bedrock and was observed to have the appearance of severely weather or decomposed shale.

5.4 Bedrock

Bedrock at the site consisted of predominantly gray SHALE which was slightly to highly weathered and very weak to moderately strong. Zones of INTERBEDDED SHALE AND SANDSTONE or SANDSTONE bedrock were encountered in Borings B-007, B-008 and B-009, with several limestone seams also noted in Boring B-004. Zones of carbonaceous shale or coal were encountered in Borings B-003, B-004 and B-005. Core recovery ranged from 72% to 100%, with an average of 95%. RQD measurements ranged from 0% to 85% with an average of 50%.

As previously noted, ten (10) unconfined compressive strength tests and four (4) slake durability tests were performed on recovered rock core samples. Results of the unconfined compressive strength tests are summarized in Table 5-1 and the results of the slake durability tests are presented in Table 5-2.

Table 5-1 Summary of Unconfined Compressive Strength Test Results

Boring ID	Sample ID	Sample Depth (ft)	Sample Elevation	Rock Type	UCS (psi)
B-001-0-22	NQ-13	37.0 – 37.4	1154.5 – 1154.1	Shale	2,245
B-002-0-22	NQ-3	8.6 – 9.0	1141.1 – 1140.7	Shale	1,368
B-002-0-22	NQ-5	19.5 – 19.9	1130.2 – 1129.8	Shale	3,975
B-003-0-22	NQ-13	40.5 – 40.9	1177.3 – 1176.9	Shale	2,024
B-007-0-22	NQ-11	31.2 – 31.6	1161.5 – 1161.1	Shale	1,050
B-007-0-22	NQ-14	44.1 – 44.5	1148.6 – 1148.2	Shale	2,062
B-008-0-22	NQ-5	10.7 – 11.1	1134.5 – 1134.1	Sandstone	9,862
B-008-0-22	NQ-6	20.9 – 21.3	1124.3 – 1123.7	Sandstone	6,748
B-009-0-22	NQ-10	27.0 – 27.4	1150.2 – 1149.8	Shale	4,754
B-009-0-22	NQ-11	32.4 – 32.8	1144.8 – 1144.4	Sandstone	9,376

Table 5-2 Summary of Slake Durability Test Results

Boring ID	Sample ID	Sample Depth (ft)	Sample Elevation	Rock Type	SDI (%)
B-001-0-22	NQ-12	28.0 – 33.0	1163.5 – 1158.5	Shale	3.5
B-003-0-22	NQ-16	51.0 – 56.0	1166.8 – 1161.8	Shale	12.5
B-007-0-22	NQ-12	32.4 – 37.4	1160.3 – 1155.3	Shale	20.4
B-009-0-22	NQ-10	23.0 – 28.0	1154.2 – 1149.2	Shale	9.4

5.5 DCP Test Findings

Five (5) Wildcat DCP explorations were performed at various locations on the hillside on the north side of the tunnel, and one (1) DCP was performed below the retaining wall at the northwest corner of the trestle bridge abutment. The general locations and findings of these six (6) DCPs are described below.

- Three (3) DCPs (D-006-1, D-006-2 and D-006-3) were performed as near to the existing timber retaining walls along the north side path access as could safely be reached. These DCPs generally encountered the following:

  - Very-soft to medium-stiff (or very-loose to loose) with occasional stiff/medium-dense zones near the bottom of the 5- to 6-foot deep DCP's.
  - D-006-1 encountered stiff to very-stiff/medium-dense materials approximately 3 feet below grade.
  - Each of these DCPs terminated by refusal on what was assumed to be bedrock or the top of the existing tunnel.
- Two (2) DCPs (D-008-1 and D-008-2) were performed on the west side of the path to assess, if possible, the depth to bedrock in between Borings B-005, B-006 and B-009.
  - DCP D-008-1 which was performed just north of the walking path leading to the upper resting platform encountered generally very-stiff/medium-dense soil to a depth of approximately 5 feet, followed by 1 foot of hard/dense soil.
  - Below the hard/dense soils, D-008-1 re-entered stiff to very stiff/medium dense soils which then softened into medium-stiff to stiff/loose to medium-dense soils until the termination of the test.
  - DCP D-008-2 remained in very-stiff to hard/medium-dense to dense soils until encountering blow-count refusal near a depth of 6.5 feet. Based on the depth to bedrock in the surrounding borings, we do not believe that bedrock was the cause of the blow-count refusal.
- The DCP performed at the trestle bridge abutment (D-010-1) encountered primarily medium-stiff to stiff/loose to medium-dense soils until encountering a sudden hard/dense material near a depth of 10.5 feet. This sudden hard/dense material may be existing bedrock.

5.6 Groundwater observation

Seepage was noted in four (4) borings (B-002, B-004, B-006 and B-008) between the depths of 3 and 21 feet. The remaining borings were dry prior to coring, or at the termination of Boring B-010 where coring was not performed. All groundwater measurements should be considered temporary, short-term observations, and should not be assumed to be representative of the long-term static groundwater level. Groundwater levels can fluctuate due to seasonal variations in precipitation, construction activities, etc.

6.0 Analyses and Recommendations

The intent of this project is to improve the safety and usability of the National Road Bikeway trail by incorporating multiple improvements between CR 9 and US 40. Based on the Stage 3 Status Set plans prepared by ms and provided to S&ME on July 18, 2023, the currently planned improvements include the following:

- <u>North Side of Tunnel</u>
  - Construct soldier pile with lagging walls on both sides of the trail extending approximately 139 feet north of the north end of the tunnel.
  - These walls are expected to range from 6 to 26 feet high (above the top of the drilled shafts), with a strut positioned at the top of the walls where the wall height is 22 feet or greater.
  - The soldier piles will be supported by 36-inch diameter drilled shafts socketed 5.7 to 18.7 feet into bedrock.
  - Behind the walls, soil backfill will be placed to create general 2H:1V slopes to buttress the existing rock and soil slopes.
  - Replace the failing wood retaining walls along the access path and down to the path with modular block type walls.

- South Side of Tunnel
  - Extend the tunnel approximately 90 feet to the south of the existing tunnel opening with a cast-in-place arched concrete tunnel.
  - This tunnel extension will be supported by spread footings beneath each vertical side wall with dimensions of 8 feet wide and 2.5 feet thick. The spread footings are expected to bear near El. 1144.25.
  - Construct soldier pile with lagging wingwalls beginning at the south end of the tunnel extension for an additional 72 feet. These soldier pile walls are anticipated to range from 6 to 28 feet high (above the top of the drilled shafts) with a strut at the top of the walls where the wall height is 24 feet or greater.
  - These soldier piles will be supported by 36-inch diameter drilled shafts socketed 5.7 to 18.7 feet into bedrock.
  - Behind the walls, embankment fill will be placed over the tunnel extension at slopes ranging from 2H:1V to 5H:1V and behind the soldier pile wall at a 2H:1V slope.
- Trestle Bridge Northwest Abutment Wall
  - Replace a failing wood retaining wall at the northwest corner of the bridge with a modular block type wall.

Recommendations for the design and construction of these improvements are provided in the following sections. Portions of these recommendations were provided previously in Geotechnical Design Memorandums dated August 16 and 26, 2022.

6.1 Drilled Shafts for Soldier Pile and Lagging Walls

Based on available plans, we understand the proposed soldier pile with lagging retaining walls are to be constructed on the north and south sides of the existing tunnel and will range from approximately 6 to 28 feet in height. When the height of the walls equals or exceeds 20 feet, struts will be placed at intervals to provide additional lateral support.

6.1.1 Axial Resistance

S&ME has performed analyses to estimate the shaft and tip resistance for drilled shafts socketed into bedrock and which will support the proposed soldier pile walls. A summary of the recommended nominal and factored resistances is provided in Tables 6-1 and 6-2. Calculations for estimating the bearing resistance values are provided in Appendix III.

Table 6-1 Recommended Nominal and Factored Unit End Bearing Resistance Values for Drilled Shafts Socketed into Bedrock (Strength Limit State)

Substructure Element	Rock Type	Elevation Range	Nominal Unit Tip Resistance* (q_p)	Resistance Factor (φ_{qp}) for Tip Resistance**	Factored Unit Tip Resistance*
South End of Tunnel (B-002-0-22)	Shale	1144.7 – 1135.7	7 ksf	0.5	3.5 ksf
	Shale	1135.7 – 1124.2	1430 ksf	0.5	715 ksf
North End of Tunnel (B-008-0-22)	Shale	1139.7 – 1134.5	10 ksf	0.5	5.0 ksf
	Sandstone	1134.5 – 1122.6	2430 ksf	0.5	1215 ksf
	Shale	1122.6 – 1120.2	1430 ksf	0.5	715 ksf

* For vertical loading only. ** Table 10.5.5.2.4-1 of the AASHTO LRFD.

Table 6-2 Recommended Nominal and Factored Unit Side Resistance Values for Drilled Shafts Socketed into Bedrock (Strength Limit State)

Substructure Element	Rock Type	Elevation Range	Nominal (Unfactored) Unit Shaft Resistance (q_s)*	Resistance Factor (φ_{qs}) for Shaft Resistance**	Factored Unit Shaft Resistance*
South End of Tunnel (B-002-0-22)	Shale	1144.7 – 1135.7	4 ksf	0.55	2.2 ksf
	Shale	1135.7 – 1124.2	34 ksf	0.55	18.7 ksf
North End of Tunnel (B-008-0-22)	Shale	1139.7 – 1134.5	10 ksf	0.55	5.5 ksf
	Sandstone	1134.5 – 1122.6	34 ksf	0.55	18.7 ksf
	Shale	1122.6 – 1120.2	34 ksf	0.55	18.7 ksf

* For vertical loading only. ** Table 10.5.5.2.4-1 of the AASHTO LRFD (side resistance in rock)

Drilled shafts should be designed in accordance with Section 305.4 of the 2020 ODOT *BDM*, with shaft and rock socket diameters determined in accordance with Section 305.4.4.2.

As the amount of movement necessary to develop shaft friction resistance is less than that needed to develop end bearing (tip) resistance, unless an on-site static load test is planned at this site, drilled shafts used to support the proposed abutments and piers should be designed for axial load carrying capacity using either shaft friction resistance only or end bearing (tip) resistance only.

The drilled shafts must also have sufficient length to resist both the applied axial and lateral loading.

6.1.2 Lateral Earth Pressures

Values of soil unit weight and earth pressure design coefficients recommended for use during design of drilled shaft walls at this site for in-situ soils are provided in Table 6-3. The earth pressure coefficient to be used should be determined based on the anticipated and/or allowable movement of the structural system being considered. These parameters are not applicable to new backfill soils placed above the existing ground surface.

Table 6-3 Lateral Earth Pressure Parameter Recommendations for In-Situ Soil

Soil Type	Angle of Internal Friction (deg.)	Earth Pressure Coefficient			Unit Weight (pcf)
		At-Rest (K_o)	Active (K_a)	Passive (K_p)	
Medium-dense to dense Gravel with Sand (A-1-b), Gravel with Sand, Silt and Clay (A-2-6), or Coarse and Fine Sand (A-3a)	32	0.47	0.31	3.25	125

Lateral earth pressures exerted on the portion of the walls above the trail and which will be backfilled by new fill materials must be designed to withstand lateral earth pressures as well as hydrostatic pressures that may develop behind the walls. The magnitude of the lateral earth pressures varies based on soil type, permissible wall movement, and the configuration of the backfill.

To minimize lateral earth pressures, the zone behind the retaining walls should be backfilled with granular soil, and the backfill should be effectively drained. For effective drainage, a zone of free-draining gravel (*CMS* Item 518.03) should be used directly behind the tunnel for a minimum thickness of 24 inches in accordance with ODOT *CMS* Item 518.05. This granular zone should drain to either weepholes or a pipe, so that hydrostatic pressures do not develop against the retaining walls.

The type of backfill beyond the free-draining granular zone will govern the magnitude of the pressure to be used for structural design. Pressures of a relatively low magnitude will be developed by using granular backfill, whereas a cohesive (clay) backfill will result in the development of much higher pressures.

To reduce the earth pressure acting on the walls, it is recommended that granular backfill be used behind the walls and tunnel structure. The backfill should be placed in a wedge formed by the back of the structures and a line rising from the base of the wall at an angle no greater than 60 degrees from the horizontal. Granular backfill behind the soldier pile walls should be compacted in accordance with *CMS* Items 203 and 611.06. Over-compaction in areas directly behind the walls should be avoided as this might cause damage to the structure.

6.1.3 Lateral Loading – LPILE Parameters

Table 6-4 includes recommended p-y models, rock unit weights, and the unconfined compressive strength to be used in lateral load analyses for the retaining wall structures. These parameters are based on the bedrock and lab data shown on the boring logs, and recommended values given in the LPile 2019 user's manual and guidance provided by ODOT Office of Geotechnical Engineering (OGE).

Table 6-4 LPile 2019 Input Parameters for Drilled Shafts (Massive Rock P-Y Model)

Substructure Element	Stratum	Rock Type	Effective Unit Weight	Unconfined Compressive Strength	Hoek-Brown Material Index	Poisson's Ratio	GSI	Rock Mass Modulus (psi)
South End	1144.7 – 1135.7	Shale	90 pcf	500	6	0.09	20	3,100
	1135.7 – 1124.2	Shale	90 pcf	3,975	6	0.09	60	56,800
North End	1139.7 – 1134.5	Shale	90 pcf	1,368	6	0.09	25	3,100
	1134.5 – 1122.6	Sandstone	90 pcf	6,750	17	0.20	75	535,000
	1122.6 – 1120.2	Shale	90 pcf	3,975	6	0.09	60	56,800

6.1.4 *Drilled Shafts - Construction Recommendations*

In general, the new drilled shafts should be constructed in accordance with Item 524 of the *ODOT Construction and Materials Specifications* (*CMS*). S&ME recommends that provisions be made for providing a temporary casing during drilled shaft excavation above the bedrock, since the granular soils encountered above the bedrock may cave during drilled shaft construction. The casing should extend into the underlying bedrock to seal the shafts from contamination with water, soil, and loose rock fragments. The temporary casing may then be removed during concrete placement; however, precautions should be taken to ensure that the structural integrity of the shafts is not compromised by caving of material during removal of the casing. The concrete level (head) should be maintained at least 5 feet above the bottom of the casing during withdrawal to prevent the entry of soil/rock and water into the shafts. Sumps may be required to remove water accumulation (seepage) from the drilled shafts beneath the depth of encountered groundwater level, otherwise placement of concrete should use approved tremie or pumping methods.

All drilled shaft construction should be observed by a qualified geotechnical engineer or an experienced technician working under direction of the engineer to ensure that the drilled shafts are installed plumb, that the shaft bottoms are sufficiently clean and dry prior to concrete placement, and that the shafts extend into the appropriate bearing stratum as recommended.

In addition, S&ME also suggests that the following items be considered:

- *Determination/Verification of Bearing Surface*: Verification of the bearing surface will be required. Ideally, the bedrock socket and bottom surface should be directly observed by a trained inspector. To facilitate this, the contract plans should indicate that the contractor attempt to dewater the shafts following drilling. However, if it is impossible to fully dewater the shafts, determination of the bearing surface will have to be made based on the type of material extracted from the hole and the degree of drilling difficulty.
- *Bottom Clean-Out*: Whether the shafts will be designed to resist axial loads in end-bearing or side-friction, bottom clean out is important. In general, the specifications contained in Item 524 of the ODOT *CMS* and *Construction Administration Manual of Procedures* (*MOP*) are acceptable. Verification of the clean-out may

be performed by visual inspection if the excavations are dry or by using a submersible electronic inspection device (MiniSID) if the excavations are wet.

- *Steel Reinforcement*: If it is intended to fully reinforce the shafts, provisions will need to be made to permit either lengthening or shortening the reinforcing cages on site as required to reach the shaft bottom.
- *Concrete Integrity*: If the shafts are constructed in the dry, the potential for the inclusion of voids or pockets of deleterious material within the shafts is minimized. If wet method shaft construction (see Section 305.4.4.6 of the ODOT *BDM*) is necessary, construction of a demonstration drilled shaft will also be required.

The ODOT *BDM* Item 305.4.5 also requires Thermal Integrity Profiling (TIP) testing per ASTM D7949 Method B for at least 10 percent of all drilled shafts, including at least one shaft per substructure unit. Plan notes for TIP testing are provided in Section 600 of the *BDM*.

6.2 Spread Footings

6.2.1 Tunnel Extension (South Side)

We understand that the proposed tunnel extension will be supported by spread footings which will be roughly 8 feet wide and 2.5 feet thick and bearing at approximate El. 1144.25. Based on the results of the borings, S&ME has performed analyses to estimate the nominal and factored bearing resistance values for spread footings founded on existing bedrock at this elevation. A summary of the recommended nominal and factored bearing resistances are provided in Table 6-5.

All existing tunnel foundations should be removed prior to the construction of the new tunnel extension foundations, and all bedrock that becomes disturbed or loosened during the demolition and foundation excavation operations should be removed prior to placement of concrete for the new foundations. Sufficient longitudinal reinforcing steel should be provided to strengthen continuous footings against any abrupt differential settlements.

Foundation bearing surfaces should be kept dry and free from standing water during all construction activities. If the foundation materials become wet or loose, additional excavation may be necessary prior to placing foundation concrete. Sumps may be required to pump water accumulations (seepage) from the foundation excavations.

Table 6-5 Recommended Nominal and Factored Bearing Resistance Values for the Tunnel Extension Foundations[‡]

Substructure Element	Rock Type	Elevation Range	Limit State	Nominal Bearing Resistance* (q_n)	Resistance Factor (φ_b)**	Factored Bearing Resistance (q_R)
South End of Tunnel (B-002-0-22)	Shale (highly to severely weathered)	1144.7 – 1135.7	Service	20 ksf	1.0	20 ksf
			Strength	26 ksf	0.45	11.7 ksf
	Shale (slightly to moderately weathered)	1135.7 – 1124.2	Service	20 ksf	1.0	20 ksf
			Strength	80 ksf	0.45	36 ksf

* For vertical loading only, service limit state values are currently taken from presumptive values given in Table C10.6.2.6.1-1.
** Resistance Factor for Strength Limit State is given in Table 10.5.5.2.2-1 of the AASHTO LRFD.
‡ See Plates 28 through 35 in Appendix C for calculations.

6.2.2 *North Side Entrance Path Modular Block Walls*

Due to the significantly deteriorated and generally unsafe nature of the existing timber retaining walls along the access path to the path level on the north side of the tunnel, S&ME understands that new modular block type walls are proposed to be constructed. Based on preliminary drawings provided by ms on October 11, 2022, S&ME understands the proposed walls will be approximately 4 to 12 feet high and are expected to bear near El. 1174. Based on the elevation of the top of bedrock in Borings B-006 (El. 1185.9) and B-007 (El. 1176.8) and refusal depths in DCPs D-006-1 (~El. 1175), D-006-2 (~El. 1172.5) and D-006-3 (~El. 1171), we anticipate these walls will bear on existing shale bedrock. As no explorations were able to be performed into the bedrock in the immediate area surrounding the existing timber walls, we have assumed that the upper few feet of bedrock immediately below the walls will be similar in nature to the generally moderately weathered shale encountered in the upper portion of Borings B-006, B-007, B-008 and B-009. Accordingly, we recommend the nominal and factored resistances as provided in Table 6-6 be used to design the north side access path retaining walls.

Table 6-6 Recommended Nominal and Factored Bearing Resistance Values for the North Side Access Path Walls[‡]

Substructure Element	Rock Type	Elevation Range	Limit State	Nominal Bearing Resistance* (q_n)	Resistance Factor (φ_b)**	Factored Bearing Resistance (q_R)
North End Path Modular Block Walls	Shale	Below El. 1174	Service	20 ksf	1.0	20 ksf
			Strength	57 ksf	0.45	25.6 ksf

* For vertical loading only, service limit state values are currently taken from presumptive values given in Table C10.6.2.6.1-1.
** Resistance Factor for Strength Limit State is given in Table 10.5.5.2.2-1 of the AASHTO LRFD.
‡ See Plate 36 in Appendix C for calculations.

An engineer from S&ME should be present to examine the condition of the bedrock at the planned bearing elevations as the excavations for these foundations are made. If the condition of the shale beneath these foundations is observed to be more weathered and or weaker than that encountered in the borings, S&ME requests the opportunity to revise the recommended bearing resistance values presented in the above table.

6.2.3 SR 9 Trestle Bridge - Northwest Abutment Wall

Based on the ground surface elevation of Boring B-010, and DCP D-010-1 performed near the failing retaining wall at the northwest abutment of the trestle bridge, S&ME anticipates the base of the proposed modular block replacement wall will bear in the very-stiff CLAY (A-7-6) encountered in Boring B-010 at the approximate proposed foundation bearing level of El. 1078. It is recommended that spread foundations for the headwalls be founded a minimum of 33 inches below surrounding grades in accordance with frost code requirements (Figure 305-3 of the 2020 ODOT *Bridge Design Manual*, *BDM*).

Table 6-7 summarizes the recommended nominal and factored bearing resistances (q_n and q_R) at the service and strength limit states for a proposed modular block wall bearing on the very-stiff cohesive soils encountered below the anticipated bearing elevation and accounting for the placement of the wall on an existing slope. To achieve the recommended factored bearing resistances provided in Table 6-7, the bearing surfaces should be carefully cleaned prior to placement of the modular blocks or any required bedding material. Calculations are included in Appendix III.

Table 6-7: Recommended Nominal and Factored Bearing Resistance Values for the Trestle Bridge Abutment Wall‡

Proposed Bearing Elevation (ft)	Limit State	Nominal Bearing Resistance, q_n (ksf)	Resistance Factor, φ_b	Factored Bearing Resistance, q_R (ksf)
El. 1078	Service	8.0*	1.0	8.0
	Strength	10.7	0.5	5.3

* AASHTO LRFD Table C10.6.2.6.1-1.
‡ See Plates 37 through 42 in Appendix C for calculations.

The foundation bearing surfaces should be kept dry and free from standing water during all construction activities. If the foundation materials become wet or loose, additional excavation may be necessary prior to placing the modular blocks or required bedding. Sumps may be required to pump any surface water accumulations that enter the excavation.

Recommendations regarding sliding, eccentricity and external (global) stability for the proposed retaining wall at the trestle bridge are not within our requested scope of work. If required, these analyses will be performed by others.

6.3 Stability Analyses

Cross sections provided by ms (see Appendix IV) show new fill being placed behind the proposed soldier pile and lagging walls and on the sides and on top of the tunnel extension. This new fill is generally shown to be placed up to the top of the existing hillsides on both sides of the path, except for the sections near the far north and south termini of the project and near the north end of the existing tunnel. In these areas, more significant portions of the existing ravine slopes are not being covered by new fill, as the new fill would need to be placed with a slope that is steeper than 2H:1V. Placement of unreinforced fill slopes steeper than 2H:1V is not recommended.

S&ME performed stability evaluations of both side slopes of the cross section at the north end of the existing tunnel (Sta. 706+66.50). At this section (see Plate 20 in Appendix IV), the proposed 2H:1V slopes behind the walls intersect the existing hillsides near the approximate elevation of the top of rock with approximately 14 to 20 feet of natural soil above the top of rock and which would not be supported by the new fill. The existing soil slopes above the bedrock are currently at inclinations ranging from approximately 0.5H:1V to 0.75H:1V. Based on our observations at the site, these severely over-steepened slopes appear to be "intact" primarily due to "reinforcement" from the existing trees and their root systems and other vegetation (bio stabilization). Disturbance or damage to this "bio-reinforcement" during construction (i.e., vibrations, grubbing, backfill placement) may result in failure of these over-steepened soil slopes.

To assess the contribution of the bio stabilization, S&ME performed global stability analyses of the right and left hillsides at Sta. 706+66.50 under two conditions. The first (and current) condition included a layer of bio-stabilized soil in the upper 3 to 5 feet of the existing ground profile by incorporating a cohesion component to the strength condition of the existing soil. The cohesion was adjusted until the factor of safety was approximately 1.0, which is the point of incipient failure. The second condition then modeled the existing soil slopes without the cohesion component, which would then provide an estimate of the factor of safety of these slopes with the bio-stabilization removed or disturbed. These Factors of Safety were estimated to range from 0.2 to 0.41, which indicates failure will have occurred.

These analyses, the results of which are provided in Appendix III, Plates 43, 44, 46 and 47 were performed using the two-dimensional limit-state computer program SLIDE2 (v9.025). The Spencer method was used for the limit equilibrium calculations. The strength parameters used to represent the soil layers were determined by performing an analysis of the soils by soil type and index property characteristics and comparison to strength values (i.e., peak, fully softened and residual) from literature correlations.

To address areas of the project where over steepened slopes are present, S&ME recommends the following:

- If the proposed 2H:1V slopes behind the walls extend a significant distance up the slope and are expected to intersect the existing slopes above the top of rock elevation, continue the 2H:1V slope by regrading the existing slope to an inclination no steeper than 2H:1V. This may require slope regrading work to be performed outside of the existing right-of-way. This approach would apply from approximately Sta. 705+28.50 to Sta. 706+66.50, from Sta. 713+00 (left) to Sta. 713+25 (left), and from Sta. 713+25 to Sta. 713+48.

- For fill being placed above the tunnel extension, adjust the fill inclination so that new fill intersects the top of the slope on the existing hillside. If this requires an inclination steeper than 2H:1V, regrade the portion of the existing hillside to a 2H:1V slope as discussed in the first bullet above. This approach would apply from approximately Sta. 712+10.2 to Sta. 713+00 and from Sta. 713+00 (right) to Sta. 713+25 (right).

In addition to the bio stabilization assessment discussed above, S&ME also performed an assessment of the stability of the slopes at Sta. 706+66.50 after existing hillsides were regraded to a maximum inclination of 2H:1V, as just described. The regraded slopes included a 1-foot-thick bio stabilized surface representing conditions after the restoration of vegetation. The analyses of the regraded slopes achieved a factor of safety exceeding 1.3 (see Plates 45 and 48 in Appendix III).

S&ME also performed stability analyses for a multiple wall sections of the proposed modular block retaining wall that is planned to replace the existing timber retaining walls along the access path to the north side of the tunnel. Results of these stability analyses indicate that a factor of safety exceeding 1.5 is anticipated for the global stability of the modular block wall. Additional analyses were performed on the slopes uphill of the proposed walls where it is proposed to regrade the slopes to a 2H:1V inclination. To achieve the minimum required factor of safety for this condition (minimum of 1.3), the upper 5 feet of the regraded slope should be over-excavated and recompacted in accordance with *CMS* Item 203 and the benching recommendations in Section 6.4 of this report. Output from the stability analyses for the retaining wall and regraded slopes are included on Plates 49 through 53 in Appendix III.

6.4 Embankment Construction

Currently proposed project drawings supplied by ms indicate that new fill will be placed to construct the slopes behind proposed retaining walls and to fill over the top of the tunnel extension. Recommendations for the placement of fill and the preparation of existing ground surfaces are provided in the following sections.

6.4.1 Site Preparation

We recommend that all vegetation, topsoil, pavement, and miscellaneous materials be removed from the footprint of the proposed fill slopes. Prior to the placement of any new fill, existing debris and talus at the base of the existing rock faces on both ends of the tunnel should be removed. This material may also be used as borrow material for backfill of the walls and tunnel provided it meets the criteria for backfill material type and drainage characteristics (see also Section 6.4.3).

6.4.2 Benching and Special Benching

After all unsuitable materials have been removed and prior to commencing fill placement, it is recommended that horizontal benches be cut into all existing sloping surfaces composed of soil which are steeper than 8(H):1(V) to permit placement and compaction of new fill in horizontal lifts. Where new fill is to be placed on an existing ground surface with a slope between 8(H):1(V) and 4(H):1(V), S&ME recommends that benching of the existing ground be performed in accordance with Item 203.05 of the ODOT *CMS*. At locations where the existing ground surface is steeper than 4(H):1(V), S&ME recommends "Special Benching" procedures as outlined in Section 800 "Special Benching and Sidehill Embankment Fills" in the ODOT *Geotechnical Design Manual* (*GDM*) and the ODOT *Construction Inspection Manual of Procedures* (*CIMP*) should be performed. Additionally, in accordance with Section 800, wherever "Special Benching" is used, Plan Note G109 from the ODOT L&D Manual, Vol. 3, should be included in the General Notes.

Where the proposed embankment configuration will require a minimal width of new fill to be placed against a steeper sloping surface, it likely will be difficult to properly compact the new fill in a horizontal fashion. Sketches illustrating several "typical" Special Benching configurations for sidehill fills on various slopes are included in Figures 800-1, 800-3 and 800-4 of the ODOT *GDM*. These configurations require a minimum distance of 8 feet between the crest of the bench back-slopes and the face of the new slope to permit compaction and grading equipment to work on a horizontal surface.

Where the last (highest) benches encompass the top of the existing slope, S&ME recommends that consideration be given to utilizing the approach outlined in Figure 800-2 of the ODOT *GDM* which constructs an over-steepened slope of temporary fill near the top of the existing slope. This process would provide sufficient width (minimum 8-foot width) for the compaction equipment without having to over-excavate and replace potentially competent sections of the existing slope. Once the fill has been placed and properly compacted to the top of existing hillside, the temporary fill may then be "shaved" off to the final designed embankment configuration. The use of smaller (narrower) compaction equipment may be considered to reduce the minimum width (8 feet) between the crest of the bench back-slopes and the face of the new slope.

During any required Special Benching procedures, S&ME also recommends the following: 1) only one (1) bench be exposed at any given time and that excavation of the next bench should not be permitted until embankment fill placement and compaction has been completed to within 1 to 2 feet of the top of the backslope of the previous bench; and, 2) the length of any given bench that is exposed should not exceed the quantity of embankment fill which may be properly placed and compacted in one (1) day.

6.4.3 Borrow Requirements and Compaction Criteria

New embankment fill should consist of inorganic soil free of all miscellaneous materials, cobbles, and boulders, which is placed in uniform, thin layers and then compacted in accordance with either *CMS* Item 203. Further, borrow materials should be selected in accordance with recommendations provided in Section 6.1.2 to avoid excessive lateral earth pressures acting on the retaining walls and tunnel extension walls.

Borrow materials should not be placed in a frozen condition or upon a frozen surface, and any sloping surfaces on which new fill is to be placed should first be benched in accordance with the recommendations presented in Section 6.4.2 of this report.

Compaction requirements for the construction of earthen embankments are based on ODOT *CMS* Item 203.07.B, which specifies a minimum percent compaction based on the dry unit weight of the type of soil fill being placed as borrow. At the time of this submittal, it is unknown if a borrow source will be required for this project. S&ME recommends that, if a borrow site is required, that sampling and testing of this borrow material be performed prior to construction to verify that the borrow soils are suitable for the planned construction.

6.4.4 Compaction/Moisture Conditioning Concerns

Exposed soil surfaces should be protected from exposure to water prior to regrading or new fill placement. Exposure of cohesive soils to water will result in a decrease in soil strength and an increase in compressibility and should be prevented. Seepage or surface runoff should not be permitted to collect and stand on exposed soil surfaces. Soils loosened/softened by standing water and/or by construction activities should be moisture conditioned (if feasible) or removed from the embankment prior to the placement of additional embankment material. The areas around the proposed construction should be graded such that all water runoff is directed away from the new site improvements during and upon completion of construction.

6.5 Groundwater Considerations

During this exploration, seepage was encountered in four (4) borings ranging from 3 to 16 feet below existing grades. Accordingly, no significant sources of groundwater are anticipated to be encountered during construction.

Surface water and groundwater (if any) should be controlled during construction as the presence of water may loosen or soften soils, causing then to exhibit instability. The quantity of water is anticipated to be limited and may likely be controlled by bailing or with portable pumps. S&ME recommends that the sides and bottoms of all excavations be closely monitored during the construction of the structure. If the soil or shale bedrock at the bottom of an excavation become softened or disturbed by construction activity or exposure to weather, it is recommended that the disturbed/softened material be undercut in accordance with the recommendations provided in Section 6.4 of this report or be removed and the footing elevation be lowered to suitable bearing material.

6.6 Temporary Excavation Considerations

In Federal Register, Volume 54, No. 209 (October 1989), the United States Department of Labor, Occupational Safety and Health Administration (OSHA) amended its "Construction Standards for Excavations, 29 CFR, Part 1926, Subpart P". This document was issued to better ensure the safety of workers entering trenches or excavations. It is mandated by this federal regulation that excavations be constructed in accordance with the OSHA guidelines. It is our understanding that these regulations are being strictly enforced and if they are not closely followed, the owner and the contractor could be liable for substantial penalties.

The contractor is solely responsible for designing and constructing stable, temporary excavations and should shore, slope, or bench the sides of the excavations as required to maintain stability of both the excavation sides and bottom. The contractor's "responsible person", as defined in 29 CFR, Part 1926, should evaluate the soil exposed in the excavations as part of the contractor's safety procedures. In no case should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations. If an excavation, including a trench is extended to a depth of more than twenty (20) feet, it will be necessary to have the side slopes designed by a professional engineer registered in the state where the construction is occurring.

We provide this information solely as a service to our client. S&ME does not assume responsibility for construction site safety or the contractor's or other parties' compliance with local, state, and federal safety or other regulations.

7.0 Final Considerations

This report has been prepared in accordance with generally accepted geotechnical engineering practice for specific application to this project. The conclusions and recommendations contained in this report are based upon applicable standards of our practice in this geographic area at the time this report was prepared. No other representation or warranty either express or implied, is made.

We relied on project information given to us to develop our conclusions and recommendations. If project information described in this report is not accurate, or if it changes during project development, we should be notified of the changes so we can modify our recommendations based on this additional information if necessary.

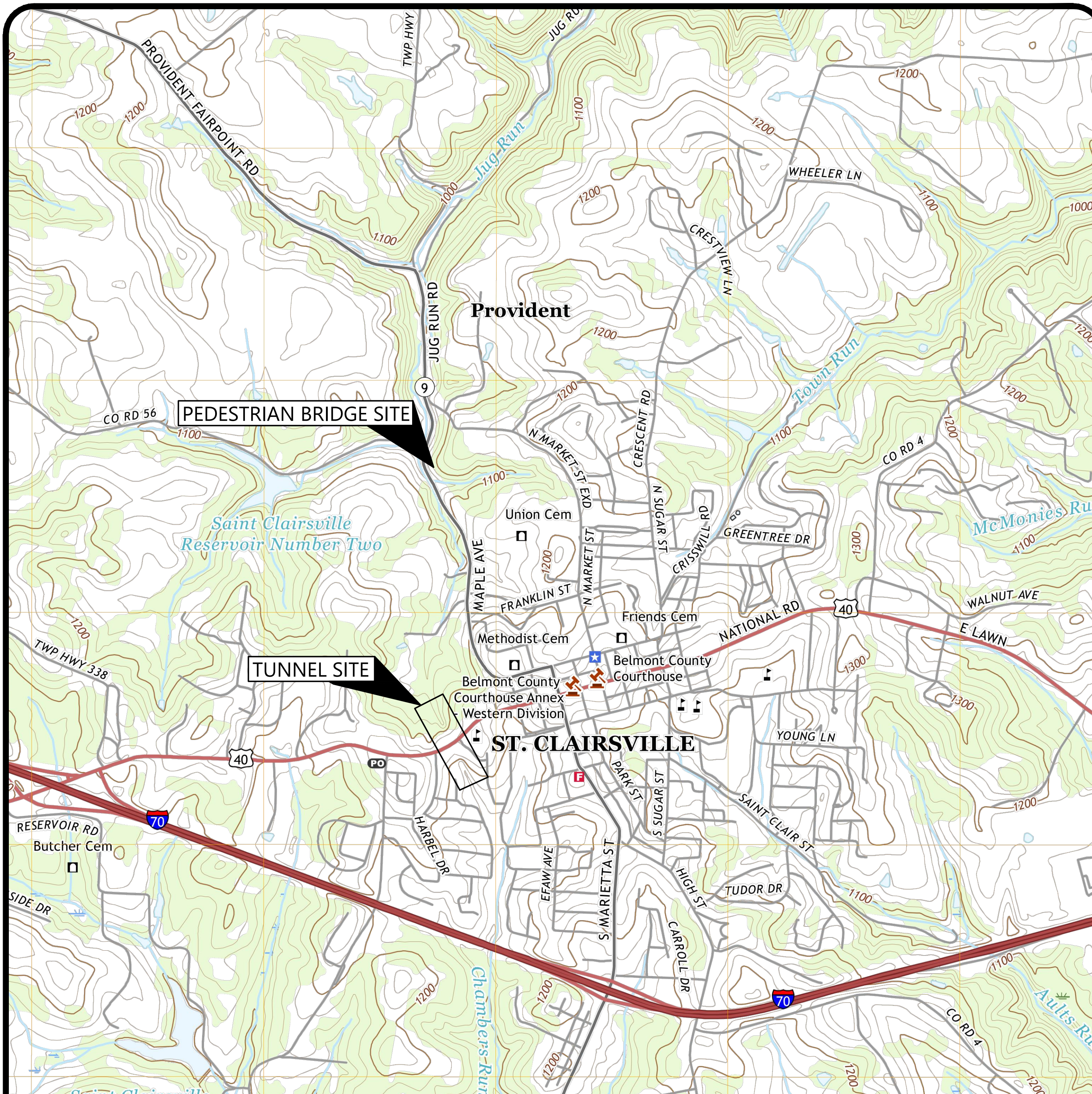
Our conclusions and recommendations are based on limited data from a field exploration program. Subsurface conditions can vary widely between explored areas. Some variations may not become evident until construction. If conditions are encountered that appear different than those described in our report, we should be notified. This report should not be construed to represent subsurface conditions for the entire site.

Unless specifically noted otherwise, our field exploration program did not include an assessment of regulatory compliance, environmental conditions or pollutants or presence of any biological materials (mold, fungi, bacteria). If there is a concern about these items, other studies should be performed. S&ME can provide a proposal and perform these services if requested.

S&ME should be retained to review the final plans and specifications to confirm that earthwork and other recommendations are properly interpreted and implemented. The recommendations in this report are contingent on S&ME's review of final plans and specifications followed by our observation and monitoring of earthwork construction activities.

Appendices

Appendix I – General Project Information and Boring Logs



N

Project Location
Belmont County, Ohio

USGS Mapping:
St. Clairsville USGS Quad

0 2000 4000
GRAPHIC SCALE (IN FEET)

Vicinity Map

Structure Foundation Exploration
BEL-National Road Tunnel
St. Clairsville, Belmont County, Ohio

SCALE:	FIGURE NO.
GRAPHIC	1
DATE:	
10-17-2022	
PROJECT NUMBER	
210435B	

Drawing Path: T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\CAD\Construction\Plan of Borings.dwg

N

NOTE: AERIAL IMAGERY COURTESY OF OGRIP, OBTAINED FALL 2020

LEGEND

B-001-0-22 BORING NUMBER AND LOCATION

0 60 120
GRAPHIC SCALE (IN FEET)

Drawing Path: T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\CAD\Construction\Plan of Borings.dwg

Plan of Borings

Structure Foundation Exploration
BEL-National Road Tunnel
St. Clairsville, Belmont County, Ohio

SCALE:	GRAPHIC
DATE:	10-18-2022
PROJECT NUMBER	210435B
FIGURE NO.	2A

NOTE: AERIAL IMAGERY COURTESY OF OGRIP, OBTAINED FALL 2020

N

0 60 120

GRAPHIC SCALE (IN FEET)

LEGEND

B-001-0-22 BORING NUMBER AND LOCATION

D-001-1-22 DCP NUMBER AND LOCATION

Drawing Path: T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\CAD\Construction\Plan of Borings.dwg

S&ME	**Plan of Borings**	SCALE: GRAPHIC	FIGURE NO.
	Structure Foundation Exploration BEL-National Road Tunnel St. Clairsville, Belmont County, Ohio	DATE: 10-18-2022 PROJECT NUMBER 210435B	**2B**

N

NOTE: AERIAL IMAGERY COURTESY OF OGRIP, OBTAINED FALL 2020

LEGEND

B-001-0-22 BORING NUMBER AND LOCATION

D-001-1-22 DCP NUMBER AND LOCATION

0 20 40

GRAPHIC SCALE (IN FEET)

Drawing Path: T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\CAD\Construction\Plan of Borings.dwg

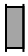
Plan of Borings - Trustle Bridge Retaining Wall

Structure Foundation Exploration
BEL-National Road Tunnel
St. Clairsville, Belmont County, Ohio

SCALE:	FIGURE NO.
GRAPHIC	2C
DATE:	
10-18-2022	
PROJECT NUMBER	
210435B	

EXPLANATION OF SYMBOLS AND TERMS USED ON BORING LOGS FOR SAMPLING AND DESCRIPTION OF SOIL

SAMPLING DATA

	-	Indicates sample was attempted within this depth interval.
2 3 5	-	The number of blows required for each 6-inch increment of penetration of a “Standard” 2-inch O.D. split-barrel sampler, driven a distance of 18 inches by a 140-pound hammer freely falling 30 inches (SPT). The raw “blowcount” or “N” is equal to the sum of the second and third 6-inch increments of penetration.
N_{60}	-	Corrected Blowcount = [(Drill Rod Energy Ratio) / (0.60 Standard)] X N
SS	-	Split-barrel sampler, any size.
ST	-	Shelby tube sampler, 3″ O.D., hydraulically pushed.
R	-	Refusal of sampler in very-hard or dense soil, or on a resistant surface.
50-4”	-	Number of blows (50) to drive a split-barrel sampler a certain distance (4 inches), other than the normal 6-inch increment.

DEPTH DATA

W	-	Depth of water or seepage encountered during drilling.
▽	-	Depth to water in boring at the end of drilling (EOD).
▼ 5 days	-	Depth to water in monitoring well or piezometer in boring a certain number of days (5) after termination of drilling.
TR	-	Depth to top of rock.

SOIL DESCRIPTIONS

Soils have been classified in general accordance with Section 603 of the most recent ODOT SGE, and described in general accordance with Section 602, including the use of special adjectives to designate approximate percentages of minor components as follows:

Adjective	Percent by Weight
trace	1 to 10
little	10 to 20
some	20 to 35
“and”	35 to 50

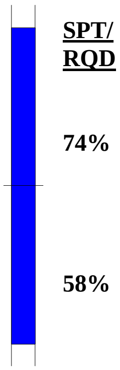
The following terms are used to describe density and consistency of soils:

Term (Granular Soils)	Blows per foot (N_{60})
Very-loose	Less than 5
Loose	5 to 10
Medium-dense	11 to 30
Dense	31 to 50
Very-dense	Over 50

Term (Cohesive Soils)	Qu (tsf)
Very-soft	Less than 0.25
Soft	0.25 to 0.5
Medium-stiff	0.5 to 1.0
Stiff	1.0 to 2.0
Very-stiff	2.0 to 4.0
Hard	Over 4.0

EXPLANATION OF SYMBOLS AND TERMS USED ON BORING LOGS FOR SAMPLING AND DESCRIPTION OF ROCK

SAMPLING DATA



When bedrock is encountered and rock core samples are attempted, the length of core recovered and lost during the core run is reported in the "REC" column. The type of rock core barrel utilized is recorded under the heading "Sampling Method" at the top of the boring log, and also in the "SAMPLE ID" column. Rock-core barrels can be of either single- or double-tube construction, and a special series of double-tube barrels, designated by the suffix M, may also be used to obtain maximum core recovery in very-soft or fractured rock. Four basic groups of barrels are used most often in subsurface investigations for engineering purposes, and these groups and the diameters of the cores obtained are as follows:

AX, AW, AXM, AWM	-	1-1/8 inches
BX, BW, BXM, BWM	-	1-5/8 inches
NX, NW, NXM, NWM	-	2-1/8 inches
NQ, NQ2	-	1-7/8 inches

Rock Quality Designation (RQD) is expressed as a percentage and is obtained by summing the total length of all core pieces which are at least 4 inches long and then dividing this sum by, either, the total length of core run or the length of the core run in a particular bedrock stratum. The RQD value is reported as a percentage in the "SPT/RQD" column. It has been found that there is a reasonably good relationship between the RQD value and the general quality of rock for engineering purposes. This relationship is shown as follows:

RQD - %	General Quality
0 - 25	Very-poor
25 - 50	Poor
50 - 75	Fair
75 - 90	Good
90 - 100	Excellent

ROCK HARDNESS

Recovered bedrock samples are described in general accordance with Section 605 of the 2007 ODOT SGE and subsequent revisions, where necessary. The following terms are used to describe rock hardness:

Term	Meaning
Very Weak	Rock can be excavated readily with the point of a pick and carved with a knife. Pieces 1 inch or greater in thickness can be broken by finger pressure. Can be scratched with a fingernail.
Weak	Rock can be grooved or gouged readily by a knife or pick, and can be excavated in small fragments with moderate blows from a pick point. Small, thin pieces may be broken with finger pressure.
Slightly Strong	Rock can be grooved or gouged 0.05 inches deep with firm pressure from a knife or pick point, and can be excavated in small chips to pieces of 1 inch maximum size using hard blows from the point of a geologist's pick.
Moderately Strong	Rock can be scratched with a knife or pick. Grooves or gouges to ¼ inch deep can be excavated by hard blows of a geologist's pick. Requires moderate hammer blows to detach a hand specimen.
Strong	Rock can be scratched with a knife or pick only with difficulty. Requires hard hammer blows to detach a hand specimen. Sharp and resistant edges are present on hand specimens.
Very Strong	Rock cannot be scratched by a knife or sharp pick. Breaking of hand specimens requires repeated hard blows of a geologist's hammer.
Extremely Strong	Rock cannot be scratched by a knife or sharp pick. Chipping of hand specimens requires repeated hard blows of a geologist's hammer.

S&ME JOB: 210435B

PROJECT: BEL-NATIONAL ROAD TUNNEL TYPE: STRUCTURE PID: 108774 BR ID: N/A START: 6/14/22 END: 6/14/22	DRILLING FIRM / OPERATOR: OTB / C. SVITAK SAMPLING FIRM / LOGGER: S&ME / A. KHAN DRILLING METHOD: 3.25" HSA / NQ SAMPLING METHOD: SPT / NQ	DRILL RIG: OTB MOBILE B-57 HAMMER: CME AUTOMATIC CALIBRATION DATE: 11/25/20 ENERGY RATIO (%): 90*	STATION / OFFSET: 712+79, 63' RT ALIGNMENT: NATIONAL RD BIKEWAY ELEVATION: 1191.5 (MSL) EOB: 50.0 ft. COORD: 40.077226 N, 80.908075 W

EXPLORATION ID **B-001-0-22**

MATERIAL DESCRIPTION AND NOTES	ELEV. 1191.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
TOPSOIL - 14 INCHES	1190.3																	
FILL: Stiff to very-stiff brown **SILTY CLAY**, little fine to coarse sand, trace fine gravel, many wood fragments, few roots, damp.		1 - 2.5	2 2 2	6	50	SS-1	1.5-2.5	-	-	-	-	-	-	-	-	23	A-6b (V)	
	1188.0																	
Very-stiff brown mottled with gray **CLAY**, "and" silt, little fine to coarse sand, trace fine gravel, few roots, damp.		3.5 - 5	3 4 3	11	50	SS-2	2.5-3.5	2	6	8	44	40	42	23	19	19	A-7-6 (12)	
	1185.0	6 - 7.5	3 5 4	14	50	SS-3A	2.5-3.5	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
Stiff to very-stiff brown **SILTY CLAY**, little fine to coarse sand, trace fine gravel, few coal fragments, damp.						SS-3B	2.0-2.5	-	-	-	-	-	-	-	-	19	A-6b (V)	
		8.5 - 10	2 4 7	17	67	SS-4	2.0-3.5	-	-	-	-	-	-	-	-	20	A-6b (V)	
		11 - 12.5	2 2 3	8	100	SS-5	1.0-2.0	4	6	7	50	33	38	20	18	22	A-6b (11)	
	1178.5																	
Very-stiff to hard gray **SILTY CLAY**, trace fine to coarse saand, trace fine gravel, probable decomposed shale, few shale fragments, iron oxide staining, dry to damp.		13.5 - 15	6 7 7	21	61	SS-6	3.5-4.5+	-	-	-	-	-	-	-	-	11	A-6b (V)	
		16 - 17.5	11 13 18	47	100	SS-7	4.5+	4	5	4	58	29	35	19	16	10	A-6b (10)	
		18.5 - 20	10 30 43	110	50	SS-8	4.5+	-	-	-	-	-	-	-	-	7	A-6b (V)	
	1170.5	21 TR																
SHALE, gray, highly weathered, very weak to weak.		21	50-5"	-	100	SS-9	-	-	-	-	-	-	-	-	-	3	Rock (V)	
	1167.5	24	50-4"	-	100	SS-10	-	-	-	-	-	-	-	-	-	8	Rock (V)	
SHALE, gray to greenish gray, slightly weathered, very weak to slightly strong, laminated to medium bedding, highly to moderately fractured, slightly rough, blocky/disturbed/seamy, good to fair condition, gravel/broken rock zones from 24.0' to 24.4', 25.1' to 25.5', 31.1' to 31.5'; RQD = 45%, REC = 93%. - @ 28.0' to 33.0' SDI = 3.5%		24 - 29	33		79	NQ-11											CORE	

PID: 108774	BR ID: N/A	PROJECT: BEL-NATIONAL ROAD TUNNEL	STATION / OFFSET: 712+79, 63' RT	START: 6/14/22	END: 6/14/22	PG 2 OF 2	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 1161.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, gray to greenish gray, slightly weathered, very weak to slightly strong, laminated to medium bedding, highly to moderately fractured, slightly rough, blocky/disturbed/seamy, good to fair condition, gravel/broken rock zones from 24.0' to 24.4', 25.1' to 25.5', 31.1' to 31.5'; RQD = 45%, REC = 93%. *(continued)*		31, 32, 33	22		88	NQ-12											CORE	
- @ 37.0' to 37.4' Qu = 2,245 psi		34, 35, 36, 37, 38	58		100	NQ-13											CORE	
		39, 40, 41, 42, 43	40		100	NQ-14											CORE	
	1141.5	44, 45, 46, 47, 48, 49, EOB 50	62		95	NQ-15											CORE	

NOTES:
- Borehole was dry prior to coring.
- Water measured at a depth of 11' after completion of coring.
- SS-5, SS-7 and SS-9 were obtained from an offset boring approximately 2 feet from the original boring.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

S&ME JOB: 210435B

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: OTB / C. SVITAK	DRILL RIG: OTB MOBILE B-57	STATION / OFFSET: 712+88, 1' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 11/25/20	ELEVATION: 1144.7 (MSL) EOB: 25.5 ft.
START: 6/15/22 END: 6/15/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 90*	COORD: 40.077278 N, 80.907857 W

EXPLORATION ID: **B-002-0-22**

MATERIAL DESCRIPTION AND NOTES	ELEV. 1144.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT - 4 INCHES	1144.4																	
FILL: Medium-dense to dense brownish gray **GRAVEL WITH SAND**, trace silt, trace clay, dry to damp.	1142.7	1 – 2	7 12 12	36	44	SS-1A	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
Dense brown **COARSE AND FINE SAND**, some fine gravel, trace silt, damp.	1141.2	W 1141.7 (3); TR				SS-1B	-	-	-	-	-	-	-	-	-	8	A-3a (V)	
SHALE, gray, highly weathered, very weak to weak.	1139.7	4	26 50-5"	-	100	SS-2	-	-	-	-	-	-	-	-	-	3	Rock (V)	
SHALE, gray, highly to severely weathered, weak to slightly strong, thinly laminated to very thin bedded, highly fractured to fractured, narrow to open, slickensided to slightly rough, disintegrated, poor condition, RQD = 39%, REC = 84%. - @ 8.6' to 9.0' Qu = 1,368 psi	1130.7	5 – 10	55		85	NQ-3											CORE	
		11 – 15	40		78	NQ-4											CORE	
SHALE, gray, slightly to moderately weathered, slightly to moderately strong, thinly laminated to medium bedded, fractured to moderately fractured, narrow, slightly rough to rough, very blocky, good condition, RQD = 67%, REC = 100%. - @ 19.5' to 19.9' Qu = 3,975 psi	1119.2	16 – 25; EOB	62		100	NQ-5											CORE	

NOTES:
- Seepage noted at 3.0' during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 5.0' after completion of coring.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

PROJECT: BEL-NATIONAL ROAD TUNNEL TYPE: STRUCTURE PID: 108774 BR ID: N/A START: 7/21/22 END: 7/21/22	DRILLING FIRM / OPERATOR: S&ME / T. FROST SAMPLING FIRM / LOGGER: S&ME / A. KHAN DRILLING METHOD: 3.25" HSA / NQ SAMPLING METHOD: SPT / NQ	DRILL RIG: S&ME ATV D50 (R61) HAMMER: CME AUTOMATIC CALIBRATION DATE: 6/7/22 ENERGY RATIO (%): 69.8	STATION / OFFSET: 712+13, 91' LT ALIGNMENT: NATIONAL RD BIKEWAY ELEVATION: 1217.8 (MSL) EOB: 76.0 ft. COORD: 40.077570 N, 80.907681 W	EXPLORATION ID **B-003-0-22** PAGE 1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 1217.8	DEPTHS
TOPSOIL - 4 INCHES	1217.5	
PROBABLE FILL: Stiff brown **CLAY**, "and" silt, little fine to coarse sand, trace fine gavel, damp to moist.	1214.8	
Very-stiff to hard gray **CLAY**, "and" silt, trace fine to coarse gravel, trace fine to coarse sand, damp.	1211.1	
Very-stiff to hard dark gray and black **ELASTIC CLAY**, "and" silt, some fine to coarse sand, trace fine gravel, many coal and carbonaceous shale fragments, damp.	1207.3	
Hard gray **CLAY**, some silt, trace fine to coarse sand, trace fine gravel, similar to severely weathered and decomposed shale, damp.	1199.3	W 1199.3 TR
SHALE, gray, highly weathered, carbonaceous.	1196.8	
SHALE, dark gray, slightly weathered, weak to slightly strong, laminated to thick bedded, fractured to slightly fractured, narrow to open, very blocky, good condition, carbonaceous from 21.0' to 23.0', 52.0' to 53.0' and 75.2' to 75.7', RQD = 59%, REC = 98%.		

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
3 3 4	8	67	SS-1	1.5-2.0	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
3 4 6	12	67	SS-2	2.5-3.0	10	2	2	40	46	41	24	17	13	A-7-6 (11)	
3 4 9	15	100	SS-3A	4.0-4.5	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
			SS-3B	3.5-4.5	-	-	-	-	-	-	-	-	46	A-7-5 (V)	
8 8 6	16	72	SS-4	-	10	9	16	45	20	60	44	16	37	A-7-5 (11)	
8 9 9	21	78	SS-5	4.5+	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
9 18 21	45	100	SS-6	4.5+	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
10 12 15	31	94	SS-7	-	1	2	3	24	70	46	27	19	21	A-7-6 (13)	
30 40 50	105	100	SS-8	-	-	-	-	-	-	-	-	-	6	Rock (V)	
50-0"	-	100	SS-9	-	-	-	-	-	-	-	-	-	1	Rock (V)	
65		98	NQ-10		-	-	-	-	-	-	-	-	-	CORE	
65		100	NQ-11											CORE	

Depth scale: 1 – 29

PID: 108774	BR ID: N/A	PROJECT: BEL-NATIONAL ROAD TUNNEL	STATION / OFFSET: 712+13, 91' LT	START: 7/21/22	END: 7/21/22	PG 2 OF 3	B-003-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 1187.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, dark gray, slightly weathered, weak to slightly strong, laminated to thick bedded, fractured to slightly fractured, narrow to open, slightly rough, very blocky, good condition, carbonaceous from 21.0' to 23.0', 52.0' to 53.0' and 75.2' to 75.7', RQD = 59%, REC = 98%. *(continued)*		31–36	58		95	NQ-12											CORE	
		36–41	50		100	NQ-13											CORE	
- @ 40.5' to 40.9' Qu = 2,024 psi		41–46	40		92	NQ-14											CORE	
		46–51	63		100	NQ-15											CORE	
- @ 51.0' to 56.0' SDI = 12.5%		51–56	58		100	NQ-16											CORE	
		56–61	47		100	NQ-17											CORE	

PID: 108774	BR ID: N/A	PROJECT: BEL-NATIONAL ROAD TUNNEL	STATION / OFFSET: 712+13, 91' LT	START: 7/21/22	END: 7/21/22	PG 3 OF 3	B-003-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 1155.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, dark gray, slightly weathered, weak to slightly strong, laminated to thick bedded, fractured to slightly fractured, narrow to open, slightly rough, very blocky, good condition, carbonaceous from 21.0' to 23.0', 52.0' to 53.0' and 75.2' to 75.7', RQD = 59%, REC = 98%. *(continued)*		63–66	83		95	NQ-18											CORE	
		66–71	58		98	NQ-19											CORE	
	1141.8	71–76 EOB	58		97	NQ-20											CORE	

NOTES:
- No water observed during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 3.5' after completion of coring.
- Borehole caved at 21.0' after removal of drilling tools.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

S&ME JOB: 210435B

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: OTB / C. SVITAK	DRILL RIG: OTB MOBILE B-57	STATION / OFFSET: 711+14, 63' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 11/25/20	ELEVATION: 1230.0 (MSL) EOB: 39.0 ft.
START: 6/13/22 END: 6/13/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 90*	COORD: 40.077784 N, 80.907920 W

EXPLORATION ID: **B-004-0-22**

MATERIAL DESCRIPTION AND NOTES	ELEV. 1230.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
TOPSOIL - 4 INCHES	1229.7																	
Medium-stiff to stiff brown **SILTY CLAY**, some fine to coarse gravel, little fine to coarse, few roots, damp.		1 – 2	4 2 2	6	0	SS-1	-	-	-	-	-	-	-	-	-	21	A-6b (V)	
		4 – 5	2 2 3	8	33	SS-2	0.5-1.5	26	7	8	33	26	38	21	17	14	A-6b (8)	
	1221.5	6 – 7.5	1 1 9	15	33	SS-3	0.5-1.5	-	-	-	-	-	-	-	-	23	A-6b (V)	
Medium-stiff to stiff brown and gray **SILTY CLAY**, little fine to coarse sand, trace fine gravel, damp. - @ 8.5' organic odor - @ 13.5' iron oxide staining - @ 14.5' few coal fragments		8.5 – 10	2 3 4	11	100	SS-4	0.5-1.5	4	6	6	48	36	39	19	20	23	A-6b (12)	
	1213.0	13.5 – 15	2 6 4	15	72	SS-5	1.0-1.5	-	-	-	-	-	-	-	-	22	A-6b (V)	
Very-stiff to hard gray **CLAY**, trace fine to coarse sand, trace fine gravel, dry to damp.	1210.5	18.5 – 20	4 7 7	21	94	SS-6A	3.5-4.5	1	2	3	22	72	41	21	20	14	A-7-6 (12)	
						SS-6B	4.5+	-	-	-	-	-	-	-	-	-	A-6b (V)	
Hard gray **SILTY CLAY**, little fine to coarse gravel, trace fine to coarse sand, probable decomposed shale, iron oxide staining, dry. - @ 19.5' few coal fragments	W 1209.0	23.5 – 25	7 18 23	62	50	SS-7	4.5+	-	-	-	-	-	-	-	-	12	A-6b (V)	
		28.5 – 30	12 15 23	57	94	SS-8	4.5+	12	1	3	44	40	39	20	19	10	A-6b (12)	

S&ME ODOT LOG (8.5X11) - SGE 01/2019 - OH DOT.GDT - 2/8/23 18:17 - R:\SERVICE LINES\CS-2557\CLEVELAND\01 - LABORATORY\02 - GINTW\PROJECTS\210435B.GPJ

PID: 108774	BR ID: N/A	PROJECT: BEL-NATIONAL ROAD TUNNEL	STATION / OFFSET: 711+14, 63' LT	START: 6/13/22	END: 6/13/22	PG 2 OF 2	B-004-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 1200.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
Hard gray **SILTY CLAY**, little fine to coarse gravel, trace fine to coarse sand, probable decomposed shale, iron oxide staining, dry. *(continued)*	1197.0	31–33																
SHALE, gray, highly weathered, very weak to weak.	1196.0	TR 33–34	50-5"	-	40	SS-9	-	-	-	-	-	-	-	-	-	10	Rock (V)	
SHALE, gray, slightly weathered, weak to moderately strong, laminated to medium bedded, highly fractured to slightly fractured, narrow, slightly rough, very blocky, good condition, carbonaceous from 34' to 35', few limestone seams beginning at 37.7', RQD = 62%, REC = 98%.	1191.0	34–39 EOB	62		98	NQ-10											CORE	

NOTES:
- SS-1 moisture content performed on auger cuttings recovered from 1.0' to 2.5'.
- Seepage noted at 21' during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 26' after completion of coring.
- Borehole caved at 24' after augers were removed.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: S&ME / T. FROST	DRILL RIG: S&ME ATV D50 (R61)	STATION / OFFSET: 707+99, 94' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 6/7/22	ELEVATION: 1221.9 (MSL) EOB: 26.3 ft.
START: 7/18/22 END: 7/18/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 69.8	COORD: 40.078383 N, 80.908906 W

EXPLORATION ID **B-005-0-22**

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 1221.9	DEPTHS
TOPSOIL - 4 INCHES	1221.6	
FILL: Very-stiff to hard brown and gray **SILT AND CLAY**, some fine to coarse sand, some fine to coarse gravel, few roots, damp to moist.	1218.2	
FILL: Medium-stiff to stiff brown and dark brown **CLAY**, "and" fine to coarse gravel (brick fragments), some fine to coarse sand, little silt, few sandstone fragments, damp.	1213.9	
Stiff to very-stiff brown mottled with gray **SILTY CLAY**, some to "and" silt, little fine to coarse sand, trace fine gravel, damp.	1210.6	
Very-stiff black **ELASTIC CLAY**, "and" silt, little fine to coarse sand, trace fine gravel, few coal fragments, damp.	1208.9	
Hard brown and gray **CLAY**, "and" silt, little fine to coarse sand, trace fine gravel, similar to severely weathered shale, damp.	1200.6	TR
SHALE, black, moderately weathered, weak to slightly strong, very thin to thin bedded, carbonaceous, highly fractured to fractured, narrow, slightly rough, blocky/disturbed/seamy, fair condition, coal fragments from 21.3' to 21.4', RQD = 11%, REC = 69%.	1197.8	
SHALE, dark gray, slightly weathered, weak, medium bedded, slightly carbonaceous, moderately to slightly fractured, narrow to tight, slightly rough, very blocky, good condition, RQD = 96%, REC = 100%.	1195.6	EOB

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
3-3-4	8	44	SS-1	3.5-4.5	-	-	-	-	-	-	-	-	19	A-6a (V)
15-15-7	26	89	SS-2A	-	-	-	-	-	-	-	-	-	26	A-6a (V)
			SS-2B	1.0-1.5	37	15	11	19	18	42	25	17	15	A-7-6 (2)
2-2-3	6	22	SS-3	0.5-1.0	-	-	-	-	-	-	-	-	31	A-7-6 (V)
3-3-4	8	78	SS-4	1.5-3.5	-	-	-	-	-	-	-	-	26	A-6b (V)
3-7-13	23	89	SS-5A	1.0-1.5	-	-	-	-	-	-	-	-	30	A-6b (V)
			SS-5B	2.0-2.5	1	5	12	46	36	61	44	17	46	A-7-5 (15)
5-12-17	34	100	SS-6	4.0-4.5	-	-	-	-	-	-	-	-	17	A-7-6 (V)
9-18-23	48	100	SS-7	4.5+	1	7	5	45	42	43	24	19	16	A-7-6 (12)
9-9-13	26	72	SS-8	4.5+	-	-	-	-	-	-	-	-	6	A-7-6 (V)
3-50-5"	-	100	SS-9A	-	-	-	-	-	-	-	-	-	11	A-7-6 (V)
			SS-9B	-									5	Rock (V)
47		82	NQ-10		-	-	-	-	-	-	-	-	-	CORE

HOLE SEALED

NOTES:
- No water observed during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 15.0' after coring.
- Borehole caved at 22.0' after removal of drilling tools.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

S&ME JOB: 210435B

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: S&ME / T. FROST	DRILL RIG: S&ME ATV D50 (R61)	STATION / OFFSET: 707+23, 49' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 6/7/22	ELEVATION: 1203.2 (MSL) EOB: 26.5 ft.
START: 7/20/22 END: 7/20/22	SAMPLING METHOD: SPT / NQ / ST	ENERGY RATIO (%): 69.8	COORD: 40.078737 N, 80.908558 W

EXPLORATION ID: **B-006-0-22**

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES

Material Description and Notes	Elev. (top 1203.2)
TOPSOIL - 2 INCHES	1203.0
Hard brown **SILT AND CLAY**, little fine to coarse sand, trace fine gravel, few roots, damp.	1197.7
Stiff to very-stiff gray and gray mottled with brown **CLAY**, "and" silt, trace fine to coarse sand, few coal fragments, damp to moist. - Shelby tube obtained from 8.0' to 10.0' in offset boring.	1188.9
Very-dense orangish-brown **GRAVEL WITH SAND AND SILT**, little clay, damp to moist.	1187.7
Very-stiff orangish-brown **CLAY**, some fine gravel, some silt, trace fine to coarse sand, damp to moist.	1184.7
SHALE, gray, moderately weathered, laminated to thin bedding, highly to moderately fractured, narrow to open, slightly rough, disintegrated to blocky/disturbed/seamy, poor to fair condition, RQD = 21%, REC = 85%.	1176.7

Depths: W 1188.9 (14.3'); W 1187.2 (16'); TR at 18.5'; EOB at 26.5'.

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
7-9-9	21	94	SS-1	4.5+	-	-	-	-	-	-	-	-	13	A-6a (V)	
7-7-7	16	89	SS-2	4.0-4.5	6	6	7	39	42	36	24	12	14	A-6a (9)	
4-7-9	19	72	SS-3	3.0-4.0	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
		69	ST-11	-	0	2	3	39	56	46	23	23	26	A-7-6 (14)	
3-3-9	14	100	SS-4	1.0-1.5	-	-	-	-	-	-	-	-	36	A-7-6 (V)	
3-2-2	5	28	SS-5	1.0-4.0	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
5-15-19	40	100	SS-6A	1.0-3.0	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
			SS-6B	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)	
5-4-6	12	100	SS-7	2.0-2.5	30	5	3	28	34	44	27	17	25	A-7-6 (9)	
50-5"	-	100	SS-8		-	-	-	-	-	-	-	-	6	Rock (V)	
0		88	NQ-9											CORE	
30		83	NQ-10											CORE	

NOTES:
- Seepage encountered at 14.3' and 16' during drilling.
- Water measured at a depth of 18' after completion of coring.
- Borehole caved at 25.0' after removal of drilling tools.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: S&ME / T. FROST	DRILL RIG: S&ME ATV D50 (R61)	STATION / OFFSET: 706+35, 71' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 6/7/22	ELEVATION: 1192.7 (MSL) EOB: 57.4 ft.
START: 7/19/22 END: 7/19/22	SAMPLING METHOD: SPT / NQ / ST	ENERGY RATIO (%): 69.8	COORD: 40.078983 N, 80.908620 W

EXPLORATION ID **B-007-0-22**

PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 1192.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
TOPSOIL - 4 INCHES	1192.4																	
Stiff to hard brown mottled with gray **CLAY**, some silt, trace fine to coarse sand, trace fine gravel, few medium-stiff zones, few coal fragments near 6', damp.		1–2	1 2 2	5	72	SS-1	0.5-1.0	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
		4–5	3 5 6	13	78	SS-2	2.5-3.5	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
	1184.7	6–7	4 6 8	16	78	SS-3	2.5-4.5	1	1	2	33	63	45	25	20	19	A-7-6 (13)	
Stiff to very-stiff brown mottled with gray **SILT AND CLAY**, some fine to coarse gravel, some fine to coarse sand, few coal fragments, damp. - Shelby tube obtained from 8.0' to 10.0' in offset boring.		8			81	ST-17	-	25	14	9	25	27	34	21	13	16	A-6a (5)	
		9–10	4 4 6	12	89	SS-4	1.0-3.5	-	-	-	-	-	-	-	-	16	A-6a (V)	
	1179.7	11–12	3 5 7	14	94	SS-5	2.5-3.5	-	-	-	-	-	-	-	-	14	A-6a (V)	
Hard gray **SANDY SILT**, some clay, little fine gravel, few shale fragments, similar to severely weathered shale, dry.	1176.7	14–15	6 6 13	22	100	SS-6	4.5+	16	5	1	46	32	35	25	10	13	A-4a (8)	
SHALE, brown, gray and red, highly to slightly weathered, very weak to weak, laminated to thin bedded, highly to moderately fractured, narrow to open, slightly rough, blocky/disturbed/seamy, poor condition, friable from 21.0' to 22.6', brown from 17.0' to 21.0' and reddish-gray from 24.4' to 26.4', RQD = 30%, REC = 89%.		16 TR	20 50-5"	-	100	SS-7		-	-	-	-	-	-	-	-	11	Rock (V)	
		17	0		100	NQ-8											CORE	
		18–22	17		72	NQ-9											CORE	
		23–27	30		92	NQ-10											CORE	
		28–29																

PID: 108774	BR ID: N/A	PROJECT: BEL-NATIONAL ROAD TUNNEL	STATION / OFFSET: 706+35, 71' LT	START: 7/19/22	END: 7/19/22	PG 2 OF 2	B-007-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 1162.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE, brown, gray and red, highly to slightly weathered, very weak to weak, laminated to thin bedded, highly to moderately fractured, narrow to open, slightly rough, blocky/disturbed/seamy, poor condition, friable from 21.0' to 22.6', brown from 17.0' to 21.0' and reddish-gray from 24.4' to 26.4', RQD = 30%, REC = 89%. *(continued)* - @ 31.2' to 31.6' Qu = 1,050 psi - @ 32.4' to 37.4' SDI = 20.4%	1157.3	31–35	47		100	NQ-11											CORE	
SHALE, gray, slightly weathered (moderately weathered from 47.4' to 50.0'), weak to slightly strong, very thin to medium bedded, fractured to slightly fractured, narrow, slightly rough, very blocky, fair to good condition, RQD = 62%, REC = 96%. - @ 44.1' to 44.5' Qu = 2,062 psi	1139.9	35–52	48		97	NQ-12											CORE	
			67		88	NQ-13											CORE	
			65		100	NQ-14											CORE	
			47		98	NQ-15											CORE	
SANDSTONE, gray with dark gray, slightly weathered, medium grained, moderately strong, thin bedded, fractured to moderately fractured, narrow, very rough, blocky, good condition, RQD = 86%, REC = 100%.	1136.9	53–55	77		100	NQ-16											CORE	
SHALE, gray and light brown, slightly to moderately weathered, weak, thin bedded, highly to moderately fractured, narrow to open, slightly rough, very blocky, fair to good condition, RQD = 47%, REC = 100%.	1135.3	56–57 EOB																

NOTES:
- No water observed during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 18' after completion of coring.
- Borehole caved at 25.0' after removal of drilling tools.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

S&ME JOB: 210435B

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: OTB / C. SVITAK	DRILL RIG: OTB MOBILE B-57	STATION / OFFSET: 705+90, 0' LT	EXPLORATION ID B-008-0-22
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY	
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 11/25/20	ELEVATION: 1145.2 (MSL) EOB: 25.0 ft.	PAGE 1 OF 1
START: 6/16/22 END: 6/16/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 90*	COORD: 40.079012 N, 80.908919 W	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1145.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT - 6 INCHES	1144.7																	
FILL: Medium-dense grayish black **GRAVEL WITH SAND**, trace silt, trace clay, damp.	1142.2	W 1143.2	9 10 9	29	67	SS-1	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
Medium-dense gray **GRAVEL WITH SAND, SILT AND CLAY**, damp.	1141.4	TR	8 35 50-5"	-	100	SS-2A	-	-	-	-	-	-	-	-	-	11	A-2-6 (V)	
SHALE, gray, highly weathered, very weak to weak.	1139.7					SS-2B	-	-	-	-	-	-	-	-	-	5	Rock (V)	
			50	-	67	SS-3	-	-	-	-	-	-	-	-	-	4	Rock (V)	
SHALE, gray, slightly weathered, very weak to weak, thinly laminated to thin bedded, highly fractured to moderately fractured, narrow to open, slightly rough, blocky/disturbed/seamy, fair condition, RQD = 23%, REC = 100%.	1134.5		23		100	NQ-4											CORE	
INTERBEDDED SANDSTONE (90%) AND SHALE (10%), RQD = 81%, REC = 92%. **SANDSTONE**, gray, slightly weathered, strong, laminated to thick bedded, highly fractured to slightly fractured, narrow, slightly rough to rough, very blocky, good condition. **SHALE**, dark gray, slightly weathered, moderately strong, laminated, highly fractured to slightly fractured, narrow, slightly rough, very blocky, good condition. - @ 10.7' to 11.1' Qu = 9,862 psi - @ 20.9' to 21.3' Qu = 6,748 psi	1122.6		85		92	NQ-5											CORE	
SHALE, gray, slightly weathered, weak to moderately strong, thin to medium bedded, fractured to slightly fractured, narrow, slightly rough, very blocky, good condition, RQD = 90%, REC = 97%.	1120.2	EOB 25	80		96	NQ-6											CORE	

NOTES:
- Seepage noted at 3.0' during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 3.0' after completion of coring.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

S&ME ODOT LOG (8.5X11) - SGE 01/2019 - OH DOT.GDT - 2/8/23 18:17 - R:\SERVICE LINES\CS-2557\CLEVELAND\01 - LABORATORY\02 - GINT\WPROJECTS\210435B.GPJ

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: S&ME / T. FROST	DRILL RIG: S&ME ATV D50 (R61)	STATION / OFFSET: 705+63, 57' RT	EXPLORATION ID B-009-0-22
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY	
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 6/7/22	ELEVATION: 1177.2 (MSL) EOB: 41.0 ft.	PAGE 1 OF 2
START: 7/20/22 END: 7/20/22	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 69.8	COORD: 40.079012 N, 80.909145 W	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1177.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
TOPSOIL - 2 INCHES	1177.0																	
Hard brown mottled with gray **SILTY CLAY**, trace fine to coarse sand, trace fine gravel, damp.		1 – 2.5	2 6 6	14	56	SS-1	4.5+	-	-	-	-	-	-	-	-	19	A-6b (V)	
		3.5 – 5	4 8 10	21	89	SS-2	4.5+	1	2	3	30	64	39	23	16	16	A-6b (10)	
	1171.7																	
Hard reddish-brown **SILT AND CLAY**, trace fine to coarse sand, trace fine gravel, damp.		6 – 7.5	5 7 7	16	67	SS-3	4.5+	-	-	-	-	-	-	-	-	18	A-6a (V)	
		8.5 – 10	4 6 8	16	78	SS-4	4.0-4.5	2	2	3	43	50	38	24	14	19	A-6a (10)	
	1166.7																	
Hard gray and brown **SILT AND CLAY**, trace fine to coarse sand, trace fine gravel, few shale fragments, similar to severely weathered shale, dry.		11 – 12.5	12 24 30	63	89	SS-5	4.5+	-	-	-	-	-	-	-	-	9	A-6a (V)	
		13.5 – 15	11 11 15	30	100	SS-6	4.5+	3	3	2	54	38	35	23	12	10	A-6a (9)	
	1161.2	TR 16																
SHALE, gray, slightly to moderately weathered, slightly to moderately strong, thin to medium bedded, highly to moderately fractured, narrow to open, slightly rough, very blocky, fair to good condition, RQD = 49%, REC = 99%.		16 – 16.9	35 50-5"	-	100	SS-7		-	-	-	-	-	-	-	-	6	Rock (V)	
		17 – 18	0		100	NQ-8											CORE	
		18 – 23	60		98	NQ-9											CORE	
- @ 23.0' to 28.0' SDI = 9.4%		23 – 28	37		100	NQ-10											CORE	
- @ 27.0' to 27.4' Qu = 4,757 psi																		
		28 – 29																

PID: 108774	BR ID: N/A	PROJECT: BEL-NATIONAL ROAD TUNNEL	STATION / OFFSET: 705+63, 57' RT	START: 7/20/22	END: 7/20/22	PG 2 OF 2	B-009-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 1147.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
INTERBEDDED SHALE (70%) AND SANDSTONE (30%), RQD = 56%, REC = 96%. **SHALE**, gray and brown, slightly weathered, slightly to moderately strong, thin to medium bedded, highly to moderately fractured, narrow to open, slightly rough, very blocky, fair to good condition. **SANDSTONE**, light and dark gray, slightly weathered, medium grained, strong, thin to medium bedded, fractured to slightly fractured, narrow, very rough, blocky, good condition. - @ 32.4' to 32.8' Qu = 9,376 psi	1146.7	31 – 33	80		100	NQ-11											CORE	
		33 – 38	30		93	NQ-12											CORE	
	1136.2	38 – 41 EOB	72		97	NQ-13											CORE	

NOTES:
- No water observed during drilling.
- Borehole was dry prior to coring.
- Water measured at a depth of 17' after completion of coring.
- Borehole caved at 21.0' after removal of drilling tools.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

PROJECT: BEL-NATIONAL ROAD TUNNEL	DRILLING FIRM / OPERATOR: OTB / C. SVITAK	DRILL RIG: OTB MOBILE B-57	STATION / OFFSET: 667+98, 1' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: S&ME / A. KHAN	HAMMER: CME AUTOMATIC	ALIGNMENT: NATIONAL RD BIKEWAY
PID: 108774 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 11/25/20	ELEVATION: 1087.6 (MSL) EOB: 15.0 ft.
START: 6/16/22 END: 6/16/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90*	COORD: 40.088966 N, 80.909453 W

EXPLORATION ID: **B-010-0-22**

MATERIAL DESCRIPTION AND NOTES	ELEV. 1087.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT - 17 INCHES	1086.2	0-1.4																
FILL: Medium-dense black **COARSE AND FINE SAND**, some fine gravel, little silt, trace clay, few coal fragments, damp.	1084.1	1.5-3.0	3 3 4	11	67	SS-1	-	-	-	-	-	-	-	-	-	15	A-3a (V)	
FILL: Very-stiff (est.) grayish brown **SILT AND CLAY**, "and" fine to coarse sand, little fine gravel, few shale fragments, dry to damp.		3.5-5.0	2 4 5	14	50	SS-2	-	20	22	15	29	14	31	20	11	17	A-6a (2)	
	1080.8	6.0-7.5	2 4 7	17	78	SS-3A	-	-	-	-	-	-	-	-	-	14	A-6a (V)	
FILL: Medium-dense gray **GRAVEL** (shale and sandstone fragments), little to some fine to coarse sand, trace silt, dry.	1079.1					SS-3B	-	-	-	-	-	-	-	-	-	2	A-1-a (V)	
POSSIBLE FILL: Very-stiff brown and gray **CLAY**, some silt, some fine to coarse sand, little fine to coarse gravel, few coal fragments, dry to damp.		8.5-10.0	2 3 4	11	67	SS-4	2.5-3.5	17	9	12	21	41	41	23	18	21	A-7-6 (9)	
	1075.1	11.0-12.5	2 3 3	9	67	SS-5	2.0-2.7	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
Very-stiff brown **SILT AND CLAY**, some fine to coarse sand, trace fine gravel, damp.	1073.7	13.5-15.0	3 2 3	8	67	SS-6A	2.0-3.5	-	-	-	-	-	-	-	-	18	A-6a (V)	
Very-stiff to hard brown **CLAY**, "and" silt, trace fine to coarse sand, trace fine gravel, moist.	1072.6	EOB 15				SS-6B	3.0-4.5	1	2	5	46	46	46	25	21	33	A-7-6 (14)	

NOTES:
- No water observed during drilling.
- Borehole caved at a depth of 12' and was observed to be dry.

NOTES: SEE ABOVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLASTIC HOLE PLUG DEVICE; SOIL CUTTINGS MIXED WITH BENTONITE

WILDCAT DYNAMIC CONE LOG

PROJECT NUMBER: 210435B
DATE STARTED: 07-22-2022
DATE COMPLETED: 07-22-2022

HOLE #: D-006-1-22
CREW: A. Khan, H. Fisher
PROJECT: BEL-National Road Tunnel
ADDRESS: N Main Street, St. Clairsville, OH
LOCATION: Sta. 706+88, 0.2 Rt.

SURFACE ELEVATION: 1179
WATER ON COMPLETION: Dry
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	0	0.0		0	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 1 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
-	3	13.3	•••	3	VERY LOOSE	SOFT
- 2 ft	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
-	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
-	10	44.4	••••••••••••	12	MEDIUM DENSE	STIFF
- 3 ft	11	48.8	••••••••••••••	13	MEDIUM DENSE	STIFF
- 1 m	12	53.3	•••••••••••••••	15	MEDIUM DENSE	STIFF
-	22	84.9	••••••••••••••••••••••••	24	MEDIUM DENSE	VERY STIFF
- 4 ft	12	46.3	•••••••••••••	13	MEDIUM DENSE	STIFF
-	20	77.2	••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
-	20	77.2	••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
- 5 ft	16	61.8	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
-	12	46.3	•••••••••••••	13	MEDIUM DENSE	STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 6 ft	30	115.8	•••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

PROJECT NUMBER: 210435B
DATE STARTED: 07-22-2022
DATE COMPLETED: 07-22-2022

HOLE #: D-006-2-22
CREW: A. Khan, H. Fisher
PROJECT: BEL-National Road Tunnel
ADDRESS: 247 W Main Street, St. Clairsville, OH
LOCATION: Sta. 706+77, 12.5' Lt.

SURFACE ELEVATION: 1178
WATER ON COMPLETION: Dry
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	0	0.0		0	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 1 ft	2	8.9	••	2	VERY LOOSE	SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 2 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
- 3 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 1 m	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	3.9	•	1	VERY LOOSE	VERY SOFT
- 4 ft	3	11.6	•••	3	VERY LOOSE	SOFT
-	8	30.9	••••••••	8	LOOSE	MEDIUM STIFF
-	13	50.2	••••••••••••••	14	MEDIUM DENSE	STIFF
- 5 ft	18	69.5	••••••••••••••••••••	19	MEDIUM DENSE	VERY STIFF
-	21	81.1	•••••••••••••••••••••••	23	MEDIUM DENSE	VERY STIFF
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

PROJECT NUMBER: 210435B
DATE STARTED: 07-22-2022
DATE COMPLETED: 07-22-2022

HOLE #: D-006-3-22
CREW: A. Khan, H. Fisher
PROJECT: BEL-National Road Tunnel
ADDRESS: 247 W Main Street, St. Clairsville, OH
LOCATION: Sta. 706+79, 11.6' Lt.

SURFACE ELEVATION: 1176
WATER ON COMPLETION: Dry
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	0	0.0		0	VERY LOOSE	VERY SOFT
-	0	0.0		0	VERY LOOSE	VERY SOFT
- 1 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
- 2 ft	2	8.9	••	2	VERY LOOSE	SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
-	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
- 3 ft	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
- 1 m	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 4 ft	8	30.9	••••••••	8	LOOSE	MEDIUM STIFF
-	8	30.9	••••••••	8	LOOSE	MEDIUM STIFF
-	3	11.6	•••	3	VERY LOOSE	SOFT
- 5 ft	30	115.8	•••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-						
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

PROJECT NUMBER: 210435B
DATE STARTED: 09-29-2022
DATE COMPLETED: 09-29-2022

HOLE #: D-008-1-22
CREW: A. Khan, K. Harper
PROJECT: BEL-National Road Tunnel
ADDRESS: 247 W Main Street, St. Clairsville, OH
LOCATION: Sta. 707+17, 20.5' Rt.

SURFACE ELEVATION: 1200
WATER ON COMPLETION: Dry
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
- 1 ft	10	44.4	••••••••••••	12	MEDIUM DENSE	STIFF
-	23	102.1	••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	18	79.9	••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
- 2 ft	19	84.4	•••••••••••••••••••••••	24	MEDIUM DENSE	VERY STIFF
-	18	79.9	••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
-	20	88.8	••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
- 3 ft	20	88.8	••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
- 1 m	23	102.1	••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	19	73.3	••••••••••••••••••••	20	MEDIUM DENSE	VERY STIFF
- 4 ft	18	69.5	•••••••••••••••••••	19	MEDIUM DENSE	VERY STIFF
-	16	61.8	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
-	20	77.2	•••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
- 5 ft	26	100.4	••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	30	115.8	••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	32	123.5	••••••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 6 ft	30	115.8	••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	25	96.5	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
- 2 m	15	57.9	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
- 7 ft	18	61.6	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
-	28	95.8	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	21	71.8	•••••••••••••••••••	20	MEDIUM DENSE	VERY STIFF
- 8 ft	13	44.5	••••••••••••	12	MEDIUM DENSE	STIFF
-	17	58.1	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	26	88.9	••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
- 9 ft	11	37.6	••••••••••	10	LOOSE	STIFF
-	10	34.2	•••••••••	9	LOOSE	STIFF
-	7	23.9	••••••	6	LOOSE	MEDIUM STIFF
- 3 m 10 ft	8	27.4	•••••••	7	LOOSE	MEDIUM STIFF
-	9	27.5	•••••••	7	LOOSE	MEDIUM STIFF
-	13	39.8	•••••••••••	11	MEDIUM DENSE	STIFF
-	17	52.0	••••••••••••••	14	MEDIUM DENSE	STIFF
- 11 ft	11	33.7	•••••••••	9	LOOSE	STIFF
-	19	58.1	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	12	36.7	••••••••••	10	LOOSE	STIFF
- 12 ft	13	39.8	•••••••••••	11	MEDIUM DENSE	STIFF
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

PROJECT NUMBER: 210435B
DATE STARTED: 09-29-2022
DATE COMPLETED: 09-29-2022

HOLE #: D-008-2-22
CREW: A. Khan, K. Harper
PROJECT: BEL-National Road Tunnel
ADDRESS: 247 W Main Street, St. Clairsville, OH
LOCATION: Sta. 706+30, 72.5' Rt.

SURFACE ELEVATION: 1186
WATER ON COMPLETION: Dry
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	4	17.8	•••••	5	LOOSE	MEDIUM STIFF
-	14	62.2	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
- 1 ft	27	119.9	••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	26	115.4	•••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	27	119.9	••••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 2 ft	20	88.8	••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
-	20	88.8	••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
-	26	115.4	•••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 3 ft	21	93.2	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
- 1 m	22	97.7	•••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	25	96.5	••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
- 4 ft	32	123.5	•••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	23	88.8	••••••••••••••••••••••••	25	MEDIUM DENSE	VERY STIFF
-	27	104.2	••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
- 5 ft	30	115.8	•••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	30	115.8	•••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	30	115.8	•••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 6 ft	30	115.8	•••••••••••••••••••••••••••••••	25+	DENSE	HARD
-	31	119.7	••••••••••••••••••••••••••••••••	25+	DENSE	HARD
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

PROJECT NUMBER:	210435B
DATE STARTED:	09-29-2022
DATE COMPLETED:	09-29-2022
HOLE #:	D-010-1-22
CREW:	A. Khan, K. Harper
PROJECT:	BEL-National Road Tunnel
ADDRESS:	SR 9, St. Clairsville, OH
LOCATION:	Sta. 667+97, 15.9' Rt.
SURFACE ELEVATION:	1082
WATER ON COMPLETION:	Dry
HAMMER WEIGHT:	35 lbs.
CONE AREA:	10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	6	26.6	•••••••	7	LOOSE	MEDIUM STIFF
-	8	35.5	••••••••••	10	LOOSE	STIFF
- 1 ft	9	40.0	•••••••••••	11	MEDIUM DENSE	STIFF
-	12	53.3	•••••••••••••••	15	MEDIUM DENSE	STIFF
-	12	53.3	•••••••••••••••	15	MEDIUM DENSE	STIFF
- 2 ft	13	57.7	••••••••••••••••	16	MEDIUM DENSE	VERY STIFF
-	14	62.2	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
-	18	79.9	••••••••••••••••••••••	22	MEDIUM DENSE	VERY STIFF
- 3 ft	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
- 1 m	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	7	27.0	•••••••	7	LOOSE	MEDIUM STIFF
- 4 ft	8	30.9	••••••••	8	LOOSE	MEDIUM STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 5 ft	11	42.5	••••••••••••	12	MEDIUM DENSE	STIFF
-	11	42.5	••••••••••••	12	MEDIUM DENSE	STIFF
-	13	50.2	••••••••••••••	14	MEDIUM DENSE	STIFF
- 6 ft	14	54.0	•••••••••••••••	15	MEDIUM DENSE	STIFF
-	12	46.3	•••••••••••••	13	MEDIUM DENSE	STIFF
- 2 m	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 7 ft	5	17.1	••••	4	VERY LOOSE	SOFT
-	7	23.9	••••••	6	LOOSE	MEDIUM STIFF
-	18	61.6	•••••••••••••••••	17	MEDIUM DENSE	VERY STIFF
- 8 ft	12	41.0	•••••••••••	11	MEDIUM DENSE	STIFF
-	10	34.2	•••••••••	9	LOOSE	STIFF
-	7	23.9	••••••	6	LOOSE	MEDIUM STIFF
- 9 ft	9	30.8	••••••••	8	LOOSE	MEDIUM STIFF
-	10	34.2	•••••••••	9	LOOSE	STIFF
-	7	23.9	••••••	6	LOOSE	MEDIUM STIFF
- 3 m 10 ft	7	23.9	••••••	6	LOOSE	MEDIUM STIFF
-	35	107.1	•••••••••••••••••••••••••••••••	25+	MEDIUM DENSE	VERY STIFF
-	50	153.0	•••	25+	DENSE	HARD
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

JOB NUMBER : **210435B**
PROJECT : **BEL-NATIONAL ROAD TUNNEL**
PID : **108774**

LABORATORY LOG OF SHELBY TUBES

Boring : **B-006-0-22**	Sample : **ST-11**	Boring : **B-007-0-22**	Sample : **ST-17**	Boring :	Sample :
Depth : **8.0' - 10.0'**	Recovery : **16.5"**	Depth : **8.0' - 10.0'**	Recovery : **19.5"**	Depth :	Recovery :

Boring B-006-0-22, Sample ST-11 (depth scale 0, 12, 24, 36)

- VOID
- OUT — Disturbed - Discarded
- I SAVE
- II SAVE
- III AL/MA
- IV SAVE

Stiff (est.) gray mottled with brown **CLAY**, "and" silt, trace fine to coarse sand, damp.

MC = 26.4%
UDW = 94.7 pcf

30" Tube

Boring B-007-0-22, Sample ST-17 (depth scale 0, 12, 24, 36)

- VOID
- I SAVE
- II SAVE
- III AL/MA
- IV SAVE

Stiff (est.) brown mottled with gray **SILT AND CLAY**, some fine to coarse gravel, some fine to coarse sand, damp.

MC = 16.5%
UDW = 118.4 pcf

30" Tube (damaged at bottom by coarse gravel)

Third column (depth scale 0, 12, 24, 36)

LEGEND

- Consolidation, Incremental
- Consolidation, C R S
- Permeability, Vertical / Horizontal
- Swelling, Test
- Wax
- Unconfined Compression Test
- Triaxial Compression Test

H - Hand Penetrometer (tsf)
Ds - Direct Shear
LOI - Loss on Ignition
AL - Atterberg Limits
MA - Sieve/Hydrometer
SG - Specific Gravity

TV - Torvane (tsf)
POR - Porosity
UDW - Unit Dry Weight
MC - Moisture Content
D_R - Relative Density
S - Sieve

Appendix II – Rock Core Lab Test Results

BORING B-001-0-22

Run #:	Depth		Recovery		RQD	
NQ-11	24.0’	28.0’	38/48	79%	16/48	33%
NQ-12	28.0’	33.0’	53/60	88%	13/60	22%
NQ-13	33.0’	38.0’	60/60	100%	35/60	58%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-001-0-22 (CONTINUED)

Run #:	Depth		Recovery		RQD	
NQ-13	33.0’	38.0’	60/60	100%	35/60	58%
NQ-14	38.0’	43.0’	60/60	100%	24/60	60%
NQ-15	43.0’	50.0’	80/84	95%	52/84	62%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-001-0-22 (CONTINUED)

Run #:	Depth		Recovery		RQD	
NQ-15	43.0'	50.0'	80/84	95%	52/84	62%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-002-0-22

Run #:	Depth		Recovery		RQD	
NQ-3	5.0'	10.5'	56/66	85%	36/66	55%
NQ-4	10.5'	15.5'	47/60	78%	24/60	40%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-002-0-22 (CONTINUED)

BR: NQ-5
15.5’

ER: NQ-5
25.5’

Run #:	Depth		Recovery		RQD	
NQ-5	15.5’	25.5’	120/120	100%	74/120	62%

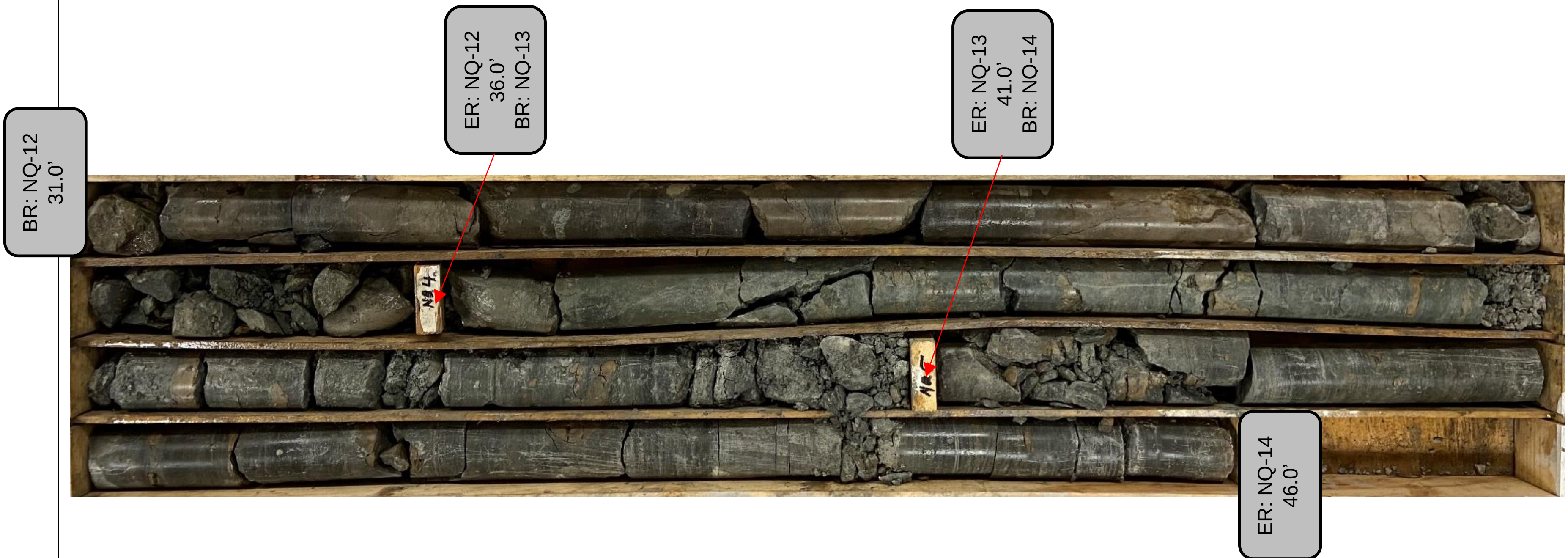
BEL-NATIONAL RD TUNNEL   PID 108774

BORING B-003-0-22

Run #:	Depth		Recovery		RQD	
NQ-10	21.0’	26.0’	59/60	98%	39/60	65%
NQ-11	26.0’	31.0’	60/60	100%	39/60	65%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-003-0-22 (CONTINUED)



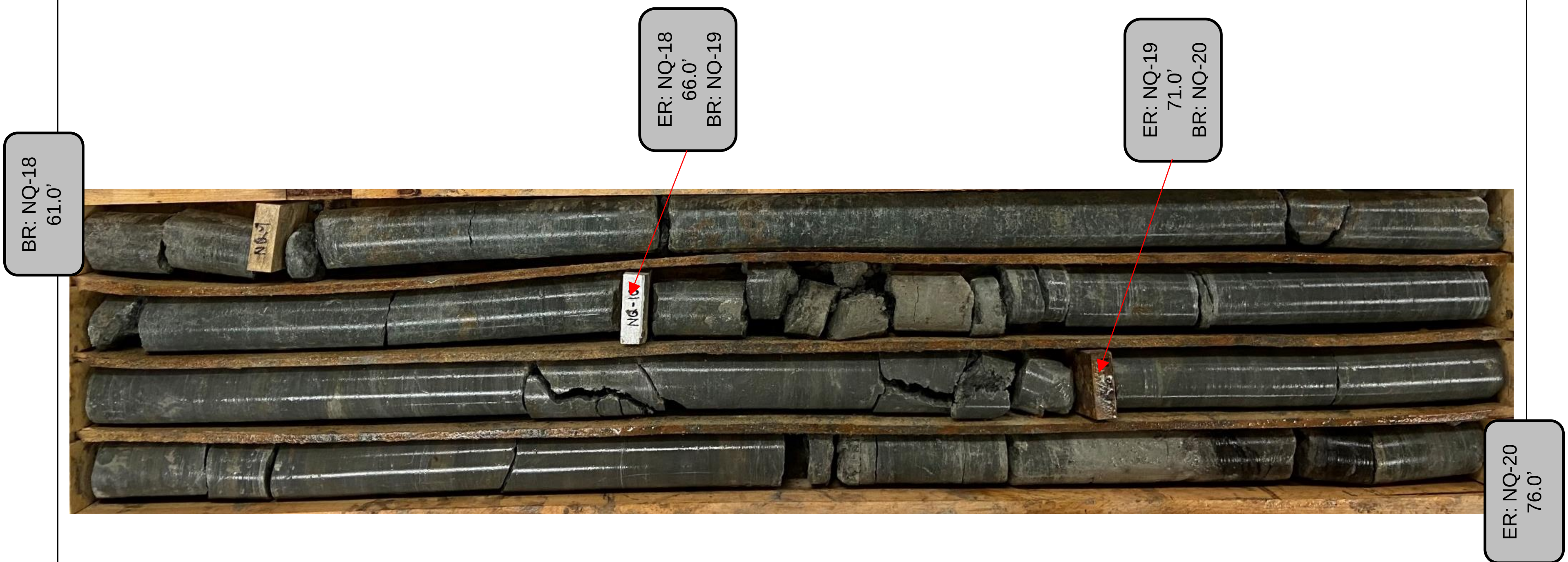
Run #:	Depth		Recovery		RQD	
NQ-12	31.0’	36.0’	57/60	95%	35/60	58%
NQ-13	36.0’	41.0’	60/60	100%	30/60	50%
NQ-14	41.0’	46.0’	55/60	92%	24/60	40%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-003-0-22 (CONTINUED)

Run #:	Depth		Recovery		RQD	
NQ-15	46.0'	51.0'	60/60	100%	38/60	63%
NQ-16	51.0'	56.0'	60/60	100%	35/60	58%
NQ-17	56.0'	61.0'	60/60	100%	28/60	47%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-003-0-22 (CONTINUED)



Run #:	Depth		Recovery		RQD	
NQ-18	61.0'	66.0'	57/60	95%	50/60	83%
NQ-19	66.0'	71.0'	59/60	98%	35/60	58%
NQ-20	71.0'	76.0'	58/60	97%	35/60	58%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-004-0-22

Run #:	Depth		Recovery		RQD	
NQ-10	34.0’	39.0’	59/60	98%	37/60	62%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-005-0-22

Run #:	Depth		Recovery		RQD	
NQ-10	21.3'	26.3'	49/60	82%	28/60	47%

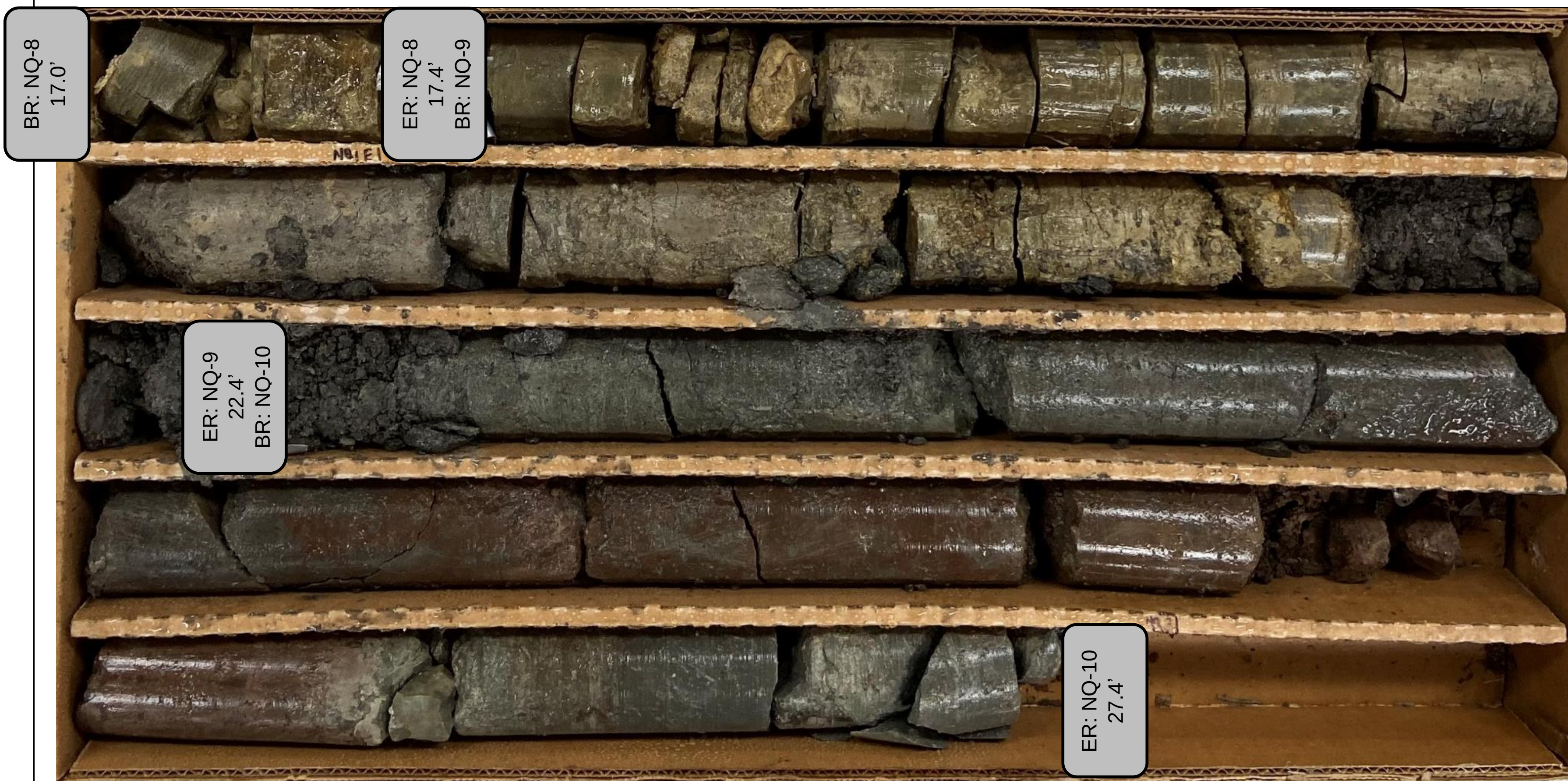
BEL-NATIONAL RD TUNNEL PID 108774

BORING B-006-0-22

Run #:	Depth		Recovery		RQD	
NQ-9	19.5'	21.5'	21/24	88%	0/24	0%
NQ-10	21.5'	26.5'	50/60	83%	18/60	30%

BEL-NATIONAL RD TUNNEL   PID 108774

BORING B-007-0-22

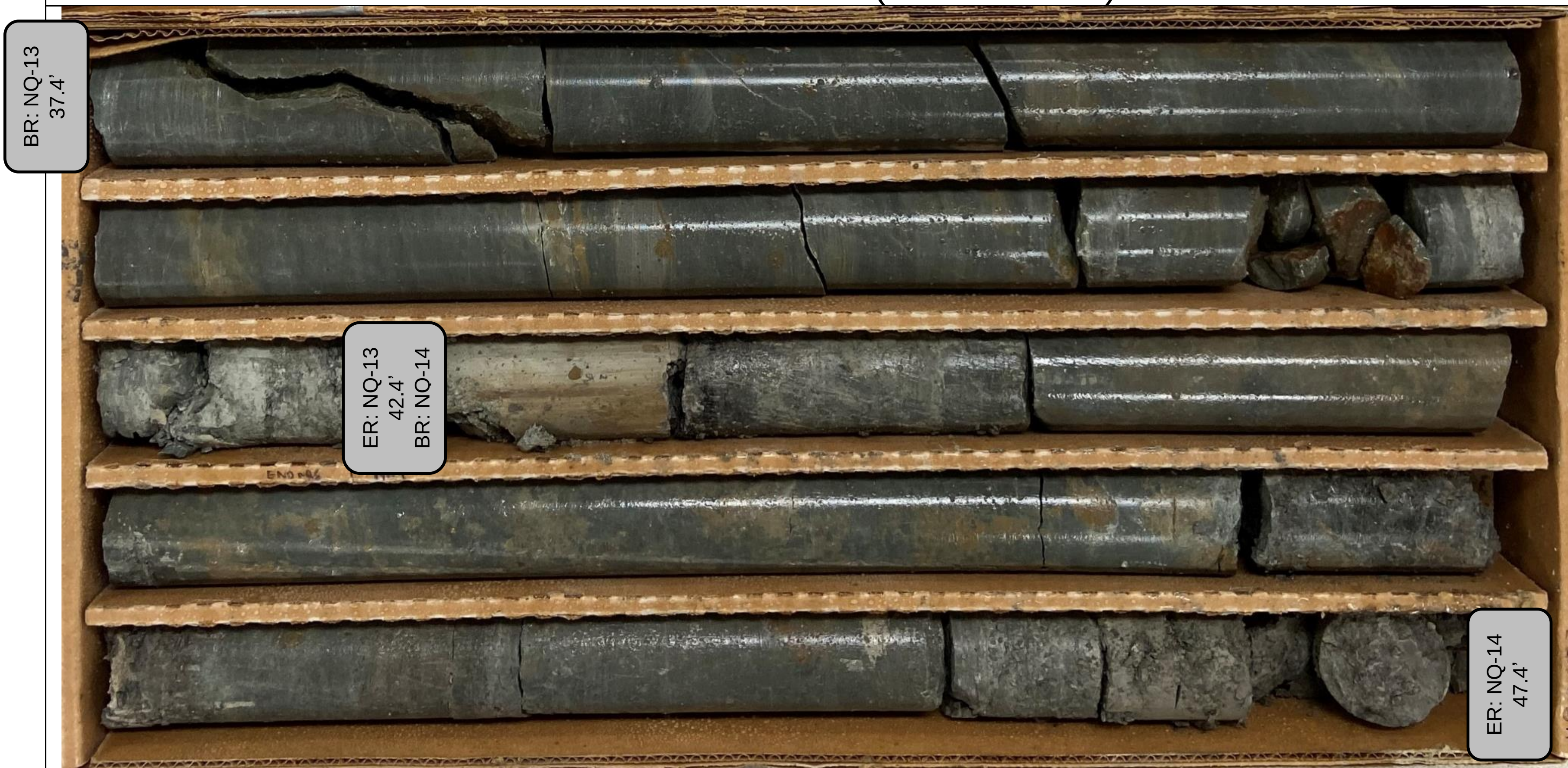


Run #:	Depth		Recovery		RQD	
NQ-8	17.0'	17.4'	5/5	100%	0/5	0%
NQ-9	17.4'	22.4'	43/60	72%	10/60	17%
NQ-10	22.4'	27.4'	55/60	92%	18/60	30%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-007-0-22 (CONTINUED)

Run #:	Depth		Recovery		RQD	
NQ-11	27.4'	32.4'	60/60	100%	28/60	47%
NQ-12	32.4	37.4'	58/60	97%	29/60	48%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-007-0-22 (CONTINUED)



Run #:	Depth		Recovery		RQD	
NQ-13	37.4'	42.4'	53/60	88%	40/60	67%
NQ-14	42.4'	47.4'	60/60	100%	39/60	65%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-007-0-22 (CONTINUED)

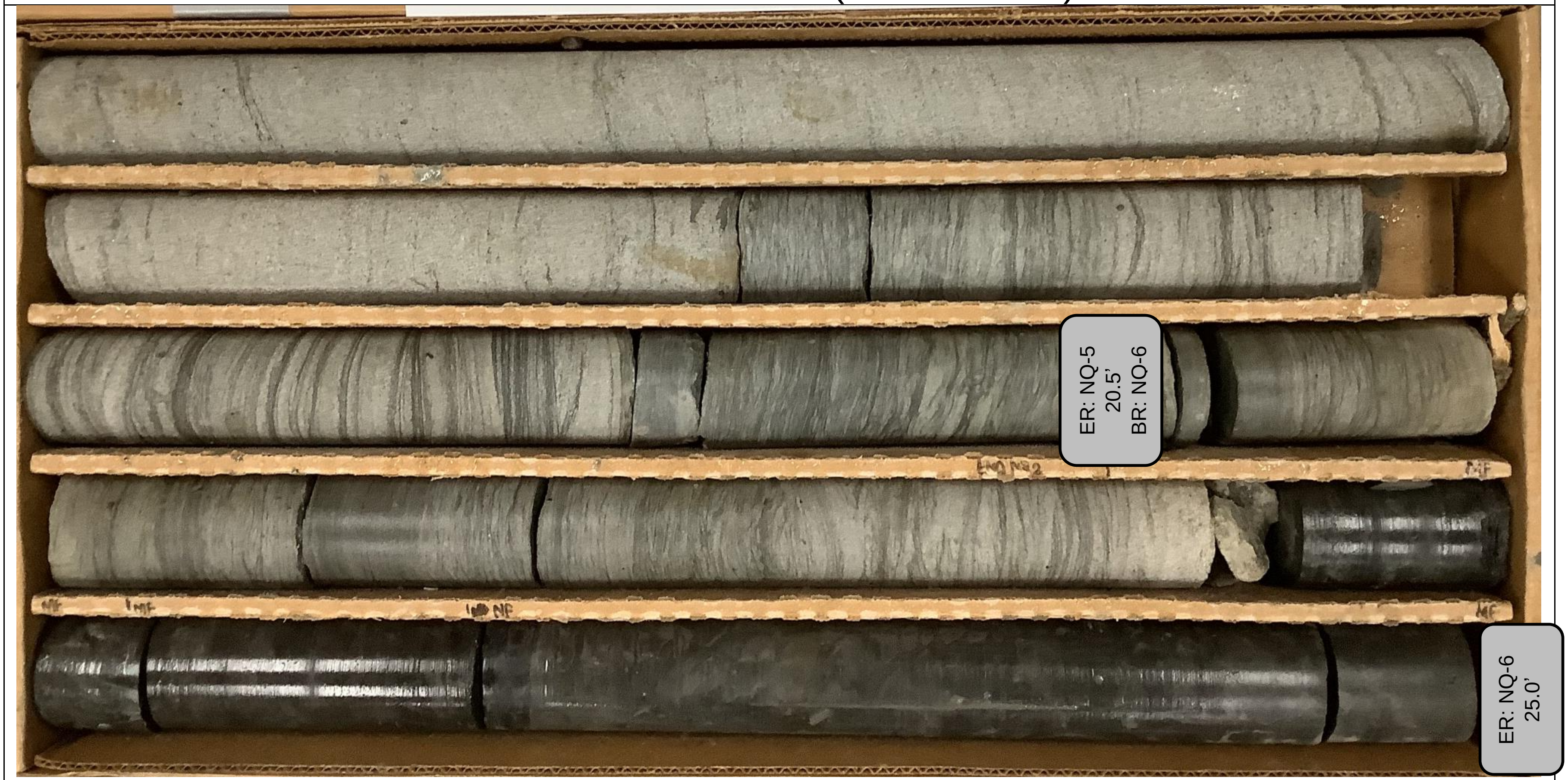
Run #:	Depth		Recovery		RQD	
NQ-15	47.4’	52.4’	59/60	98%	28/60	47%
NQ-16	52.4’	57.4’	60/60	100%	46/60	77%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-008-0-22

Run #:	Depth		Recovery		RQD	
NQ-4	5.5'	10.7'	62/62	100%	14/62	23%
NQ-5	10.7'	20.5'	108/118	92%	100/118	85%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-008-0-22 (CONTINUED)



Run #:	Depth		Recovery		RQD	
NQ-5	10.7'	20.5'	108/118	92%	100/118	85%
NQ-6	20.5'	25.0	52/54	96%	43/54	80%

BEL-NATIONAL RD TUNNEL PID 108774

BORING B-009-0-22

Run #:	Depth		Recovery		RQD	
NQ-8	17.0’	18.0’	12/12	100%	0/12	0%
NQ-9	18.0’	23.0’	59/60	98%	36/60	60%
NQ-10	23.0’	28.0’	60/60	100%	22/60	37%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-009-0-22 (CONTINUED)

Run #:	Depth		Recovery		RQD	
NQ-10	23.0'	28.0'	60/60	100%	22/60	37%
NQ-11	28.0'	33.0'	60/60	100%	48/60	80%
NQ-12	33.0'	38.0'	56/60	93%	18/60	30%
BEL-NATIONAL RD TUNNEL PID 108774						

BORING B-009-0-22 (CONTINUED)

Run #:	Depth		Recovery		RQD	
NQ-12	33.0'	38.0'	56/60	93%	18/60	30%
NQ-13	38.0'	41.0'	35/36	97%	26/36	72%

BEL-NATIONAL RD TUNNEL PID 108774

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	07/26/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	07/20/22
Client Name:	ms consultants, inc.		
Client Address:	425 Literary Road, Suite 100 Cleveland, OH 44113	Received Date:	07/07/22
Boring ID:	B-001-0-22 / NQ-13	Depth/Elev., ft:	37.0' - 37.4'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***1.7*** % ***Dry Unit Weight*** ***162.0*** pcf

Compressive Strength ***2,245*** psi

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543. Specimen was capped using Sulfur in accordance with ASTM C617, based on previous similar samples. Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.**

Paula J. Manning	Paula J. Manning	Laboratory Manager	7/27/2022
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

PLATE 22

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	08/03/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/02/22
Client Name:	ms consultants, inc.		
Client Address:	425 Literary Road, Suite 100 Cleveland, OH 44113	Received Date:	07/07/22
Boring ID:	B-002-0-22 / NQ-3	Depth/Elev., ft:	8.6' - 9.0'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***1.5*** % ***Dry Unit Weight*** ***165.0*** pcf

Compressive Strength ***1,368*** psi

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using Sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	8/3/2022
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	08/03/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/02/22
Client Name:	ms consultants, inc.		
Client Address:	425 Literary Road, Suite 100 Cleveland, OH 44113	Received Date:	07/07/22
Boring ID:	B-002-0-22 / NQ-5	Depth/Elev., ft:	19.5' - 19.9'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content	***1.2*** **%**	***Dry Unit Weight***	***163.6*** **pcf**
Compressive Strength	***3,975*** **psi**		

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using Sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	8/3/2022
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	09/13/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/31/22
Client Name:	ms consultants, inc.		
Client Address:	2221 Schrock Rd., Columbus, Ohio 43229	Received Date:	07/07/22
Boring ID:	B-003-0-22 / NQ-13	Depth/Elev., ft:	40.5' - 40.9'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***2.0*** % ***Dry Unit Weight*** ***158.0*** pcf

Compressive Strength ***2,024*** psi

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen contained horizontal fractures.**

Specimen end preparation was not done in accordance with ASTM D4543. Specimen was capped using sulfur in accordance with ASTM C617, based on previous similar samples. Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	9/14/2022
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

PLATE 25

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	09/13/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/29/22
Client Name:	ms consultants, inc.		
Client Address:	2221 Schrock Rd., Columbus, Ohio 43229	Received Date:	07/07/22
Boring ID:	B-007-0-22 / NQ-11	Depth/Elev., ft:	31.2' - 31.6'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***2.1*** **%** ***Dry Unit Weight*** ***164.7*** **pcf**

Compressive Strength ***1,050*** **psi**

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**

Specimen was capped using sulfur in accordance with ASTM C617, based on previous similar samples.

Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J Manning	Laboratory Manager	9/13/2022
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	09/13/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/29/22
Client Name:	ms consultants, inc.		
Client Address:	2221 Schrock Rd., Columbus, Ohio 43229	Received Date:	07/07/22
Boring ID:	B-007-0-22 / NQ-14	Depth/Elev., ft:	44.1' - 44.5'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***1.9*** **%** ***Dry Unit Weight*** ***165.4*** **pcf**

Compressive Strength ***2,062*** **psi**

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	*Paula J. Manning*	Laboratory Manager	9/13/2022
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	07/26/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	07/20/22
Client Name:	ms consultants, inc.		
Client Address:	425 Literary Road, Suite 100 Cleveland, OH 44113	Received Date:	07/07/22
Boring ID:	B-008-0-22 / NQ-5	Depth/Elev., ft:	10.7' - 11.1'
Sample Description:	SANDSTONE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content	***2.7*** **%**	***Dry Unit Weight***	***152.3*** **pcf**
Compressive Strength	***9,862*** **psi**		

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using Sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	7/27/2022
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	07/27/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	07/20/22
Client Name:	ms consultants, inc.		
Client Address:	425 Literary Road, Suite 100 Cleveland, OH 44113	Received Date:	07/07/22
Boring ID:	B-008-0-22 / NQ-6	Depth/Elev., ft:	20.9' - 21.3'
Sample Description:	SANDSTONE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***1.7*** % ***Dry Unit Weight*** ***156.0*** pcf

Compressive Strength ***6,748*** psi

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using Sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	7/27/2022
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	09/13/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/29/22
Client Name:	ms consultants, inc.		
Client Address:	2221 Schrock Rd., Columbus, Ohio 43229	Received Date:	07/07/22
Boring ID:	B-009-0-22 / NQ-10	Depth/Elev., ft:	27.0' - 27.4'
Sample Description:	SHALE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***1.1*** % ***Dry Unit Weight*** ***167.0*** pcf

Compressive Strength ***4,757*** psi

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	9/13/2022
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D7012C-01
Revision No. 1
Revision Date: 07/14/17

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D 7012 Method C

Quality Assurance

S&ME, Inc. - Columbus: 6190 Enterprise Court, Dublin, Ohio 43016

Project No.:	210435B	Report Date:	09/13/22
Project Name:	BEL-National Road Tunnel	Test Date(s):	08/24/22
Client Name:	ms consultants, inc.		
Client Address:	2221 Schrock Rd., Columbus, Ohio 43229	Received Date:	07/07/22
Boring ID:	B-009-0-22 / NQ-11	Depth/Elev., ft:	32.4' - 32.8'
Sample Description:	SANDSTONE, gray		

Angle of load relative to lithology: Approximately perpendicular to bedding plane

Test Results

Moisture Content ***0.8*** % ***Dry Unit Weight*** ***161.9*** pcf

Compressive Strength ***9,376*** psi

Before Test

After Test

Strain rate: 0.03 in/min.

Notes / Deviations / References: **Specimen end preparation was not done in accordance with ASTM D4543.**
Specimen was capped using sulfur in accordance with ASTM C617, based on previous similar samples.
Test results for specimens not meeting this requirement may differ from test results obtained from specimens meeting this requirement.

Paula J. Manning	Paula J. Manning	Laboratory Manager	9/13/2022
Technical Responsibility	*Signature*	*Position*	*Date*

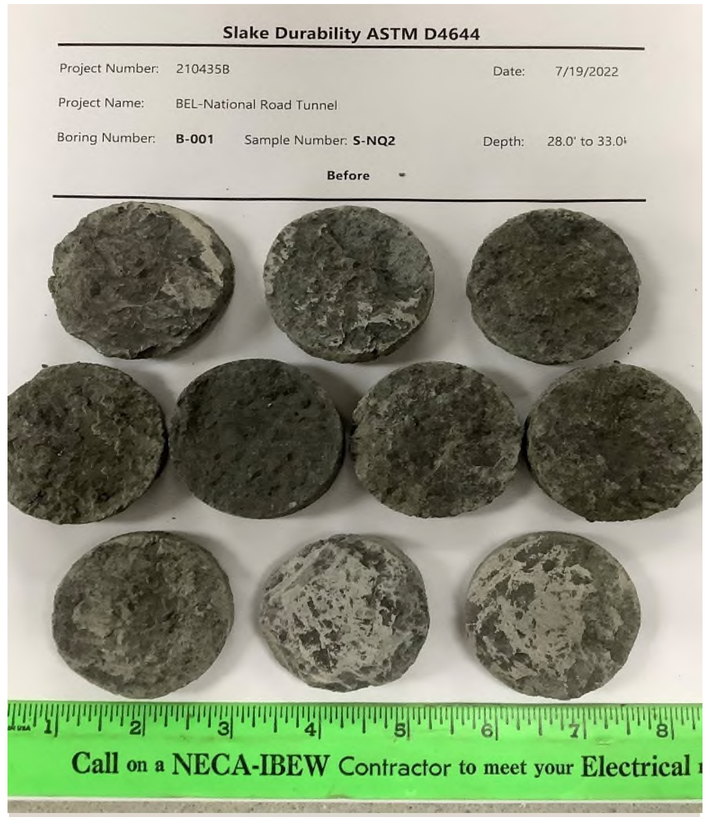
Slake Durability Index Test Report

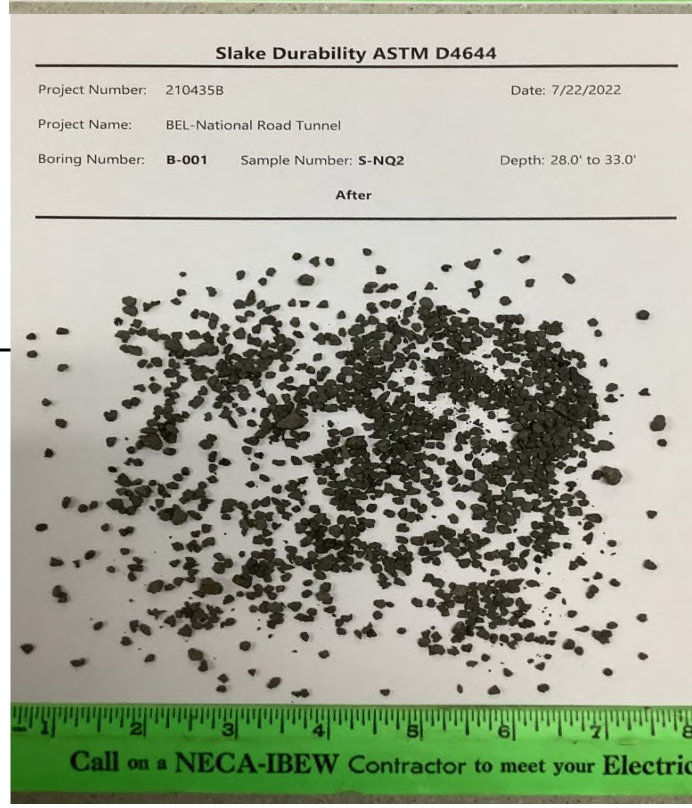
ASTM D 4644

S&ME, Inc. - Columbus 6190 Enterprise Court, Dublin, Ohio 43016

Project Information
Project Name
BEL-National Road Tunnel
Project Number
210435B

Specimen Information
Boring ID
B-001-0-22 NQ-12
Sample Depth, feet
28.0' to 33.0'
Sample Description
Shale
Water Temperature, ºC
23.4





Test Results
Natural Water Content, %
5.5
Slake Durability Index, 1st cycle, %
19.7
Slake Durability Index, 2nd cycle, %
3.5

Description of Fragments	Date Tested	Testing Technician
Type III	7/19/2022	EG

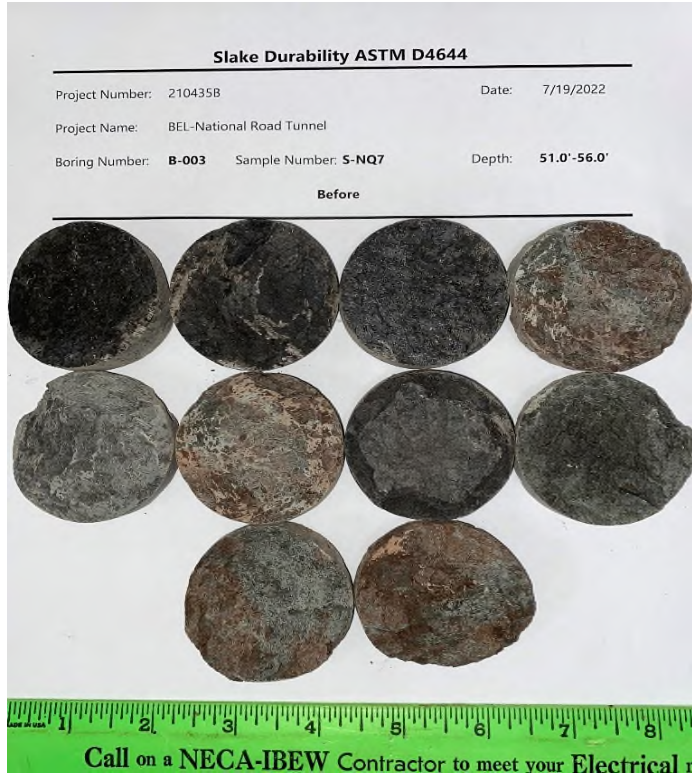
Slake Durability Index Test Report

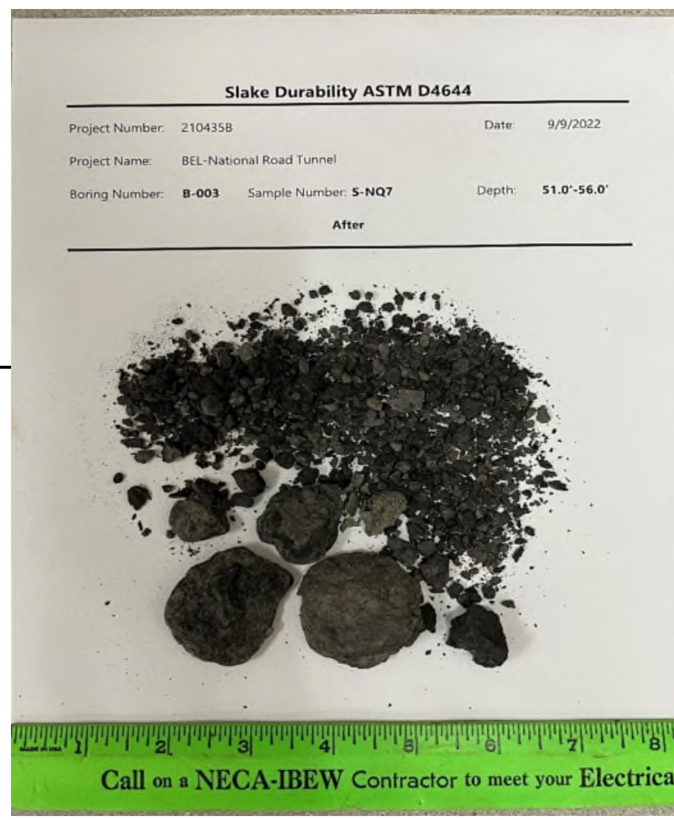
ASTM D 4644

S&ME, Inc. - Columbus 6190 Enterprise Court, Dublin, Ohio 43016

Project Information
Project Name
BEL-National Road Tunnel
Project Number
210435B

Specimen Information
Boring ID
B-003-0-22 NQ-16
Sample Depth, feet
51.0' to 56.0'
Sample Description
Shale
Water Temperature, °C
22.3





Test Results
Natural Water Content, %
4.4
Slake Durability Index, 1st cycle, %
44.1
Slake Durability Index, 2nd cycle, %
12.5

Description of Fragments	Date Tested	Testing Technician
Type II	9/6/2022	EG

Slake Durability Index Test Report

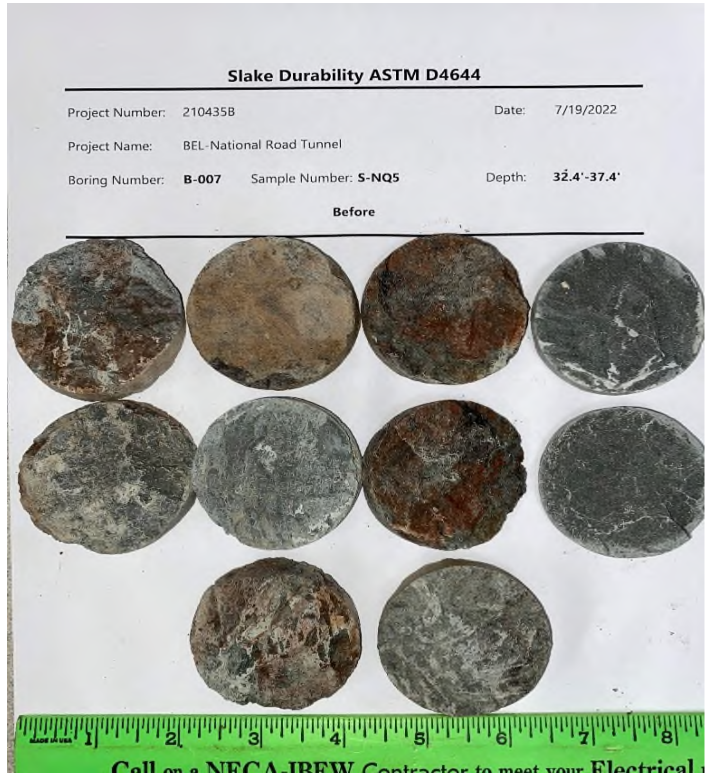
ASTM D 4644

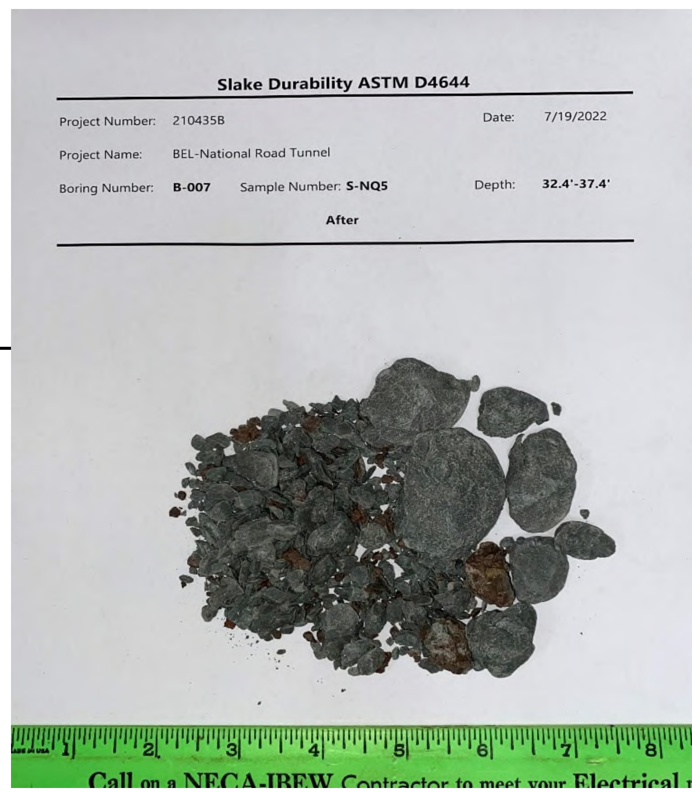
S&ME, Inc. - Columbus 6190 Enterprise Court, Dublin, Ohio 43016

Project Information
Project Name
BEL-National Road Tunnel
Project Number
210435B

Specimen Information
Boring ID
B-007-0-22 NQ-12
Sample Depth, feet
32.4' to 37.4'
Sample Description
Claystone (vso to soft shale)
Water Temperature, ^{o}C
21.9

Test Results
Natural Water Content, %
4.6
Slake Durability Index, 1st cycle, %
28.1
Slake Durability Index, 2nd cycle, %
20.4





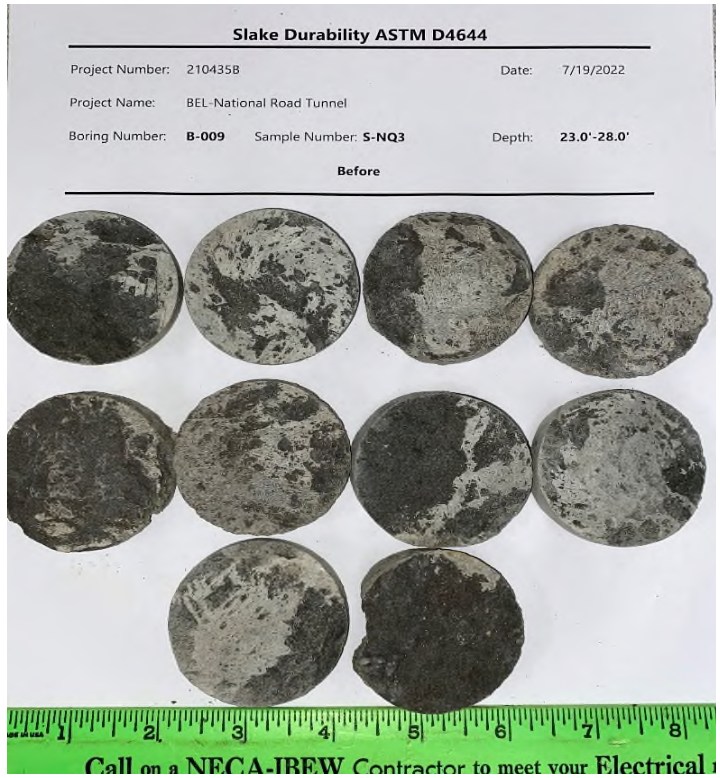
Description of Fragments	Date Tested	Testing Technician
Type II	9/1/2022	EG

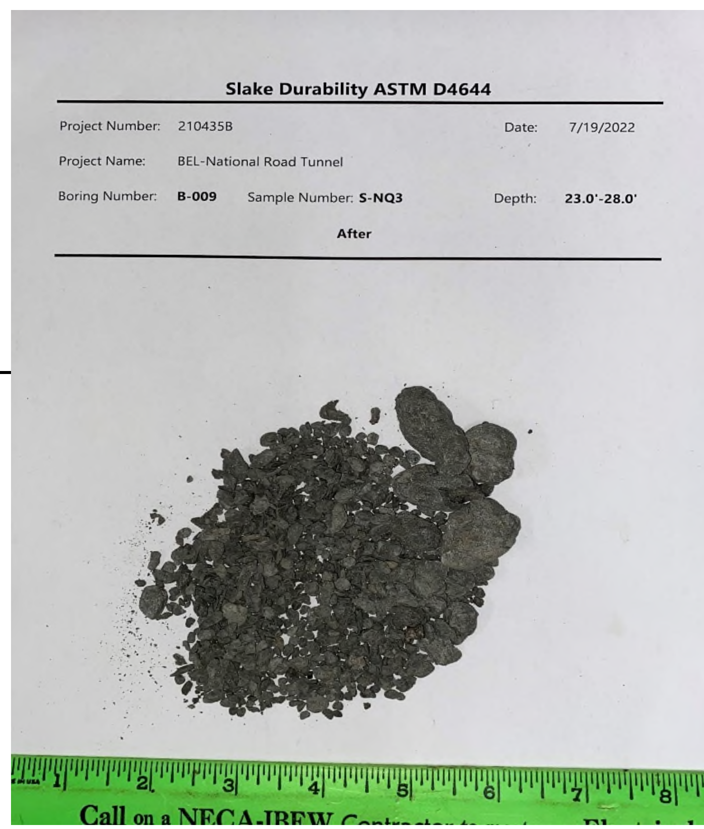
Slake Durability Index Test Report

ASTM D 4644

S&ME, Inc. - Columbus 6190 Enterprise Court, Dublin, Ohio 43016

Project Information	
Project Name	
BEL-National Road Tunnel	
Project Number	
210435B	
Specimen Information	
Boring ID	
B-009-0-22 NQ-10	
Sample Depth, feet	
23.0' to 28.0'	
Sample Description	
Shale	
Water Temperature, °C	
21.9	
Test Results	
Natural Water Content, %	
4.7	
Slake Durability Index, 1st cycle, %	
32.9	
Slake Durability Index, 2nd cycle, %	
9.4	





Description of Fragments	Date Tested	Testing Technician
Type II	9/1/2022	EG

Appendix III – Calculation Output

Project Number:	210435B	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Checked By:	RSW
Client Name:	ms consultants, inc.	Date:	7/18/2023

Version 2.0 (8/31/16)

DRILLED SHAFTS IN ROCK - RESISTANCE CALCULATION SUMMARY (AASHTO LRFD, 9th EDITION)

(Example calculations with reference equations and information are provided on additional sheets)

Bridge Structure Identification		South End Soldier Pile Wall	
Boring ID	B-002-0-22	Foundation Element Description	Ret. Walls
Surface Elev.	1149.7	Top of Shaft / Base of Shaft Cap Elevation	1148

Analysis Desc.	Term/Info Description	Unit	Layer 1	Layer 2	Layer 3	Layer 4
Boring/Layer Information	Bedrock Type/Description		Shale	Shale		
	Layer Top Depth (from G.S.)	ft	5.5	14		
	Layer Top Elevation	MSL	1144.2	1135.7		
	Layer Bottom Depth (from G.S.)	ft	14	25.5		
	Layer Bottom Elevation	MSL	1135.7	1124.2		
	Layer Thickness	ft	8.5	11.5		
GSI Index Calculation (AASHTO LRFD, 7th Edition; Hoek, et al., 2013; Bieniawski, Z.T. 1989)	RQD	%	32	68		
	Discontinuity Length Rating		E	B		
	Separation Rating		E	C		
	Roughness Rating		D	C		
	Infilling Rating		E	B		
	Weathering Rating		D	B		
	Estimated JCond89 Value		2	20		
	Estimated GSI Value (quan.)		19	64		
	Estimated GSI Value (qual.)		20	55		
	Design GSI Value		20	60		
Unit Side Resistance Calculations (AASHTO LRFD, 7th Edition)	Compressive Strength, q_u	psi	500	3975		
	Concrete Strength, f'_c	psi	4000	4000		
	Fractured Rock? (Susceptible to Caving?)		Yes	No		
	Joint Condition		Open	Closed		
	Regression Coefficient, C		0.5	1.0		
	q_s (Eqn. 10.8.3.5.4b-1)	ksf	6.18	34.84		
	Reduction Factor, α_E		0.51	0.83		
	q_s (Eqn. 10.8.3.5.4b-2)	ksf	4.1	18.79		
	q_s (Design)	**ksf**	**4**	**34**		
	q_s (Design)	**tsf**	**2**	**17**		

Definition of Bedrock Type Abbreviations:

SS = Sandstone | *SH = Shale* | *in/b = interbedded with*

SLTS = Siltstone | *CLST = Claystone*

PLATE 1

Project Number:	210435B	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Checked By:	RSW
Client Name:	ms consultants, inc.	Date:	7/18/2023

Version 2.0 (8/31/16)

DRILLED SHAFTS IN ROCK - RESISTANCE CALCULATION SUMMARY (AASHTO LRFD, 9TH EDITION) - CONTINUED

		Term/Info Description	Unit	Layer 1	Layer 2	Layer 3	Layer 4
Unit End Bearing Resistance Calculations	Intermediate Parameters Required for GSI Empirical Approach, AASHTO LRFD Eqn. 10.8.3.5.4c-2	Compressive Strength, q_u	ksf	72.00	572.40		
		Disturbance Factor, D		1	0.1		
		Empirical Parameter, s		0.0000016	0.0100750		
		Empirical Parameter, a		0.5437	0.5028		
		Constant, m_i (Table 10.4.6.4-1)		6	6		
		Empirical Parameter, m_b		0.0198	1.3338		
		Depth of Soil Cover	ft	4	4		
		Average γ_m of Soil Cover	pcf	125	125		
		Average γ_m of Bedrock	pcf	150	150		
		Depth to Water Table	ft	25	25		
		Estimated Shaft Tip Depth (BGS)	ft	25	25		
		Vertical Effective Stress, σ'_{vb}	ksf	3.65	3.65		
		Intermediate Parameter, A		5.34	80.81		
	Intermediate Parameters Required for Canadian Geotechnical Society Solution (Eqn. 13-21 from FHWA-NHI-10-016, GEC 10)	Rock Socket Diameter, B	ft	3	3		
		Rock Socket Embedment, D_s	ft	20	20		
		s_v Selection ID		10	6		
		s_v	ft	0.16	1		
		t_d Selection ID		1	4		
		t_d	in	0.5	0.05		
		Check 1		YES	YES		
		Check 2		NO	YES		
		USE t_d/s_v		0.02	0.004		
		NEW s_v		2.08333	N/A		
		Check 3		YES	YES		
		USE s_v/B		0.694	0.333		
		K_{sp}		0.14	0.225		
		d		3.4	3.4		
	Solutions & Design Strength Selection	q_p (Eqn. 10.8.3.5.4c-1)	ksf	180	1431		
		q_p (Eqn. 10.8.3.5.4c-2)	ksf	7.41	334.6		
		q_p (FHWA-IF-99-025, Eqn. 11.6)	ksf	LOW RQD	LOW RQD		
		q_p (FHWA-NHI-10-016, Eqn. 13-21)	ksf	102.82	1313.66		
		q_p (Design)	**ksf**	**7**	**1430**		
		q_p (Design)	**tsf**	**3.5**	**715**		

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Checked By:	RSW
Client Name:	ms consultants, inc.	Foundation Element:	Ret. Walls	Date:	7/18/2023

Version 2.0 (8/31/16)

ESTIMATION OF JOINT CONDITION FACTOR ($JCond_{89}$) FOR BEDROCK LAYERS (See Hoek, et al., 2013; Bieniawski, 1989)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS				
Discontinuity Length (Persistence) Rating	E	0	A	B	C	D	E
			< 1 m	1 m to 3 m	3 m to 10 m	10 m to 20 m	> 20 m
			RELATIVE RATING				
			6	4	2	1	0
Separation (Aperature) Rating	E	0	A	B	C	D	E
			None	< 0.1 mm	0.1 mm to 1.0 mm	1.0 mm to 5.0 mm	> 5.0 mm
			RELATIVE RATING				
			6	5	4	1	0
Roughness Rating	D	1	A	B	C	D	E
			Very Rough	Rough	Slightly Rough	Smooth	Slickensided
			RELATIVE RATING				
			6	5	3	1	0
Infilling (Gouge) Rating	E	0	A	B	C	D	E
			None	Hard Infilling < 5 mm	Hard Infilling > 5 mm	Soft Infilling < 5 mm	Soft Infilling > 5 mm
			RELATIVE RATING				
			6	4	2	2	0
Weathering Rating	D	1	A	B	C	D	E
			Unweathered	Slightly Weathered	Moderate Weathering	Highly Weathered	Decomposed
			RELATIVE RATING				
			6	5	3	1	0

Layer $JCond_{89}$
2

References:
Hoek, E., Carter, T.G., Diederichs, M.S., *Quantification of the Geological Strength Index Chart* , 47th US Rock Mechanics / Geomechanics Symposium, San Francisco, CA, June 2013
Bieniawski, Z.T. 1989. *Engineering Rock Mass Classification* . New York: Wiley Interscience.

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	14' - 25.5'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1135.7' - 1124.2'	Checked By:	RSW
Client Name:	ms consultants, inc.	Foundation Element:	Ret. Walls	Date:	7/18/2023

Version 2.0 (8/31/16)

ESTIMATION OF JOINT CONDITION FACTOR ($JCond_{89}$) FOR BEDROCK LAYERS (See Hoek, et al., 2013; Bieniawski, 1989)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS				
Discontinuity Length (Persistence) Rating	B	4	A	B	C	D	E
			< 1 m	1 m to 3 m	3 m to 10 m	10 m to 20 m	> 20 m
			RELATIVE RATING				
			6	4	2	1	0
Separation (Aperature) Rating	C	4	A	B	C	D	E
			None	< 0.1 mm	0.1 mm to 1.0 mm	1.0 mm to 5.0 mm	> 5.0 mm
			RELATIVE RATING				
			6	5	4	1	0
Roughness Rating	C	3	A	B	C	D	E
			Very Rough	Rough	Slightly Rough	Smooth	Slickensided
			RELATIVE RATING				
			6	5	3	1	0
Infilling (Gouge) Rating	B	4	A	B	C	D	E
			None	Hard Infilling < 5 mm	Hard Infilling > 5 mm	Soft Infilling < 5 mm	Soft Infilling > 5 mm
			RELATIVE RATING				
			6	4	2	2	0
Weathering Rating	B	5	A	B	C	D	E
			Unweathered	Slightly Weathered	Moderate Weathering	Highly Weathered	Decomposed
			RELATIVE RATING				
			6	5	3	1	0

Layer $JCond_{89}$	
20	

References:
Hoek, E., Carter, T.G., Diederichs, M.S., *Quantification of the Geological Strength Index Chart* , 47th US Rock Mechanics / Geomechanics Symposium, San Francisco, CA, June 2013
Bieniawski, Z.T. 1989. *Engineering Rock Mass Classification* . New York: Wiley Interscience.

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine Unit Side Resistance, q_s (Utilizing 2 Methods)*

Method 1: AASHTO LRFD Equation 10.8.3.5.4b-1

$$\frac{q_s}{p_a} = C\sqrt{\frac{q_u}{p_a}}$$

where:

q_s = unit side resistance (ksf)

q_u = compressive strength of rock (ksf)

p_a = atmospheric pressure (2.12 ksf)

C = Regression Coefficient (see right)

Input Information

q_u =	500	psi
f'_c =	4000	psi
C =	0.5	

Note: *The lesser of q_u or f'_c (compressive strength of concrete) should be used for the value of q_u in Equation 10.8.3.5.4b-1.*

q_s =	6.18	ksf
q_s =	3.09	tsf

Discussion on Regression Coefficient C (from C10.8.3.5.4b)

"The recommended value of the regression coefficient C = 1.0 is applicable to normal rock sockets, defined as sockets constructed with conventional equipment and resulting in nominally clean sidewalls without resorting to special procedures or artificial roughening. Rock that is prone to smearing or rapid deterioration upon exposure to atmospheric conditions, water, or slurry are outside the normal range and may require additional measures to insure reliable side resistance. Rocks exhibiting this type of behavior include clay shales and other argillaceous rocks. Rock that cannot support construction of an unsupported socket without caving is also outside the normal and will likely exhibit lower side resistance than given by Eq. 10.8.3.5.4b-1 with C = 1.0. For additional guidance on assessing the magnitude of C, See Brown et al. (2010)."

Discussion on Regression Coefficient C (from Brown et al. 2010)

"The most recent regression analysis of available load test data is reported by Kulhawy et al. (2005) and demonstrates that the mean value of the coefficient C is approximately equal to 1.0. The authors recommend the use of Equation [10.8.3.5.4b-1] with C = 1.0 for design of "normal" rock sockets. A lower bound value of C = 0.63 was shown to encompass 90% of the load test results...Considering the most recent research on side resistance in rock, in particular the work cited above by Kulhawy et al. (2005) that incorporates the original data of Horvath and Kenney (1979) plus additional data compiled over the ensuing 25+ years, <u>Equation [10.8.3.5.4b-1] with C = 1.0 is recommended for routine design of rock sockets.</u> For rock that cannot be drilled without some type of artificial support, such as casing or by grouting ahead of the excavation, the reduction factors ... based on RQD are recommended for application to the resistance calculated by Equation [10.8.3.5.4b-2]. The resistance factor recommended with use of Equations [10.8.3.5.4b-1] and [10.8.3.5.4b-2] is ϕ = 0.55 based on fitting to ASD with a factor of safety FS = 2.5, as discussed in Chapter 10 and presented in Table 10-5. Artificial roughening of rock sockets through the use of grooving tools or other measures can increase side resistance compared to normal sockets. Regression analysis of the available load test data by Kulhawy and Prakoso (2007) suggests a mean value of C = 1.9 with use of Equation [10.8.3.5.4b-1] for roughened sockets. It is strongly recommended that load tests or local experience be used to verify values of C greater than 1.0. However, the advantages of achieving higher resistance by sidewall roughening often justify the cost of load tests." (emphasis added)

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - Determine Unit Side Resistance, q_s (Utilizing 2 Methods) - Continued

Method 2: AASHTO LRFD Equation 10.8.3.5.4b-2

$$\frac{q_s}{p_a} = 0.65\alpha_E\sqrt{\frac{q_u}{p_a}}$$

where:

q_s = unit side resistance (ksf)

q_u = compressive strength of rock (ksf)

p_a = atmospheric pressure (2.12 ksf)

α_E = joint modification factor (Table 10.8.3.5.4b-1)

Joint Modification Factor, α_E

Table 10.8.3.5.4b-1

RQD (%)	Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

Input Information

q_u =	500	psi
f'_c =	4000	psi
RQD =	32	%
Fractured Rock =	Yes	*(i.e. susceptible to caving)*
Joint Type =	Open	

α_E = 0.51 (Table 10.8.3.5.4b-1)

q_s = 4.1 ksf

q_s = 2.05 tsf

SUMMARY

q_s (routine design) = 6.18 ksf *(eqn. 10.8.3.5.4b-1)*

q_s (fractured rock) = 4.1 ksf *(eqn. 10.8.3.5.4b-2)*

q_s (design) = 4 ksf

q_s (design) = 2 ksf

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

	Calc	Check
Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods)*

Method 1: AASHTO LRFD Equation 10.8.3.5.4c-1

$$q_p = 2.5 q_u$$

where:

q_p = unit end bearing resistance (ksf)

q_u = compressive strength of rock (ksf)

Note: The lesser of q_u or f'_c (compressive strength of concrete) should be used for the value of q_u in Equation 10.8.3.5.4b-1.

q_u = 500 psi

f'_c = 4000 psi

q_p = 180 ksf

q_p = 90 tsf

Discussion on the use of Equation 10.8.3.5.4c-1

"If the rock below the base of the drilled shaft to a depth of 2.0B is either intact or tightly jointed, i.e., no compressible material or gouge-filled seams (including no solution cavities or voids below the base of the drilled shaft per C10.8.3.5.4c), and the depth of the socket is greater than 1.5B."

Method 1: AASHTO LRFD Equation 10.8.3.5.4c-2

$$q_p = A + q_u \left[m_b \left(\frac{A}{q_u} \right) + s \right]^a$$

where:

q_u = compressive strength of rock (ksf)

A = defined by Equation 10.8.3.5.4c-3 (see right)

m_b, *s*, *a* = Hoek-Brown strength parameters for the fractured rock mass determined from *GSI* (see Article 10.4.6.4)

Note: The lesser of q_u or f'_c (compressive strength of concrete) should be used for the value of q_u in Equation 10.8.3.5.4b-2.

Discussion on the use of Equation 10.8.3.5.4c-2

"If the rock below the base of the shaft to a depth of 2.0B is jointed, the joints have random orientation and the condition of the joints can be evaluated per Equation 10.8.3.5.4c-2....Equation 10.8.3.5.4c-1 should be used as un upper-bound limit to base resistance calculated by Equation 10.8.2.5.4c-2, unless local experience or load tests can be used to validate higher values.

Equation 10.8.3.5.4c-3

$$A = \sigma'_{vb} + q_u \left[m_b \frac{(\sigma'_{v,b})}{q_u} + s \right]^a$$

where:

$\sigma'_{v,b}$ = vertical effective stress at the socket bearing elevation (tip elevation)

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

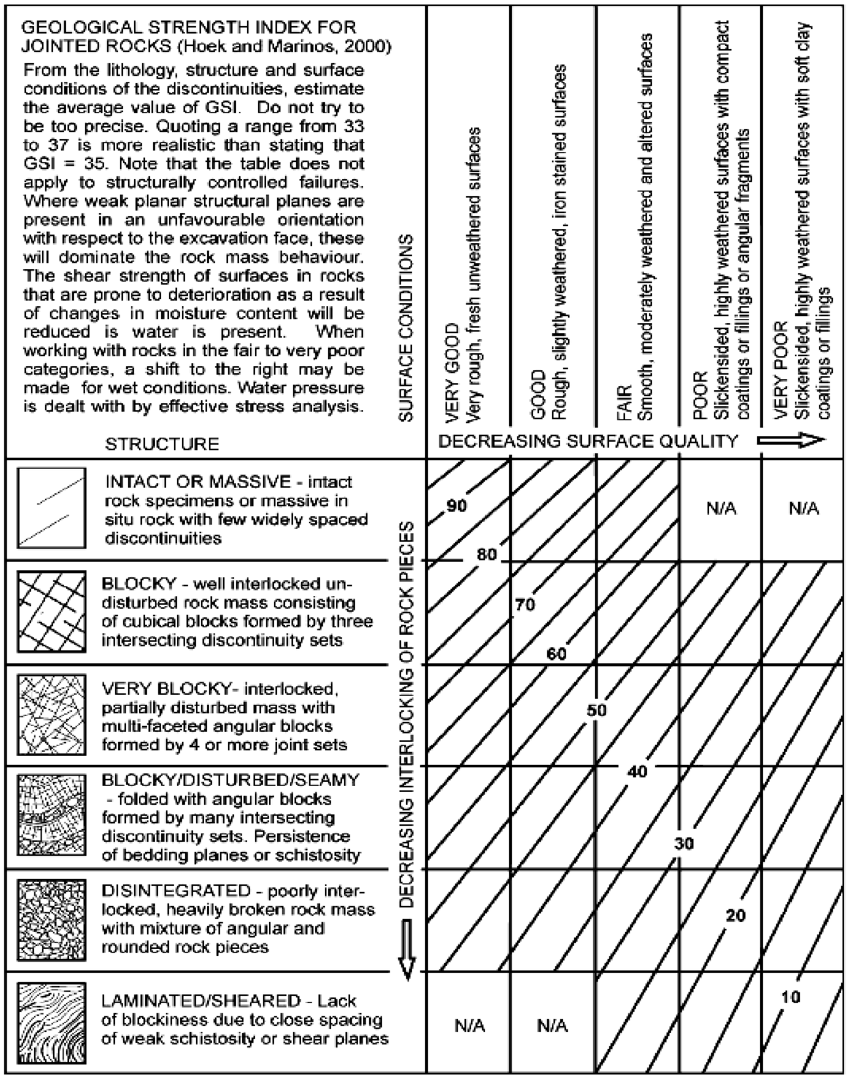


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

From Article 10.4.6.4

$$s = e^{\left(\frac{GSI-100}{9-3D}\right)}$$ Equation 10.4.6.4-2

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{\frac{-GSI}{15}} - e^{\frac{-20}{3}}\right)$$ Equation 10.4.6.4-3

$$m_b = m_i e^{\left(\frac{GSI-100}{28-14D}\right)}$$ Equation 10.4.6.4-4

where:

GSI = Geological Strength Index *(see Figures 10.4.6.4-1 and 10.4.6.4-2)*

D = Disturbance factor (dim)

m_i = Constant by Rock Group (see Table 10.4.6.4-1)

Note: Only the portion of Table 10.4.6.4-1 including rock types found in Ohio is shown below. Full table may be viewed in Article 10.4.6.4.

Table 10.4.6.4-1 Values of the Constant m_i by Rock Group (after Marinos and Hoek 2000, with updated values from Rocscience, Inc., 2007)

Rock type	Class	Group	Texture: Coarse	Texture: Medium	Texture: Fine	Texture: Very fine
SEDIMENTARY	Clastic		Conglomerate (21 ± 3) Breccia (19 ± 5)	Sandstone 17 ± 4	Siltstone 7 ± 2 Greywacke (18 ± 3)	Claystone 4 ± 2 Shale (6 ± 2) Marl (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestone (10 ± 5)	Micritic Limestone (8 ± 3)	Dolomite (9 ± 3)
		Evaporites		Gypsum 10 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2

Project Number:	210435B	Boring(s):	B-002-0-22			*Version 2.0 (8/31/16)*
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'			
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Calc / Check By:	BKS	RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls	Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

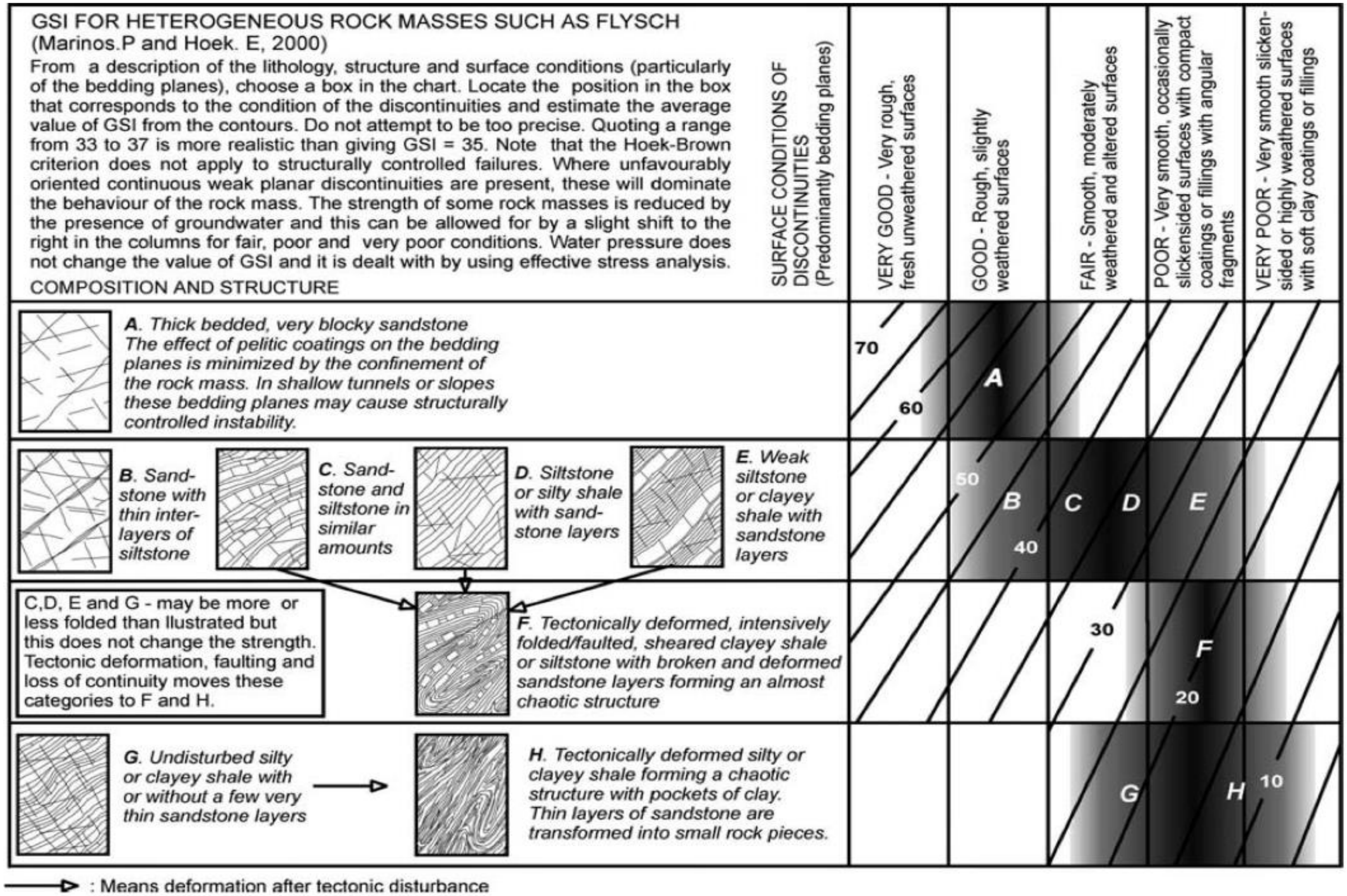


Figure 10.4.6.4-2—Determination of *GSI* for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

Note: Additional information on the GSI method may be found in "Hoek's Corner" on the Rocsciences website (https://www.rocscience.com/education/hoeks_corner), which contains additional articles on the background, assumption, purposes, estimation and calculation of GSI. Of special note are the articles titled "GSI: A Geologically Friendly Tool for Rock Mass Strength Estimation" (Marinos, P. and Hook, E. 2000) and "Quantification of the Geological Strength Index Chart" (Hoek, E., Carter, T.G., Diederichs, M.S., 2013).

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

	Calc	Check
Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Step 1: Estimate GSI and Hoek-Brown strength parameters using analytical method outlined in "Quantification of the Geological Strength Index Chart" (Hoek, E., Carter, T.G., Diederichs, M.S., 2013) and visually by using Figures 10.4.6.4-1 and 10.4.6.4-2

RQD = 32

$JCond_{89}$ = 2

GSI (Quan.) = 19 $GSI = 1.5JCond_{89} + RQD/2$

GSI (Qual.) = 20 from Figures 10.4.6.4-1 & 10.4.6.4-2

GSI (Design) = 20

D = 1

m_i = 6

s = 0.0000016

a = 0.5437

m_b = 0.0198

Step 2: Determine vertical effective stress at shaft tip and intermediate paremeter, *A*

Unconfined Compressive Strength of Bedrock (q_u) =	72.00	ksf
Depth to bottom of Soil Cover & Decomposed Rock (D_s) =	4	ft
Average Unit Weight of Soil Cover ($\gamma_{m,soil}$) =	125	pcf
Average Unit Weight of Bedrock ($\gamma_{m,rock}$) =	150	pcf
Depth to Water Table (D_w) =	25	ft
Estimated Shaft Tip Depth Below Ground Surface (D_t) =	25	ft

$$\sigma'_{v,b} = D_s\gamma'_{soil} + (D_t - D_s)\gamma'_{rock}$$

where:

when below water table	when above water table
$\gamma'_{soil} = \gamma_{m,soil} - 62.4$	$\gamma'_{soil} = \gamma_{m,soil}$
$\gamma'_{rock} = \gamma_{m,rock} - 62.4$	$\gamma'_{rock} = \gamma_{m,rock}$

σ'_{vb} = 3.65 ksf

A = 5.34

Step 3: Determine estimated tip resistance

q_p = 7.42 ksf

q_p = 3.71 tsf

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Method 3: FHWA-IF-99-025 Equation 11-6

$$q_p = 4.83(q_u)^{0.51}$$

RQD = 32

q_u = 500 psi

q_u = 3.45 MPa

q_p = LOW RQD MPa

q_p = LOW RQD ksf

q_p = LOW RQD tsf

where:

q_p = unit end bearing resistance (MPa)

q_u = compressive strength of rock (MPa) (1 psi = 0.00689475728 MPa)

NOTE: Equation 11-6 should only be used when the following are true:
1) Rock mass has an RQD value between 70% and 100%;
2) Closed joints are approximately horizontal; and
3) q_u > 0.5 MPa (5.2 tsf or 72.5 psi)

Method 4: FHWA-NHI-10-016 Equations 13-21 thru 13-23

Equation 13-21:

$$q_p = q_{BN} = 3q_u K_{sp} d$$

Equation 13-22:

$$K_{sp} = \frac{3 + \frac{s_v}{B}}{10\sqrt{1 + 300\frac{t_d}{s_v}}}$$

Equation 13-23:

$$d = 1 + 0.4\frac{D_s}{B} \leq 3.4$$

where:

q_p = unit end bearing resistance (ksf)

q_u = compressive strength of rock (ksf)

s_v = vertical spacing between discontinuities

t_d = aperature (thickness) of discontinuities

B = socket diameter (ft)

D_s = depth of socket (rock) embedment (ft)

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

	Calc	Check
Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Method 4: FHWA-NHI-10-016 Equations 13-21 thru 13-23 (continued)

B =	3	ft
D_s =	20	ft
s_v Selection ID =	10	
s_v =	0.16	ft
t_d Selection ID =	1	
t_d =	0.5	in

Check 1:	Is B > 1 ft	
B =	3	
PASS CHECK?	YES	
Check 2:	Is $0 < t_d/s_v < 0.02$	
t_d/s_v =	0.26	
PASS CHECK?	NO	If no, adjust s_v
USE t_d/s_v =	0.02	
NEW s_v =	2.08333	ft
Check 3:	Is $0.05 < s_v/B < 2.0$	
s_v/B =	0.694	
PASS CHECK?	YES	
USE s_v/B =	0.694	

Adapted from Table 600-14 in 2007 ODOT SGE, July 2014 Update

Selection ID	Degree of Fracturing	Spacing, s_v (ft)	Design Value, s_v (ft)	Design Value, s_v (mm)
1	Unfractured	> 10.0	10	3048
2	Intact to Unfractured	$3.0 < s_v$	8	2438
3	Intact	$3.0 < s_v < 10.0$	6	1829
4	Slightly Fractured to Intact	$1.0 < s_v < 10.0$	4	1219
5	Slightly Fractured	$1.0 < s_v < 3.0$	2	610
6	Moderately to Slightly Fractured	$0.33 < s_v < 3.0$	1	305
7	Moderately Fractured	$0.33 < s_v < 1.0$	0.67	204
8	Fractured to Moderately Fractured	$0.16 < s_v < 1.0$	0.5	152
9	Fractured	$0.16 < s_v < 0.33$	0.25	76
10	Highly Fractured to Fractured	$s_v < 0.33$	0.16	49
11	Highly Fractured	$s_v < 0.16$	0.1	30

Adapted from Table 600-15 in 2007 ODOT SGE, July 2014 Update

Selection ID	Condition of Fractures	Aperture, t_d (in)	Design Value, t_d (in)	Design Value, t_d (mm)
1	Open	$0.2 < t_d$	0.5	13
2	Narrow to Open	$0.05 < t_d$	0.15	3.8
3	Narrow	$0.05 < t_d < 0.2$	0.1	2.5
4	Tight to Narrow	$t_d < 0.2$	0.05	1.3
5	Tight	$t_d < 0.05$	0.02	0.5

*Selections 2, 4, 6, 8 & 10 represents cross overs between two descriptions

Project Number:	210435B	Boring(s):	B-002-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'
Client Name:	ms consultants, inc.	Analysis Purpose:	Ret. Walls

Version 2.0 (8/31/16)

	BKS	RSW
Calc / Check By:	BKS	RSW
Date:	07/17/23	07/18/23

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Method 4: FHWA-NHI-10-016 Equations 13-21 thru 13-23 (continued)

q_u = 500 psi

q_u = 72 ksf

K_{sp} = 0.14

d = 3.4

q_p = 102.82 ksf

q_p = 51.41 tsf

End Bearing Resistance, q_p Summary

Method	Reference	q_p Value	Unit
1	AASHTO LRFD Eqn. 10.8.3.5.4c-1	180	ksf
2	AASHTO LRFD Eqn. 10.8.3.5.4c-2	7.42	ksf
3	FHWA-IF-99-025 Eqn. 11-6	N/A	ksf
4	FHWA-NHI-10-016 Eqn. 13-21	102.82	ksf

q_p (Design) = 7 ksf

q_p (Design) = 3.5 tsf

Project Number:	210435B	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Date:	8/26/2022
Project Location:	St. Clairsville, Ohio	Checked By:	RSW
Client Name:	ms consultants, inc.	Date:	10/19/2022

Version 2.0 (8/31/16)

DRILLED SHAFTS IN ROCK - RESISTANCE CALCULATION SUMMARY (AASHTO LRFD, 9th EDITION)

(Example calculations with reference equations and information are provided on additional sheets)

Bridge Structure Identification		North End Soldier Pile Wall	
Boring ID	B-008-0-22	Foundation Element Description	North Walls
Surface Elev.	1145.2	Top of Shaft / Base of Shaft Cap Elevation	1143

Analysis Desc.	Term/Info Description	Unit	Layer 1	Layer 2	Layer 3	Layer 4
Boring/Layer Information	Bedrock Type/Description		Shale	Sandstone	Shale w/ Coal	
	Layer Top Depth (from G.S.)	ft	5.5	10.7	22.6	
	Layer Top Elevation	MSL	1139.7	1134.5	1122.6	
	Layer Bottom Depth (from G.S.)	ft	10.7	22.6	25	
	Layer Bottom Elevation	MSL	1134.5	1122.6	1120.2	
	Layer Thickness	ft	5.2	11.9	2.4	
GSI Index Calculation (AASHTO LRFD, 9th Edition; Hoek, et al., 2013; Bieniawski, Z.T. 1989)	RQD	%	23	85	80	
	Discontinuity Length Rating		C	B	C	
	Separation Rating		C	B	B	
	Roughness Rating		C	B	C	
	Infilling Rating		C	A	A	
	Weathering Rating		D	B	B	
	Estimated JCond89 Value		12	25	21	
	Estimated GSI Value (quan.)		29.5	80	71.5	
	Estimated GSI Value (qual.)		25	75	55	
	Design GSI Value		25	75	60	
Unit Side Resistance Calculations (AASHTO LRFD, 9th Edition)	Compressive Strength, q_u	psi	1368	6750	3975	
	Concrete Strength, f'_c	psi	4000	4000	4000	
	Fractured Rock? (Susceptible to Caving?)		Yes	No	No	
	Joint Condition		Open	Closed	Closed	
	Regression Coefficient, C		0.5	1.0	1.0	
	q_s (Eqn. 10.8.3.5.4b-1)	ksf	10.22	34.94	34.84	
	Reduction Factor, α_E		0.47	0.93	0.9	
	q_s (Eqn. 10.8.3.5.4b-2)	ksf	6.24	21.12	20.38	
	q_s (Design)	**ksf**	**10**	**34**	**34**	
	q_s (Design)	**tsf**	**5**	**17**	**17**	

Definition of Bedrock Type Abbreviations:

SS = Sandstone | *SH = Shale* | *in/b = interbedded with*

SLTS = Siltstone | *CLST = Claystone*

Project Number:	210435B	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Date:	8/26/2022
Project Location:	St. Clairsville, Ohio	Checked By:	RSW
Client Name:	ms consultants, inc.	Date:	10/19/2022

Version 2.0 (8/31/16)

DRILLED SHAFTS IN ROCK - RESISTANCE CALCULATION SUMMARY (AASHTO LRFD, 9TH EDITION) - CONTINUED

		Term/Info Description	Unit	Layer 1	Layer 2	Layer 3	Layer 4
Unit End Bearing Resistance Calculations	Intermediate Parameters Required for GSI Empirical Approach, AASHTO LRFD Eqn. 10.8.3.5.4c-2	Compressive Strength, q_u	ksf	196.99	972.00	572.40	
		Disturbance Factor, D		1	0.1	0.2	
		Empirical Parameter, s		0.0000037	0.0564973	0.0085493	
		Empirical Parameter, a		0.5313	0.5009	0.5028	
		Constant, m_i (Table 10.4.6.4-1)		6	17	6	
		Empirical Parameter, m_b		0.0283	6.6417	1.2269	
		Depth of Soil Cover	ft	4	4	4	
		Average γ_m of Soil Cover	pcf	125	125	125	
		Average γ_m of Bedrock	pcf	150	150	150	
		Depth to Water Table	ft	25	25	25	
		Estimated Shaft Tip Depth (BGS)	ft	10.5	22.5	25	
		Vertical Effective Stress, σ'_{vb}	ksf	1.475	3.275	3.65	
		Intermediate Parameter, A		3.70	275.64	76.05	
	Intermediate Parameters Required for Canadian Geotechnical Society Solution (Eqn. 13-21 from FHWA-NHI-10-016, GEC 10)	Rock Socket Diameter, B	ft	3	3	3	
		Rock Socket Embedment, D_s	ft	5	17	20	
		s_v Selection ID		8	6	8	
		s_v	ft	0.5	1	0.5	
		t_d Selection ID		2	4	4	
		t_d	in	0.15	0.05	0.05	
		Check 1		YES	YES	YES	
		Check 2		NO	YES	YES	
		USE t_d/s_v		0.02	0.004	0.008	
		NEW s_v		0.625	N/A	N/A	
		Check 3		YES	YES	YES	
		USE s_v/B		0.208	0.333	0.167	
		K_{sp}		0.121	0.225	0.172	
		d		1.7	3.3	3.4	
	Solutions & Design Strength Selection	q_p (Eqn. 10.8.3.5.4c-1)	ksf	492.48	2430	1431	
		q_p (Eqn. 10.8.3.5.4c-2)	ksf	7.29	1630.26	311.98	
		q_p (FHWA-IF-99-025, Eqn. 11.6)	ksf	LOW RQD	547.62	545.95	
		q_p (FHWA-NHI-10-016, Eqn. 13-21)	ksf	119.42	2145.45	1004.22	
		q_p (Design)	**ksf**	**10**	**2430**	**1430**	
		q_p (Design)	**tsf**	**5**	**1215**	**715**	

Project Number:	210435B	Boring(s):	B-008-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'	Date:	8/26/2022
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'	Checked By:	RSW
Client Name:	ms consultants, inc.	Foundation Element:	North Walls	Date:	10/19/2022

Version 2.0 (8/31/16)

ESTIMATION OF JOINT CONDITION FACTOR ($JCond_{89}$) FOR BEDROCK LAYERS (See Hoek, et al., 2013; Bieniawski, 1989)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS				
Discontinuity Length (Persistence) Rating	C	2	A	B	C	D	E
			< 1 m	1 m to 3 m	3 m to 10 m	10 m to 20 m	> 20 m
			RELATIVE RATING				
			6	4	2	1	0
Separation (Aperature) Rating	C	4	A	B	C	D	E
			None	< 0.1 mm	0.1 mm to 1.0 mm	1.0 mm to 5.0 mm	> 5.0 mm
			RELATIVE RATING				
			6	5	4	1	0
Roughness Rating	C	3	A	B	C	D	E
			Very Rough	Rough	Slightly Rough	Smooth	Slickensided
			RELATIVE RATING				
			6	5	3	1	0
Infilling (Gouge) Rating	C	2	A	B	C	D	E
			None	Hard Infilling < 5 mm	Hard Infilling > 5 mm	Soft Infilling < 5 mm	Soft Infilling > 5 mm
			RELATIVE RATING				
			6	4	2	2	0
Weathering Rating	D	1	A	B	C	D	E
			Unweathered	Slightly Weathered	Moderate Weathering	Highly Weathered	Decomposed
			RELATIVE RATING				
			6	5	3	1	0

Layer $JCond_{89}$	
12	

References:

Hoek, E., Carter, T.G., Diederichs, M.S., *Quantification of the Geological Strength Index Chart* , 47th US Rock Mechanics / Geomechanics Symposium, San Francisco, CA, June 2013

Bieniawski, Z.T. 1989. *Engineering Rock Mass Classification* . New York: Wiley Interscience.

Project Number:	210435B	Boring(s):	B-008-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	10.7' - 22.6'	Date:	8/26/2022
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1134.5' - 1122.6'	Checked By:	RSW
Client Name:	ms consultants, inc.	Foundation Element:	North Walls	Date:	10/19/2022

Version 2.0 (8/31/16)

ESTIMATION OF JOINT CONDITION FACTOR ($JCond_{89}$) FOR BEDROCK LAYERS (See Hoek, et al., 2013; Bieniawski, 1989)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS				
Discontinuity Length (Persistence) Rating	B	4	A	B	C	D	E
			< 1 m	1 m to 3 m	3 m to 10 m	10 m to 20 m	> 20 m
			RELATIVE RATING				
			6	4	2	1	0
Separation (Aperature) Rating	B	5	A	B	C	D	E
			None	< 0.1 mm	0.1 mm to 1.0 mm	1.0 mm to 5.0 mm	> 5.0 mm
			RELATIVE RATING				
			6	5	4	1	0
Roughness Rating	B	5	A	B	C	D	E
			Very Rough	Rough	Slightly Rough	Smooth	Slickensided
			RELATIVE RATING				
			6	5	3	1	0
Infilling (Gouge) Rating	A	6	A	B	C	D	E
			None	Hard Infilling < 5 mm	Hard Infilling > 5 mm	Soft Infilling < 5 mm	Soft Infilling > 5 mm
			RELATIVE RATING				
			6	4	2	2	0
Weathering Rating	B	5	A	B	C	D	E
			Unweathered	Slightly Weathered	Moderate Weathering	Highly Weathered	Decomposed
			RELATIVE RATING				
			6	5	3	1	0

Layer $JCond_{89}$
25

References:
Hoek, E., Carter, T.G., Diederichs, M.S., *Quantification of the Geological Strength Index Chart* , 47th US Rock Mechanics / Geomechanics Symposium, San Francisco, CA, June 2013
Bieniawski, Z.T. 1989. *Engineering Rock Mass Classification* . New York: Wiley Interscience.

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	22.6' - 25'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1122.6' - 1120.2'
Client Name:	ms consultants, inc.	Foundation Element:	North Walls

Calculated By:	BKS
Date:	8/26/2022
Checked By:	RSW
Date:	10/19/2022

Version 2.0 (8/31/16)

ESTIMATION OF JOINT CONDITION FACTOR ($JCond_{89}$) FOR BEDROCK LAYERS (See Hoek, et al., 2013; Bieniawski, 1989)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS				
Discontinuity Length (Persistence) Rating	C	2	A	B	C	D	E
			< 1 m	1 m to 3 m	3 m to 10 m	10 m to 20 m	> 20 m
			RELATIVE RATING				
			6	4	2	1	0
Separation (Aperature) Rating	B	5	A	B	C	D	E
			None	< 0.1 mm	0.1 mm to 1.0 mm	1.0 mm to 5.0 mm	> 5.0 mm
			RELATIVE RATING				
			6	5	4	1	0
Roughness Rating	C	3	A	B	C	D	E
			Very Rough	Rough	Slightly Rough	Smooth	Slickensided
			RELATIVE RATING				
			6	5	3	1	0
Infilling (Gouge) Rating	A	6	A	B	C	D	E
			None	Hard Infilling < 5 mm	Hard Infilling > 5 mm	Soft Infilling < 5 mm	Soft Infilling > 5 mm
			RELATIVE RATING				
			6	4	2	2	0
Weathering Rating	B	5	A	B	C	D	E
			Unweathered	Slightly Weathered	Moderate Weathering	Highly Weathered	Decomposed
			RELATIVE RATING				
			6	5	3	1	0

Layer $JCond_{89}$
21

References:
Hoek, E., Carter, T.G., Diederichs, M.S., *Quantification of the Geological Strength Index Chart* , 47th US Rock Mechanics / Geomechanics Symposium, San Francisco, CA, June 2013
Bieniawski, Z.T. 1989. *Engineering Rock Mass Classification* . New York: Wiley Interscience.

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - *Determine Unit Side Resistance, q_s (Utilizing 2 Methods)*

Method 1: AASHTO LRFD Equation 10.8.3.5.4b-1

$$\frac{q_s}{p_a} = C\sqrt{\frac{q_u}{p_a}}$$

where:

q_s = unit side resistance (ksf)

q_u = compressive strength of rock (ksf)

p_a = atmospheric pressure (2.12 ksf)

C = Regression Coefficient (see right)

Input Information

q_u =	1368	psi
f'_c =	4000	psi
C =	0.5	

Note: *The lesser of q_u or f'_c (compressive strength of concrete) should be used for the value of q_u in Equation 10.8.3.5.4b-1.*

q_s = **10.22** ksf

q_s = **5.11** tsf

Discussion on Regression Coefficient C (from C10.8.3.5.4b)

"The recommended value of the regression coefficient C = 1.0 is applicable to normal rock sockets, defined as sockets constructed with conventional equipment and resulting in nominally clean sidewalls without resorting to special procedures or artificial roughening. Rock that is prone to smearing or rapid deterioration upon exposure to atmospheric conditions, water, or slurry are outside the normal range and may require additional measures to insure reliable side resistance. Rocks exhibiting this type of behavior include clay shales and other argillaceous rocks. Rock that cannot support construction of an unsupported socket without caving is also outside the normal and will likely exhibit lower side resistance than given by Eq. 10.8.3.5.4b-1 with C = 1.0. For additional guidance on assessing the magnitude of C, See Brown et al. (2010)."

Discussion on Regression Coefficient C (from Brown et al. 2010)

"The most recent regression analysis of available load test data is reported by Kulhawy et al. (2005) and demonstrates that the mean value of the coefficient C is approximately equal to 1.0. The authors recommend the use of Equation [10.8.3.5.4b-1] with C = 1.0 for design of "normal" rock sockets. A lower bound value of C = 0.63 was shown to encompass 90% of the load test results...Considering the most recent research on side resistance in rock, in particular the work cited above by Kulhawy et al. (2005) that incorporates the original data of Horvath and Kenney (1979) plus additional data compiled over the ensuing 25+ years, <u>Equation [10.8.3.5.4b-1] with C = 1.0 is recommended for routine design of rock sockets.</u> For rock that cannot be drilled without some type of artificial support, such as casing or by grouting ahead of the excavation, the reduction factors ... based on RQD are recommended for application to the resistance calculated by Equation [10.8.3.5.4b-2]. The resistance factor recommended with use of Equations [10.8.3.5.4b-1] and [10.8.3.5.4b-2] is ϕ = 0.55 based on fitting to ASD with a factor of safety FS = 2.5, as discussed in Chapter 10 and presented in Table 10-5. Artificial roughening of rock sockets through the use of grooving tools or other measures can increase side resistance compared to normal sockets. Regression analysis of the available load test data by Kulhawy and Prakoso (2007) suggests a mean value of C = 1.9 with use of Equation [10.8.3.5.4b-1] for roughened sockets. It is strongly recommended that load tests or local experience be used to verify values of C greater than 1.0. However, the advantages of achieving higher resistance by sidewall roughening often justify the cost of load tests." (emphasis added)

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

	Calc	Check
Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - *Determine Unit Side Resistance, q_s (Utilizing 2 Methods) - Continued*

Method 2: AASHTO LRFD Equation 10.8.3.5.4b-2

$$\frac{q_s}{p_a} = 0.65\alpha_E\sqrt{\frac{q_u}{p_a}}$$

where:

q_s = unit side resistance (ksf)

q_u = compressive strength of rock (ksf)

p_a = atmospheric pressure (2.12 ksf)

α_E = joint modification factor (Table 10.8.3.5.4b-1)

Joint Modification Factor, α_E

Table 10.8.3.5.4b-1

RQD (%)	Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

Input Information

q_u =	1368	psi
f'_c =	4000	psi
RQD =	23	%
Fractured Rock =	Yes	*(i.e. susceptible to caving)*
Joint Type =	Open	

α_E = 0.47 (Table 10.8.3.5.4b-1)

q_s = 6.24 ksf

q_s = 3.12 tsf

SUMMARY

q_s (routine design) = 10.22 ksf *(eqn. 10.8.3.5.4b-1)*

q_s (fractured rock) = 6.24 ksf *(eqn. 10.8.3.5.4b-2)*

q_s (design) = 10 ksf

q_s (design) = 5 ksf

Project Number:	210435B	Boring(s):	B-008-0-22			
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'			
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'	Calc / Check By:	BKS	RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls	Date:	08/26/22	10/19/22

Version 2.0 (8/31/16)

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods)*

Method 1: AASHTO LRFD Equation 10.8.3.5.4c-1

$$q_p = 2.5q_u$$

q_u = 1368 psi

f'_c = 4000 psi

q_p = 492.48 ksf

q_p = 246.24 tsf

where:

q_p = unit end bearing resistance (ksf)

q_u = compressive strength of rock (ksf)

Note: The lesser of q_u or f'_c (compressive strength of concrete) should be used for the value of q_u in Equation 10.8.3.5.4b-1.

Discussion on the use of Equation 10.8.3.5.4c-1

"If the rock below the base of the drilled shaft to a depth of 2.0B is either intact or tightly jointed, i.e., no compressible material or gouge-filled seams (including no solution cavities or voids below the base of the drilled shaft per C10.8.3.5.4c), and the depth of the socket is greater than 1.5B."

Method 2: AASHTO LRFD Equation 10.8.3.5.4c-2

$$q_p = A + q_u\left[m_b\left(\frac{A}{q_u}\right) + s\right]^a$$

where:

q_u = compressive strength of rock (ksf)

A = defined by Equation 10.8.3.5.4c-3 (see right)

m_b, s, a = Hoek-Brown strength parameters for the fractured rock mass determined from *GSI* (see Article 10.4.6.4)

Note: The lesser of q_u or f'_c (compressive strength of concrete) should be used for the value of q_u in Equation 10.8.3.5.4b-2.

Discussion on the use of Equation 10.8.3.5.4c-2

"If the rock below the base of the shaft to a depth of 2.0B is jointed, the joints have random orientation and the condition of the joints can be evaluated per Equation 10.8.3.5.4c-2....Equation 10.8.3.5.4c-1 should be used as un upper-bound limit to base resistance calculated by Equation 10.8.2.5.4c-2, unless local experience or load tests can be used to validate higher values.

Equation 10.8.3.5.4c-3

$$A = \sigma'_{vb} + q_u\left[m_b\frac{(\sigma'_{v,b})}{q_u} + s\right]^a$$

where:

$\sigma'_{v,b}$ = vertical effective stress at the socket bearing elevation (tip elevation)

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

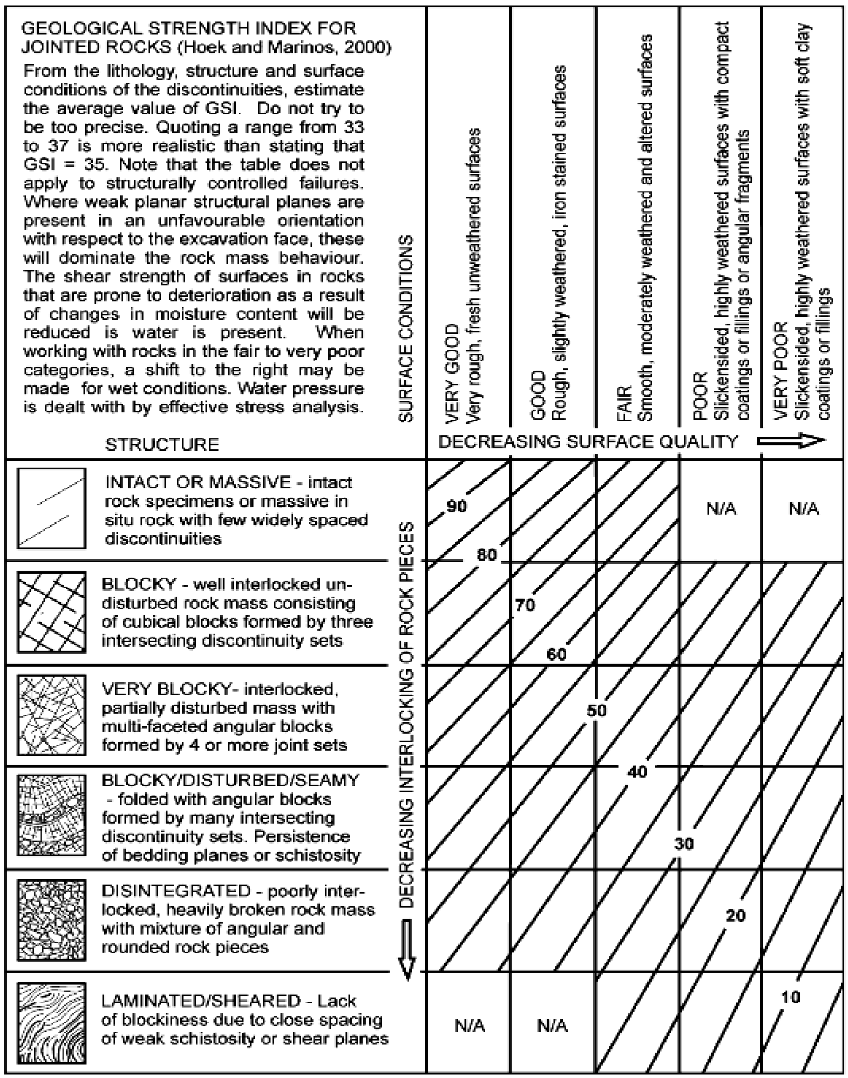


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

From Article 10.4.6.4

$$s = e^{\left(\frac{GSI-100}{9-3D}\right)} \qquad \text{Equation 10.4.6.4-2}$$

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{\frac{-GSI}{15}} - e^{\frac{-20}{3}}\right) \qquad \text{Equation 10.4.6.4-3}$$

$$m_b = m_i e^{\left(\frac{GSI-100}{28-14D}\right)} \qquad \text{Equation 10.4.6.4-4}$$

where:

GSI = Geological Strength Index *(see Figures 10.4.6.4-1 and 10.4.6.4-2)*

D = Disturbance factor (dim)

m_i = Constant by Rock Group (see Table 10.4.6.4-1)

Note: Only the portion of Table 10.4.6.4-1 including rock types found in Ohio is shown below. Full table may be viewed in Article 10.4.6.4.

Table 10.4.6.4-1 Values of the Constant m_i by Rock Group (after Marinos and Hoek 2000, with updated values from Rocscience, Inc., 2007)

Rock type	Class	Group	Texture			
			Coarse	Medium	Fine	Very fine
SEDIMENTARY	Clastic		Conglomerate (21 ± 3) Breccia (19 ± 5)	Sandstone 17 ± 4	Siltstone 7 ± 2 Greywacke (18 ± 3)	Claystone 4 ± 2 Shale (6 ± 2) Marl (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestone (10 ± 5)	Micritic Limestone (8 ± 3)	Dolomite (9 ± 3)
		Evaporites		Gypsum 10 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2

Project Number:	210435B	Boring(s):	B-008-0-22		
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'		
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'	Calc / Check By:	BKS / RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls	Date:	08/26/22 / 10/19/22

Version 2.0 (8/31/16)

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

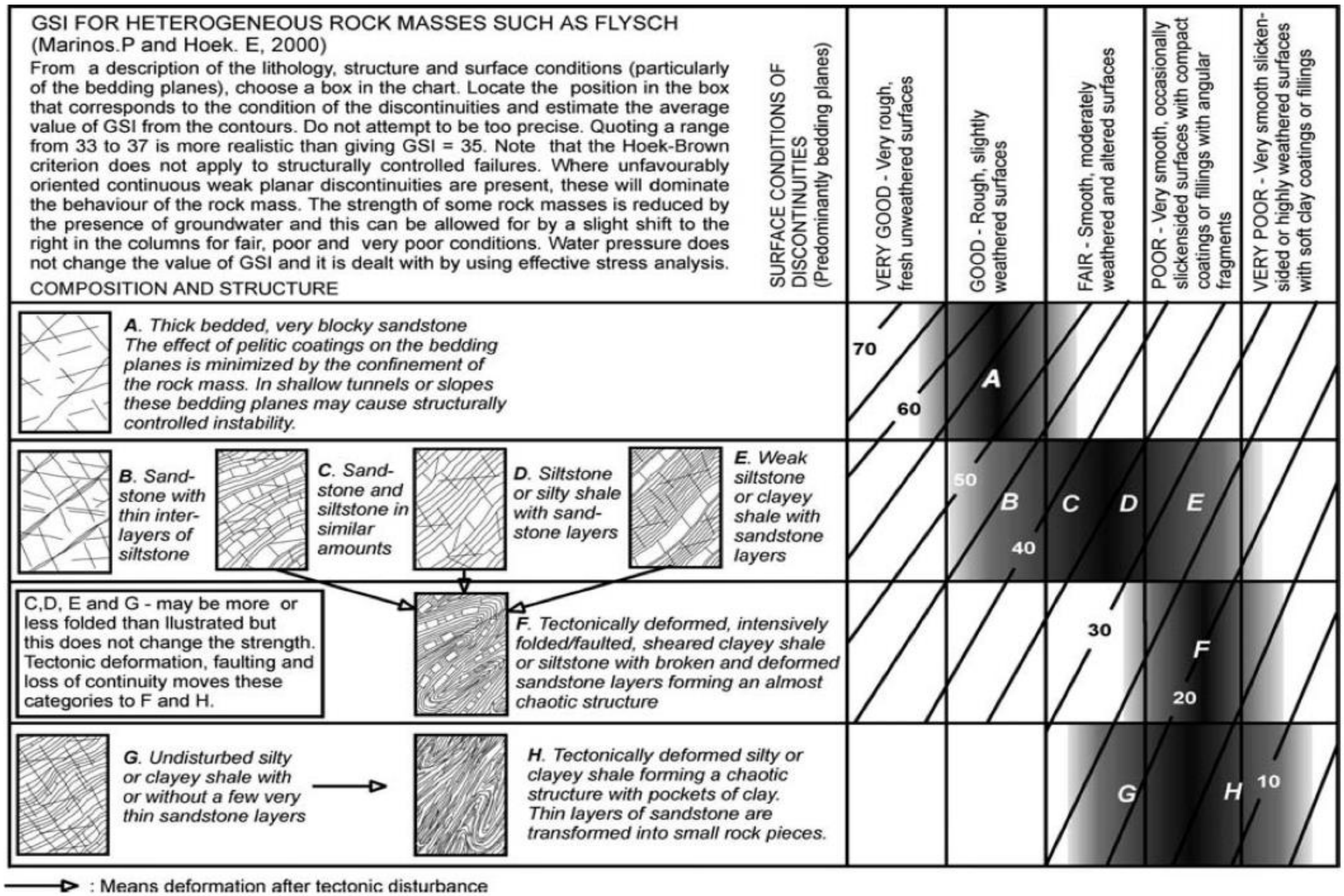


Figure 10.4.6.4-2—Determination of *GSI* for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

Note: Additional information on the GSI method may be found in "Hoek's Corner" on the Rocsciences website (https://www.rocscience.com/education/hoeks_corner), which contains additional articles on the background, assumption, purposes, estimation and calculation of GSI. Of special note are the articles titled "GSI: A Geologically Friendly Tool for Rock Mass Strength Estimation" (Marinos, P. and Hook, E. 2000) and "Quantification of the Geological Strength Index Chart" (Hoek, E., Carter, T.G., Diederichs, M.S., 2013).

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

	Calc	Check
Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued

Step 1: Estimate GSI and Hoek-Brown strength parameters using analytical method outlined in "Quantification of the Geological Strength Index Chart" (Hoek, E., Carter, T.G., Diederichs, M.S., 2013) and visually by using Figures 10.4.6.4-1 and 10.4.6.4-2

RQD = 23

$JCond_{89}$ = 12

GSI (Quan.) = 29.5 $GSI = 1.5JCond_{89} + RQD/2$

GSI (Qual.) = 25 from Figures 10.4.6.4-1 & 10.4.6.4-2

GSI (Design) = 25

D = 1

m_i = 6

s = 0.0000037

a = 0.5313

m_b = 0.0283

Step 2: Determine vertical effective stress at shaft tip and intermediate paremeter, *A*

Unconfined Compressive Strength of Bedrock (q_u) =	196.99	ksf
Depth to bottom of Soil Cover & Decomposed Rock (D_s) =	4	ft
Average Unit Weight of Soil Cover ($\gamma_{m,soil}$) =	125	pcf
Average Unit Weight of Bedrock ($\gamma_{m,rock}$) =	150	pcf
Depth to Water Table (D_w) =	25	ft
Estimated Shaft Tip Depth Below Ground Surface (D_t) =	10.5	ft

$$\sigma'_{v,b} = D_s\gamma'_{soil} + (D_t - D_s)\gamma'_{rock}$$

where:

when below water table	when above water table
$\gamma'_{soil} = \gamma_{m,soil\ -62.4}$	$\gamma'_{soil} = \gamma_{m,soil}$
$\gamma'_{rock} = \gamma_{m,rock\ -62.4}$	$\gamma'_{rock} = \gamma_{m,rock}$

σ'_{vb} = 1.475 ksf

A = 3.7

Step 3: Determine estimated tip resistance

q_p = 7.3 ksf

q_p = 3.65 tsf

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

	BKS	RSW
Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Method 3: FHWA-IF-99-025 Equation 11-6

$$q_p = 4.83(q_u)^{0.51}$$

RQD = 23

q_u = 1368 psi

q_u = 9.43 MPa

q_p = LOW RQD MPa

q_p = LOW RQD ksf

q_p = LOW RQD tsf

where:

q_p = unit end bearing resistance (MPa)

q_u = compressive strength of rock (MPa) (1 psi = 0.00689475728 MPa)

NOTE: Equation 11-6 should only be used when the following are true:

1) Rock mass has an RQD value between 70% and 100%;
2) Closed joints are approximately horizontal; and
3) q_u > 0.5 MPa (5.2 tsf or 72.5 psi)

Method 4: FHWA-NHI-10-016 Equations 13-21 thru 13-23

Equation 13-21: $$q_p = q_{BN} = 3q_u K_{sp} d$$

Equation 13-22: $$K_{sp} = \frac{3 + \frac{s_v}{B}}{10\sqrt{1 + 300\frac{t_d}{s_v}}}$$

Equation 13-23: $$d = 1 + 0.4\frac{D_s}{B} \le 3.4$$

where:

q_p = unit end bearing resistance (ksf)

q_u = compressive strength of rock (ksf)

s_v = vertical spacing between discontinuities

t_d = aperature (thickness) of discontinuities

B = socket diameter (ft)

D_s = depth of socket (rock) embedment (ft)

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Method 4: FHWA-NHI-10-016 Equations 13-21 thru 13-23 (continued)

B =	3	ft
D_s =	5	ft
s_v Selection ID =	8	
s_v =	0.5	ft
t_d Selection ID =	2	
t_d =	0.15	in

Check 1:	Is B > 1 ft	
B =	3	
PASS CHECK?	YES	
Check 2:	Is $0 < t_d/s_v < 0.02$	
t_d/s_v =	0.025	
PASS CHECK?	NO	If no, adjust s_v
USE t_d/s_v =	0.02	
NEW s_v =	0.625	ft
Check 3:	Is $0.05 < s_v/B < 2.0$	
s_v/B =	0.208	
PASS CHECK?	YES	
USE s_v/B =	0.208	

Adapted from Table 600-14 in 2007 ODOT SGE, July 2014 Update

Selection ID	Degree of Fracturing	Spacing, s_v	Design Value, s_v	
		(ft)	(ft)	(mm)
1	Unfractured	> 10.0	10	3048
2	Intact to Unfractured	$3.0 < s_v$	8	2438
3	Intact	$3.0 < s_v < 10.0$	6	1829
4	Slightly Fractured to Intact	$1.0 < s_v < 10.0$	4	1219
5	Slightly Fractured	$1.0 < s_v < 3.0$	2	610
6	Moderately to Slightly Fractured	$0.33 < s_v < 3.0$	1	305
7	Moderately Fractured	$0.33 < s_v < 1.0$	0.67	204
8	Fractured to Moderately Fractured	$0.16 < s_v < 1.0$	0.5	152
9	Fractured	$0.16 < s_v < 0.33$	0.25	76
10	Highly Fractured to Fractured	$s_v < 0.33$	0.16	49
11	Highly Fractured	$s_v < 0.16$	0.1	30

Adapted from Table 600-15 in 2007 ODOT SGE, July 2014 Update

Selection ID	Condition of Fractures	Aperture, t_d	Design Value, t_d	
		(in)	(in)	(mm)
1	Open	$0.2 < t_d$	0.5	13
2	Narrow to Open	$0.05 < t_d$	0.15	3.8
3	Narrow	$0.05 < t_d < 0.2$	0.1	2.5
4	Tight to Narrow	$t_d < 0.2$	0.05	1.3
5	Tight	$t_d < 0.05$	0.02	0.5

*Selections 2, 4, 6, 8 & 10 represents cross overs between two descriptions

Project Number:	210435B	Boring(s):	B-008-0-22
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 10.7'
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1139.7' - 1134.5'
Client Name:	ms consultants, inc.	Analysis Purpose:	North Walls

Version 2.0 (8/31/16)

Calc / Check By:	BKS	RSW
Date:	08/26/22	10/19/22

Driiled Shafts in Rock - Example Calculations - *Determine End Bearing Resistance, q_p (Utilizing 4 Methods) - Continued*

Method 4: FHWA-NHI-10-016 Equations 13-21 thru 13-23 (continued)

q_u = 1368 psi

q_u = 196.99 ksf

K_{sp} = 0.121

d = 1.7

q_p = **119.42** ksf

q_p = **59.71** tsf

End Bearing Resistance, q_p Summary

Method	Reference	q_p Value	Unit
1	AASHTO LRFD Eqn. 10.8.3.5.4c-1	492.48	ksf
2	AASHTO LRFD Eqn. 10.8.3.5.4c-2	7.3	ksf
3	FHWA-IF-99-025 Eqn. 11-6	N/A	ksf
4	FHWA-NHI-10-016 Eqn. 13-21	119.42	ksf

q_p (Design) = **10** ksf

q_p (Design) = **5** tsf

Project Number:	210435B	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Checked By:	RSW
Client Name:	ms consultants, inc.	Date:	7/18/2023

Version 2.0
(6/11/2015)

SHALLOW FOUNDATION BEARING RESISTANCE CALCULATION SUMMARY

(Example calculations with reference equations and information are provided on additional sheets)

Bridge Structure Identification			South End Tunnel Extension Footings		
Boring ID	B-002-0-22		Foundation Element Description		Tunnel Footings
Surface Elev.	1149.7		Footing Base Elevation		1144.25
Analysis Desc.	**Term/Info Description**	**Unit**	**Layer 1**	**Layer 2**	**Layer 3**
Boring/Layer Information	Bedrock Type/Description		Shale	Shale	
	Layer Top Depth (from G.S.)	ft	5.5	14	
	Layer Top Elevation	MSL	1144.2	1135.7	
	Layer Bottom Depth (from G.S.)	ft	14	25.5	
	Layer Bottom Elevation	MSL	1135.7	1124.2	
	Layer Thickness	ft	8.5	11.5	
Rock Mass Rating (RMR) Information (per AASHTO LRFD 10.6.3.2)	Compressive Strength, q_u	psi	500	3975	
	RQD	%	32	68	
	Joint Spacing Selection		D to E	C to D	
	Joint Condition Selection		E	B	
	Groundwater Selection		B	B	
	Analysis Type Selection		Foundations	Foundations	
	Joint Strike and Dip Selection		B	B	
	RMR		21	57	
Nominal Bearing Resistance Calculations (per AASHTO LRFD 10.6.3.1.1 & 10.6.3.2)	Compressive Strength, q_u	psi	500	3975	
	Rock Type (A, B or C)		B	B	
	m		0.036	0.466	
	s		0.00000195	0.00076295	
	q_N (Carter & Kulhawy, 1988)	ksf	0.62	82.65	
	Rock Type Selection ID (NAVFAC)		3	3	
	q_N (Presumptive, NAVFAC 1986)	ksf	100	100	
	Rock Type Selection ID (Peck)		5	3	
	q_N (Suggested Values, Peck 1974)	ksf	150	600	
	q_N (Use)	ksf	See Bieniawski	80	
	q_N (Use)	**tsf**	**See Bieniawski**	**40**	
Factored Bearing Resistance (per AASHTO LRFD 10.6.3.1.1)	q_N (Layer 2)	ksf	80	*(per AASHTO LRFD Table 10.5.5.2.2-1)*	
	φ_b	ksf	0.45	$q_R = \varphi_b q_N$	
	q_R (Layer 2)	ksf	36		

NOTE: The presumptive NAVFAC and suggested Peck values have been multiplied by an assumed applied factor of safety of 2.5 to convert from allowable to ultimate capacities.

Version 2.0
(6/11/2015)

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Checked By:	RSW
Client Name:	ms consultants, inc.	Foundation Element:	Tunnel Footings	Date:	7/18/2023

ESTIMATION OF ROCK MASS RATING (RMR) FOR BEDROCK LAYERS (SEE AASHTO LRFD 10.4.6.4, TABLES 10.4.6.4-1, 2 & 3)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS						
Strength of Intact Rock (UC Strength, psi)	500	1	> 30000	30000 - 15000	15000 - 7500	7500 - 3610	3610 - 1495	1495 - 485	485 - 138
			RELATIVE RATING						
			15	12	7	4	2	1	0

Parameter	Specimen Result	Relative Rating					
Drill Core Quality, RQD (%)	32	8	100% - 90%	90% - 75%	75% - 50%	50% - 25%	25% - 0%
			RELATIVE RATING				
			20	17	13	8	3
Spacing of Joints (ft)	D to E	7	A	B	C	D	E
			> 10	10 - 3	3 - 1	1 - 0.167	< 0.167
			RELATIVE RATING				
			30	25	20	10	5
Condition of Joints	E	0	A	B	C	D	E
			Very Rough Surfaces Not Continuous No Separation Hard Joint Wall Rock	Slightly Rough Surfaces Separation < 0.05 in Hard Joint Wall Rock	Slightly Rough Surfaces Separation < 0.05 in Soft Joint Wall Rock	Slicken-sided Surfaces, Gouge < 0.2 in thick OR Joints Open 0.05 - 0.2 in Continuous Joints	Soft Gouge > 0.2 in OR Joints Open > 0.2 in Continuous Joints
			RELATIVE RATING				
			25	20	12	6	0

Parameter	Specimen Result	Relative Rating				
Groundwater Conditions (General Conditions criteria)	B	7	A	B	C	D
			Completely Dry	Moist Only (Interstitial Water)	Water Under Moderate Pressure	Severe Water Problems
			RELATIVE RATING			
			10	7	4	0

Strike and Dip Orientations of Joints			A	B	C	D	E
Project Type	Project Analysis	Rating	Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Tunnels		N/A	0	-2	-5	-10	-12
Foundations	B	-2	0	-2	-7	-15	-25
Slopes		N/A	0	-5	-25	-50	-60

Layer RMR	RMR Rating	100 - 81	80 - 61	60 - 41	40 - 21	20 - 0
21	Class No.	I	II	III	IV	V
	Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	14' - 25.5'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1135.7' - 1124.2'	Checked By:	RSW
Client Name:	ms consultants, inc.	Foundation Element:	Tunnel Footings	Date:	7/18/2023

Version 2.0
(6/11/2015)

ESTIMATION OF ROCK MASS RATING (RMR) FOR BEDROCK LAYERS (SEE AASHTO LRFD 10.4.6.4, TABLES 10.4.6.4-1, 2 & 3)

Parameter	Specimen Result	Relative Rating	RANGE OF VALUES AND RELATIVE RATINGS						
Strength of Intact Rock (UC Strength, psi)	3975	4	> 30000	30000 - 15000	15000 - 7500	7500 - 3610	3610 - 1495	1495 - 485	485 - 138
			RELATIVE RATING						
			15	12	7	4	2	1	0
Drill Core Quality, RQD (%)	68	13	100% - 90%	90% - 75%	75% - 50%	50% - 25%		25% - 0%	
			RELATIVE RATING						
			20	17	13	8		3	
Spacing of Joints (ft)	C to D	15	A	B	C	D		E	
			> 10	10 - 3	3 - 1	1 - 0.167		< 0.167	
			RELATIVE RATING						
			30	25	20	10		5	
Condition of Joints	B	20	A	B	C	D		E	
			Very Rough Surfaces Not Continuous No Separation Hard Joint Wall Rock	Slightly Rough Surfaces Separation < 0.05 in Hard Joint Wall Rock	Slightly Rough Surfaces Separation < 0.05 in Soft Joint Wall Rock	Slicken-sided Surfaces, Gouge < 0.2 in thick OR Joints Open 0.05 - 0.2 in Continuous Joints		Soft Gouge > 0.2 in OR Joints Open > 0.2 in Continuous Joints	
			RELATIVE RATING						
			25	20	12	6		0	
Groundwater Conditions (General Conditions criteria)	B	7	A	B		C		D	
			Completely Dry	Moist Only (Interstitial Water)		Water Under Moderate Pressure		Severe Water Problems	
			RELATIVE RATING						
			10	7		4		0	

Strike and Dip Orientations of Joints			A	B	C	D	E
Project Type	Project Analysis	Rating	Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Tunnels		N/A	0	-2	-5	-10	-12
Foundations	B	-2	0	-2	-7	-15	-25
Slopes		N/A	0	-5	-25	-50	-60

Layer RMR	RMR Rating	100 - 81	80 - 61	60 - 41	40 - 21	20 - 0
57	Class No.	I	II	III	IV	V
	Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Version 2.0
(6/11/2015)

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Checked By:	RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	Tunnel Footings	Date:	7/18/2023

Example Calculations - Determine Nominal Bearing Resistance, q_N

Analysis Method: AASHTO LRFD, 6th Edition, Equation 10.8.3.5.4c-2 (after Carter and Kulhawy, 1988)

$$q_p = \left[\sqrt{s} + \sqrt{(m\sqrt{s} + s)}\right] q_u$$

where:

q_p = unit end bearing resistance (ksf)

q_u = compressive strength of rock (ksf)

m, s = fractured rock mass parameters (see Sheet 2)

q_u =	500	psi
q_u =	72	ksf
RMR =	21	
Rocky Type =	B	
m =	0.036	(see Sheet 3)
s =	0.00000195	(see Sheet 3)

Note: RMR value may be correlated by exponential trendline equations to determine the values for m and s. See sheet 3 for background calculations and development of exponential equations to solve for m and s.

q_p =	**0.62**	ksf
q_p =	**0.31**	tsf

Rock Type Legend for Bedrock Found in Ohio (see Table 10.4.6.4-4)

Type A - Carbonate - Dolomite, Limestone and Marble

Type B - Argrillaceous - Mudstone, Siltstone, Shale and Slate

Type C - Arenaceous - Sandstone and Quartzite

Version 2.0
(6/11/2015)

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Checked By:	RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	Tunnel Footings	Date:	7/18/2023

Example Calculations - Determine Nominal Bearing Resistance, q_N - Continued

TABLE 10.4.6.4-4 (AASHTO LRFD 6th Edition)

Rock Type
- A = Carbonate rocks - dolomite, limestone and marble
- B = Lithified argrillaceous rocks - mudstone, siltstone, shale and slate
- C = Arenaceous rocks - sandstone and quartzite
- D = Fine grained igneous rocks - andesite, dolerite, diabase and rhyolite
- E = Coarse grained igneous rocks = gabbro gneiss, granite, quartz-diorite

Rock Quality	Approx. CSIR Rating (RMR Value)	Constants	A	B	C	D	E
INTACT ROCK SAMPLES	100	m	7.00	10.00	15.00	17.00	25.00
Laboratory size specimens free from discontinuities		s	1.00	1.00	1.00	1.00	1.00
VERY GOOD QUALITY ROCK MASS	85	m	2.4	3.43	5.14	5.82	8.567
Tightly interlocking undisturbed rock with unweathered joints at 3 - 10 feet.		s	0.082	0.082	0.082	0.082	0.082
GOOD QUALITY ROCK MASS	65	m	0.575	0.821	1.231	1.395	2.052
Fresh to slightly weathered rock, slightly disturbed with joints at 3 - 10 feet.		s	0.00293	0.00293	0.00293	0.00293	0.00293
FAIR QUALITY ROCK MASS	44	m	0.128	0.183	0.275	0.311	0.458
Several sets of moderately weathered joints spaced at 1 - 3 feet.		s	0.00009	0.00009	0.00009	0.00009	0.00009
POOR QUALITY ROCK MASS	23	m	0.029	0.041	0.061	0.069	0.102
Numerous weathered joints at 2 to 12 inches; some gouge. Clean compacted waste rock.		s	0.000003	0.000003	0.000003	0.000003	0.000003
VERY POOR QUALITY ROCK MASS	3	m	0.007	0.01	0.015	0.017	0.025
Numerous heavily weathered joints spaced <2 inches with gouge. Waste rock with fines.		s	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001

Version 2.0
(6/11/2015)

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Checked By:	RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	Tunnel Footings	Date:	7/18/2023

Example Calculations - Determine Nominal Bearing Resistance, q_N - Continued

Background Calculation: Determine m and s values based on RMR value

From Table 10.4.6.4-4 (see Sheet 2)

RMR	s Value (All Rock Types)	m Value (by Rock Type)		
		Type A	Type B	Type C
3	0.0000001	0.007	0.01	0.015
23	0.000003	0.029	0.041	0.061
44	0.00009	0.128	0.183	0.275
65	0.00293	0.575	0.821	1.231
85	0.082	2.4	3.43	5.14
100	1	7	10	15

Rock Type Legend for Bedrock Found in Ohio

Type A - Carbonate - Dolomite, Limestone and Marble

Type B - Argrillaceous - Mudstone, Siltstone, Shale and Slate

Type C - Arenaceous - Sandstone and Quartzite

Note: Trend equations shown below are for best fit lines using an exponential trendline (best fit regression analysis) for the m or s values shown in the table to the left for each rock type.

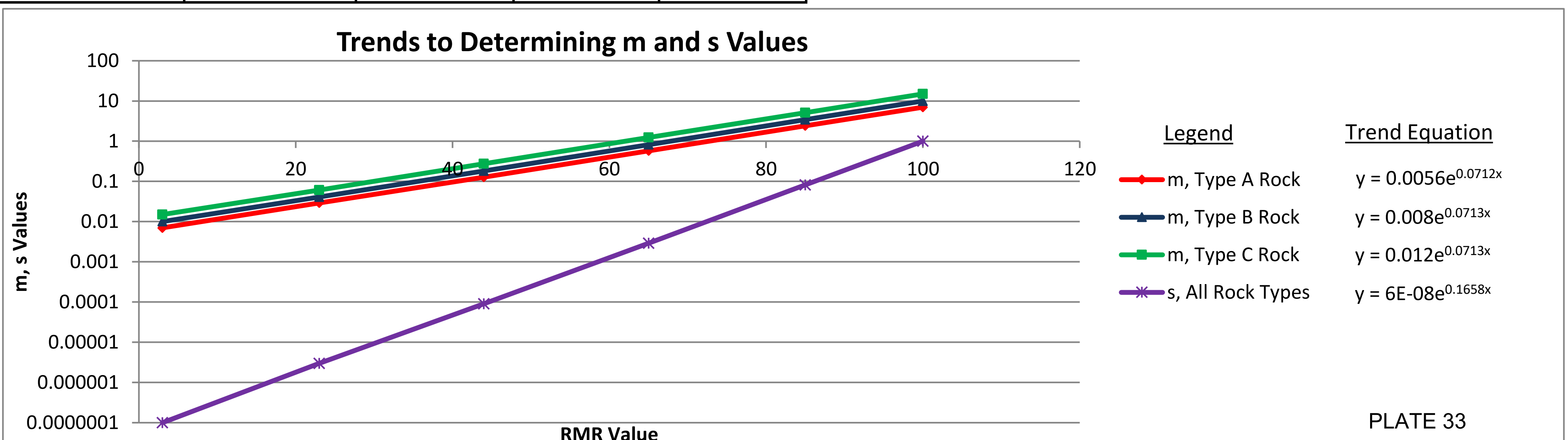


PLATE 33

Version 2.0
(6/11/2015)

Project Number:	210435B	Boring(s):	B-002-0-22	Calculated By:	BKS
Project Name:	BEL-National Rd Tunnel	Layer Depth Range:	5.5' - 14'	Date:	7/17/2023
Project Location:	St. Clairsville, Ohio	Layer Elevation Range:	1144.2' - 1135.7'	Checked By:	RSW
Client Name:	ms consultants, inc.	Analysis Purpose:	Tunnel Footings	Date:	7/18/2023

Example Calculations - Determine Nominal Bearing Resistance, q_N - Continued

Additional Alternative: Presumptive/Suggested Allowable Bearing Pressures

Table 8-9 in FHWA NHI-06-089 "Soils and Foundations, Volume 2" (modified after NAVFAC, 1986; AASHTO 2004 with 2006 Interims)

Selection ID	Rock Type (General Description)	Rock Type (Examples)	Allowable Bearing Pressure (MPa)	Allowable Bearing Pressure (ksf)
1	Massive crystalline igneous and metamorphic	Granite, diorite, basalt, gneiss, cemented conglomerate	7.7	160
2	Foliated metamorphic	Slate, schist	3.4	70
3	Sedimentary	Hard shales, siltstone, sandstone, limestone	1.9	40
4	Weathered or broken rock	All types (except clay shale), RQD < 25%	1	20
5	Compaction Shale or Highly Argillaceous	Shale	1	20

From Table 8-10 FHWA NHI-06-089 "Soils and Foundations, Volume 2" (after Peck, et al., 1974)

Selection ID	RQD (%)	Allowable Bearing Pressure (MPa)	Allowable Bearing Pressure (ksf)
1	100	29	600
2	90	19	400
3	75	12	240
4	50	6	130
5	25	3	60
6	0	1	20

Note: The bearing pressure values given in these two tables are equal to allowable bearing pressures, or roughly equivalent to factored bearing pressures. To complete the analysis using these values, nominal resistances should by calculated from the values shown in the tables by multiplying by an assumed applied factor of safety to convert from allowable (factored) to ultimate (nominal) resistances. A factor of safety of 2.5 has been applied in these analyses.

Reference Table	Selection ID	Allowable Bearing Pressure (ksf)	Nominal Bearing Resistance (ksf)
8-9	3	40	100
8-10	5	60	150

	Project No	210435B	Sheet	1	of	1
Version 2.0 (7/7/15)	Client	ms consultants, inc.	Calc. By	BKS	Date	7/17/23
	Project	BEL-National Rd Tunnel	Check By	RSW	Date	7/18/23
	Desc.	Retaining Walls				
		South End				

LRFD BEARING RESISTANCE CALCULATION - FOOTING ON BEDROCK

BEDROCK PARAMETERS (using Bieniawski, 1989, equations for ϕ' and c')

Rock Layer	Boring ID	Bedrock Description at/below Foundation Bearing Elevation	q_u psi	RMR Rating	ϕ' (deg.)	C' (psf)	D_w (ft)	γ_f (pcf)	γ_q (pcf)
Upper	B-002-0-22	Shale (between 5.5' and 14')	500	21	15.5	2184	26	152	120
Lower	B-002-0-22	Shale (between 14' and 25.5')	3975	50	30	5200	26	152	120
					5	0		152	

$$q_N = cN_c s_c i_c + \gamma_q D_f N_q s_q d_q i_q C_{wq} + \frac{1}{2}\gamma_f B N_\gamma s_\gamma i_\gamma C_{w\gamma}$$

Equation 10.6.3.1.2a-1

	Footing Dimensions			Bearing Capacity and Shape Factors						Shearing/Groundwater Factors		
Rock Layer	D_f (ft)	B (ft)	L (ft)	N_c (1)	N_q (1)	N_γ (1)	S_c (2)	S_q (2)	S_γ (2)	Dq (3)	C_{wq} (4)	$C_{w\gamma}$ (4)
Upper	4	8	100	11.00	3.90	2.70	1.028	1.022	0.968	1.2	0.5	0.5
Lower	4	8	100	30.10	18.40	22.40	1.049	1.046	0.968	1.2	0.5	0.5

NOMINAL BEARING RESISTANCE

Rock Layer	q_N (ksf)
Upper	26.6
Lower	176.3
0	0.0

FACTORED BEARING RESISTANCE

Rock Layer	Service Limit State*	Strength Limit State
Upper	20	11.9
Lower	20	79.3
0	20	0

*Refer to LRFD Table C10.6.2.6.1-1

BEARING RESISTANCE FACTORS

Limit State	Resistance Factor
Service	1.0
Strength	0.45

Article 10.5.5.1
Table 10.5.5.2.2-1 (rock)

Bieniawski (1989) Equations

$$\phi' = \frac{RMR}{2} + 5^o$$

$$c' = 0.104RMR$$ (in ksf)

REFERENCES

AASHTO LRFD Bridge Design Specifications, 6th Edition, Section 10: Foundations.

1. Bearing Capacity Factors Nc, Nq, and Nγ obtained from Table 10.6.3.1.2a-1.
2. Shape Correction Factors Sc, Sq, and Sγ obtained from Table 10.6.3.1.2a-3.
3. Depth Correction Factor Dq obtained from Table 10.6.3.1.2a-4.
4. Groundwater Correction Coefficients Cwq and Cwγ obtained from Table 10.6.3.1.2a-2.

LRFD BEARING RESISTANCE CALCULATION - FOOTING ON BEDROCK

BEDROCK PARAMETERS (using Bieniawski, 1989, equations for ϕ' and c')

Rock Layer	Boring ID	Bedrock Description at/below Foundation Bearing Elevation	q_u psi	RMR Rating	ϕ' (deg.)	C' (psf)	D_w (ft)	γ_f (pcf)	γ_q (pcf)
Upper	B-008-0-22	Shale (5.5' to 10.7')	1368	32	21	3328	26	152	120
Middle	B-008-0-22	Sandstone (10.7' to 22.6')	6750	73	41.5	7592	26	152	120
Lower	B-008-0-22	Shale (22.6' to 24.5')	3975	59	34.5	6136	26	152	120

$$q_N = cN_c s_c i_c + \gamma_q D_f N_q s_q d_q i_q C_{wq} + \frac{1}{2}\gamma_f B N_\gamma s_\gamma i_\gamma C_{w\gamma}$$

Equation 10.6.3.1.2a-1

	Footing Dimensions			Bearing Capacity and Shape Factors						Shearing/Groundwater Factors		
Rock Layer	D_f (ft)	B (ft)	L (ft)	N_c (1)	N_q (1)	N_γ (1)	S_c (2)	S_q (2)	S_γ (2)	Dq (3)	C_{wq} (4)	$C_{w\gamma}$ (4)
Upper	4	6	100	15.80	7.10	6.20	1.027	1.023	0.976	1.2	0.5	0.5
Middle	4	6	100	83.90	73.90	130.20	1.053	1.053	0.976	1.2	0.5	0.5
Lower	4	6	100	42.20	29.40	41.10	1.042	1.041	0.976	1.2	0.5	0.5

NOMINAL BEARING RESISTANCE

Rock Layer	q_N (ksf)
Upper	57.5
Middle	722.0
Lower	287.7

FACTORED BEARING RESISTANCE

Rock Layer	Service Limit State*	Strength Limit State
Upper	20	25.8
Middle	20	324.9
Lower	20	129.4

*Refer to LRFD Table C10.6.2.6.1-1

BEARING RESISTANCE FACTORS

Limit State	Resistance Factor
Service	1.0
Strength	0.45

Article 10.5.5.1
Table 10.5.5.2.2-1 (rock)

Bieniawski (1989) Equations

$$\phi' = \frac{RMR}{2} + 5^o$$

$$c' = 0.104RMR$$ (in ksf)

REFERENCES

AASHTO LRFD Bridge Design Specifications, 6th Edition, Section 10: Foundations.

1. Bearing Capacity Factors Nc, Nq, and Nγ obtained from Table 10.6.3.1.2a-1.
2. Shape Correction Factors Sc, Sq, and Sγ obtained from Table 10.6.3.1.2a-3.
3. Depth Correction Factor Dq obtained from Table 10.6.3.1.2a-4.
4. Groundwater Correction Coefficients Cwq and Cwγ obtained from Table 10.6.3.1.2a-2.

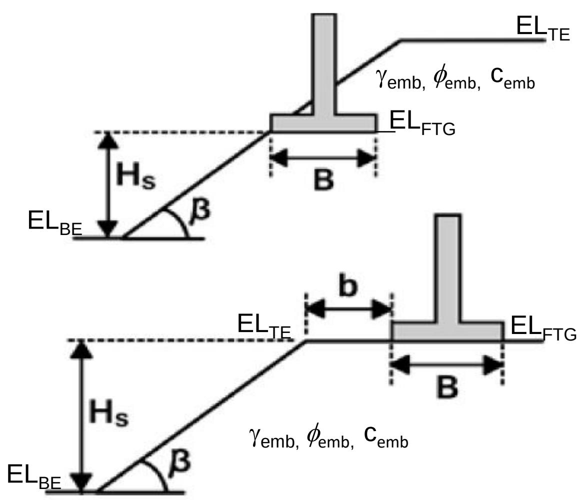
S&ME Project No:	210435B	**Calculated By:**	BKS
Client:	ms consultants, inc.	**Date:**	10/18/22
Project Name:	BEL-National Rd Tunnel	**Checked By:**	RSW
Project Location:	St. Clairsville, Ohio	**Date:**	10/19/22

Version 3.0
(5/11/2018)

GEOTECHNICAL ANALYSIS OF SHALLOW FOUNDATION ON OR NEAR SLOPE (Sheet 1 of 6)

Structure Identification, Foundation Element

Spread Footing On or Near Slopes Diagram and Design Parameters



Other Parameter Definitions

D_f = Depth of embedment at base of footing

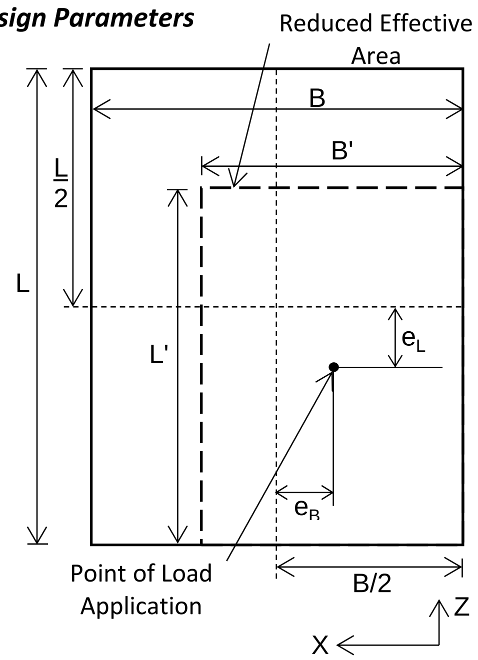
D_w = Depth to water surface from top of embankment (EL_{TE})

T_f = Thickness of footing base

Q_V = applied factored load from structural designer

Q_H = applied horizontal load, determined as the combination of factored lateral (shear) forces applied at the base of the column, as determined by the structural designer, combined with the factored lateral earth pressure forces, as applicable.

M_X & M_Z = applied factored moments about the x- and z-axis, respectively, as



EL_{WS} = Elevation of Water Surface

EL_{WS}	=	1035	
D_w	=	42.5	ft
D_f	=	3	ft

L	=	25	ft
B	=	4	ft
T_f	=	2	ft
$\gamma_{concrete}$	=	150	pcf

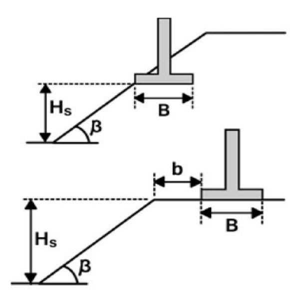
Q_V	=	0	kip
Q_H	=	0	kip
M_x	=	0	kip-ft
M_z	=	0	kip-ft

*To ensure correct usage of effective vs. saturated unit weights, break up soil layers at the water surface elevation.

Embankment Soil Fill Data

γ_{emb}	=	120	pcf
γ'_{emb}	=	120	pcf
ϕ'_{emb}	=	26	deg
c'_{emb}	=	0	psf
ϕ_{emb}	=	0	deg
c_{emb}	=	2500	psf

Figure 10.6.3.1.2c-1



Embankment & Footing Data

EL_{BE}	=	1035	
EL_{TE}	=	1087.5	
EL_{FTG}	=	1077.5	
b	=	0	ft
β	=	1.75	:1
β	=	29.74	deg

Load and Resistance Factors (Tables 3.4.1-2 and 10.5.5.2.2.1)

Sliding

γ_{DC}	=	0.9	Component - minimum
γ_{EV}	=	1.0	Vertical earth pressure - min
φ_τ	=	0.9	Precast concrete on sand
φ_τ	=	0.8	CIP concrete on sand
φ_τ	=	0.85	Concrete on clay
φ_τ	=	0.9	Soil on soil

Bearing Resistance

γ_{DC}	=	1.25	Component - maximum
γ_{EV}	=	1.35	Vertical earth pressure - maximum
φ_b	=	0.5	Munfakh et al., 2001, clay
φ_b	=	0.5	Munfakh et al., 2001, CPT in sand
φ_b	=	0.45	Munfakh et al., 2001, SPT in sand
φ_b	=	0.45	Meyerhof, 1957, all soils

S&ME Project No:	210435B	**Calculated By:**	BKS
Client:	ms consultants, inc.	**Date:**	10/18/22
Project Name:	BEL-National Rd Tunnel	**Checked By:**	RSW
Project Location:	St. Clairsville, Ohio	**Date:**	10/19/22

GEOTECHNICAL ANALYSIS OF SHALLOW FOUNDATION ON OR NEAR SLOPE (Sheet 2 of 6)

Structure Identification, Foundation Element

Interim Calculations

e_L = 0 ft $e_L = \frac{M_X}{Q_v}$ $L' = L - 2e_L$ L' = 25 ft

e_B = 0 ft $e_B = \frac{M_Z}{Q_v}$ $B' = B - 2e_B$ B' = 4 ft

Equations for e_B and e_L are taken from Equations 3.46 and 3.47 (based on Figure 3.13) in Principles of Foundation Engineering, 4th Edition (Das, 1999)

Sliding & Eccentricity

Drained Analysis (Article 10.6.3.4)

δ	=	26	deg
Tan(δ)	=	0.488	
Concrete	=	Precast	
γW_{F+S}	=	39	kip
V	=	39	kip
φ_τ	=	0.85	
C	=	0.8	
$R_R = \varphi_\tau R_\tau$	=	12.9	kip
Q_H	=	0	kip

Is $R_R > Q_H$? **Yes**

EQUATIONS - Drained Analysis

$$Q_H = Sum\ Horizontal\ Forces$$

R_τ = V tan δ
(where δ is $\phi'_{soil\ 1}$)

$$V = \gamma W_{F+S} + \gamma Q_v$$

(where W_{F+S} is the weight of the footing and soil backfill on top of the footing, see below)

Undrained Analysis (Article 10.6.3.4)

Method 1: Cohesion of Clay

$q_s = S_u$	=	2500	psf
B	=	4	ft
$R_R = \varphi_\tau R_\tau$	=	8500	plf
q_H	=	0.0	plf

Is $R_R > q_H$? **Yes**

Method 2: $^1/_2$ Vertical Effective Stress

$q_s = 0.5\sigma'_v$	=	180	psf
B	=	4	ft
$R_R = \varphi_\tau R_\tau$	=	612	plf
q_H	=	0.0	plf

Is $R_R > q_H$? **Yes**

NOTE: If the footing is supported on at least 6 inches of compacted granular material, the lesser of the two methods above should be used.

Eccentricity (Overturning) (Article 10.6.3.3)

Is e_L < L/3? **Yes**

Is e_B < B/3? **Yes**

EQUATIONS - Undrained Analysis

$$\sigma'_v = D_f \gamma_{backfill}$$

$$q_s = \text{lesser of } S_u or\ 0.5\sigma'_v$$

$$R_\tau = Bq_s$$

$$q_H = \frac{Q_H}{L}$$

q_H is the sum of horizontal forces per foot of footing

$$\gamma W_{F+S} = \gamma_{DC} LBT_f \gamma_{concrete} + \gamma_{EV} LB(D_f - T_f)\gamma'_{backfill}$$

where minimum values for γ_{DC} and γ_{EV} shall be used

NOTE: Passive resistance is neglected when checking for stability in sliding.

NOTE: "N/A" indicates that the bearing material is cohesionless and an undrained analysis is not required.

S&ME Project No:	210435B	Calculated By:	BKS
Client:	ms consultants, inc.	Date:	10/18/22
Project Name:	BEL-National Rd Tunnel	Checked By:	RSW
Project Location:	St. Clairsville, Ohio	Date:	10/19/22

Version 3.0
(5/11/2018)

GEOTECHNICAL ANALYSIS OF SHALLOW FOUNDATION ON OR NEAR SLOPE (Sheet 3 of 6)

Structure Identification, Foundation Element

Bearing Resistance for Footings On or Near Slopes (Article 10.6.3.1.2c)

		On Slopes Undrained	On Slopes Drained	Near Slopes Undrained	Near Slopes Drained
N_c	=	5.14	22.3	5.14	22.3
N_γ	=	0	12.5	0	12.5
γ'_{emb}	=	120	120	120	120
H_S	=	52.5	52.5	52.5	52.5
N_S	=	2.52	0	2.52	0
ϕ	=	0	26	0	26
B/H	=	0.0761905	0.0761905	0.0761905	0.0761905
b/B	=	0	0	0.000	0.000
RC_{BC}	=	0.837	0.562	0.837	0.562

$$q_{n-sloping\ ground} = RC_{BC} q_n = RC_{BC}\left(cN_c + 0.5\gamma B N_\gamma\right)$$

	On Slopes Undrained	On Slopes Drained	Near Slopes Undrained	Near Slopes Drained
$q_{n\text{-sloping ground}}$ =	10755.5	33017.5	10755.5	33017.5
$q_R = \varphi_b q_N$ =	5377.725	14857.875	5377.725	14857.875
σ_V =	537	537	537	537
Is $\sigma_V < q_R$?	**Yes**	**Yes**	**Yes**	**Yes**

Bearing Capacity Factors

N $_c$ (Prandtl, 1921)

$$N_c = 5.14 \text{ for } \phi_{soil\ i} = 0$$

$$N_c = \left(N_q - 1\right)\cot\phi' \text{ for } \phi_{soil\ i} > 0$$

Eqn. 3.27 (Das, 1999)

N $_q$ (Reissner, 1924)

$$N_q = e^{\pi \tan\phi'} \tan^2\left(45 + \frac{\phi'}{2}\right)$$

Eqn. 3.26 (Das, 1999)

N $_\gamma$ (Vesic, 1975)

$$N_\gamma = 2\left(N_q + 1\right)\tan\phi'$$

Eqn. 3.28 (Das, 1999)

RCBC coefficients are linearly interpolated from the values shown in Tables 10.6.3.1.2c-1 and 10.6.3.1.2c-2 on Sheets 4 through 6.

Factored Bearing Pressure Eqn.

$$\sigma_V = \frac{\sum V}{B'L'}$$

Same equations for V and γW_{F+S} as used for sliding apply, except that the maximum load factors for γ_{DC} and γ_{EV} shall be used.

*Units for the terms listed above as follows: $q_{N\text{-sloping ground}}$ and σ_v in psf, unit weight in pcf, friction angle in degrees and Hs in feet. Remaining terms listed above are dimensionless.

Structure Identification, Foundation Element

Table 10.6.3.1.2c-1 Reduction Coefficients (RC_{BC}) for Footings on Slopes

			β=10°				β=20°				β=30°				β=40°			
			Ns				*Ns*				*Ns*				*Ns*			
φ (°)	***B/H***	***b/B***	**0**	**2**	**4**	***c'*=0**	**0**	**2**	**4**	***c'*=0**	**0**	**2**	**4**	***c'*=0**	**0**	**2**	**4**	***c'*=0**
	0.1		0.89	0.89	0.88	0.00	0.89	0.88	0.87	0.00	0.85	0.84	0.83	0.00	0.77	0.76	0.74	0.00
	0.2		0.89	0.88	0.88	0.00	0.89	0.87	0.86	0.00	0.82	0.81	0.78	0.00	0.76	0.73	0.69	0.00
	0.4		0.88	0.87	0.86	0.00	0.89	0.86	0.82	0.00	0.81	0.77	0.66	0.00	0.74	0.68	0.53	0.00
0	**0.6**	**0 (On Slope)**	0.89	0.87	0.84	0.00	0.88	0.84	0.71	0.00	0.81	0.74	0.53	0.00	0.74	0.64	0.41	0.00
	1		0.87	0.84	0.75	0.00	0.87	0.79	0.56	0.00	0.80	0.66	0.42	0.00	0.73	0.56	0.33	0.00
	1.5		0.87	0.82	0.62	0.00	0.87	0.72	0.47	0.00	0.80	0.61	0.37	0.00	0.73	0.54	0.30	0.00
	3		0.87	0.73	0.47	0.00	0.87	0.67	0.37	0.00	0.83	0.62	0.31	0.00	0.80	0.59	0.28	0.00
	0.1		0.91	0.91	0.91	0.69	0.80	0.79	0.79	0.22	0.64	0.63	0.61	0.00	0.53	0.52	0.50	0.00
	0.2		0.90	0.89	0.90	0.68	0.75	0.73	0.72	0.21	0.62	0.59	0.56	0.00	0.52	0.49	0.45	0.00
	0.4		0.86	0.86	0.84	0.63	0.73	0.70	0.67	0.22	0.62	0.56	0.51	0.00	0.52	0.45	0.39	0.00
20	**0.6**	**0 (On Slope)**	0.85	0.84	0.82	0.58	0.73	0.68	0.63	0.22	0.61	0.54	0.47	0.00	0.51	0.41	0.33	0.00
	1		0.85	0.82	0.78	0.58	0.72	0.64	0.58	0.26	0.61	0.50	0.42	0.00	0.52	0.39	0.30	0.00
	1.5		0.86	0.80	0.75	0.58	0.73	0.62	0.54	0.31	0.65	0.50	0.42	0.00	0.60	0.44	0.34	0.00
	3		0.90	0.77	0.72	0.58	0.88	0.66	0.56	0.35	0.86	0.61	0.51	0.00	0.85	0.57	0.46	0.00
	0.1		0.93	0.92	0.91	0.77	0.65	0.64	0.63	0.40	0.51	0.50	0.48	0.11	0.40	0.37	0.36	0.00
	0.2		0.81	0.82	0.84	0.76	0.64	0.61	0.59	0.39	0.50	0.47	0.44	0.11	0.39	0.35	0.32	0.00
	0.4		0.79	0.79	0.78	0.72	0.63	0.59	0.55	0.37	0.50	0.43	0.39	0.13	0.39	0.32	0.27	0.00
30	**0.6**	**0 (On Slope)**	0.78	0.77	0.75	0.68	0.62	0.56	0.52	0.36	0.49	0.41	0.36	0.14	0.39	0.30	0.24	0.00
	1		0.79	0.75	0.73	0.67	0.63	0.53	0.49	0.41	0.55	0.41	0.35	0.24	0.48	0.33	0.26	0.00
	1.5		0.79	0.73	0.69	0.66	0.72	0.56	0.50	0.46	0.68	0.47	0.39	0.33	0.64	0.41	0.33	0.00
	3		0.95	0.74	0.70	0.65	0.92	0.66	0.60	0.51	0.90	0.62	0.57	0.43	0.88	0.59	0.51	0.00
	0.1		0.74	0.77	0.79	0.80	0.52	0.51	0.50	0.38	0.37	0.36	0.34	0.17	0.28	0.26	0.24	0.05
	0.2		0.69	0.69	0.69	0.78	0.51	0.48	0.47	0.37	0.37	0.33	0.30	0.16	0.27	0.23	0.20	0.05
	0.4		0.67	0.69	0.67	0.72	0.50	0.45	0.43	0.36	0.36	0.30	0.26	0.17	0.27	0.20	0.17	0.06
40	**0.6**	**0 (On Slope)**	0.67	0.67	0.64	0.66	0.50	0.43	0.43	0.34	0.40	0.34	0.26	0.17	0.32	0.22	0.18	0.08
	1		0.69	0.64	0.62	0.70	0.63	0.48	0.43	0.45	0.58	0.39	0.33	0.32	0.54	0.33	0.27	0.24
	1.5		0.76	0.65	0.61	0.74	0.74	0.53	0.48	0.56	0.71	0.47	0.40	0.47	0.68	0.43	0.36	0.41
	3		0.95	0.74	0.71	0.77	0.94	0.68	0.65	0.66	0.91	0.67	0.62	0.62	0.92	0.67	0.59	0.57

S&ME Project No:	210435B	Calculated By:	BKS
Client:	ms consultants, inc.	Date:	10/18/22
Project Name:	BEL-National Rd Tunnel	Checked By:	RSW
Project Location:	St. Clairsville, Ohio	Date:	10/19/22

Version 3.0
(5/11/2018)

GEOTECHNICAL ANALYSIS OF SHALLOW FOUNDATION ON OR NEAR SLOPE (Sheet 5 of 6)

Structure Identification, Foundation Element

Table 10.6.3.1.2c-2 Reduction Coefficients (RC_{BC}) for Footings Adjacent to Slopes

			β=10°				β=20°				β=30°				β=40°			
			Ns				*Ns*				*Ns*				*Ns*			
ϕ (°)	***B/H***	***b/B***	**0**	**2**	**4**	**c'=0**	**0**	**2**	**4**	**c'=0**	**0**	**2**	**4**	**c'=0**	**0**	**2**	**4**	**c'=0**
0	**0.2**	0	0.89	0.88	0.88	0.00	0.89	0.87	0.86	0.00	0.82	0.81	0.78	0.00	0.76	0.73	0.69	0.00
		0.5	0.97	0.96	0.96	0.00	0.95	0.93	0.91	0.00	0.92	0.89	0.87	0.00	0.86	0.83	0.76	0.00
		1.25	1.00	0.99	0.98	0.00	1.00	0.98	0.96	0.00	1.00	0.97	0.95	0.00	0.95	0.91	0.81	0.00
		2.5	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.97	0.84	0.00
		5	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.89	0.00
		10	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	0.5	0	0.92	0.91	0.88	0.00	0.85	0.82	0.76	0.00	0.77	0.73	0.63	0.00	0.71	0.65	0.52	0.00
		0.5	0.96	0.95	0.89	0.00	0.92	0.89	0.78	0.00	0.87	0.84	0.68	0.00	0.83	0.76	0.56	0.00
		1.25	0.98	0.97	0.90	0.00	0.96	0.94	0.80	0.00	0.94	0.92	0.71	0.00	0.90	0.83	0.58	0.00
		2.5	1.00	1.00	1.00	0.00	1.00	1.00	0.86	0.00	1.00	1.00	0.79	0.00	1.00	0.93	0.68	0.00
		5	1.00	1.00	1.00	0.00	1.00	1.00	0.95	0.00	1.00	1.00	0.93	0.00	1.00	1.00	0.88	0.00
		10	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	1	0	0.87	0.84	0.75	0.00	0.87	0.79	0.56	0.00	0.80	0.66	0.42	0.00	0.73	0.56	0.33	0.00
		0.5	0.95	0.91	0.82	0.00	0.92	0.83	0.65	0.00	0.86	0.73	0.46	0.00	0.81	0.67	0.40	0.00
		1.25	0.97	0.94	0.83	0.00	0.95	0.87	0.67	0.00	0.92	0.81	0.50	0.00	0.89	0.76	0.46	0.00
		2.5	1.00	0.98	0.88	0.00	1.00	0.97	0.77	0.00	1.00	1.00	0.84	0.00	0.99	0.92	0.63	0.00
		5	1.00	1.00	0.95	0.00	1.00	1.00	0.90	0.00	1.00	1.00	0.84	0.00	1.00	1.00	0.83	0.00
		10	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	2	0	0.87	0.79	0.57	0.00	0.87	0.71	0.44	0.00	0.81	0.62	0.35	0.00	0.75	0.56	0.29	0.00
		0.5	0.97	0.93	0.65	0.00	0.94	0.79	0.49	0.00	0.89	0.72	0.42	0.00	0.85	0.69	0.37	0.00
		1.25	0.99	0.98	0.73	0.00	0.99	0.91	0.57	0.00	0.98	0.86	0.51	0.00	0.96	0.83	0.47	0.00
		2.5	1.00	0.99	0.82	0.00	1.00	0.96	0.69	0.00	1.00	0.95	0.64	0.00	1.00	0.95	0.61	0.00
		5	1.00	1.00	0.96	0.00	1.00	1.00	0.87	0.00	1.00	1.00	0.84	0.00	1.00	1.00	0.81	0.00
		10	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
20	**0.2**	0	0.90	0.89	0.90	0.68	0.75	0.73	0.72	0.21	0.62	0.59	0.56	0.00	0.52	0.49	0.45	0.00
		0.5	0.78	0.87	0.86	0.70	0.74	0.76	0.74	0.40	0.63	0.65	0.63	0.00	0.52	0.56	0.52	0.00
		1.25	0.86	0.92	0.92	0.82	0.83	0.84	0.83	0.70	0.74	0.75	0.74	0.00	0.63	0.66	0.63	0.00
		2.5	0.96	0.98	0.99	0.83	0.95	0.94	0.95	0.84	0.90	0.89	0.90	0.00	0.78	0.81	0.78	0.00
		5	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.00	0.96	0.98	0.96	0.00
		10	1.00	1.00	1.00	0.84	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.00	0.99	0.99	1.00	0.00
	0.5	0	0.86	0.86	0.84	0.60	0.73	0.70	0.67	0.22	0.62	0.56	0.51	0.00	0.52	0.45	0.39	0.00
		0.5	0.84	0.91	0.92	0.71	0.80	0.80	0.79	0.40	0.70	0.68	0.67	0.00	0.62	0.59	0.56	0.00
		1.25	0.88	1.00	0.97	0.82	0.85	0.88	0.86	0.70	0.76	0.75	0.75	0.00	0.68	0.66	0.64	0.00
		2.5	0.97	1.00	1.00	0.81	0.95	0.97	0.98	0.84	0.90	0.94	0.96	0.00	0.84	0.86	0.87	0.00
		5	1.00	1.00	1.00	0.84	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
		10	1.00	1.00	1.00	0.84	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	1	0	0.85	0.82	0.78	0.58	0.72	0.64	0.58	0.26	0.61	0.50	0.42	0.00	0.52	0.39	0.30	0.00
		0.5	0.84	0.91	0.91	0.71	0.81	0.80	0.79	0.46	0.70	0.69	0.67	0.00	0.64	0.62	0.60	0.00
		1.25	0.87	0.95	0.96	0.82	0.85	0.85	0.85	0.73	0.76	0.76	0.75	0.00	0.71	0.70	0.69	0.00
		2.5	0.97	1.00	1.00	0.82	0.95	0.97	0.98	0.83	0.90	0.94	0.97	0.00	0.86	0.89	0.91	0.00
		5	1.00	1.00	1.00	0.83	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
		10	1.00	1.00	1.00	0.83	1.00	1.00	1.00	0.81	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	2	0	0.90	0.90	0.90	0.58	0.87	0.86	0.84	0.33	0.84	0.81	0.78	0.00	0.81	0.77	0.74	0.00
		0.5	0.90	0.93	0.93	0.70	0.88	0.88	0.87	0.54	0.84	0.83	0.81	0.00	0.84	0.82	0.81	0.00
		1.25	0.92	0.97	0.99	0.81	0.90	0.92	0.92	0.77	0.86	0.86	0.86	0.00	0.85	0.85	0.84	0.00
		2.5	0.98	1.00	1.00	0.81	0.97	0.98	1.00	0.81	0.93	0.97	1.00	0.00	0.92	0.96	0.99	0.00
		5	1.00	1.00	1.00	0.82	1.00	1.00	1.00	0.84	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
		10	1.00	1.00	1.00	0.82	1.00	1.00	1.00	0.84	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00

Version 3.0
(5/11/2018)

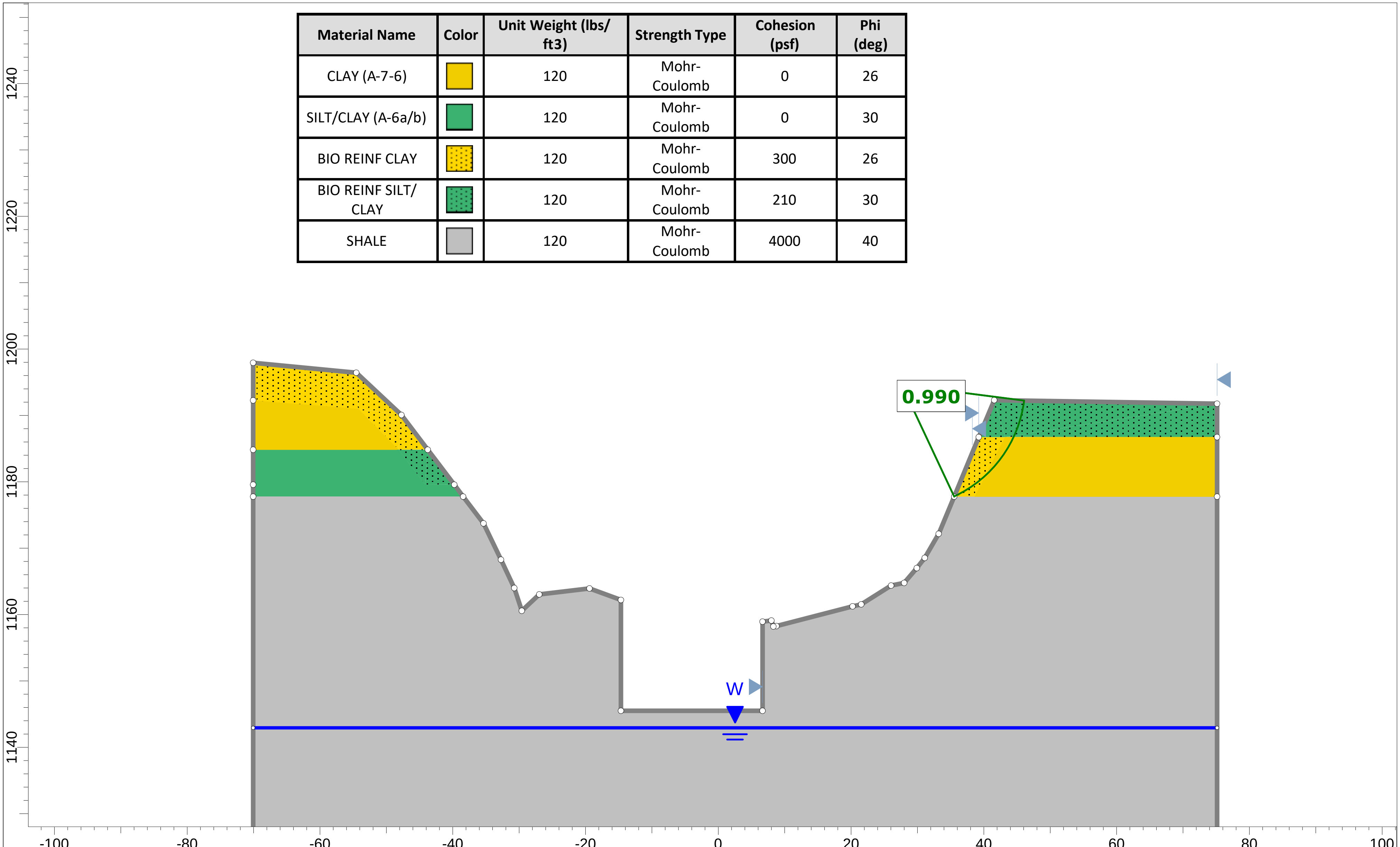
S&ME Project No:	210435B	**Calculated By:**	BKS
Client:	ms consultants, inc.	**Date:**	10/18/22
Project Name:	BEL-National Rd Tunnel	**Checked By:**	RSW
Project Location:	St. Clairsville, Ohio	**Date:**	10/19/22

Structure Identification, Foundation Element

Table 10.6.3.1.2c-2 (continued) Reduction Coefficients (RC_{BC}) for Footings Adjacent to Slopes

			β=10°				β=20°				β=30°				β=40°			
			Ns				*Ns*				*Ns*				*Ns*			
ϕ (°)	***B/H***	***b/B***	**0**	**2**	**4**	***c'=0***	**0**	**2**	**4**	***c'=0***	**0**	**2**	**4**	***c'=0***	**0**	**2**	**4**	***c'=0***
30	**0.2**	0	0.93	0.92	0.91	0.76	0.65	0.64	0.63	0.39	0.51	0.50	0.48	0.11	0.40	0.37	0.36	0.00
		0.5	0.74	0.81	0.80	0.75	0.70	0.66	0.65	0.50	0.57	0.52	0.49	0.21	0.47	0.42	0.39	0.00
		1.25	0.78	0.85	0.86	0.86	0.74	0.73	0.72	0.72	0.63	0.60	0.59	0.38	0.54	0.50	0.47	0.00
		2.5	0.84	0.92	0.93	0.99	0.81	0.82	0.83	0.94	0.72	0.73	0.74	0.74	0.64	0.62	0.61	0.00
		5	0.95	1.00	1.00	1.00	0.93	0.98	1.00	1.00	0.88	0.95	1.00	0.97	0.80	0.85	0.87	0.00
		10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	0.5	0	0.79	0.79	0.78	0.70	0.63	0.59	0.55	0.36	0.50	0.43	0.39	0.13	0.39	0.32	0.27	0.00
		0.5	0.76	0.87	0.87	0.74	0.72	0.71	0.70	0.51	0.58	0.56	0.54	0.24	0.49	0.46	0.43	0.00
		1.25	0.79	0.85	0.92	0.87	0.75	0.73	0.76	0.72	0.63	0.62	0.61	0.45	0.54	0.52	0.50	0.00
		2.5	0.87	0.91	1.00	0.99	0.84	0.85	0.90	0.98	0.74	0.78	0.80	0.80	0.67	0.70	0.71	0.00
		5	0.97	1.00	1.00	1.00	0.95	1.00	1.00	1.00	0.90	1.00	1.00	1.00	0.85	0.94	0.98	0.00
		10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	1	0	0.79	0.75	0.73	0.67	0.63	0.53	0.49	0.41	0.55	0.41	0.35	0.24	0.48	0.33	0.26	0.00
		0.5	0.78	0.87	0.89	0.74	0.75	0.74	0.74	0.51	0.64	0.62	0.60	0.35	0.59	0.56	0.54	0.00
		1.25	0.81	0.90	0.91	0.88	0.78	0.78	0.78	0.72	0.68	0.67	0.66	0.58	0.64	0.62	0.61	0.00
		2.5	0.88	0.99	1.00	0.96	0.85	0.90	0.92	0.95	0.78	0.81	0.84	0.88	0.75	0.78	0.80	0.00
		5	0.97	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.92	1.00	1.00	1.00	0.89	0.98	1.00	0.00
		10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	2	0	0.88	0.88	0.87	0.65	0.87	0.85	0.83	0.48	0.85	0.82	0.80	0.38	0.83	0.80	0.76	0.00
		0.5	0.89	0.91	0.91	0.75	0.89	0.89	0.87	0.58	0.88	0.86	0.84	0.51	0.87	0.85	0.82	0.00
		1.25	0.90	0.92	0.93	0.88	0.90	0.90	0.90	0.75	0.89	0.87	0.87	0.70	0.89	0.87	0.86	0.00
		2.5	0.97	1.00	1.00	1.00	0.96	0.97	0.98	0.98	0.92	0.94	0.96	0.95	0.91	0.92	0.94	0.00
		5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
		10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
40	**0.2**	0	0.69	0.69	0.69	0.78	0.51	0.48	0.47	0.37	0.37	0.33	0.30	0.16	0.27	0.23	0.20	0.05
		0.5	0.65	0.73	0.71	0.74	0.60	0.55	0.53	0.38	0.64	0.38	0.35	0.25	0.34	0.29	0.25	0.13
		1.25	0.68	0.77	0.75	0.86	0.63	0.60	0.58	0.55	0.74	0.44	0.42	0.39	0.39	0.34	0.31	0.25
		2.5	0.72	0.83	0.84	1.00	0.68	0.68	0.68	0.76	0.87	0.53	0.53	0.62	0.45	0.43	0.41	0.48
		5	0.80	0.93	0.95	1.00	0.76	0.82	0.85	1.00	1.00	0.72	0.76	1.00	0.57	0.61	0.63	0.94
		10	0.94	1.00	1.00	1.00	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.76	0.93	1.00	1.00
	0.5	0	0.67	0.69	0.67	0.69	0.50	0.45	0.43	0.35	0.36	0.30	0.26	0.17	0.27	0.20	0.17	0.07
		0.5	0.68	0.81	0.81	0.73	0.63	0.62	0.61	0.46	0.47	0.44	0.41	0.25	0.39	0.35	0.32	0.09
		1.25	0.70	0.82	0.84	0.85	0.65	0.65	0.66	0.60	0.51	0.49	0.47	0.40	0.43	0.41	0.39	0.18
		2.5	0.76	0.92	0.96	1.00	0.72	0.77	0.80	0.81	0.59	0.62	0.63	0.60	0.54	0.56	0.56	0.37
		5	0.84	1.00	1.00	1.00	0.81	0.91	0.94	1.00	0.71	0.82	0.88	1.00	0.67	0.77	0.83	0.84
		10	0.96	1.00	1.00	1.00	0.94	1.00	1.00	1.00	0.89	1.00	1.00	1.00	0.86	1.00	1.00	1.00
	1	0	0.69	0.64	0.62	0.70	0.63	0.48	0.43	0.45	0.58	0.39	0.33	0.32	0.54	0.33	0.27	0.24
		0.5	0.77	0.81	0.82	0.74	0.75	0.73	0.72	0.49	0.71	0.66	0.62	0.38	0.68	0.62	0.57	0.30
		1.25	0.78	0.84	0.85	0.84	0.77	0.76	0.75	0.64	0.73	0.69	0.66	0.55	0.71	0.66	0.63	0.48
		2.5	0.83	0.92	0.95	1.00	0.81	0.85	0.87	0.85	0.76	0.78	0.79	0.76	0.75	0.76	0.77	0.72
		5	0.89	1.00	1.00	1.00	0.87	0.95	0.98	1.00	0.80	0.90	0.95	1.00	0.80	0.89	0.94	1.00
		10	0.98	1.00	1.00	1.00	0.97	1.00	1.00	1.00	0.94	1.00	1.00	1.00	0.93	1.00	1.00	1.00
	2	0	0.93	0.92	0.89	0.45	0.92	0.90	0.87	0.60	0.91	0.88	0.84	0.53	0.89	0.85	0.81	0.47
		0.5	0.93	0.95	0.93	0.76	0.93	0.92	0.90	0.65	0.92	0.89	0.87	0.64	0.92	0.89	0.86	0.60
		1.25	0.93	0.95	0.94	0.86	0.93	0.93	0.92	0.78	0.93	0.91	0.89	0.74	0.93	0.90	0.88	0.74
		2.5	0.94	0.99	1.00	1.00	0.94	0.98	0.98	0.92	0.94	0.97	0.97	0.87	0.94	0.96	0.96	0.88
		5	0.95	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.96	1.00	1.00	1.00
		10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
BIO REINF CLAY		120	Mohr-Coulomb	300	26
BIO REINF SILT/CLAY		120	Mohr-Coulomb	210	30
SHALE		120	Mohr-Coulomb	4000	40



S&ME
8400 Sweet Valley Drive, Suite 404
Valley View, OH 44125
216-901-1000

SLIDEINTERPRET 9.025

Project **BEL-National Road Tunnel**

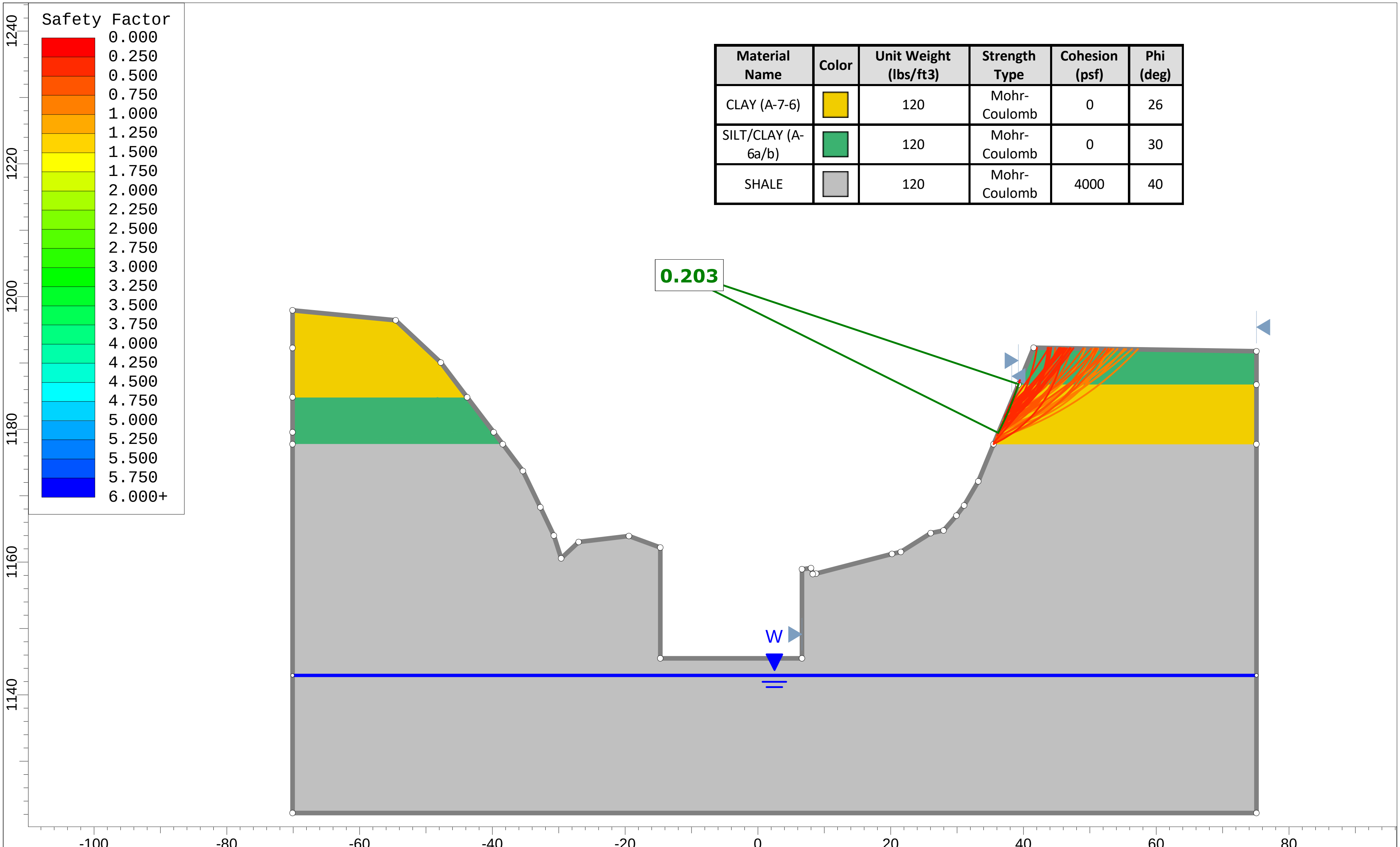
Comments

Analysis Description **Sta. 706+66.50 Right with Biostabilization**

Date 10/20/2022 *Date Revised* 10/20/2022 7:29:28 PM *Drawn by* BKS *Checked* RSW *Project No.* 210435B

Filepath T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\Sta 706+66.5 Right with Bio Stabilization.slim

PLATE 43



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
SHALE		120	Mohr-Coulomb	4000	40

S&ME
8400 Sweet Valley Drive, Suite 404
Valley View, OH 44125
216-901-1000

SLIDEINTERPRET 9.025

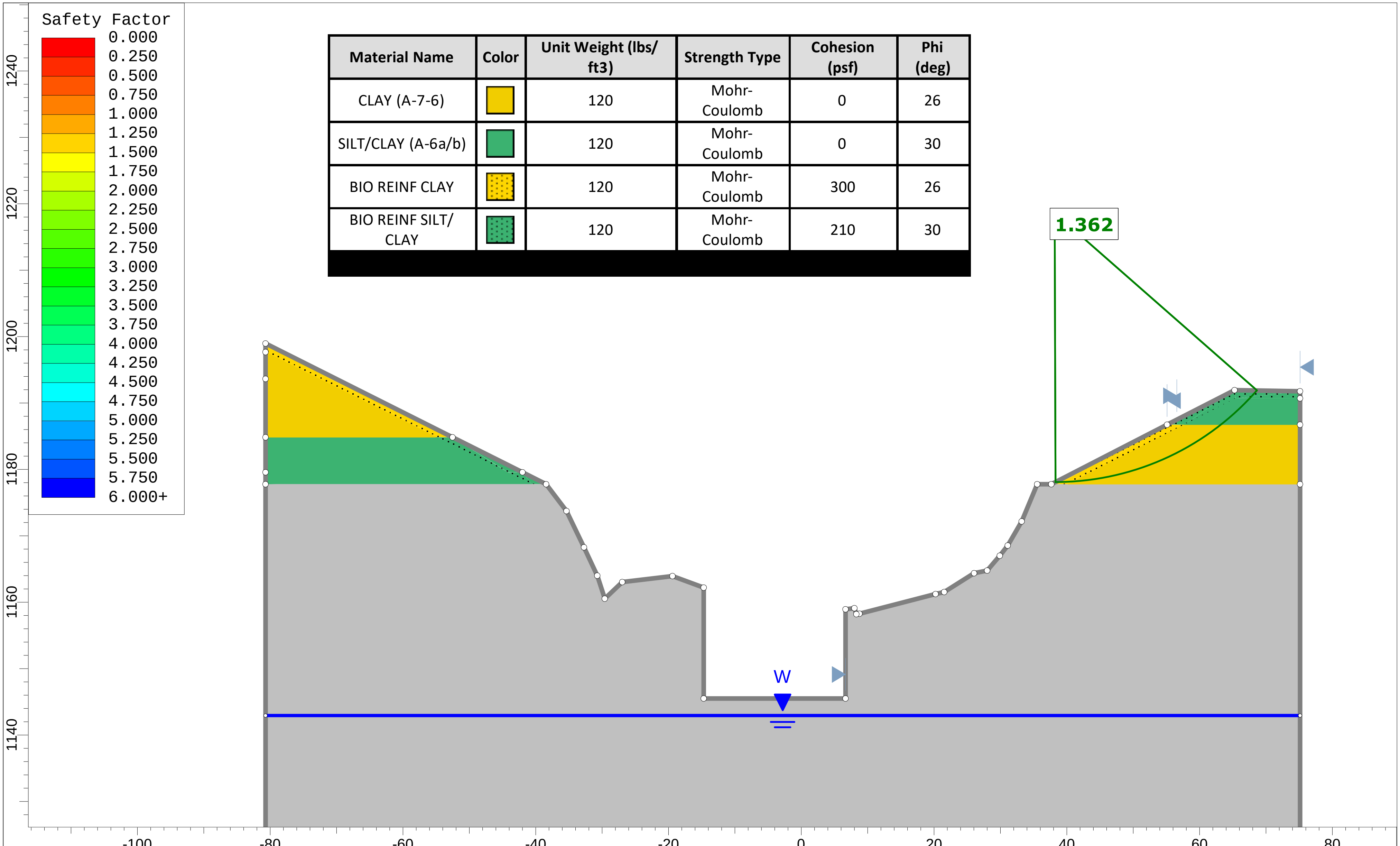
Project **BEL-National Road Tunnel**

Comments

Analysis Description **Sta. 706+66.50 Right without Biostabilization**

Date 10/20/2022 *Date Revised* 10/20/2022 8:07:24 PM *Drawn by* BKS *Checked* RSW *Project No.* 210435B

Filepath T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\Sta 706+66.5 Right without Bio Stabilization.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
BIO REINF CLAY		120	Mohr-Coulomb	300	26
BIO REINF SILT/CLAY		120	Mohr-Coulomb	210	30

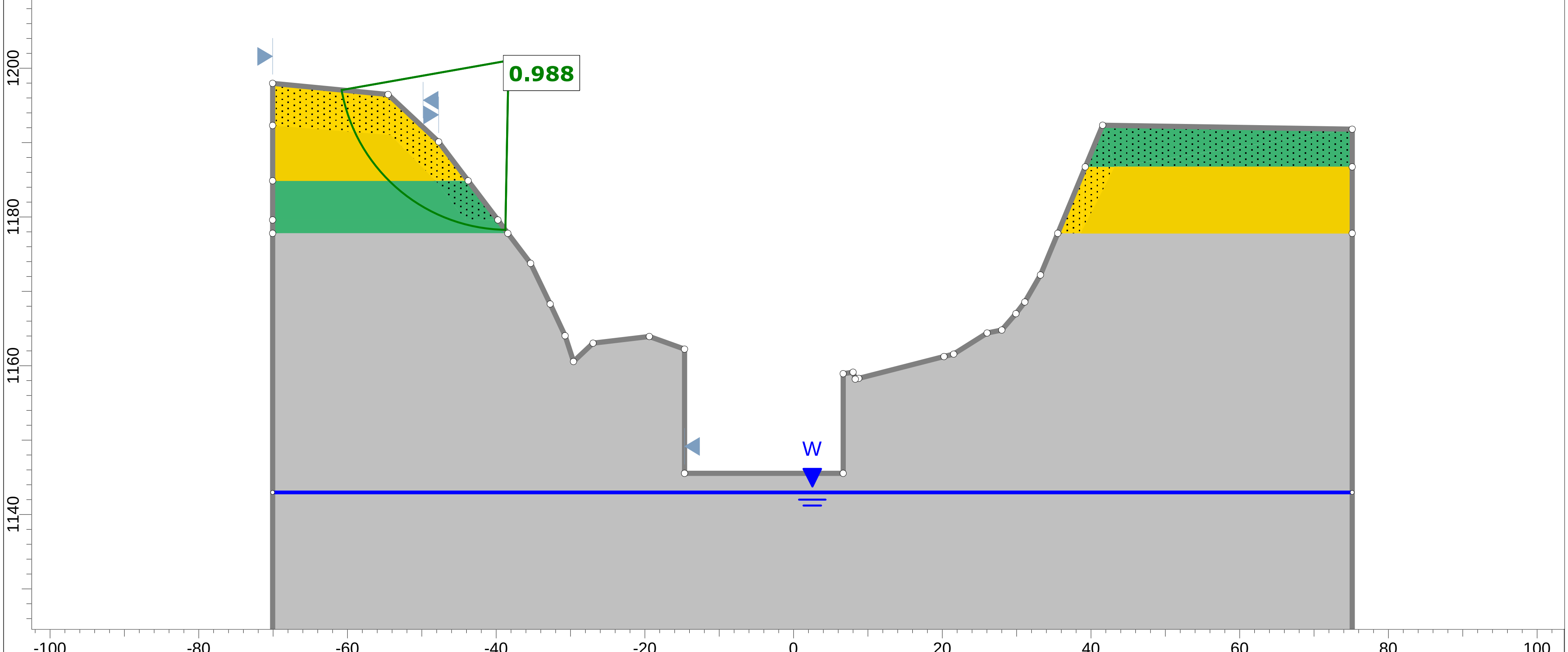
S&ME
8400 Sweet Valley Drive, Suite 404
Valley View, OH 44125
216-901-1000

SLIDEINTERPRET 9.025

Project	**BEL-National Road Tunnel**
Analysis Description	**Sta. 706+66.50 Right Regraded**
Comments	
Date	10/20/2022
Date Revised	10/20/2022 8:06:06 PM
Drawn by	BKS
Checked	RSW
Project No.	210435B
Filepath	T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\Sta 706+66.5 Right Flattened.slim

PLATE 45

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
BIO REINF CLAY		120	Mohr-Coulomb	300	26
BIO REINF SILT/CLAY		120	Mohr-Coulomb	210	30
SHALE		120	Mohr-Coulomb	4000	40



S&ME
8400 Sweet Valley Drive, Suite 404
Valley View, OH 44125
216-901-1000

SLIDEINTERPRET 9.025

Project **BEL-National Road Tunnel**

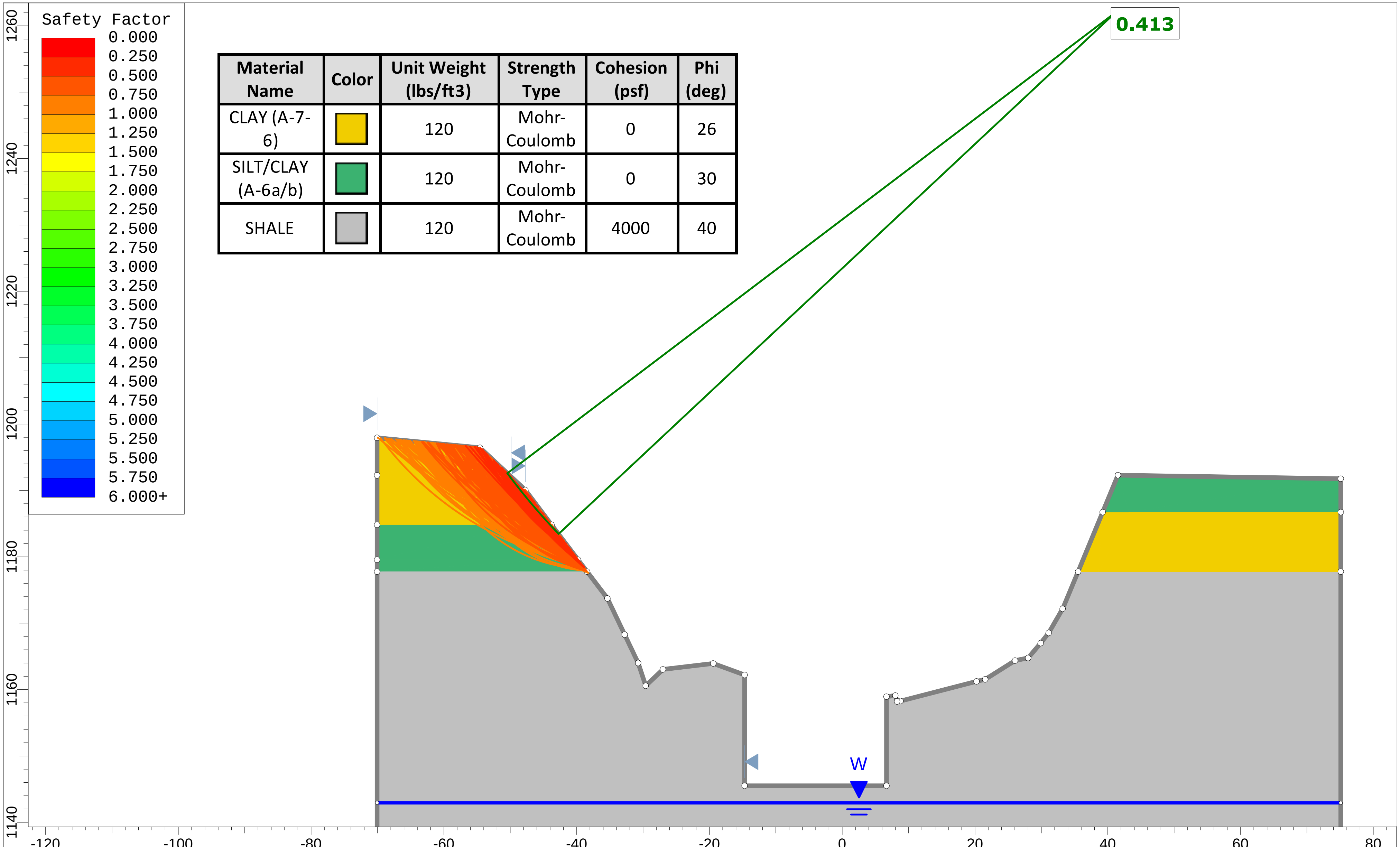
Analysis Description **Sta. 706+66.50 Left with Biostabilization**

Comments

Date 10/20/2022 | *Date Revised* 10/20/2022 7:28:47 PM | *Drawn by* BKS | *Checked* RSW | *Project No.* 210435B

Filepath T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\Sta 706+66.5 Left with Bio Stabilization.slim

PLATE 46

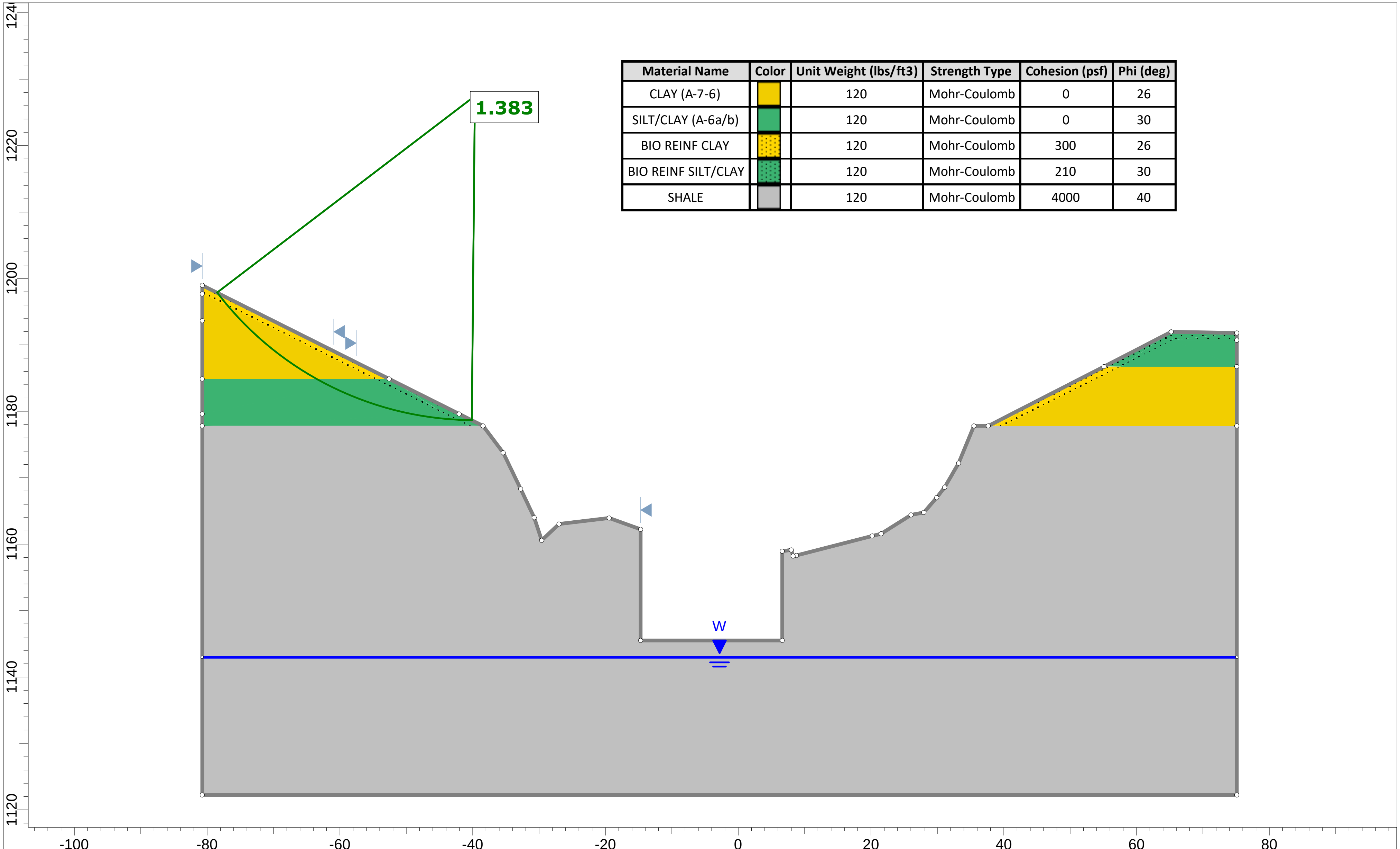


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
SHALE		120	Mohr-Coulomb	4000	40

S&ME
8400 Sweet Valley Drive, Suite 404
Valley View, OH 44125
216-901-1000

SLIDEINTERPRET 9.025

Project	BEL-National Road Tunnel
Analysis Description	Sta. 706+66.50 Left without Biostabilization
Comments	
Date	10/20/2022
Date Revised	10/20/2022 8:07:53 PM
Drawn by	BKS
Checked	RSW
Project No.	210435B
Filepath	T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\Sta 706+66.5 Left without Bio Stabilization.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
BIO REINF CLAY		120	Mohr-Coulomb	300	26
BIO REINF SILT/CLAY		120	Mohr-Coulomb	210	30
SHALE		120	Mohr-Coulomb	4000	40

S&ME
8400 Sweet Valley
Drive, Suite 404
Valley View, OH
44125
216-901-1000

SLIDEINTERPRET 9.025

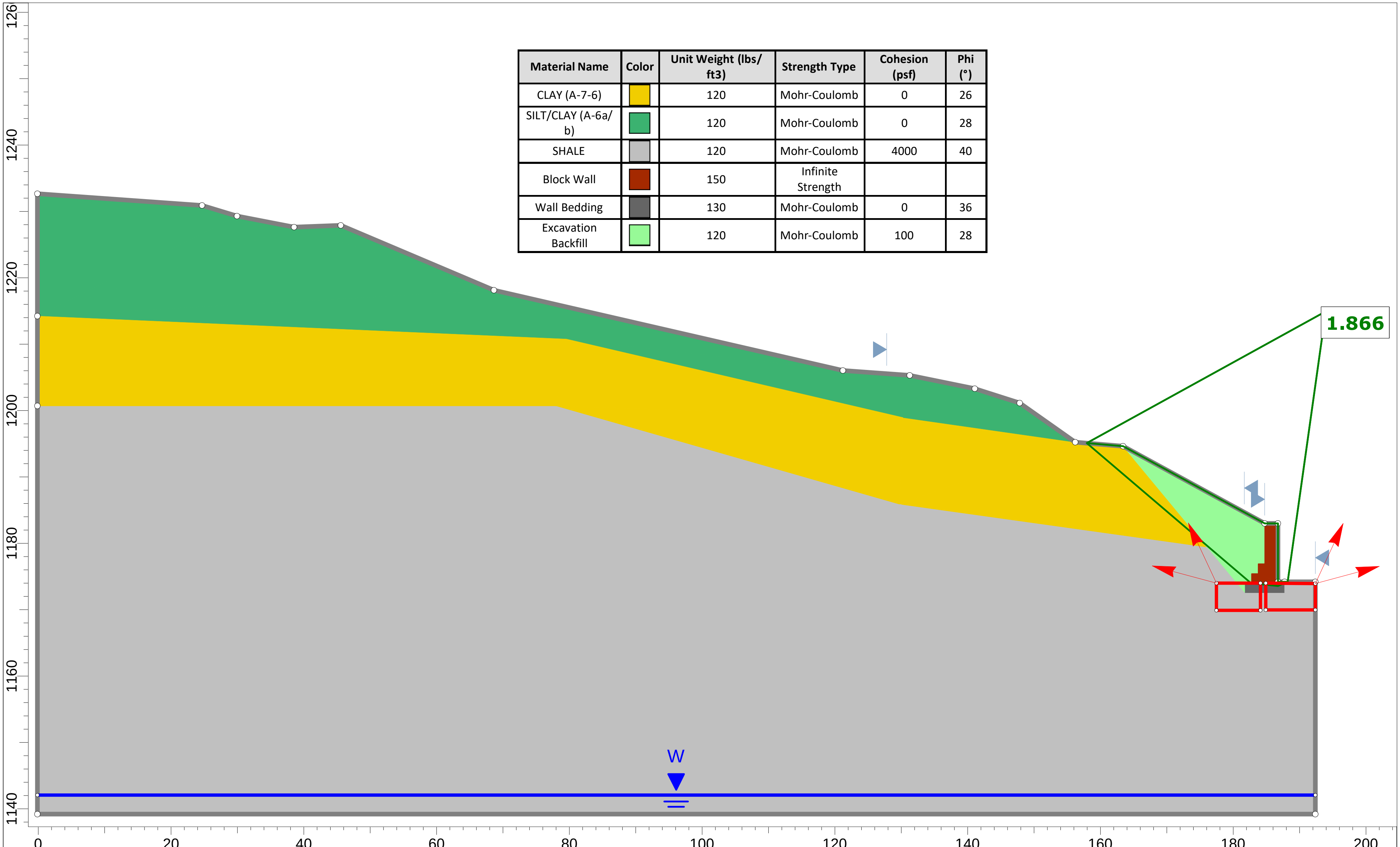
Project **BEL-National Road Tunnel**

Analysis Description **Sta. 706+66.50 Left Regraded**

Comments

Date 10/20/2022	*Date Revised* 10/20/2022 8:06:32 PM	*Drawn by* BKS	*Checked* RSW	*Project No.* 210435B

Filepath T:\GEO\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\Sta 706+66.5 Left Flattened.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	28
SHALE		120	Mohr-Coulomb	4000	40
Block Wall		150	Infinite Strength		
Wall Bedding		130	Mohr-Coulomb	0	36
Excavation Backfill		120	Mohr-Coulomb	100	28

S&ME
6190 Enterprise Court
Dublin, OH 43016

SLIDEINTERPRET 9.028

Project
BEL-National Road Tunnel

Analysis Description
Modular Block Wall Stability

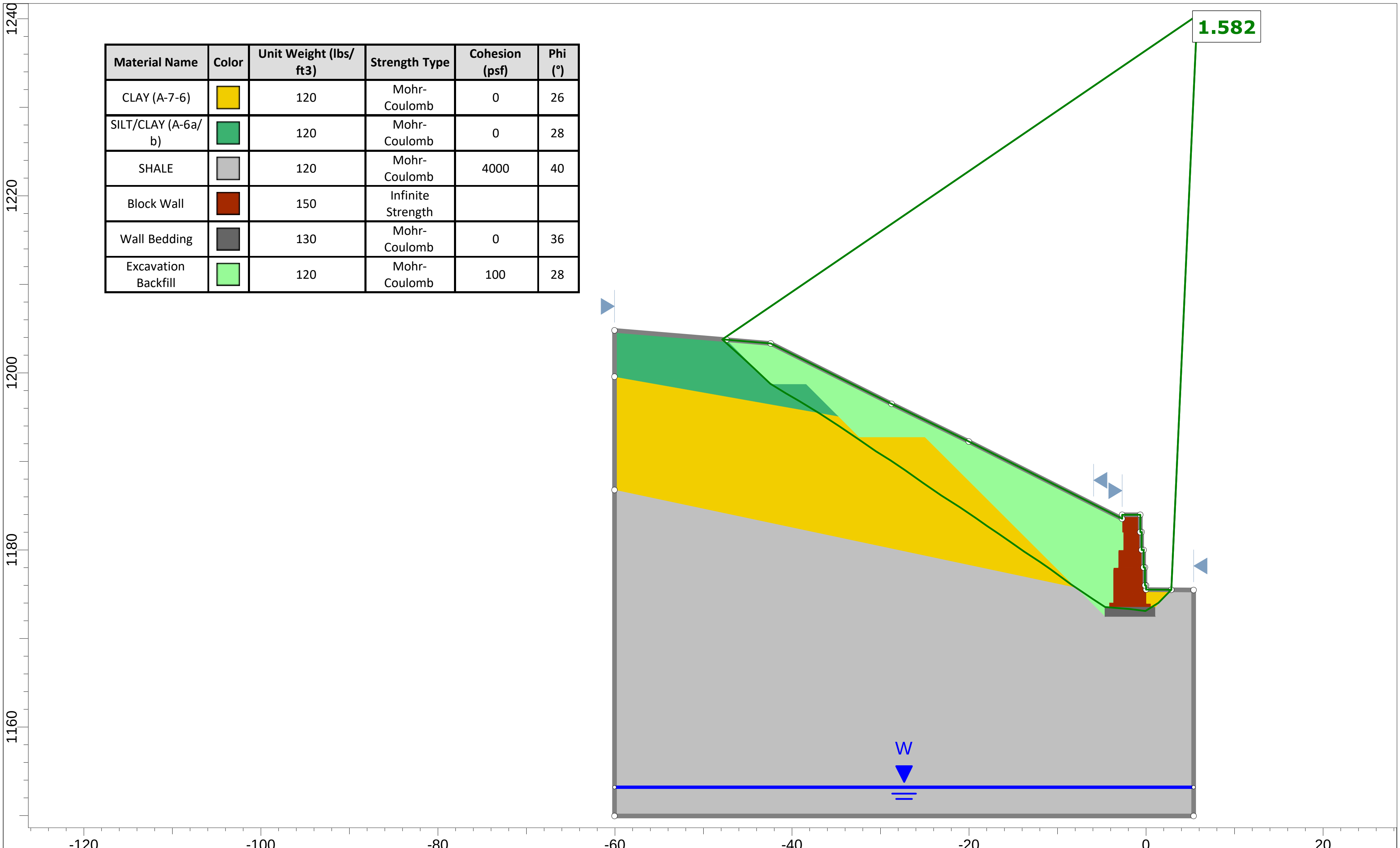
Comments

Date 10/20/2022 | *Date Revised* 7/17/2023 9:27:18 PM | *Drawn by* BKS | *Checked* RSW | *Project No.* 210435B

Filepath T:\Columbus-1170\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\2023-06 Revisions\North Face Path Access Wall-Rev #1.slim

PLATE 49

Material Name	Color	Unit Weight (lbs/ ft3)	Strength Type	Cohesion (psf)	Phi (°)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/ b)		120	Mohr-Coulomb	0	28
SHALE		120	Mohr-Coulomb	4000	40
Block Wall		150	Infinite Strength		
Wall Bedding		130	Mohr-Coulomb	0	36
Excavation Backfill		120	Mohr-Coulomb	100	28



S&ME
6190 Enterprise Court
Dublin, OH 43016

SLIDEINTERPRET 9.028

Project
BEL-National Road Tunnel

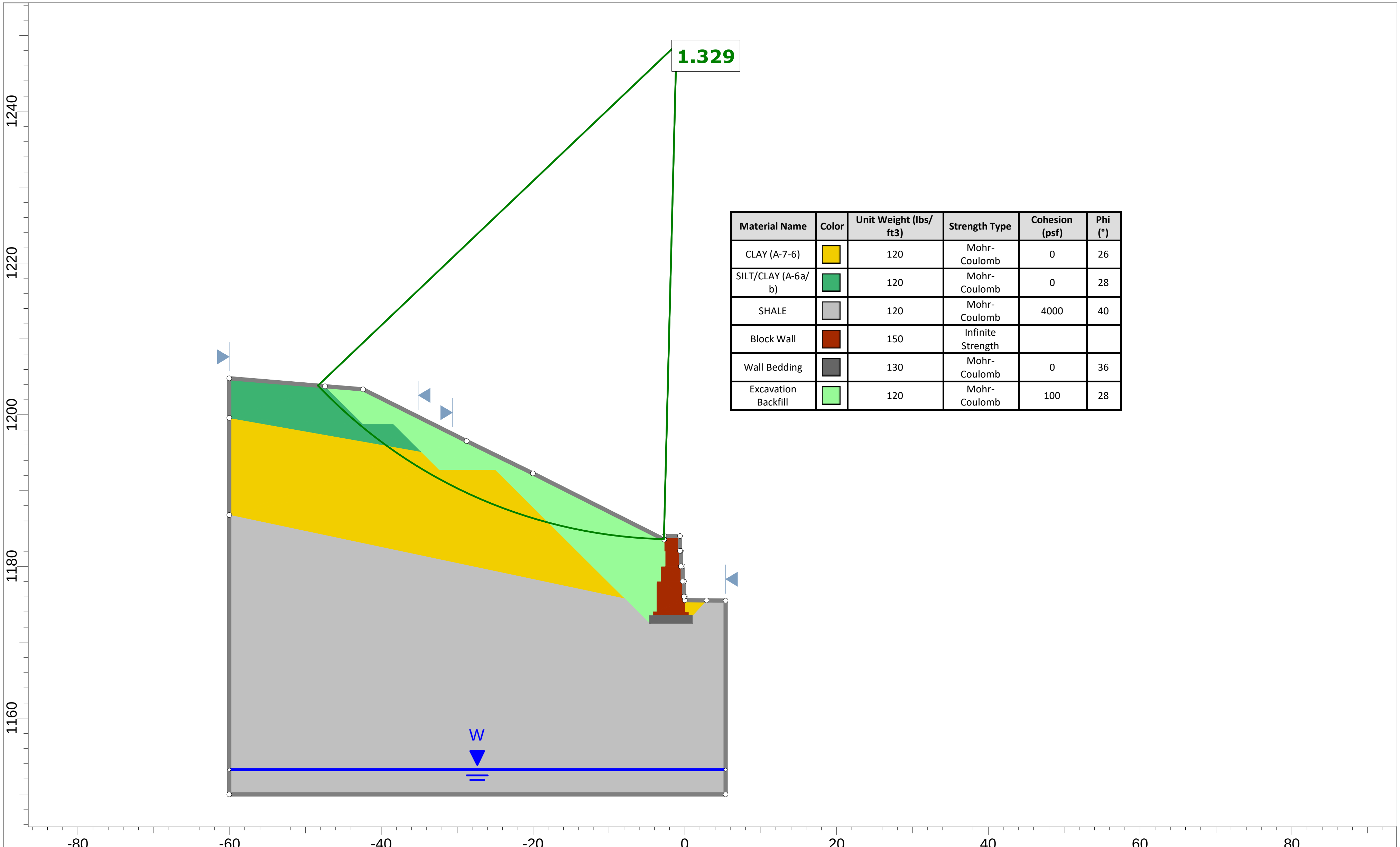
Comments

Analysis Description
Modular Block Wall Stability - Sta. 1+07

Date 7/17/2023	*Date Revised* 7/17/2023 5:01:47 PM	*Drawn by* BKS	*Checked* RSW	*Project No.* 210435B

File Name T:\Columbus-1170\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\2023-06 Revisions\Modular Block Wall Sta 1+07.slim

PLATE 50



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	28
SHALE		120	Mohr-Coulomb	4000	40
Block Wall		150	Infinite Strength		
Wall Bedding		130	Mohr-Coulomb	0	36
Excavation Backfill		120	Mohr-Coulomb	100	28

S&ME
6190 Enterprise Court
Dublin, OH 43016

SLIDEINTERPRET 9.028

Project **BEL-National Road Tunnel**

Analysis Description **Modular Block Wall Stability - Sta. 1+07 (Uphill Slope)**

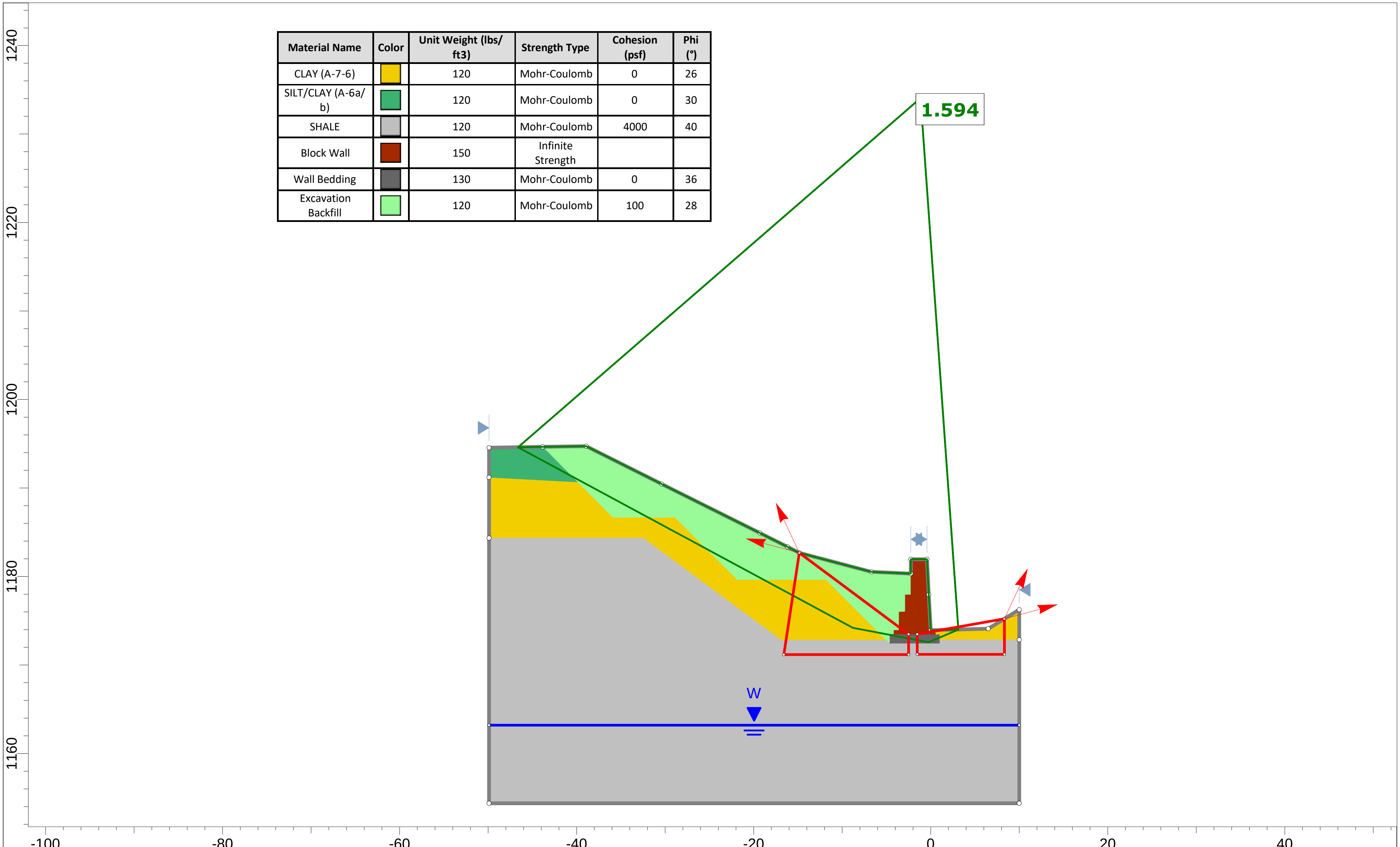
Comments

Date 7/17/2023 | *Date Revised* 7/17/2023 5:06:08 PM | *Drawn by* BKS | *Checked* RSW | *Project No.* 210435B

Filepath T:\Columbus-1170\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\2023-06 Revisions\Modular Block Wall Sta 1+07 (Upper Slope).slim

PLATE 51

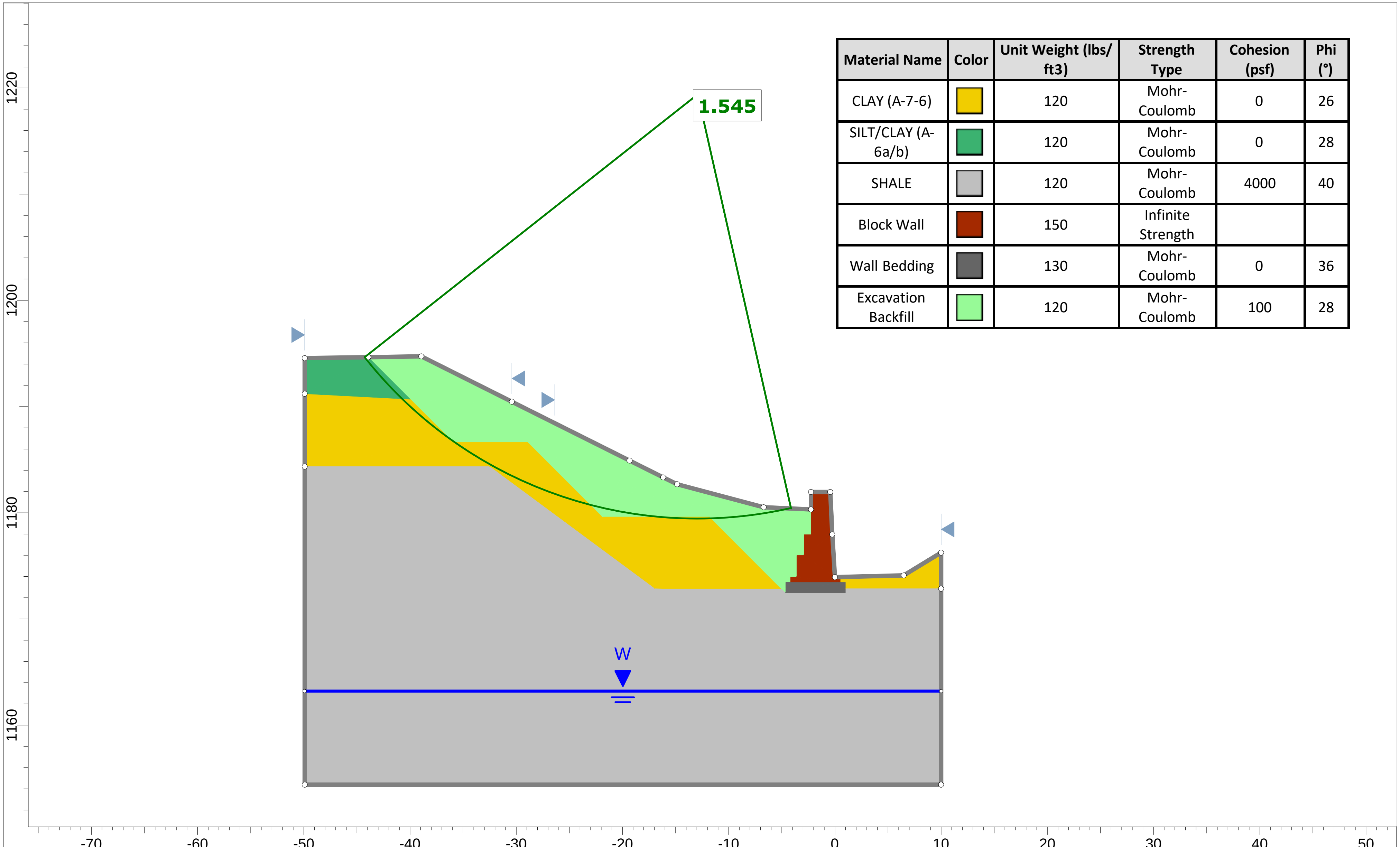
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
CLAY (A-7-6)		120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)		120	Mohr-Coulomb	0	30
SHALE		120	Mohr-Coulomb	4000	40
Block Wall		150	Infinite Strength		
Wall Bedding		130	Mohr-Coulomb	0	36
Excavation Backfill		120	Mohr-Coulomb	100	28



S&ME
6190 Enterprise Court
Dublin, OH 43016

SLIDEINTERPRET 9.028

Project	**BEL-National Road Tunnel**							*Comments*
Analysis Description	**Modular Block Wall Stability - Sta. 1+59**							
Date	2/8/2023	*Date Revised*	7/17/2023 4:46:11 PM	*Drawn by*	BKS	*Checked*	RSW	*Project No.* 210435B
File Name	T:\Columbus-1170\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\2023-06 Revisions\Modular Block Wall Sta 1+59-Rev #1.slim							



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
CLAY (A-7-6)	Yellow	120	Mohr-Coulomb	0	26
SILT/CLAY (A-6a/b)	Green	120	Mohr-Coulomb	0	28
SHALE	Grey	120	Mohr-Coulomb	4000	40
Block Wall	Dark red	150	Infinite Strength		
Wall Bedding	Dark grey	130	Mohr-Coulomb	0	36
Excavation Backfill	Light green	120	Mohr-Coulomb	100	28

S&ME
6190 Enterprise Court
Dublin, OH 43016

SLIDEINTERPRET 9.028

Project **BEL-National Road Tunnel**

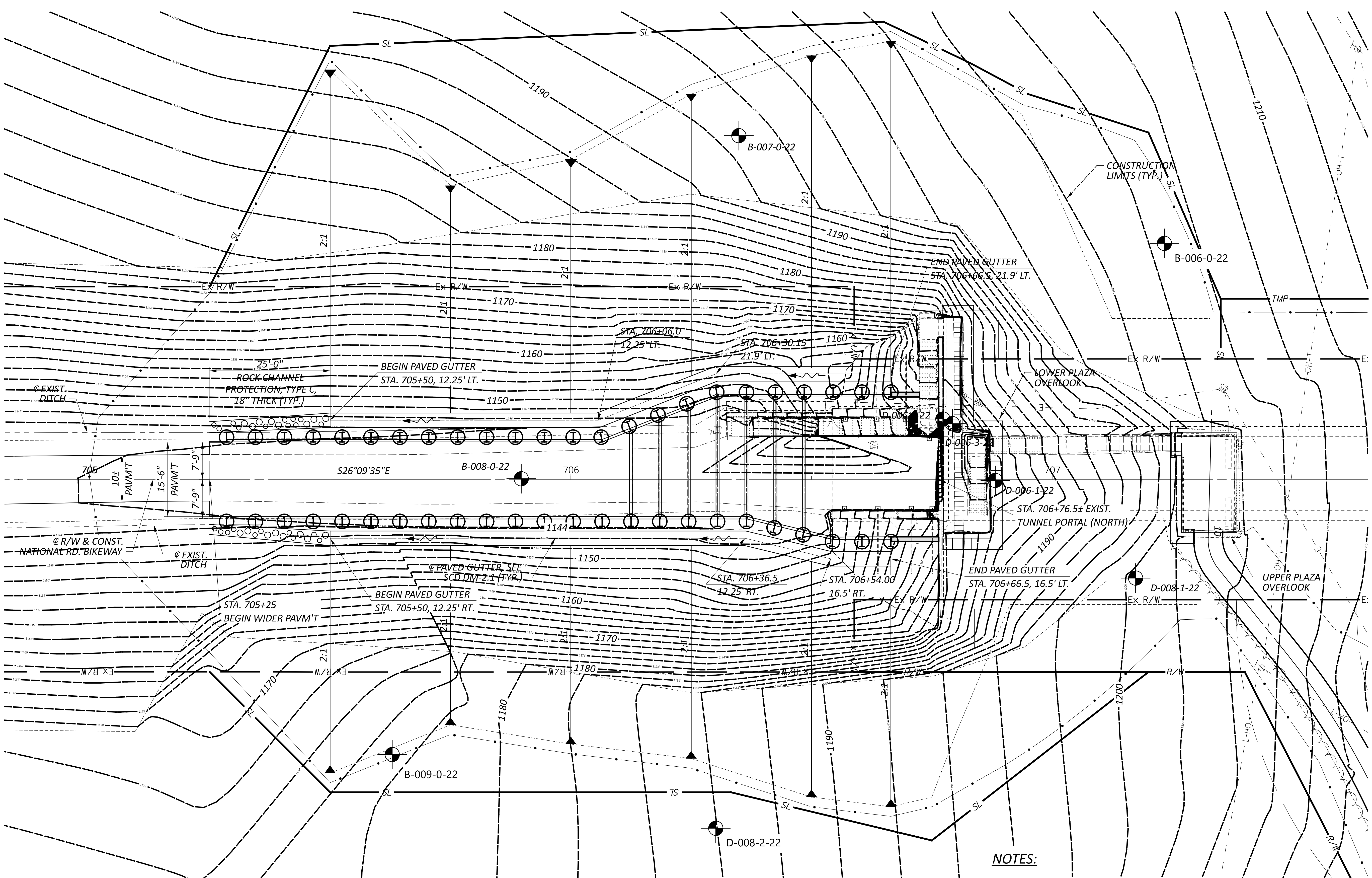
Comments

Analysis Description **Modular Block Wall Stability - Sta. 1+59 (Uphill Slope)**

Date 7/17/2023 | *Date Revised* 7/17/2023 4:51:36 PM | *Drawn by* BKS | *Checked* RSW | *Project No.* 210435B

Filepath T:\Columbus-1170\Projects\2021\210435B_ms_BEL-National Rd Tunnel_St. Clairsville OH\4 GEO\Project Docs\Calcs\Stability\2023-06 Revisions\Modular Block Wall Sta 1+59-Rev #1 (Uphill Section).slim

Appendix IV – Available Plan Drawings



PLAN

NOTES:

1. FOR LOWER AND UPPER PLAZA OVERLOOK DETAILS, SEE PLAN SHEETS 62 TO 68.
2. EARTHWORK LIMITS SHOWN ARE APPROXIMATE. ACTUAL SLOPES SHALL CONFORM TO PLAN CROSS SECTIONS.
3. FOR WALLS 1 AND 2 PLAN AND ELEVATION , SEE SHEETS 3/36 AND 4/36.

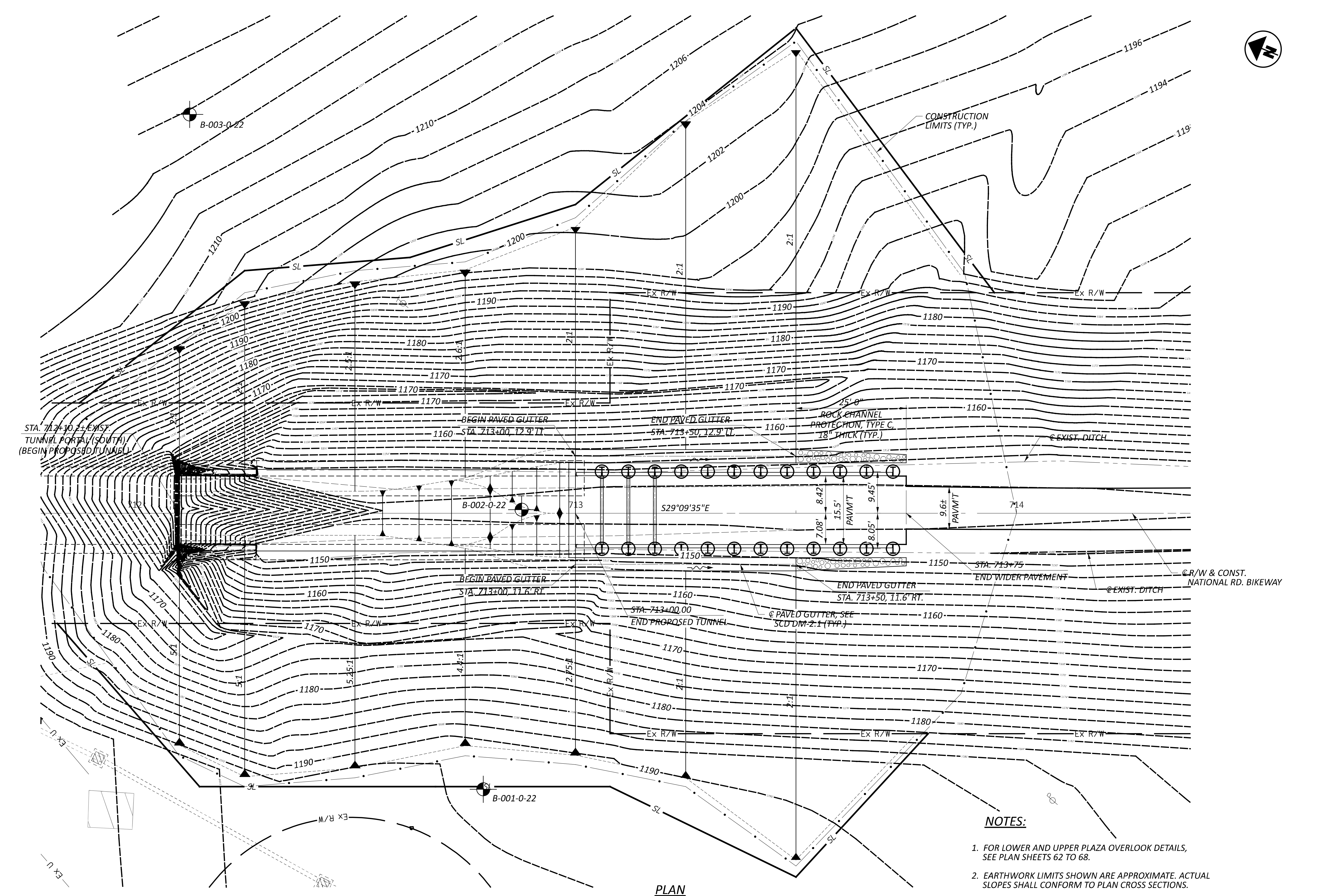
PLATE 1

SITE PLAN (NORTH PORTAL)
BEL-NATIONAL ROAD BIKEWAY

SFN	
0701572	
DESIGN AGENCY: ms consultants, inc.	
DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
1	36
SHEET	TOTAL
31	83

BEL-NATIONAL RD. BIKEWAY

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:33 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SP002.dgn



NOTES:

1. FOR LOWER AND UPPER PLAZA OVERLOOK DETAILS, SEE PLAN SHEETS 62 TO 68.
2. EARTHWORK LIMITS SHOWN ARE APPROXIMATE. ACTUAL SLOPES SHALL CONFORM TO PLAN CROSS SECTIONS.
3. FOR WALLS 3 AND 4 PLAN AND ELEVATION , SEE SHEETS 5/36 AND 6/36.

PLATE 2

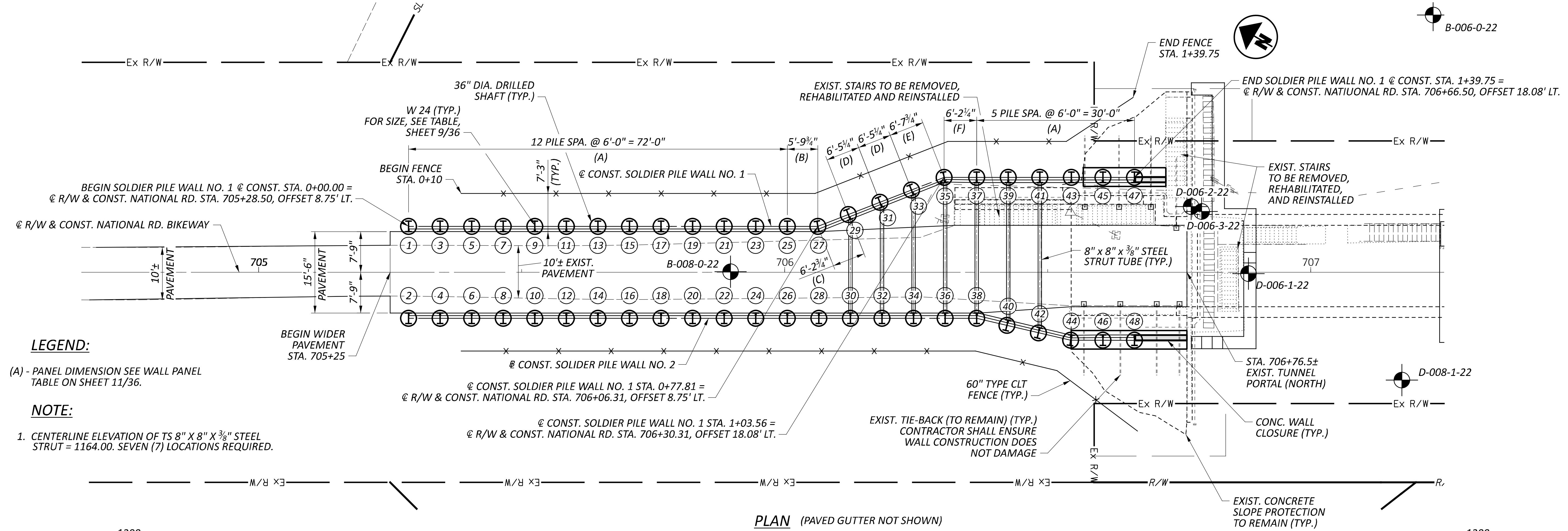
HORIZONTAL SCALE IN FEET 0 5 10 20

SITE PLAN (SOUTH PORTAL)
BEL-NATIONAL ROAD BIKEWAY

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER JDH	2-27-23
PROJECT ID	108774
SUBSET 2	TOTAL 36
SHEET 32	TOTAL 83

BEL-NATIONAL RD. BIKEWAY

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:34 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SP003.dgn



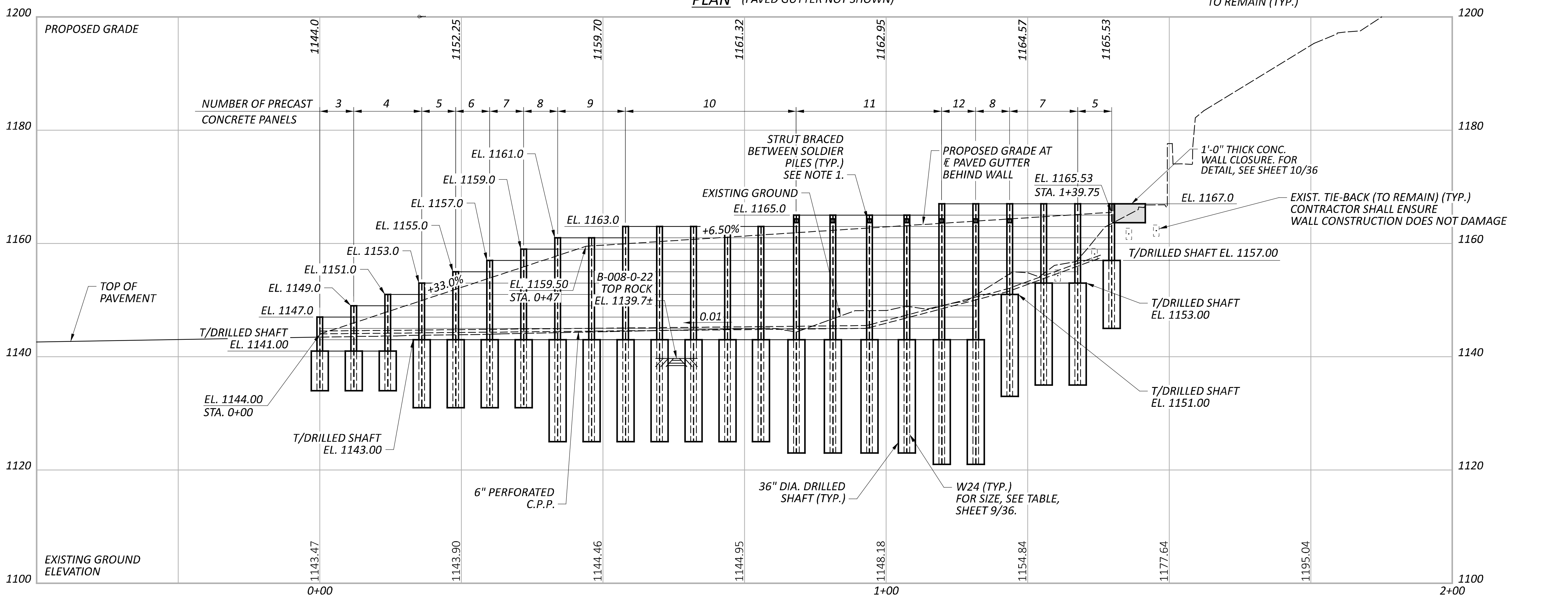
LEGEND:

(A) - PANEL DIMENSION SEE WALL PANEL TABLE ON SHEET 11/36.

NOTE:

1. CENTERLINE ELEVATION OF TS 8" X 8" X 3/8" STEEL STRUT = 1164.00. SEVEN (7) LOCATIONS REQUIRED.

PLAN (PAVED GUTTER NOT SHOWN)



DEVELOPED ELEVATION ALONG ℄ CONST. SOLDIER PILE WALL NO. 1 (FENCE NOT SHOWN)

HORIZONTAL SCALE IN FEET

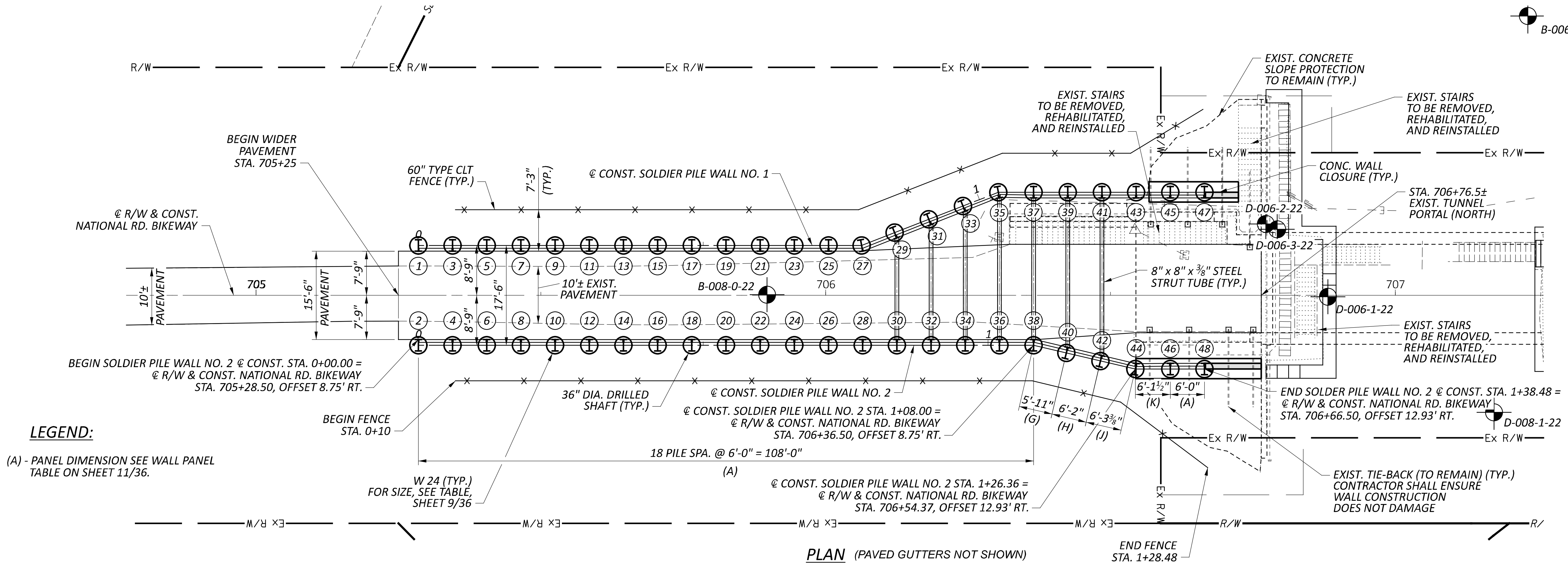
WALL NO. 1 PLAN AND ELEVATION (NORTH)
BEL-NATIONAL ROAD BIKEWAY

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER	SJR
CHECKER	WER
REVIEWER	JDH 2-27-23
PROJECT ID	108774
SUBSET / TOTAL	3 / 36
SHEET / TOTAL	33 / 83

PLATE 3

BEL-NATIONAL RD. BIKEWAY

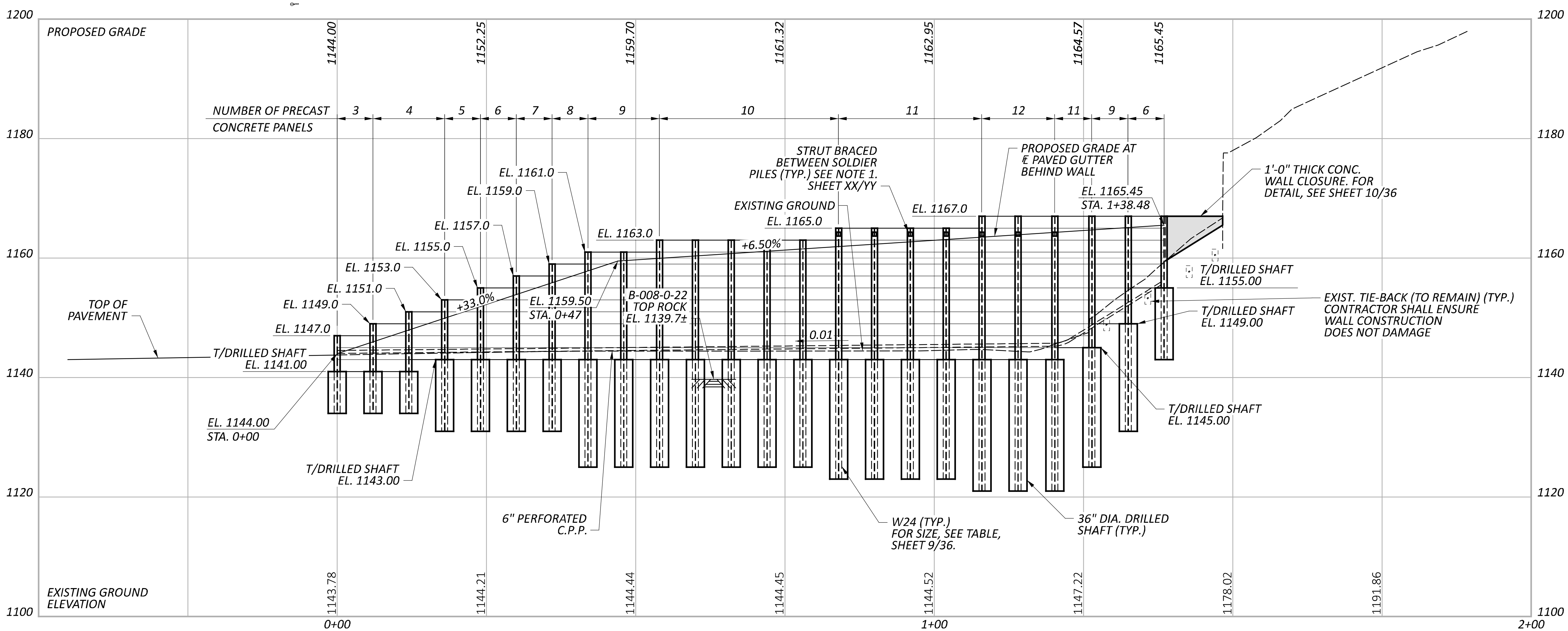
MODEL: CLX_RW_TRAIL - North Left Wall Plan [Sheet] PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:36 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_WP001.dgn



LEGEND:

(A) - PANEL DIMENSION SEE WALL PANEL TABLE ON SHEET 11/36.

PLAN (PAVED GUTTERS NOT SHOWN)



DEVELOPED ELEVATION ALONG € CONST. SOLDIER PILE WALL NO. 2 (FENCE NOT SHOWN)

HORIZONTAL SCALE IN FEET 0 5 10 20

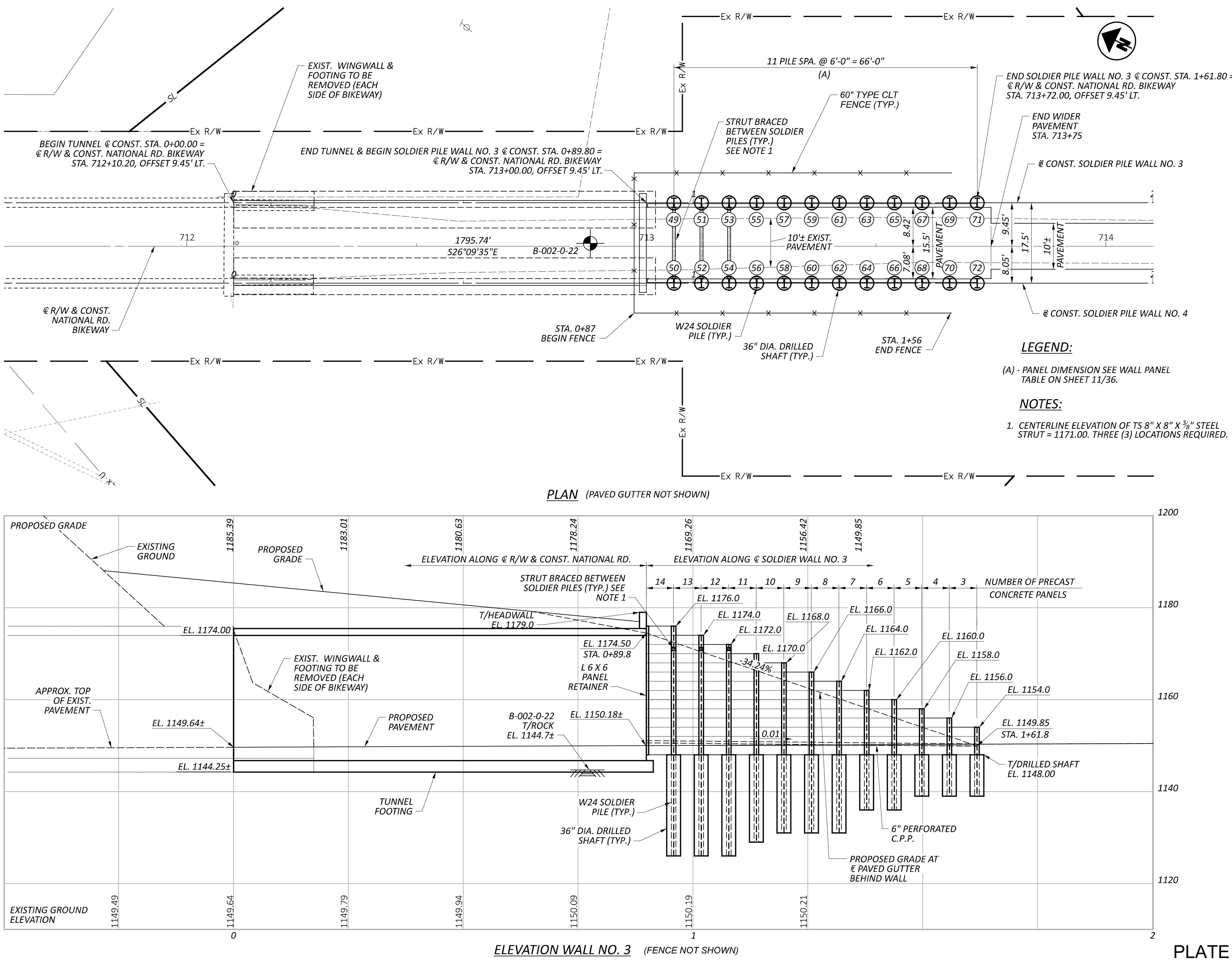
WALL NO. 2 PLAN AND ELEVATION (NORTH)
BEL-NATIONAL ROAD BIKEWAY

BEL-NATIONAL RD. BIKEWAY

MODEL: CLX_RW_TRAIL - North Left Wall Plan [Sheet] PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:37 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_WP002.dgn

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER	JDH 2-27-23
PROJECT ID	108774
SUBSET 4	TOTAL 36
SHEET 34	TOTAL 83

PLATE 4



HORIZONTAL SCALE IN FEET 0 5 10 20

LEGEND:

(A) - PANEL DIMENSION SEE WALL PANEL TABLE ON SHEET 11/36.

NOTES:

1. CENTERLINE ELEVATION OF TS 8" X 8" X 3/8" STEEL STRUT = 1171.00. THREE (3) LOCATIONS REQUIRED.

TUNNEL WALL NO.3 PLAN AND ELEVATION (SOUTH)
BEL-NATIONAL ROAD BIKEWAY

SFN 0701572

DESIGN AGENCY

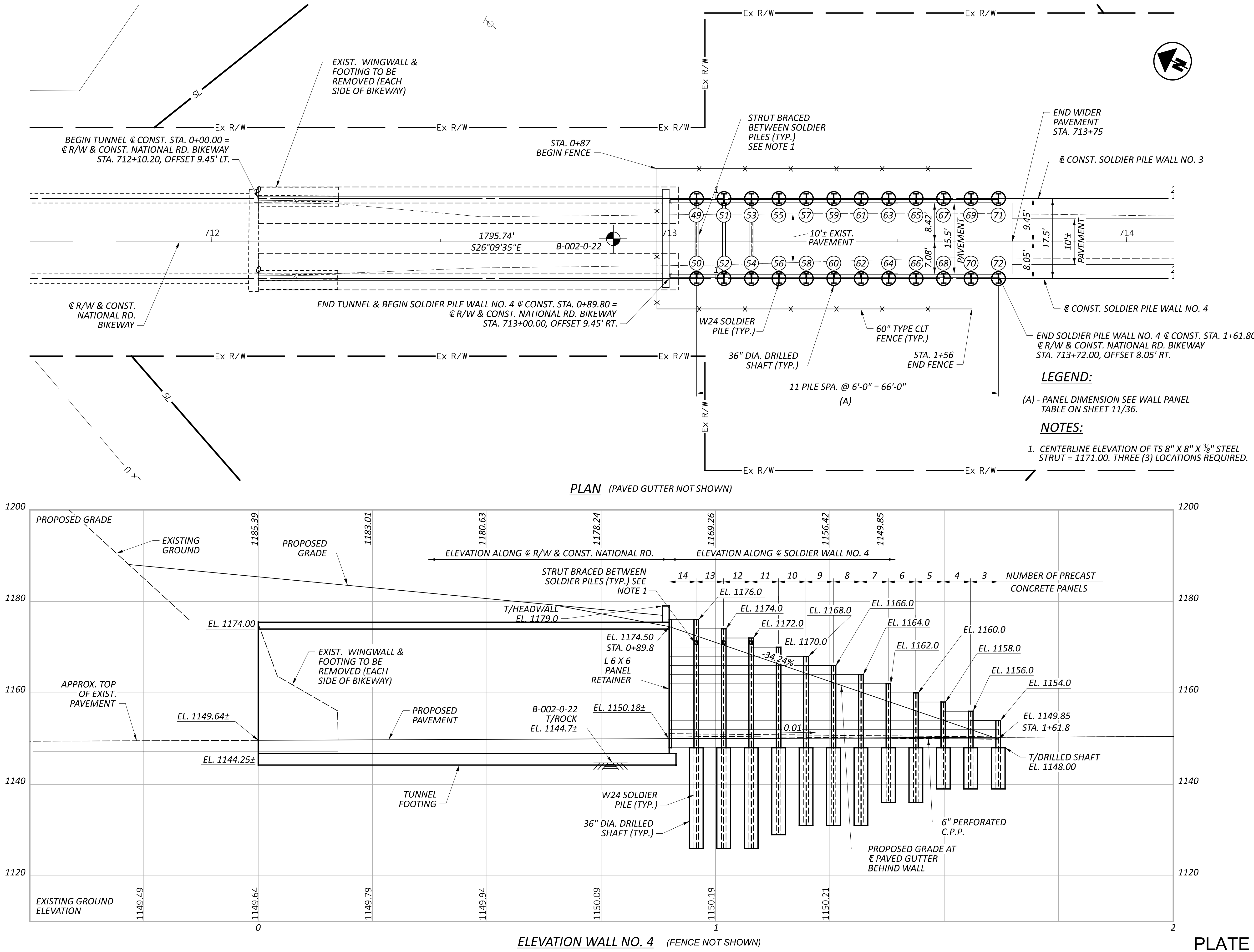
ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
5	36
SHEET	TOTAL
35	83

PLATE 5

BEL-NATIONAL RD. BIKEWAY

MODEL: CLX_RW_TRAIL - Plan 1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:38 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\Sheets\108774_SFN_0701572_WP003.dgn



LEGEND:

(A) - PANEL DIMENSION SEE WALL PANEL TABLE ON SHEET 11/36.

NOTES:

1. CENTERLINE ELEVATION OF TS 8" X 8" X 3/8" STEEL STRUT = 1171.00. THREE (3) LOCATIONS REQUIRED.

HORIZONTAL SCALE IN FEET 0 5 10 20

TUNNEL AND WALL NO. 4 PLAN AND ELEVATION (SOUTH)
BEL-NATIONAL ROAD BIKEWAY

BEL-NATIONAL RD. BIKEWAY

MODEL: CLX_RW_TRAIL - Plan 1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:40 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_WP004.dgn

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER	JDH 2-27-23
PROJECT ID	108774
SUBSET 6	TOTAL 36
SHEET 36	TOTAL 83

PLATE 6

STANDARD DRAWINGS AND SUPPLEMENTAL SPECIFICATIONS

REFER TO THE FOLLOWING STANDARD BRIDGE DRAWING(S):
DM-2.1 REVISED 01-18-13

AND TO THE FOLLOWING SUPPLEMENTAL SPECIFICATION(S):
1083 DATED 01-20-2017

DESIGN SPECIFICATIONS

THIS STRUCTURE CONFORMS TO THE 9th EDITION OF THE "LRFD BRIDGE DESIGN SPECIFICATIONS" ADOPTED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, 2020 AND THE ODOT BRIDGE DESIGN MANUAL, 2020.

DESIGN DATA

CONCRETE CLASS QC1:
COMPRESSIVE STRENGTH 4.0 KSI (TUNNEL)

CONCRETE CLASS QC2:
COMPRESSIVE STRENGTH 4.5 KSI (PRECAST PANELS)

CONCRETE CLASS QC5:
COMPRESSIVE STRENGTH 4.5 KSI (DRILLED SHAFT)
(3/8" NOMINAL MAXIMUM SIZE AGGREGATE)

CONCRETE REINFORCEMENT:

EPOXY COATED STEEL REINFORCEMENT - MINIMUM YIELD STRENGTH 60-KSI

STRUCTURAL STEEL - ASTM A709 GRADE 50W - YIELD STRENGTH 50 KSI

STEEL SOLDIER PILES - ASTM A709 GRADE 50W - YIELD STRENGTH 50 KSI

CUT LINE CONSTRUCTION JOINT PREPARATION

SAW CUT BOUNDARIES OF PROPOSED CONCRETE REMOVALS 1 INCH DEEP. REMOVE CONCRETE TO A ROUGH SURFACE. INSTALL DOWEL BARS IF SPECIFIED. PRIOR TO CONCRETE PLACEMENT ABRASIVELY CLEAN JOINT SURFACES TO REMOVE LOOSE AND DISINTEGRATED CONCRETE AND LOOSE RUST FROM EXISTING REBAR. THOROUGHLY CLEAN THE JOINT SURFACE AND OF ALL DIRT, DUST, RUST OR OTHER FOREIGN MATERIAL BY THE USE OF WATER, AIR UNDER PRESSURE, OR OTHER METHODS THAT PRODUCE SATISFACTORY RESULTS. THOROUGHLY DRENCH EXISTING CONCRETE SURFACES WITH CLEAN WATER AND ALLOW TO DRY TO A DAMP CONDITION BEFORE PLACING CONCRETE.

SUBSTRUCTURE CONCRETE REMOVAL

REMOVE CONCRETE BY MEANS OF APPROVED PNEUMATIC HAMMERS EMPLOYING POINTED AND BLUNT CHISEL TOOLS. HYDRAULIC HOE-RAM TYPE HAMMERS WILL NOT BE PERMITTED. THE WEIGHT OF THE HAMMER SHALL NOT BE MORE THAN 35 POUNDS FOR REMOVAL WITHIN 18 INCHES OF PORTIONS TO BE PRESERVED. OUTSIDE THE 18 INCH LIMIT, THE CONTRACTOR MAY USE HAMMERS NOT EXCEEDING 90 POUNDS UPON THE APPROVAL OF THE ENGINEER. DO NOT PLACE PNEUMATIC HAMMERS IN DIRECT CONTACT WITH REINFORCING STEEL THAT IS TO BE RETAINED IN THE REBUILT STRUCTURE.

FOUNDATION BEARING RESISTANCE

THE TUNNEL FOOTINGS, AS DESIGNED, PRODUCE A MAXIMUM STRENGTH LOAD PRESSURE OF 8.1 KIPS PER SQUARE FOOT. THE FACTORED BEARING RESISTANCE IS 11.7 KIPS PER SQUARE FOOT.

FOOTINGS

FOOTINGS SHALL EXTEND A MINIMUM OF 3 INCHES INTO BEDROCK OR TO THE ELEVATION SHOWN, WHICHEVER IS LOWER.

EXISTING STRUCTURE VERIFICATION

DETAILS AND DIMENSIONS SHOWN ON THESE PLANS PERTAINING TO THE EXISTING STRUCTURE HAVE BEEN OBTAINED FROM PLANS OF THE EXISTING STRUCTURE AND FROM FIELD OBSERVATIONS AND MEASUREMENTS. CONSEQUENTLY, THEY ARE INDICATIVE OF THE EXISTING STRUCTURE AND THE PROPOSED WORK BUT THEY SHALL BE CONSIDERED TENTATIVE AND APPROXIMATE. THE CONTRACTOR IS REFERRED TO C&MS, SECTIONS 102.05 AND 105.02. BASE CONTRACT BID PRICES UPON A RECOGNITION OF THE UNCERTAINTIES DESCRIBED ABOVE AND UPON A PREBID EXAMINATION OF THE EXISTING STRUCTURE. HOWEVER, THE DEPARTMENT WILL PAY FOR ALL PROJECT WORK BASED UPON ACTUAL DETAILS AND DIMENSIONS THAT HAVE BEEN VERIFIED IN THE FIELD.

ITEM 507 - STEEL PILES, MISC.: W24X___ STEEL BEAM, FURNISHED

THIS WORK SHALL CONSIST OF FURNISHING UNPAINTED STRUCTURAL STEEL MEMBERS THAT CONFORM TO ASTM A572, GRADE 50 AND CMS 711.01. DO NOT FIELD WELD OR SPLICE THOSE PARTS OF THE STRUCTURAL STEEL MEMBERS THAT WILL BE ABOVE GROUND.

THE INDIVIDUAL LENGTHS SHOWN IN THE SOLDIER PILE WALL TABLES ON SHEET XX/XX AND THE TOTAL LENGTHS SHOWN IN THE ESTIMATED QUANTITIES ARE CALCULATED FROM THE ESTIMATED TOP OF ROCK ELEVATIONS AND THE ACTUAL LENGTH OF EACH STEEL BEAM MAY VARY. THE CONTRACTOR SHOULD ANTICIPATE THAT THE STEEL BEAMS WILL NEED TO BE TRIMMED OR SPLICED BASED ON THE ACTUAL TOP OF THE ROCK.

THE DEPARTMENT WILL MEASURE STEEL BEAMS ALONG THE AXIS OF THE STEEL BEAM FROM THE TOP OF SHAFT ELEVATION TO THE BOTTOM OF THE DRILLED SHAFT, AS DETERMINED BY THE ENGINEER. THE DEPARTMENT WILL PAY FOR STEEL BEAMS AT THE CONTRACT UNIT PRICE PER FOOT ITEM 507, STEEL PILES, MISC.: W24X___ STEEL BEAM, FURNISHED.

ITEM 512 - SEALING OF CONCRETE SURFACES, AS PER PLAN, (PERMANENT GRAAFFITI PROTECTION)

APPLY A PERMANENT GRAFFITI COATING QUALIFIED ACCORDING TO S1083 THAT IS COMPATIBLE WITH THE CONCRETE SEALER OVER WHICH IT IS APPLIED. APPLY THE GRAFFITI COATING IN ACCORDANCE WITH THE MANUFACTURER'S PRINTED INSTRUCTION.

ITEM 513 - STRUCTURAL STEEL, MISC.: BRACKETS AND STRUTS

THIS WORK SHALL CONSIST OF FURNISHING STRUCTURAL MEMBERS, (TUBES AND PLATES), THAT CONFORM TO ASTM A709, GRADE 50W AND CMS 711.01. DO NOT FIELD WELD OR SPLICE THOSE PARTS OF THE STEEL SOLDIER PILES THAT WILL BE ABOVE GROUND.

THE SOLDIER PILE LENGTHS SHOWN IN THE WALL TABLES ON SHEET 9/36 ARE CALCULATED BASED ON THE ESTIMATED TOP OF ROCK ELEVATIONS AND THE ACTUAL LENGTH OF EACH SOLDIER PILE MAY VARY. THE CONTRACTOR SHOULD ANTICIPATE THAT THE SOLDIER PILES WILL NEED TO BE TRIMMED OR SPLICED BASED ON THE ACTUAL TOP OF THE ROCK.

THIS ITEM SHALL INCLUDE THE FIELD PAINTING OF ALL EXPOSED SURFACES OF THE HORIZONTAL STEEL STRUTS. PAINT SHALL BE FEDERAL COLOR NO. 595-30055 (BROWN) AND SHALL CONFORM TO CMS 514.

ITEM 524, DRILLED SHAFTS, 36" DIAMETER, ABOVE BEDROCK, AS PER PLAN
ITEM 524, DRILLED SHAFTS, 36" DIAMETER, INTO BEDROCK, AS PER PLAN

THIS WORK CONSISTS OF FURNISHING AND INSTALLING DRILLED SHAFTS FOR THE SOLDIER PILE WALLS. THE DRILLED SHAFTS ARE REINFORCED WITH STRUCTURAL STEEL MEMBERS INSTEAD OF REINFORCING STEEL CAGES. FURNISH AND INSTALL THE DRILLED SHAFTS IN ACCORDANCE WITH CMS 524 EXCEPT AS MODIFIED AND SUPPLEMENTED BELOW.

PLACE THE STEEL MEMBER WITHIN THE HOLE SO IT IS VERTICAL BETWEEN THE TOP AND BOTTOM. CENTER THE STEEL MEMBER WITHIN THE HOLE. SUPPORT THE STEEL MEMBER SO THAT IT DOES NOT MOVE DURING CONCRETE PLACEMENT.

USE CLASS QC5 CONCRETE ACCORDING TO CMS 524.10. THE CONTRACTOR MAY PLACE CONCRETE USING THE FREE FALL METHOD PROVIDED THE DEPTH OF WATER IS LESS THAN 6 INCHES AND THE CONCRETE FALLS WITHOUT STRIKING THE SIDES OF THE HOLE. POURING CONCRETE ALONG THE WEB OF THE STRUCTURAL STEEL MEMBER IS ACCEPTABLE.

CHECK THE POSITION, THE VERITICAL ALIGNMENT AND ORIENTATION OF THE STRUCTURAL MEMBER IMMEDIATELY AFTER CONCRETE PLACEMENT. MAKE CORRECTIONS AS NECESSARY TO MEET ABOVE TOLERANCES.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MEANS AND METHODS USED TO CONSTRUCT THE DRILLED SHAFTS. ANY TEMPORARY GRADING, EXCAVATION, EMBANKMENT, AGGREGATE, DRAINAGE, SHEETING, ETC. NEEDED TO COMPLETE THE WORK SHALL BE INCLUDED IN THE BID PRICE FOR THE DRILLED SHAFTS.

METHOD OF MEASUREMENT: THE DEPARTMENT WILL MEASURE DRILLED SHAFTS ABOVE BEDROCK, AS PER PLAN AND DRILLED SHAFTS INTO BEDROCK, AS PER PLAN, ALONG THE AXIS OF THE DRILLED SHAFT FROM THE PROPOSED TOP OF SHAFT ELEVATION TO THE BOTTM OF DRILLED SHAFT, AS DETERMINED BY THE ENGINEER.

PAYMENT FOR LABOR, EQUIPMENT AND MATERIALS FOR THE ABOVE SHALL BE INCLUDED IN THE PER FOOT CONTRACT PRICE FOR ITEM 524, DRILLED SHAFTS, 36" DIAMETER ABOVE BEDROCK, AS PER PLAN AND ITEM 524, DRILLED SHAFTS, 36" DIAMETER INTO BEDROCK, AS PER PLAN.

TUNNEL FALSEWORK

THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL FALSEWORK THAT IS REQUIRED TO CONSTRUCT THE TUNNEL. AT LEAST 14 DAYS PRIOR TO CONSTRUCTION OF THE TUNNEL, THE CONTRACTOR SHALL SUBMIT A DETAILED PLAN OF THE FALSEWORK THAT WILL BE REQUIRED AND BE DEVELOPED BY AN OHIO REGISTERED ENGINEER TO THE ENGINEER. APPROVAL BY THE ENGINEER IS REQUIRED BEFORE THIS WORK IS TO BE PERFORMED. PAYMENT FOR LABOR, EQUIPMENT, MATERIALS AND INCIDENTALS SHALL BE INCLUDED IN THE LUMP SUM CONTRACT PRICE FOR ITEM 503, COFFERDAMS AND EXCAVATION BRACING.

SEQUENCE OF CONSTRUCTION

PLACEMENT OF EMBANKMENT MATERIAL WITHIN THE LIMITS OF THE TUNNEL SHALL NOT BE PERFORMED UNTIL ALL TUNNEL CONSTRUCTION IS COMPLETE. THIS INCLUDES ALL CONCRETE FOOTINGS, WALLS, AND ARCH ABOVE THE SPRINGLINE.

PLACEMENT OF EMBANKMENT MATERIAL WITHIN THE LIMITS OF THE SOLDIER PILE WALLS THAT INCLUDE THE HORIZONTAL STEEL STRUT TUBES SHALL NOT BE PERFORMED UNTIL ALL STRUTS ARE IN PLACE.

GEOTECHNICAL SUBSURFACE INVESTIGATION REPORT

A GEOTECHNICAL INVESTIGATION REPORT PREPARED BY S&ME, INC. DATED FEBRUARY 10, 2023 IS AVAILABLE TO ASSIST THE CONTRACTOR IN EVALUATING EXISTING CONDITIONS.

THE REPORTS INCLUDE BORING LOGS AND LABORATORY TESTING. INDICATED STRATA BOUNDARIES SHOWN ON THE BORING LOGS ARE BASED ON ENGINEERING INTERPRETATIONS OF ALL AVAILABLE SUBSURFACE INFORMATION AND MAY NOT REFLECT THE ACTUAL VARIATIONS IN SUBSURFACE CONDITIONS BETWEEN BORINGS AND RECOVERED SAMPLES.

THE REPORTS AND BORING LOGS ARE AVAILABLE FOR THE CONTRACTOR'S INFORMATION, BUT ARE NOT A WARRANT OF SUBSURFACE CONDITIONS. THE CONTRACTOR MUST DRAW HIS OWN CONCLUSIONS OF THE SUBSURFACE CONDITIONS DEPICTED BY THE INFORMATION.

ABBREVIATIONS

BL	- BASELINE
BOT.	- BOTTOM
℄	- CENTERLINE
C.J.	- CONSTRUCTION JOINT
CLR.	- CLEAR
CONC.	- CONCRETE
CONST.	- CONSTRUCTION
C.P.P.	- CORRUGATED PLASTIC PIPE
DIA.	- DIAMETER
E.F.	- EACH FACE
EL.	- ELEVATION
ELEC.	- ELECTRIC
E.W.	- EACH WAY
EX.	- EXISTING
EXP.	- EXPANSION
EX R/W	- EXISTING RIGHT-OF-WAY
EX LA-R/W	- EXISTING LIMITED ACCESS RIGHT-OF-WAY
MAX	- MAXIMUM
MIN	- MINIMUM
NO.	- NUMBER
N.P.C.P.P	- NON-PERFORATED CORRUGATED PLASTIC PIPE
P.C.P.P	- PERFORATED CORRUGATED PLASTIC PIPE
P.E.J.F.	- PREFORMED EXPANSION JOINT FILLER
PROP.	- PROPOSED
REINF.	- REINFORCING
SPA.	- SPACING
STA.	- STATION
TYP.	- TYPICAL
W/	- WITH

GENERAL NOTES - TUNNEL EXTENSION AND SOLDIER PILE WALLS
BEL-NATIONAL ROAD BIKEWAY

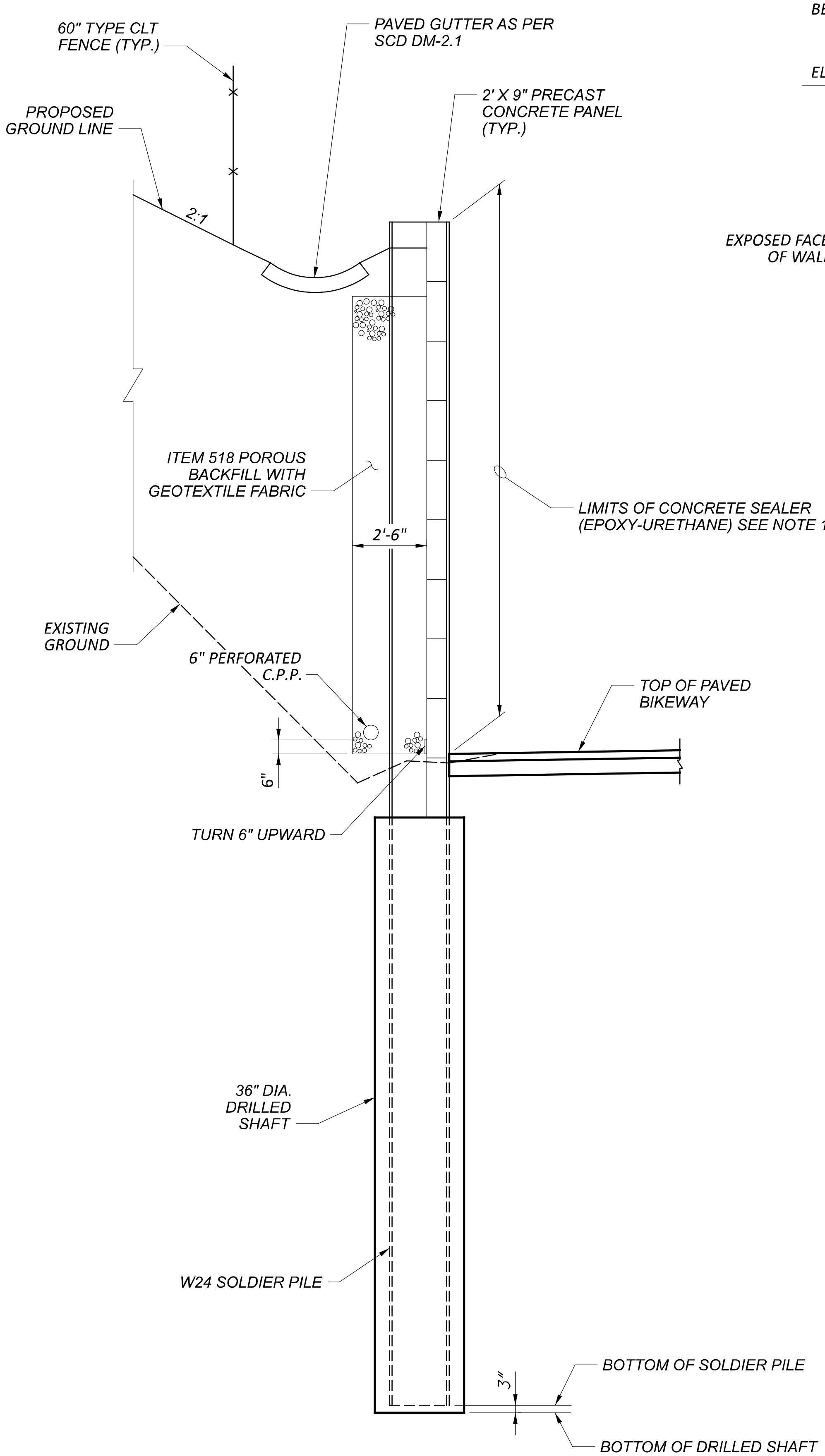
SFN 0701572
DESIGN AGENCY
ms consultants, inc.

DESIGNER SJR CHECKER WER
REVIEWER JDH 2-27-23
PROJECT ID 108774
SUBSET 7 TOTAL 36
SHEET 37 TOTAL 83

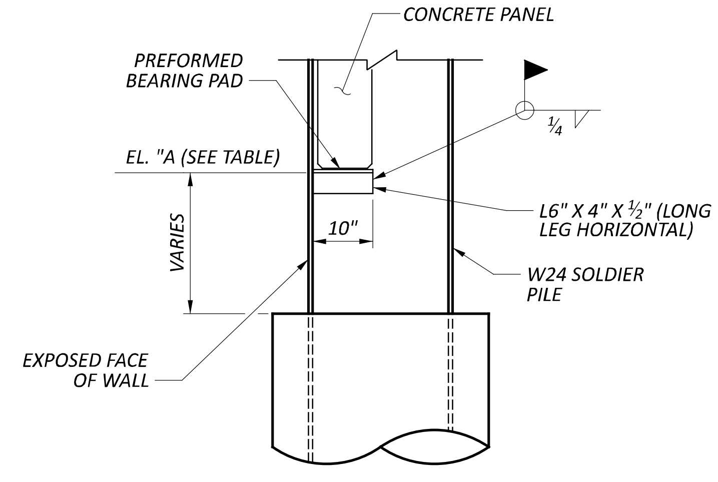
PLATE 7

BEL-NATIONAL RD. BIKEWAY

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:41 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SN002.dgn

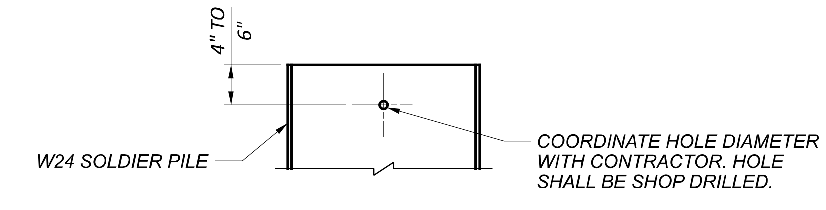


WALL SECTION



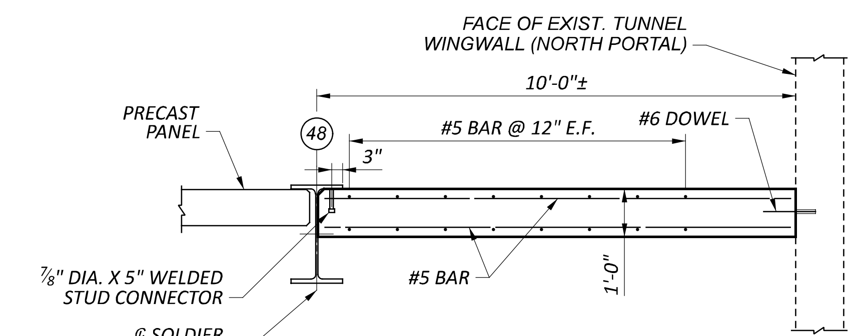
PANEL LEDGE DETAIL

ELEVATION AT TOP OF SUPPORT ANGLE	
SOLDIER PILE NUMBER	EL. "A"
5	1143.0
6	1143.0
39	1151.0
41	1153.0
42	1145.0
44	1149.0
45	1157.0
46	1155.0



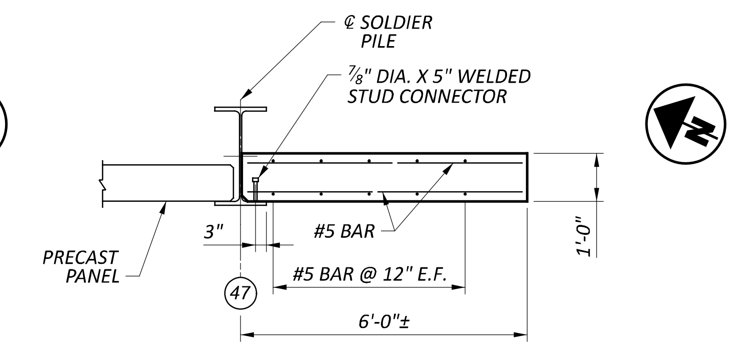
LIFTING HOLE DETAIL

(TYP. ALL SOLDIER PILES)



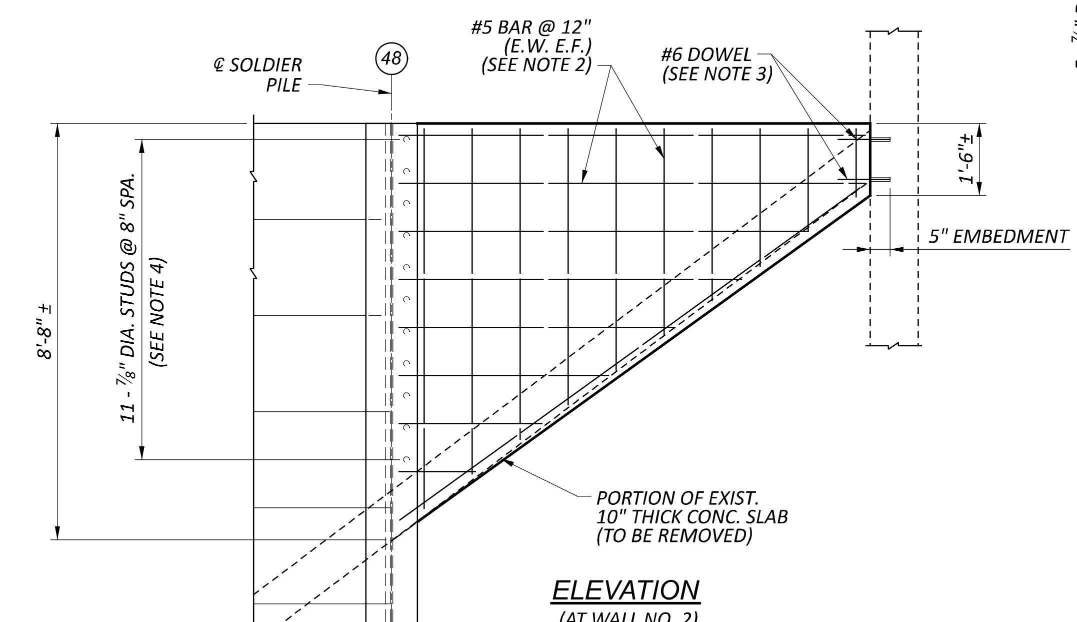
PLAN

(AT WALL NO. 2)



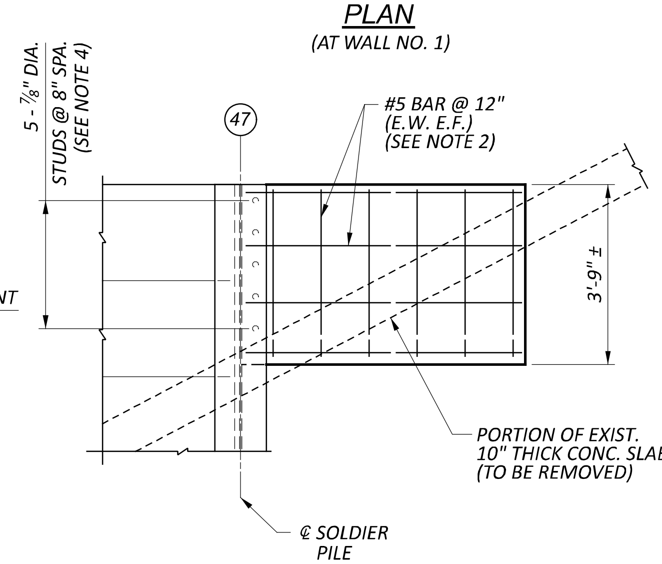
PLAN

(AT WALL NO. 1)



ELEVATION

(AT WALL NO. 2)



ELEVATION

(AT WALL NO. 1)

WALL CLOSURE DETAILS

NOTES:

1. CONTRACTOR SHALL APPLY ITEM 512 SEALING OF CONCRETE SURFACES AS PER PLAN, (PERMANENT GRAFFITI PROTECTION) OVER EPOXY-URETHANE PER SS 1083.
2. REINFORCING STEEL SHALL BE EPOXY COATED AND FIELD CUT AND PLACED TO FIT.
3. DOWELS SHALL BE PLACED IN DOWEL HOLES USING NONSHRINK, NONMETALLIC GROUT PER CMS 510.
4. 7/8" DIA. WELDED STUD CONNECTORS SHALL BE INCLUDED WITH ITEM 513, STRUCTURAL STEEL, MISC.: SOLDIER PILES, BRACKETS, AND STRUTS.

PLATE 8

TYPICAL WALL SECTION AND DETAILS
BEL-NATIONAL ROAD BIKEWAY

BEL-NATIONAL RD. BIKEWAY

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:45 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SM004.dgn

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

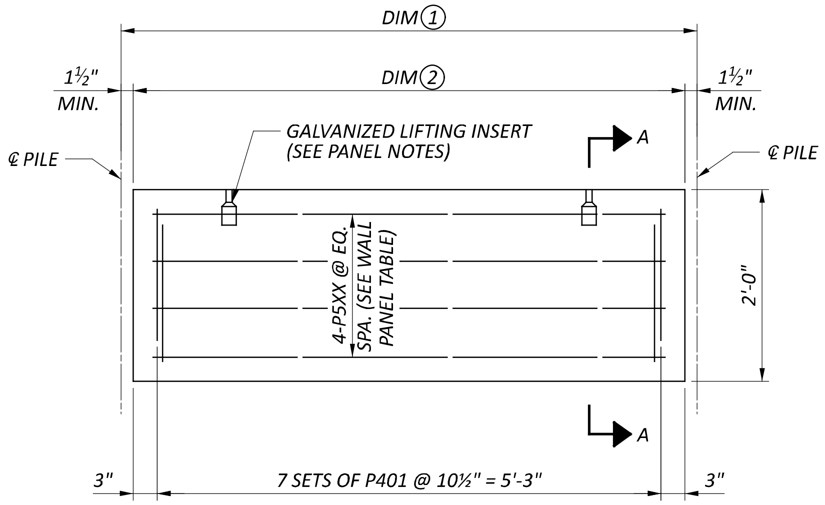
DESIGNER	CHECKER
SJR	WER

REVIEWER JDH 2-27-23

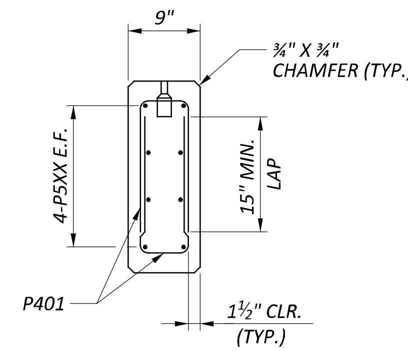
PROJECT ID 108774

SUBSET 10 TOTAL 36

SHEET 40 TOTAL 83



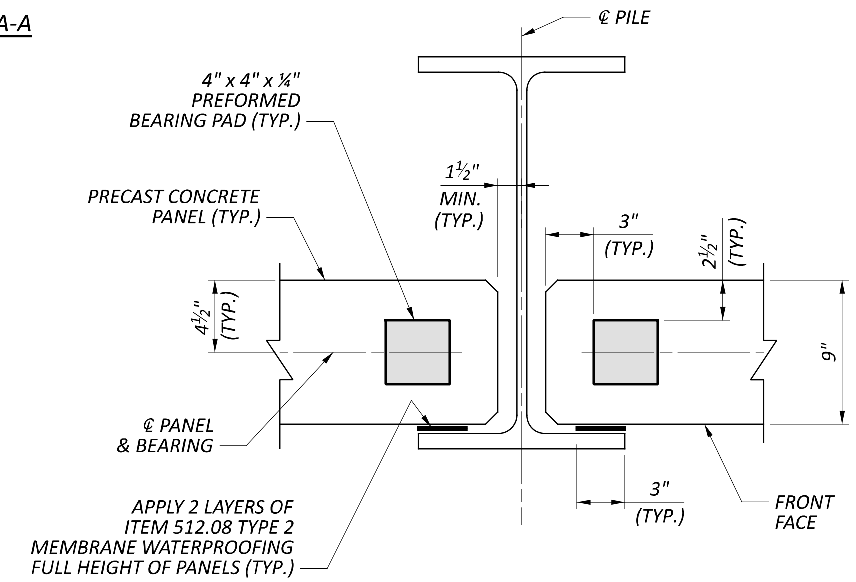
PRECAST CONCRETE PANEL DETAIL



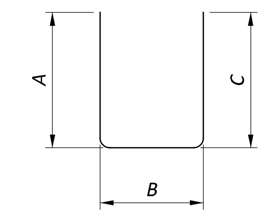
SECTION A-A

MARK	TOTAL	LENGTH	WEIGHT †	TYPE	DIMENSIONS A	B	C	D	E	INC.
PANEL BARS										
P401	8,274	3'-4"	18,423	2	1'-6"	0'-6"	1'-6"			
P501	3,864	5'-3"	21,158	ST						
P502	80	5'-0"	417	ST						
P503	80	5'-5"	452	ST						
P504	176	5'-8"	1,040	ST						
P505	88	5'-10"	535	ST						
P506	88	5'-5"	497	ST						
P507	96	5'-2"	517	ST						
P508	96	5'-5"	542	ST						
P509	88	5'-6"	505	ST						
P510	72	5'-4"	401	ST						
		TOTAL =	44,487							

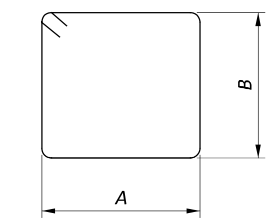
† INCLUDED WITH ITEM SPECIAL - PRECAST CONCRETE PANELS AS PER PLAN, FOR PAYMENT.



PANEL/PILE INTERFACE



TYPE-2



TYPE-3

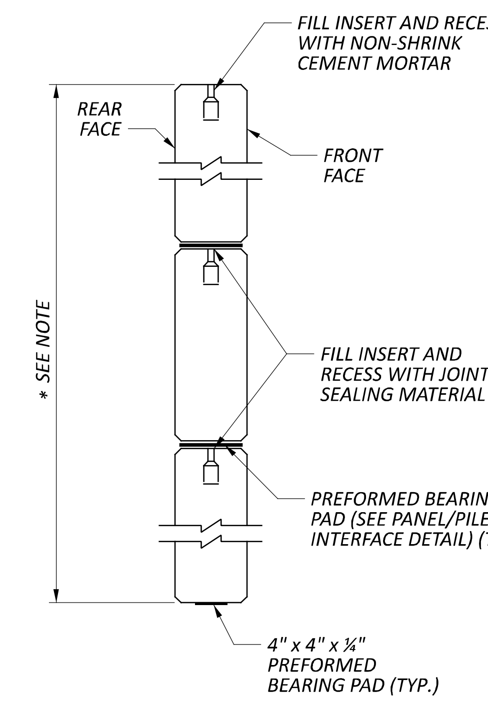
WALL PANEL TABLE			
PANEL TYPE	DIM 1	DIM 2	REBAR
A	6'-0"	5'-9"	P501
B	5'-9 ¾"	5'-6 ¾"	P502
C	6'-2 ¾"	5'-11 ¾"	P503
D	6'-5 ¼"	6'-2 ¼"	P504
E	6'-7 ¾"	6'-4 ¾"	P505
F	6'-2 ¼"	5'-11 ¼"	P506
G	5'-11"	5'-8"	P507
H	6'-2"	5'-11"	P508
J	6'-3 ⅜"	6'-0 ⅜"	P509
K	6'-1 ½"	5'-10 ½"	P510

PREFORMED BEARING PAD NOTES:

1. PREFORMED BEARING PADS SHALL BE PROVIDED BENEATH ALL PANELS AND SHALL BE ADHESIVELY BONDED TO THE TOP CONCRETE SURFACE OF THE UNDERLYING PANEL AND GRADE BEAM. THE BONDING ADHESIVE SHALL BE AN APPROVED ADHESIVE AS RECOMMENDED BY THE MANUFACTURER OF THE PREFORMED BEARING PADS.
2. PREFORMED BEARING PADS SHALL BE ETHYLENE PROYLENE DIENE MONOMER (EPDM) RUBBER PADS CONFORMING TO ASTM D2000 GRADE 2, TYPE A, CLASS A WITH A DUROMETER OF 50±5.

PANEL FABRICATION NOTES:

1. PROVIDE A SMOOTH SURFACE TO THE FRONT AND BACK OF EACH PANEL. PROVIDE PANEL NUMBER AND PRECAST FABRICATOR MARK ON BACK FACE OF EACH PANEL.
2. PRECAST PANEL REINFORCEMENT SHOWN IS FOR FINAL, ERECTED (IN PLACE) CONDITION ONLY. ADDITIONAL REINFORCEMENT MAY BE REQUIRED IN ORDER TO MEET THE CONTRACTOR'S SPECIFIC ERECTION AND HANDLING REQUIREMENTS. COORDINATE WITH THE CONTRACTOR.
3. THE NUMBER, TYPE AND LOCATION OF GALVANIZED LIFTING INSERTS SHALL BE DESIGNED BY THE PRECAST PANEL FABRICATOR. PROVIDE A ½-INCH RECESS IN THE TOP OF THE PANEL FOR EACH INSERT. FILL INSERT AND RECESS AFTER ERECTION IN PANELS BELOW TOP PANELS WITH SELF-LEVELING, I-PART POYURETHANE SEALANT CONFORMING TO ASTM C-920, TYPE S, GRADE P, CLASS 25. IN THE TOP PANELS ONLY, FILL THE RECESS WITH NON-SHRINK, NON-METALLIC GROUT CONFORMING TO MATERIAL 705.20.
4. ALL EXPOSED EDGES OF PRECAST PANELS SHALL BE CHAMFERED 3/4" x 3/4".



CONCRETE SEALING DETAIL

* APPLY NON-EPOXY SEALER TO THE REAR FACE OF EACH PANEL PRIOR TO ERECTION, IN ACCORDANCE WITH ITEM 512.03.

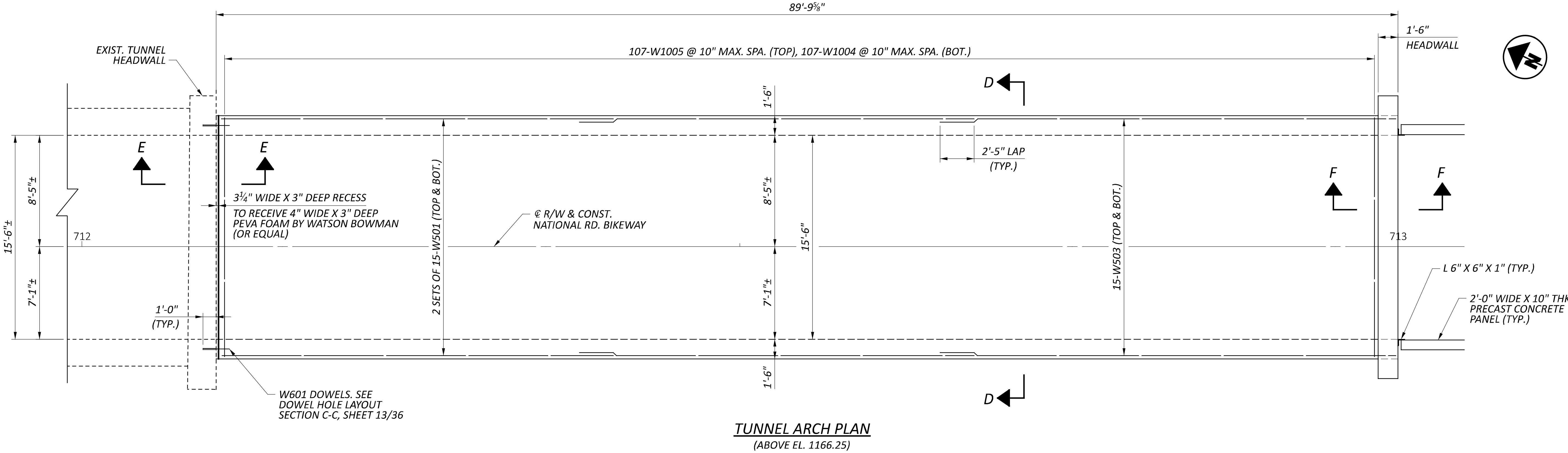
PRECAST PANEL DETAILS
BEL-NATIONAL ROAD BIKEWAY

SFN	
0701572	
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER JDH	2-27-23
PROJECT ID 108774	
SUBSET 11	TOTAL 36
SHEET 41	TOTAL 83

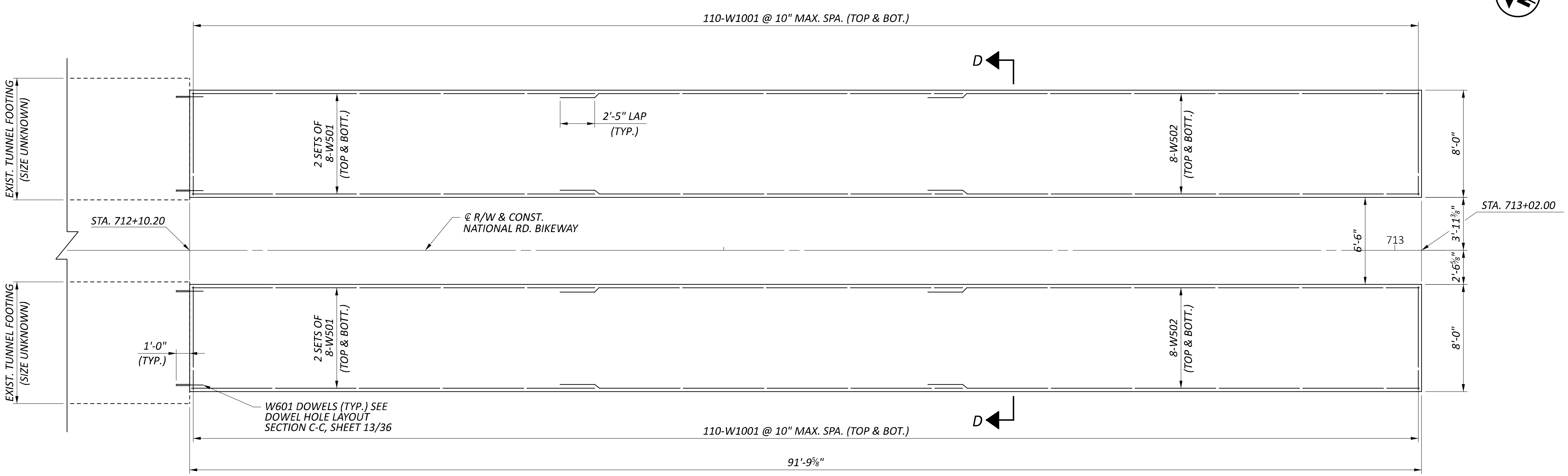
PLATE 9

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:46 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SM006.dgn

TUNNEL ARCH AND FOOTING PLAN
BEL-NATIONAL ROAD BIKEWAY



TUNNEL ARCH PLAN
(ABOVE EL. 1166.25)



FOOTING PLAN

NOTES:

1. FOR SECTION D-D, SEE SHEET 16/36.
2. FOR SECTION E-E, SEE SHEET 15/36.
3. FOR SECTION F-F, SEE SHEET 17/36.

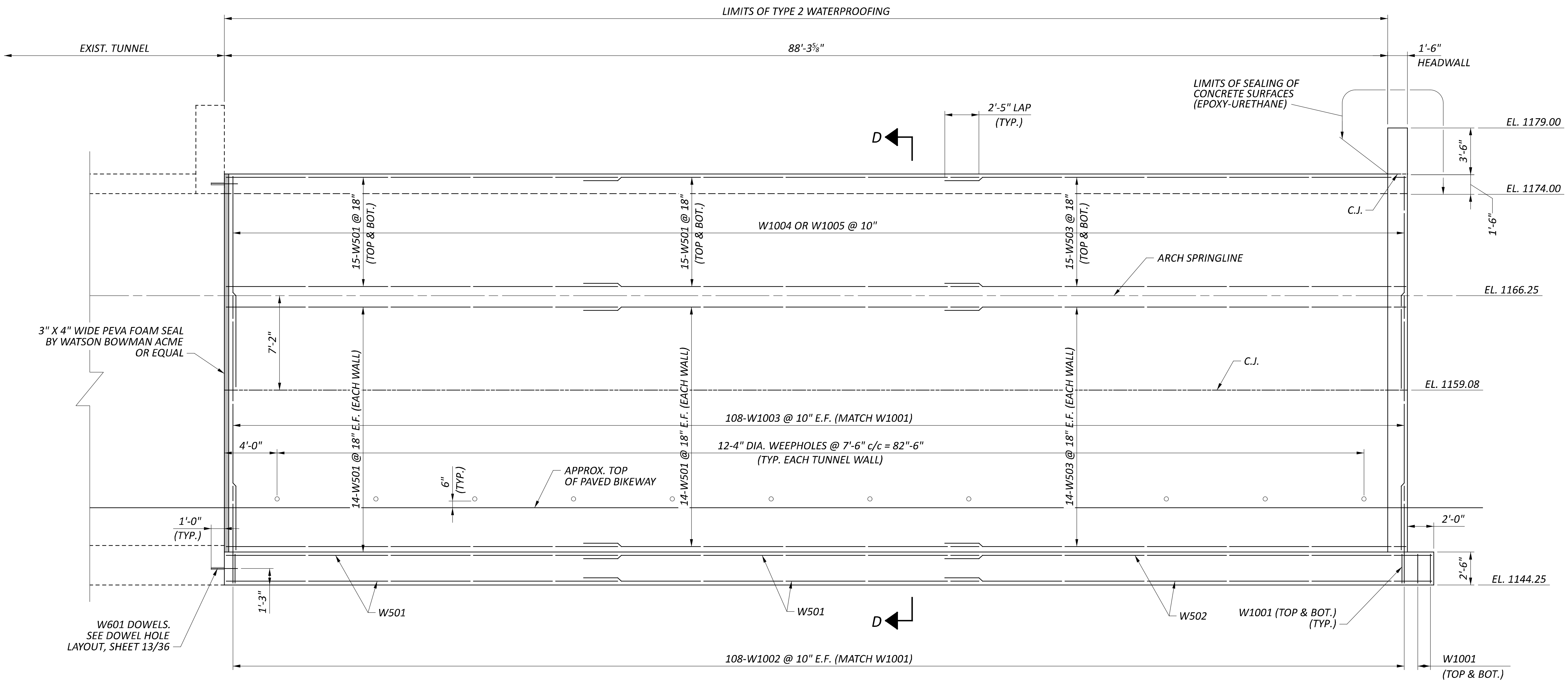
PLATE 10

HORIZONTAL SCALE IN FEET 0 1/8 1/4 1/2

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER LAW
REVIEWER JDH	2-27-23
PROJECT ID	108774
SUBSET 14	TOTAL 36
SHEET 44	TOTAL 83

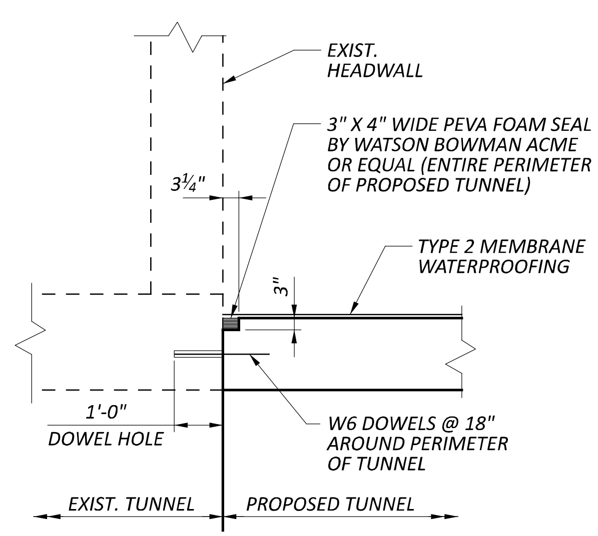
BEL-NATIONAL RD. BIKEWAY

TUNNEL ELEVATION
BEL-NATIONAL ROAD BIKEWAY

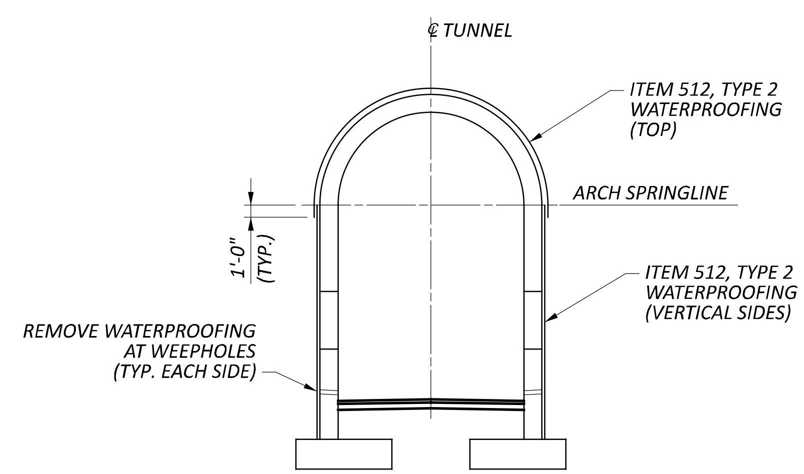


ELEVATION

(WINGWALL REINFORCEMENT NOT SHOWN)
(REINFORCING SYMMETRICAL ABOUT CENTERLINE OF TUNNEL)



SECTION E-E



TYPE 2 WATERPROOFING DETAILS

NOTES:

1. FOR TUNNEL HEADWALL DETAILS AND SECTION D-D, SEE SHEET 16/36.
2. FOR LOCATION OF SECTION E-E, SEE SHEET 17/36.

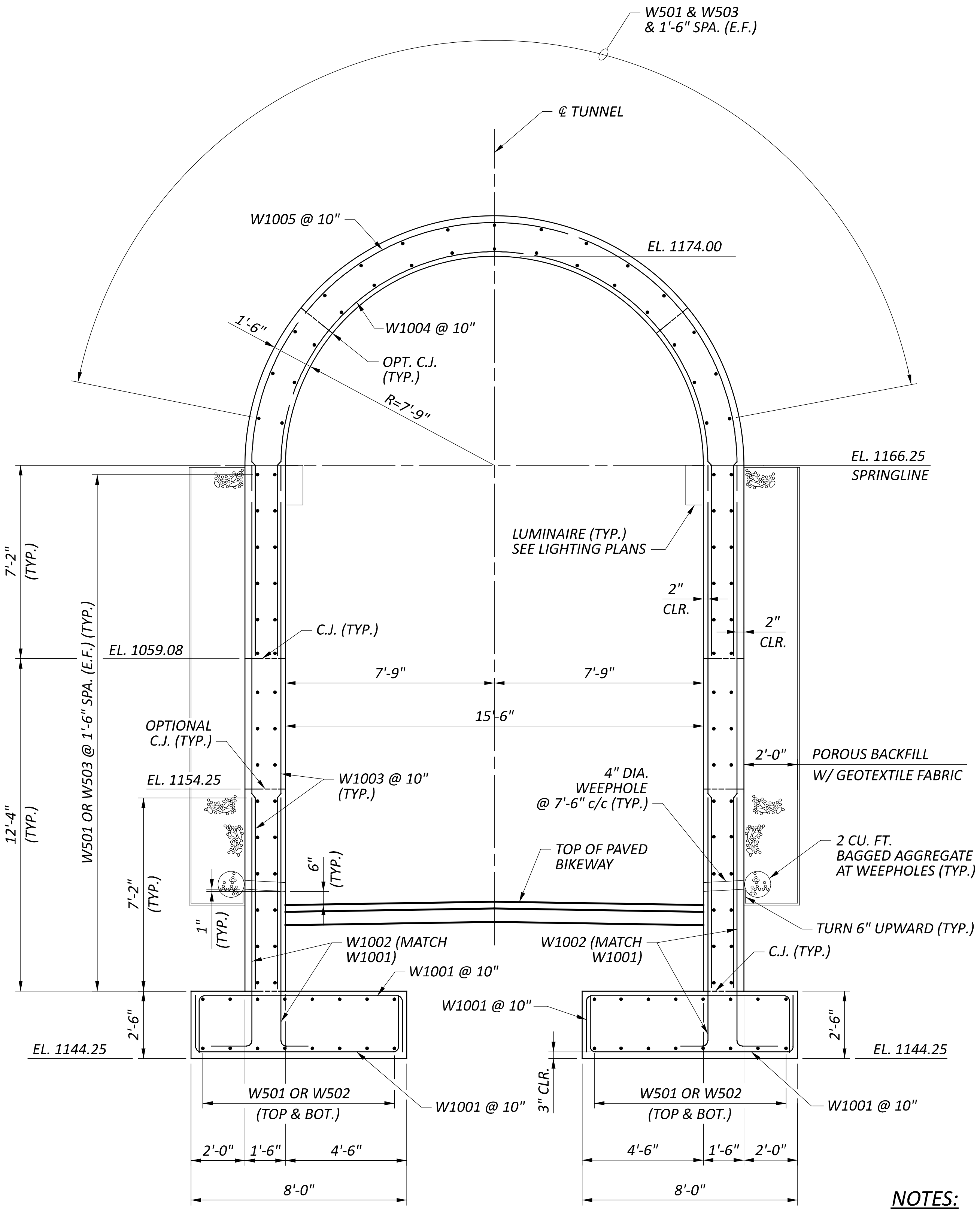
SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER: SJR	CHECKER: LAW
REVIEWER: JDH	2-27-23
PROJECT ID	108774
SUBSET 15	TOTAL 36
SHEET 45	TOTAL 83

PLATE 11

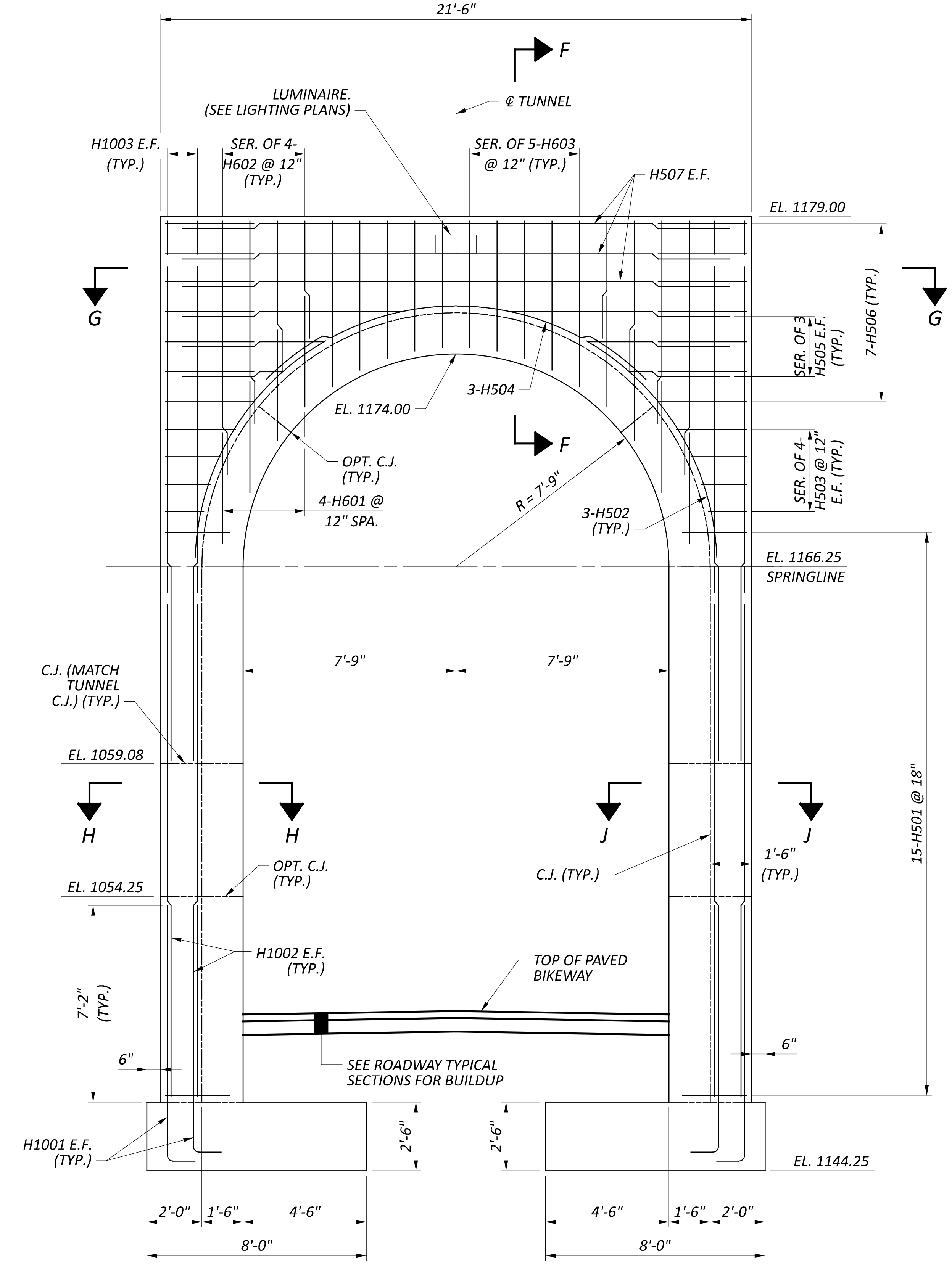
BEL-NATIONAL RD. BIKEWAY

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:50 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SM008.dgn

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:51 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SM005.dgn



SECTION D-D



TUNNEL HEADWALL

NOTES:

1. FOR LOCATION OF SECTION D-D, SEE SHEET 15/36.
2. FOR ELEVATIONS AND LIMITS OF POROUS BACKFILL, SEE BIKEWAY CROSS SECTIONS.
3. FOR SECTIONS F-F, G-G, H-H & J-J, SEE SHEET 17/36.

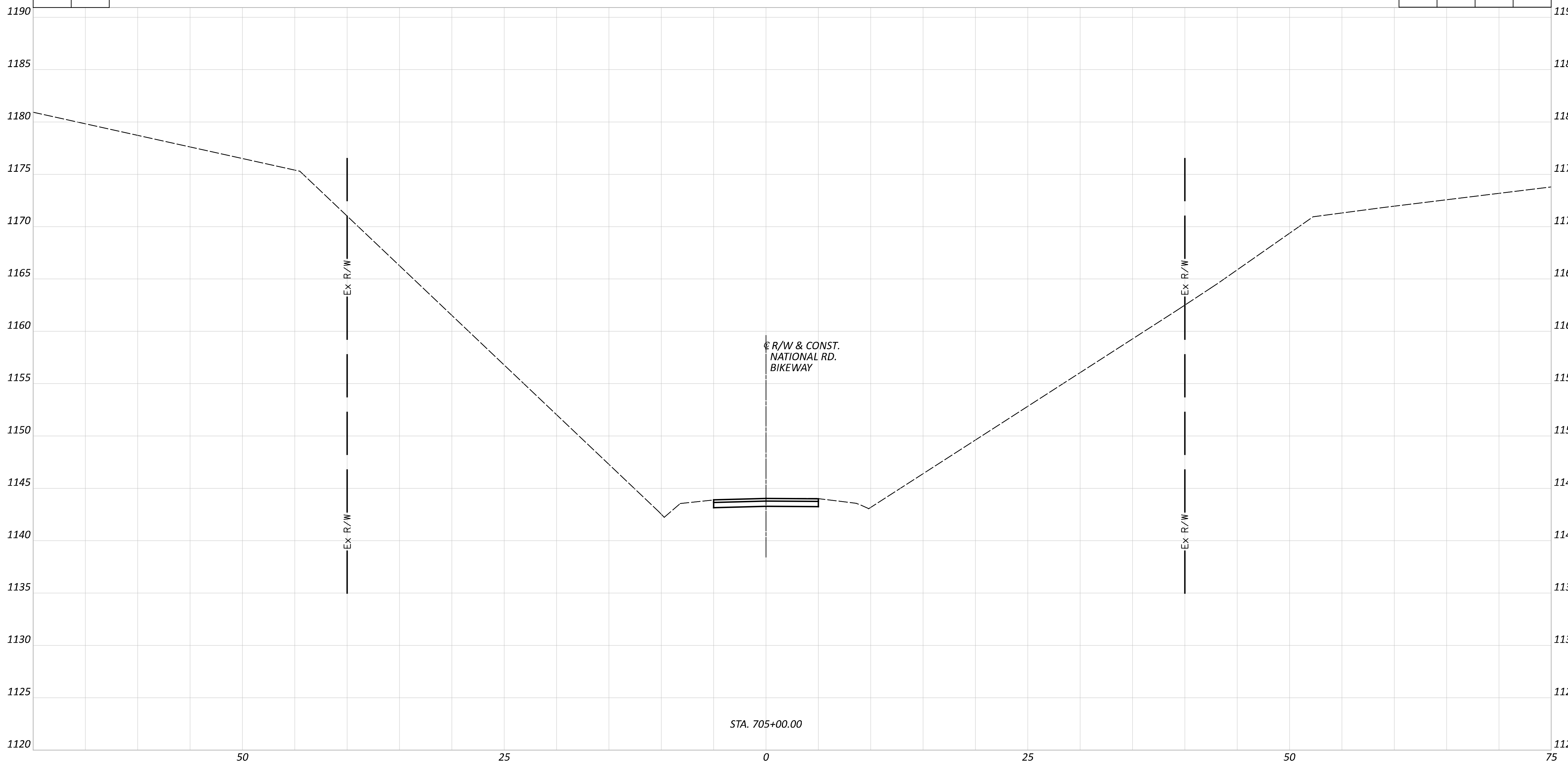
PLATE 12

TUNNEL SECTION AND HEADWALL DETAILS
BEL-NATIONAL ROAD BIKEWAY

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER: SJR	CHECKER: LAW
REVIEWER: JDH	2-27-23
PROJECT ID	108774
SUBSET: 16	TOTAL: 36
SHEET: 46	TOTAL: 83

SEEDING	
WIDTH	AREA
FT.	S.Y.
0	0

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
0	0	0	0



BEL-NATIONAL RD. BIKEWAY

MODEL: 705+00 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:54 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL-NATIONAL ROAD BIKEWAY
STA. 705+00

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER

REVIEWER
JDH 2-27-23

PROJECT ID
108774

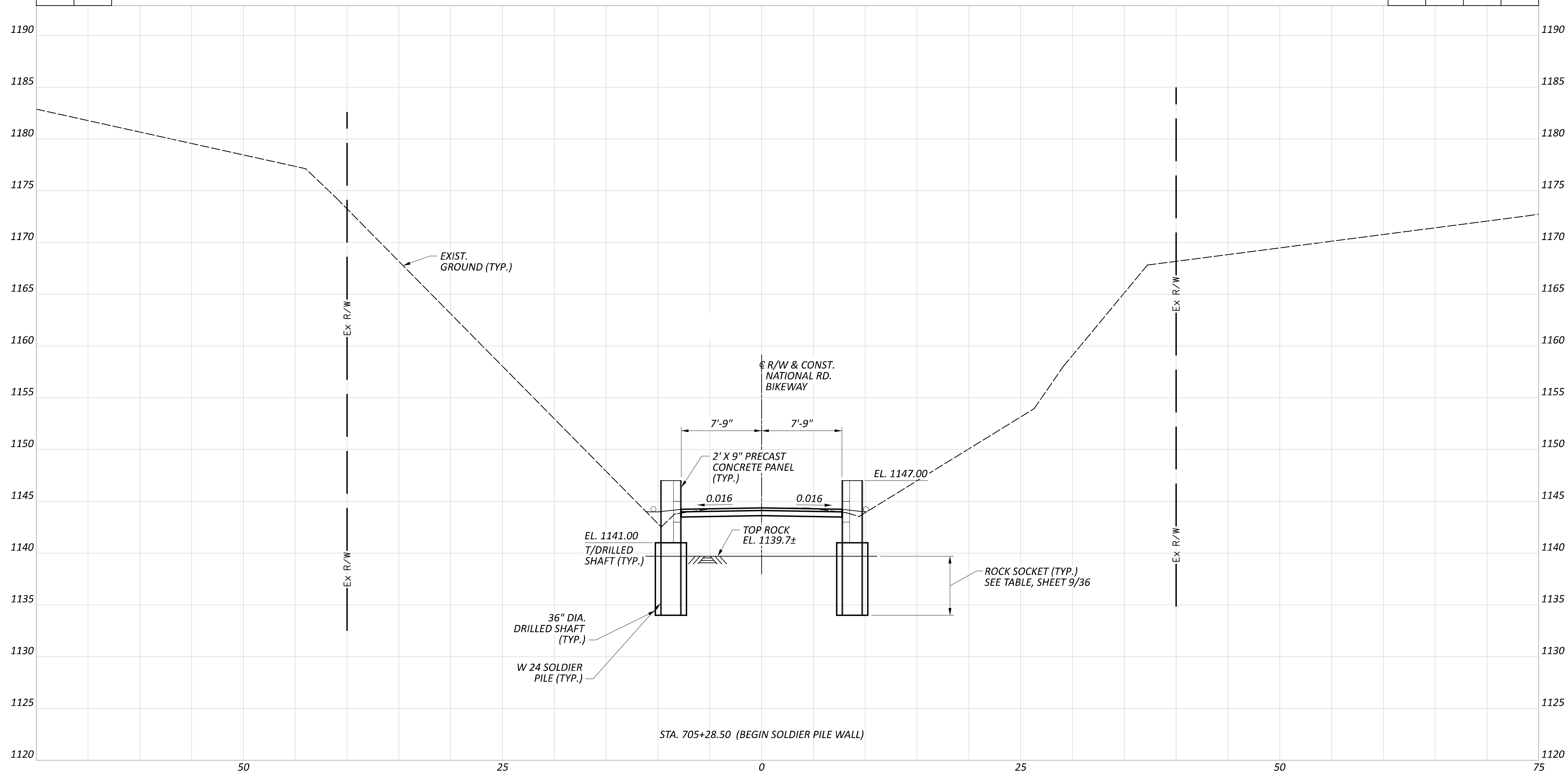
SUBSET 18 TOTAL 36

SHEET 48 TOTAL 83

PLATE 13

SEEDING	
WIDTH	AREA
FT.	S.Y.
5.9	9

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
0	3.4	0	2



BEL-NATIONAL RD. BIKEWAY

MODEL: 705+28.5 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:55 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL - NATIONAL ROAD BIKEWAY
STA. 705+28.5 - SOLDIER PILE WALL (NORTH)

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER

REVIEWER JDH 2-27-23

PROJECT ID 108774

SUBSET 19 TOTAL 36

SHEET 49 TOTAL 83

PLATE 14

SEEDING	
WIDTH	AREA
FT.	S.Y.
137.3	171

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
481.4	76.5	192	32

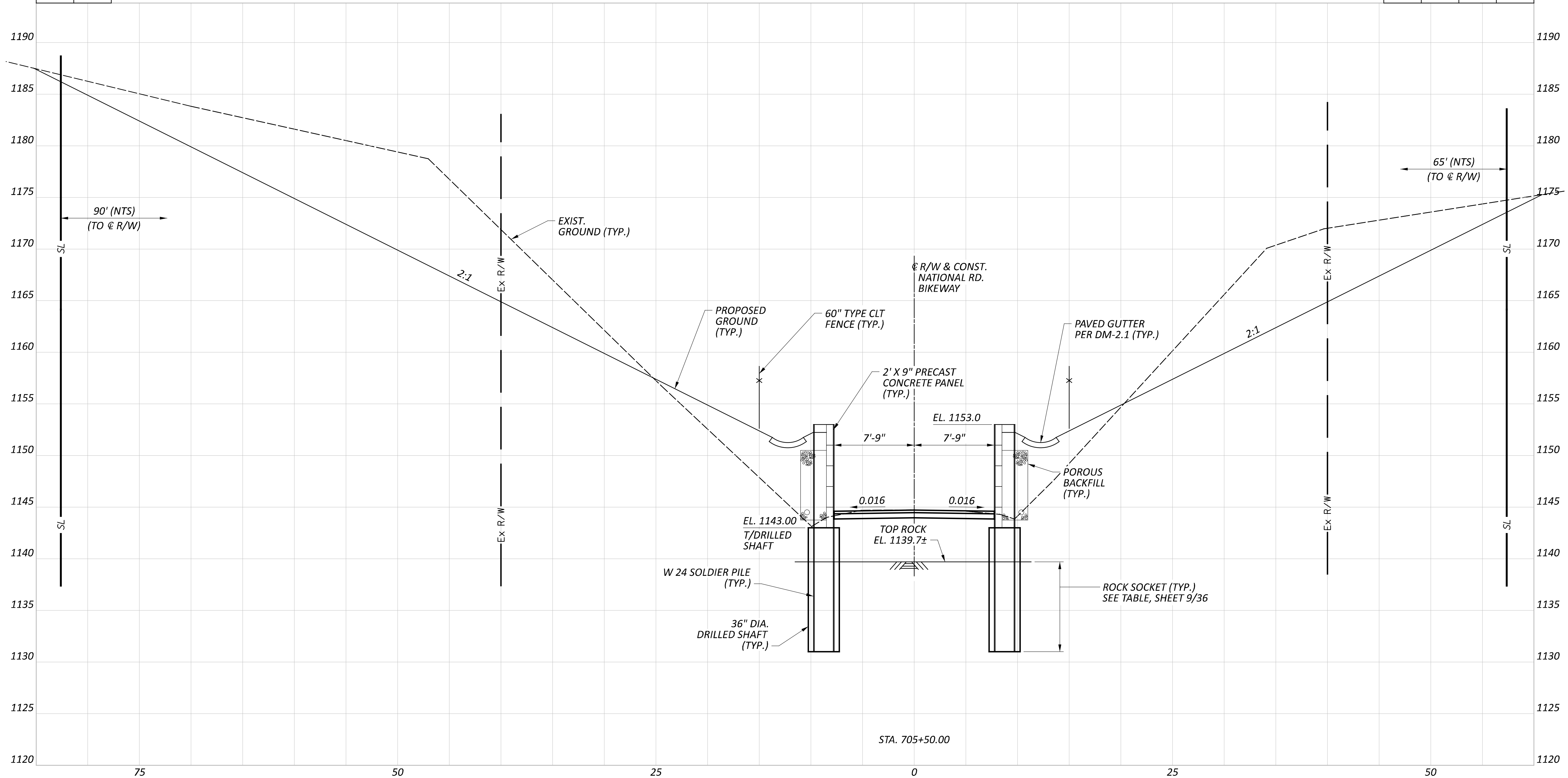


PLATE 15

BEL-NATIONAL RD. BIKEWAY

MODEL: 705+50 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:55 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

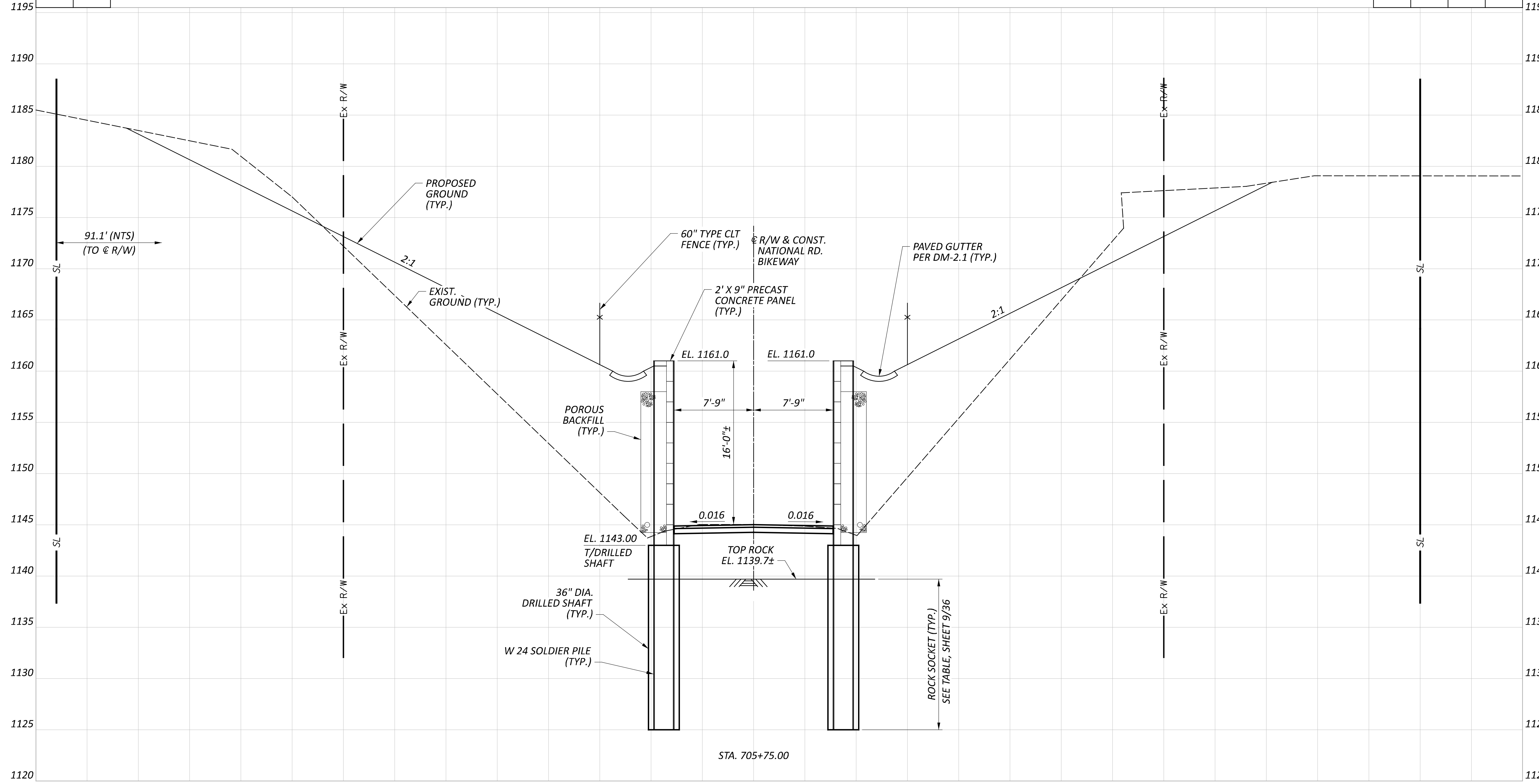
BEL - NATIONAL ROAD BIKEWAY
STA. 705+50 - SOLDIER PILE WALL (NORTH)

SFN 0701572
DESIGN AGENCY
ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
20	36
SHEET	TOTAL
50	83

SEEDING	
WIDTH	AREA
FT.	S.Y.
99	328

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
81.0	374.5	260	209



BEL-NATIONAL RD. BIKEWAY

MODEL: 705+75 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:56 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL - NATIONAL ROAD BIKEWAY
STA. 705+75 - SOLDIER PILE WALL (NORTH)

SFN 0701572

DESIGN AGENCY

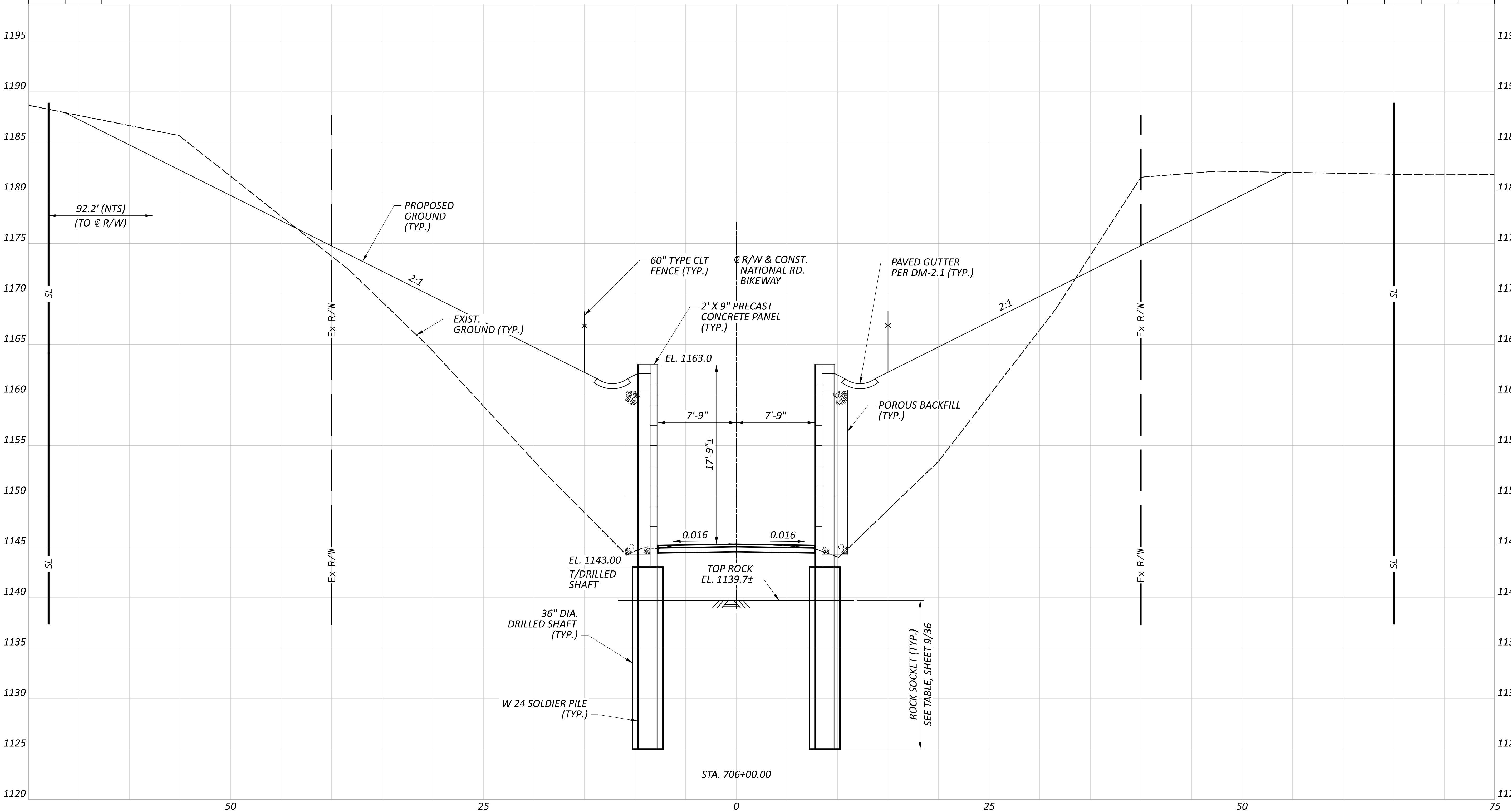
ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
21	36
SHEET	TOTAL
51	83

PLATE 16

SEEDING	
WIDTH	AREA
FT.	S.Y.
109.1	289

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
112.4	443.4	90	379



BEL-NATIONAL RD. BIKEWAY

MODEL: 706+00 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:57 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

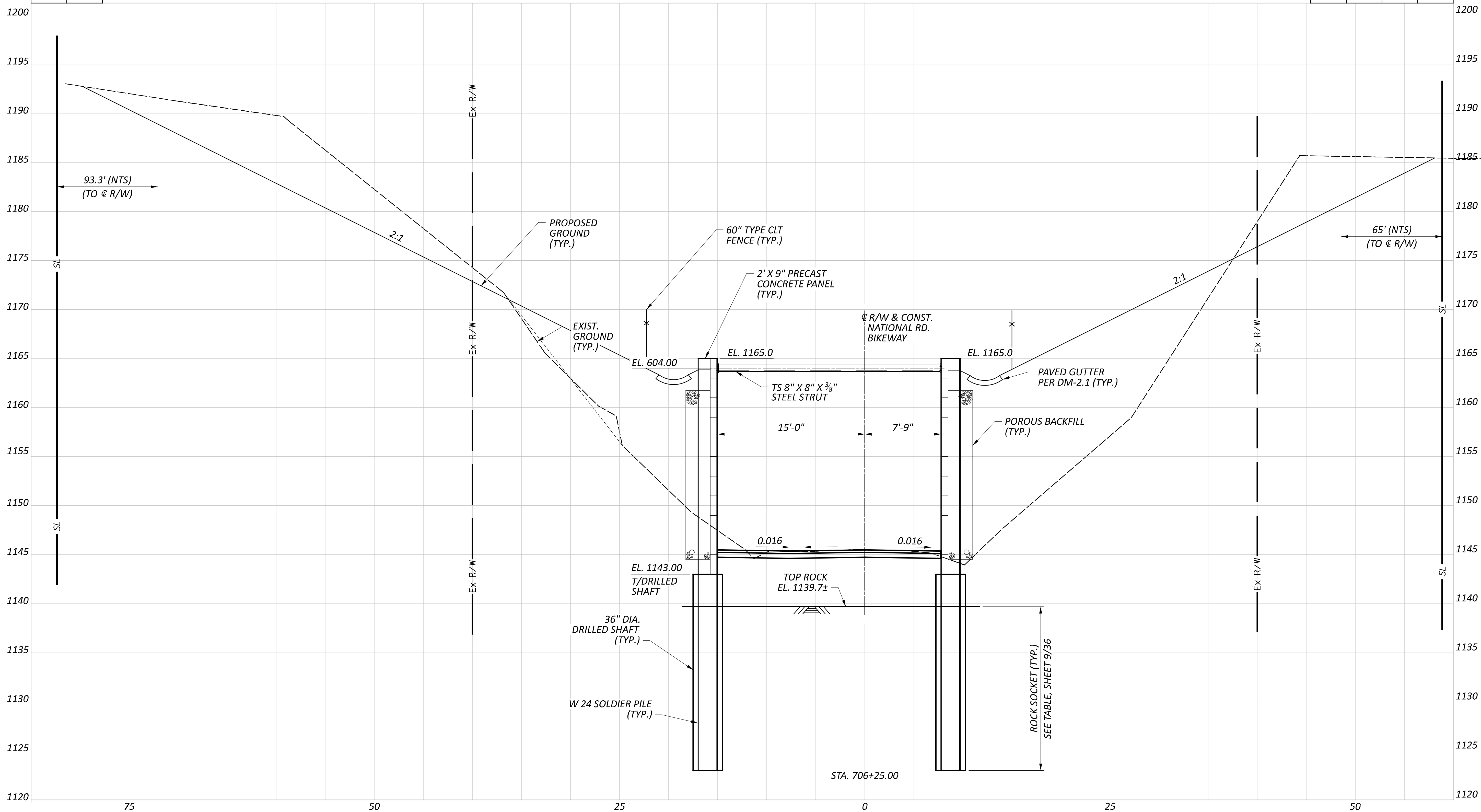
BEL - NATIONAL ROAD BIKEWAY
STA. 706+00 - SOLDIER PILE WALL (NORTH)

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER: SJR	CHECKER: WER
REVIEWER: JDH	2-27-23
PROJECT ID	108774
SUBSET: 22	TOTAL: 36
SHEET: 52	TOTAL: 83

PLATE 17

SEEDING	
WIDTH	AREA
FT.	S.Y.
120.1	318

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
232.2	408.5	160	394



BEL - NATIONAL ROAD BIKEWAY
STA. 706+25 - SOLDIER PILE WALL (NORTH)

SFN 0701572

DESIGN AGENCY: ms consultants, inc.

DESIGNER	CHECKER
SJR	WER

REVIEWER: JDH 2-27-23

PROJECT ID: 108774

SUBSET 23 TOTAL 36

SHEET 53 TOTAL 83

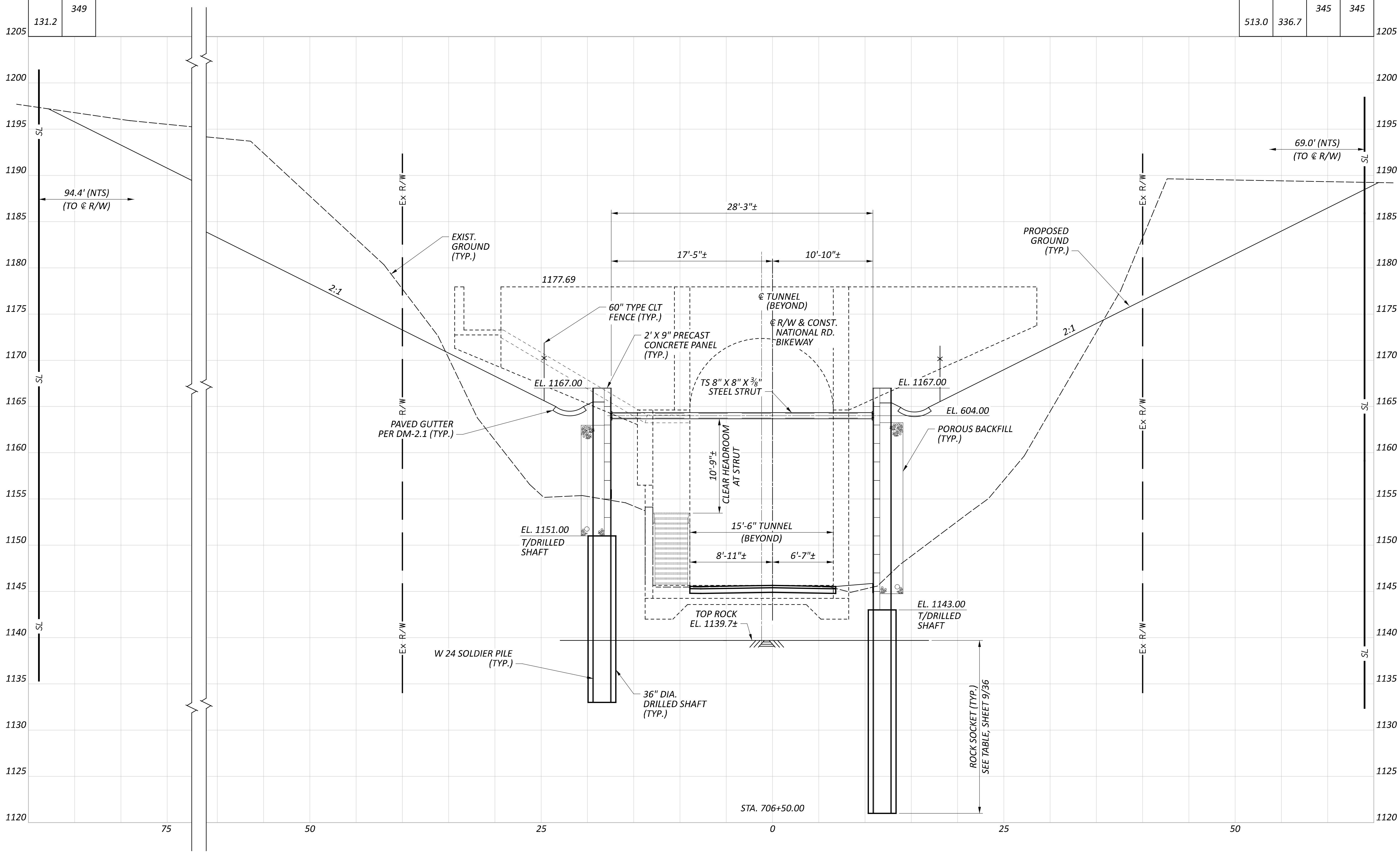
PLATE 18

BEL-NATIONAL RD. BIKEWAY

MODEL: 706+25 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:58 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SEEDING	
WIDTH	AREA
FT.	S.Y.
131.2	349

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
513.0	336.7	345	345



BEL - NATIONAL ROAD BIKEWAY
STA. 706+50 - SOLDIER PILE WALL (NORTH)

BEL-NATIONAL RD. BIKEWAY

MODEL: 706+50 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:58 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER

REVIEWER JDH 2-27-23

PROJECT ID 108774

SUBSET 24 TOTAL 36

SHEET 54 TOTAL 83

PLATE 19

SEEDING	
WIDTH	AREA
FT.	S.Y.
138.2	247

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
701.6	155.3	371	150

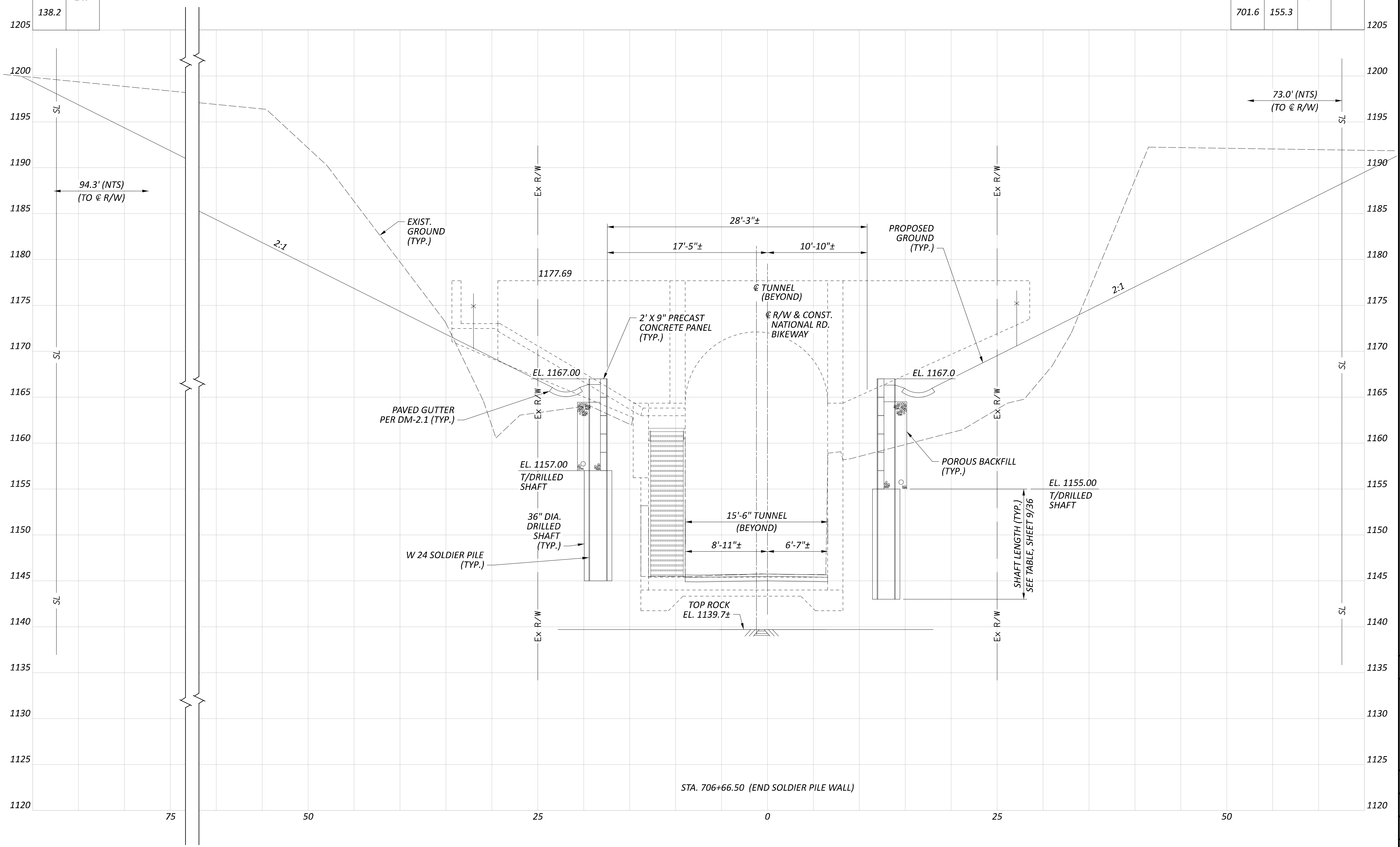


PLATE 20

BEL-NATIONAL RD. BIKEWAY

MODEL: 706+66.5 Soldier Pile Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:32:59 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

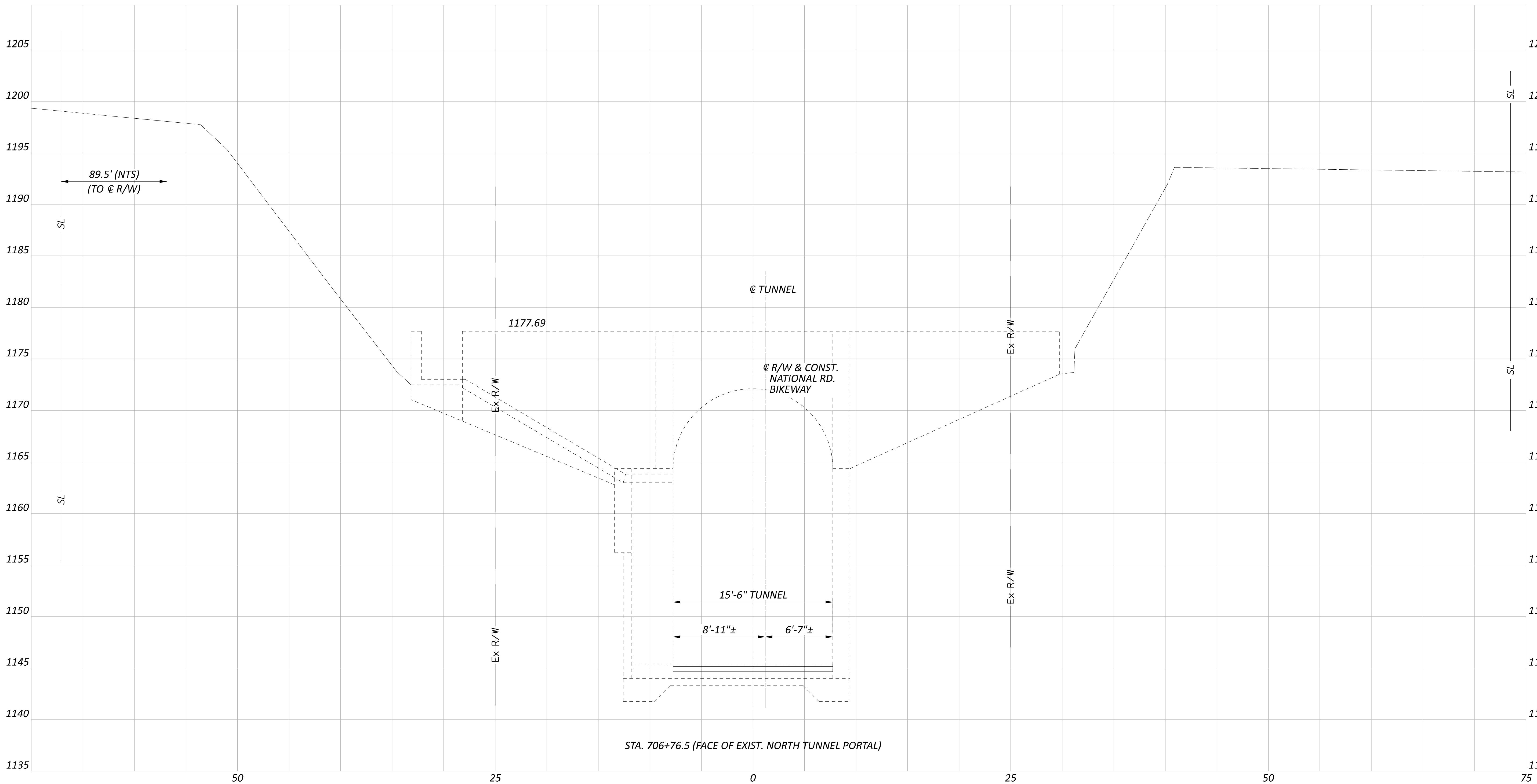
BEL - NATIONAL ROAD BIKEWAY
STA. 706+66. 5 - END SOLDIER PILE WALL (NORTH)

SFN 0701572

DESIGN AGENCY

ms consultants. inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
25	36
SHEET	TOTAL
55	83



BEL-NATIONAL RD. BIKEWAY

MODEL: 706+76.5 F Ex N Tunnel Portal PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:00 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL - NATIONAL ROAD BIKEWAY
STA. 706+66.5 - END SOLDIER PILE WALL (NORTH)

PLATE 21

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER	JDH 2-27-23
PROJECT ID	108774
SUBSET 26	TOTAL 36
SHEET 56	TOTAL 83

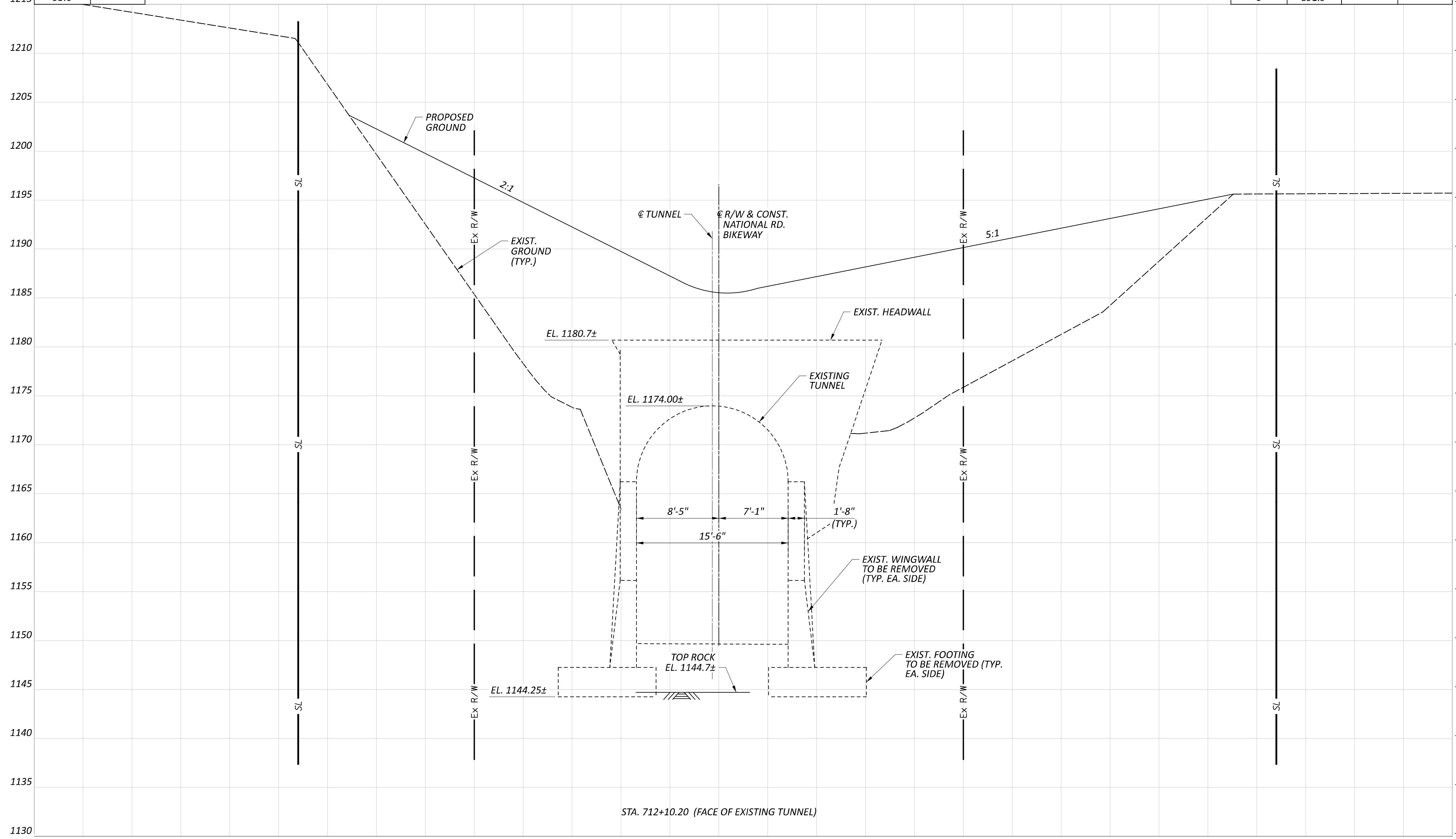
SEEDING	
WIDTH (FT)	AREA (S.Y.)
0	0

STA. 711+75.00 (NOT SHOWN)

AREA		VOLUME	
CUT (S.F.)	FILL (S.F.)	CUT (C.Y.)	FILL (C.Y.)
0	0	0	0

SEEDING	
WIDTH (FT)	AREA (S.Y.)
95.6	187

AREA		VOLUME	
CUT (S.F.)	FILL (S.F.)	CUT (C.Y.)	FILL (C.Y.)
0	891.9	0	581



STA. 712+10.20 (FACE OF EXISTING TUNNEL)

BEL - NATIONAL ROAD BIKEWAY
STA. 712+10.2 - FACE OF EXISTING TUNNEL (SOUTH)

SFN 0701572

DESIGN AGENCY: ms consultants, inc.

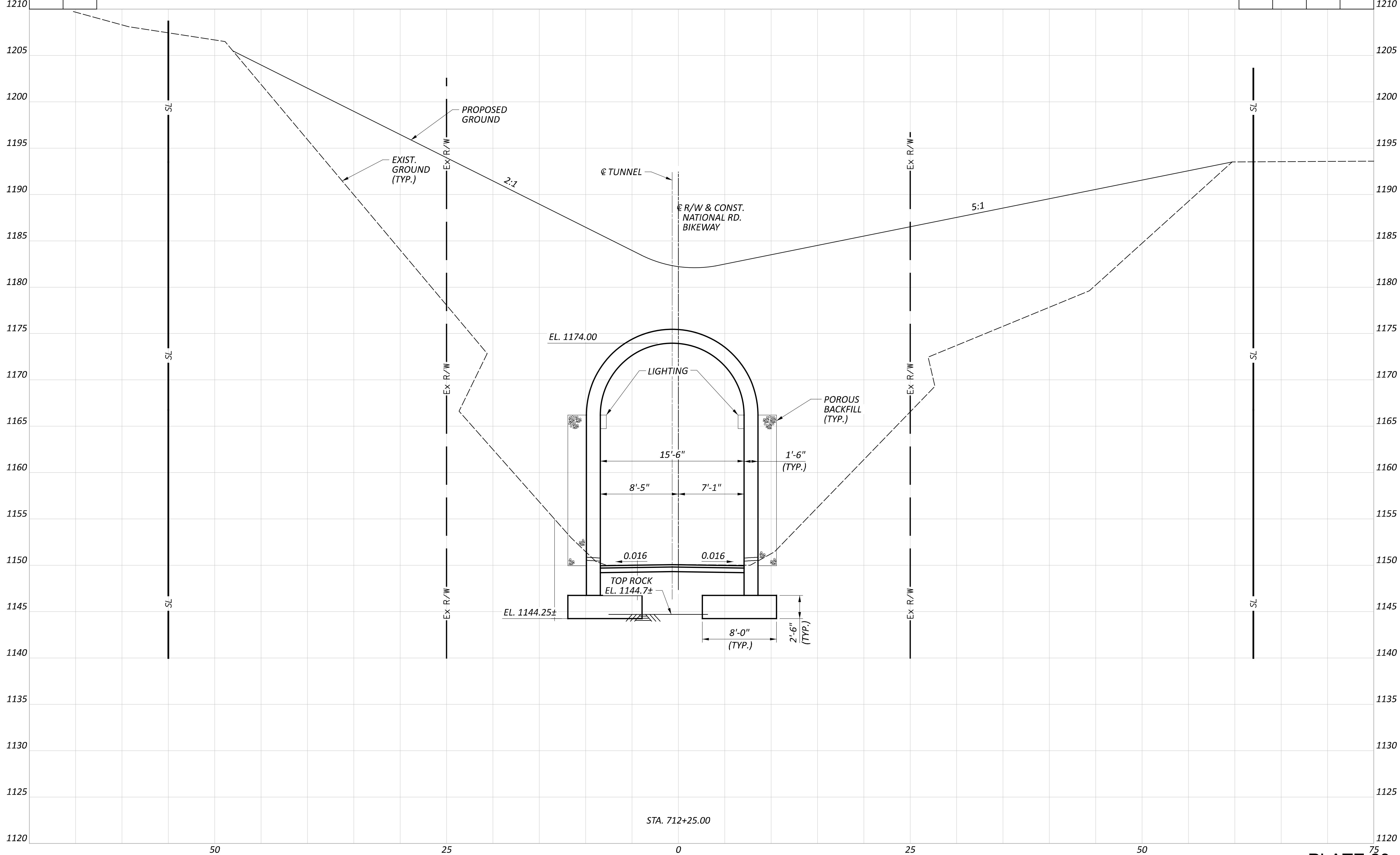
DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
27	36
SHEET	TOTAL
57	83

BEL-NATIONAL RD. BIKEWAY

MODEL: 712+10.2 Face of Exist. Tunnel - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:01 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SEEDING	
WIDTH	AREA
FT.	S.Y.
114.3	173

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
0	1520.0	0	661



BEL-NATIONAL RD. BIKEWAY

MODEL: 712+25 Tunnel Extension - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:02 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL - NATIONAL ROAD BIKEWAY
STA. 712+25 - TUNNEL EXTENSION (SOUTH)

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER

REVIEWER JDH 2-27-23

PROJECT ID 108774

SUBSET 28 TOTAL 36

SHEET 58 TOTAL 83

PLATE 23

SEEDING	
WIDTH	AREA
FT.	S.Y.
115.0	318

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
0	1576.1	0	1433

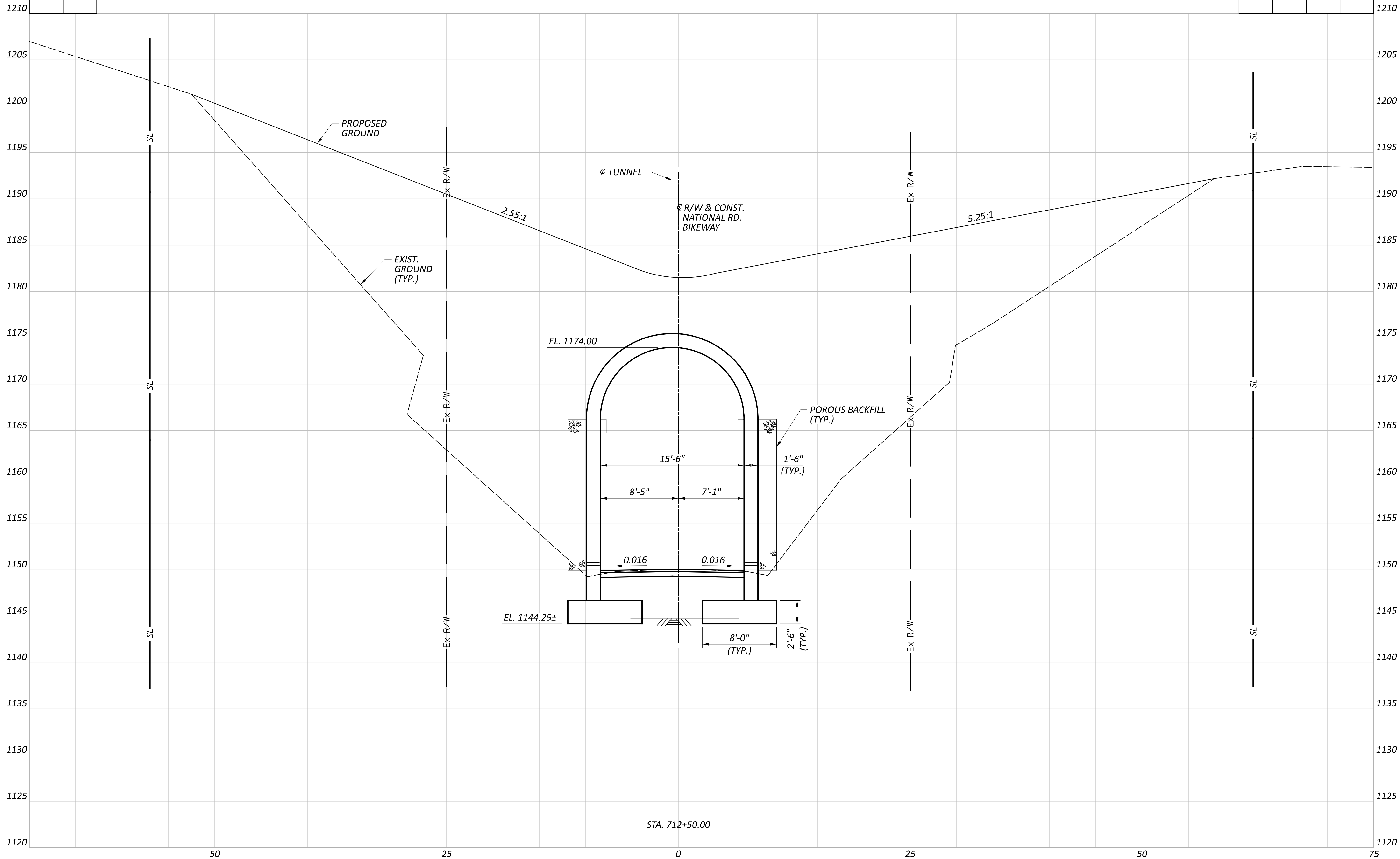


PLATE 24

BEL-NATIONAL RD. BIKEWAY

MODEL: 712+50 Tunnel Extension - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:02 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL - NATIONAL ROAD BIKEWAY
STA. 712+50 - TUNNEL EXTENSION (SOUTH)

SFN 0701572
DESIGN AGENCY
ms consultants, inc.
DESIGNER SJR | CHECKER WER
REVIEWER JDH 2-27-23
PROJECT ID 108774
SUBSET 29 | TOTAL 36
SHEET 59 | TOTAL 83

SEEDING	
WIDTH	AREA
FT.	S.Y.
113.7	318

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
0	1357.5	0	1358

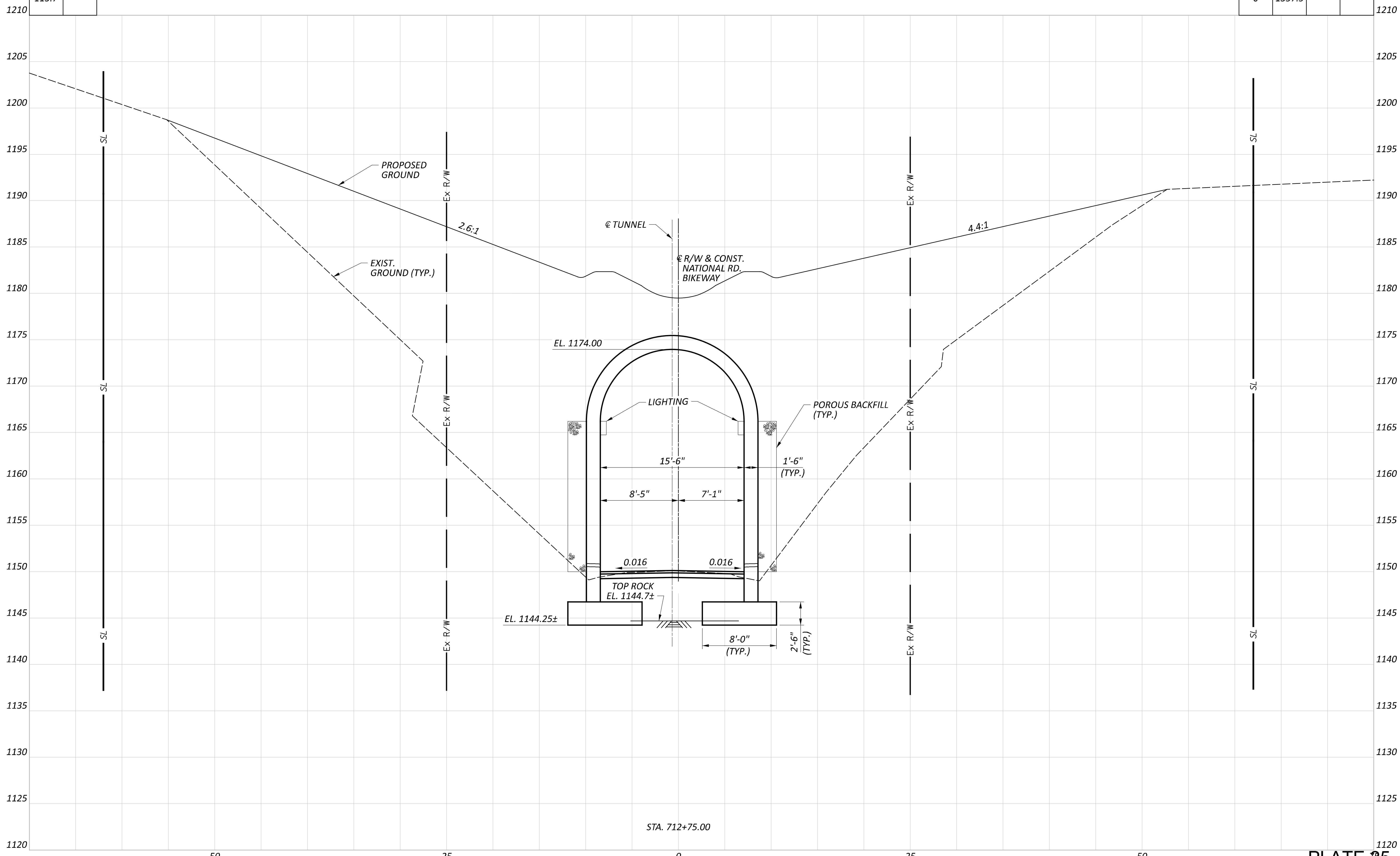


PLATE 25

BEL - NATIONAL ROAD BIKEWAY
STA. 712+75 - TUNNEL EXTENSION (SOUTH)

BEL-NATIONAL RD. BIKEWAY

MODEL: 712+75 Tunnel Extension - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:03 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SFN 0701572
DESIGN AGENCY
ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
30	36
SHEET	TOTAL
60	83

SEEDING	
WIDTH	AREA
FT.	S.Y.
107.1	307

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
19.2	766.9	9	984

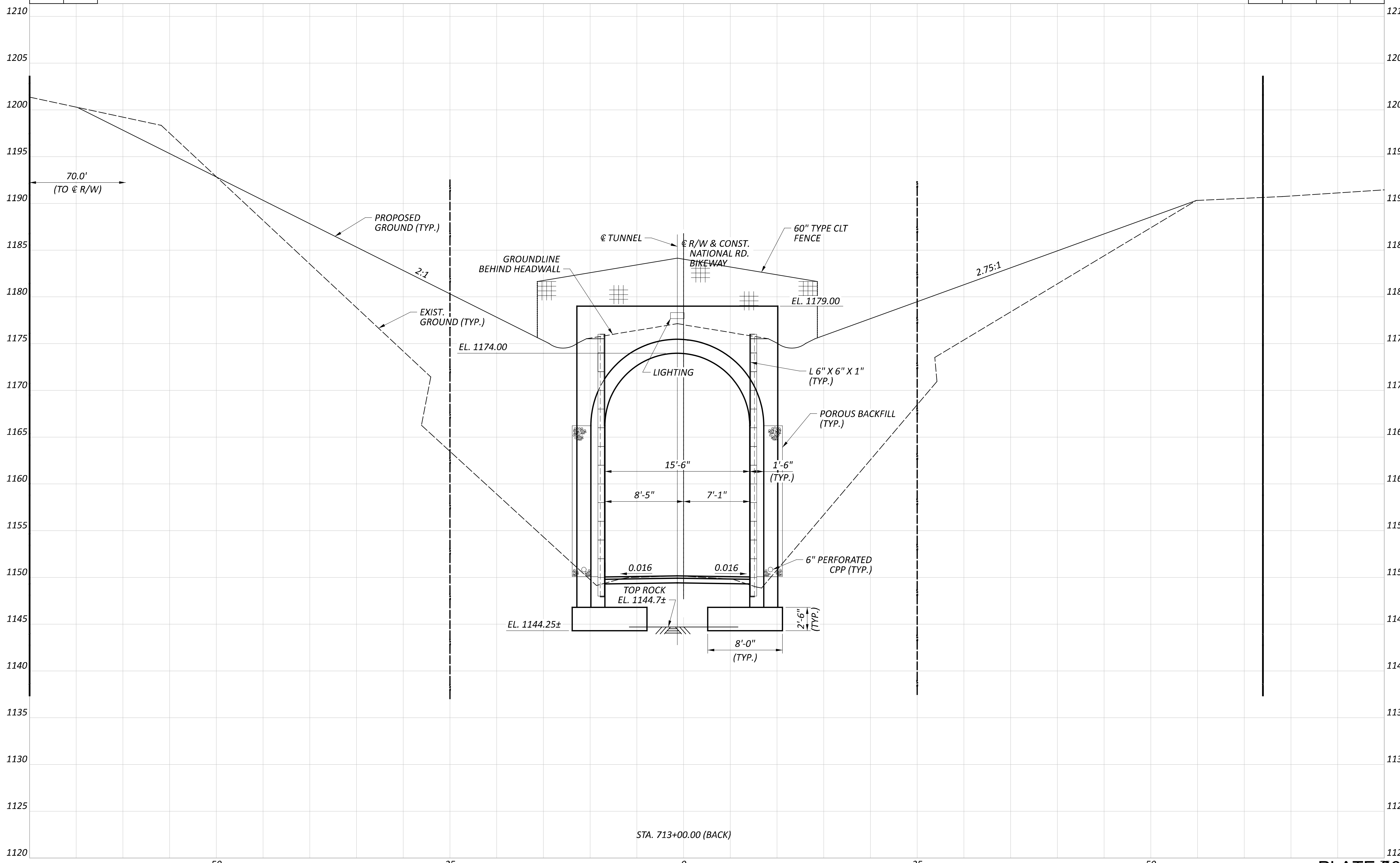


PLATE 26

BEL - NATIONAL ROAD BIKEWAY
STA. 713+00 - END TUNNEL EXTENSION (SOUTH)

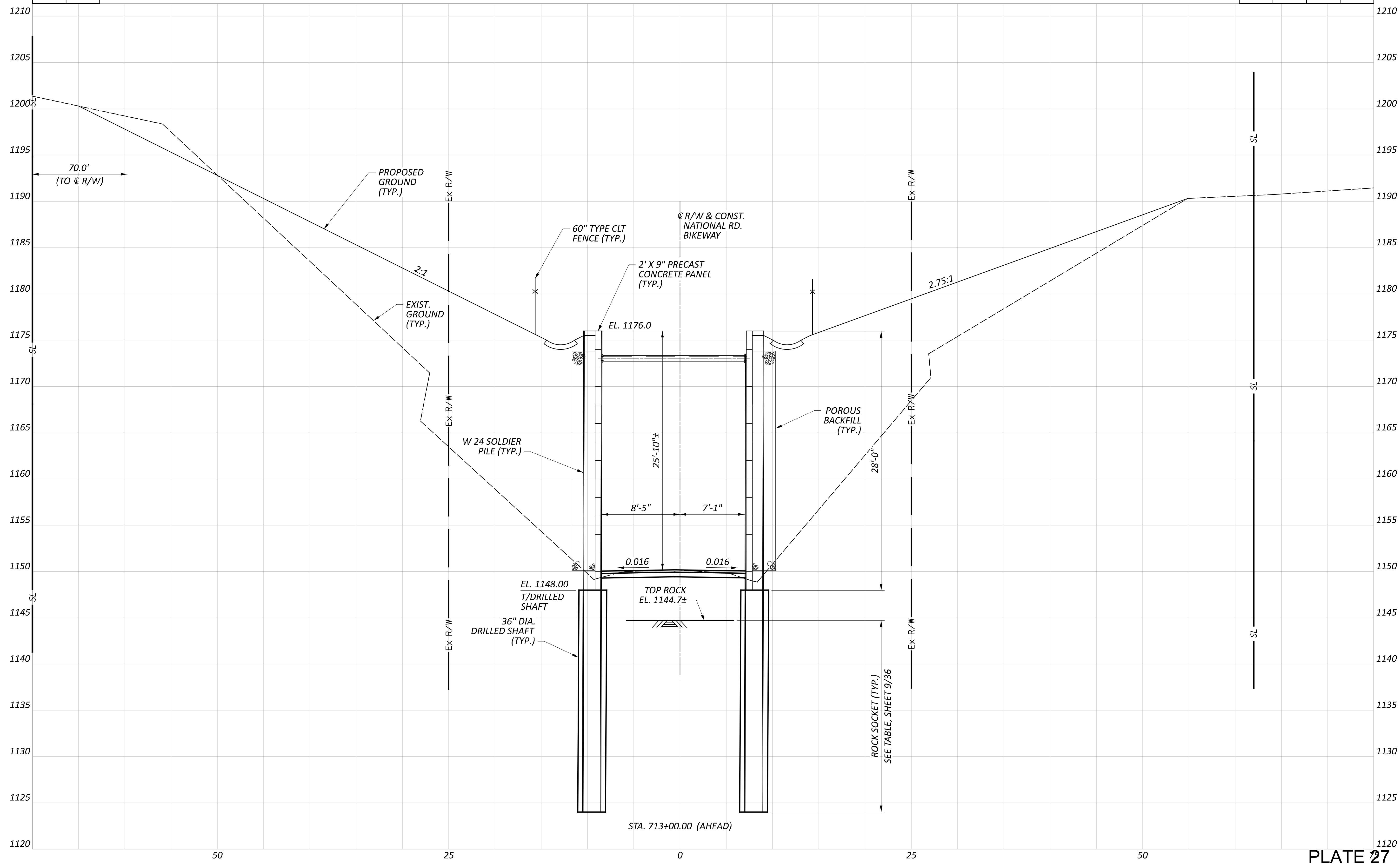
BEL-NATIONAL RD. BIKEWAY

MODEL: 713+00 Tunnel Back - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:04 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER JDH	2-27-23
PROJECT ID	108774
SUBSET 31	TOTAL 36
SHEET 61	TOTAL 83

SEEDING	
WIDTH	AREA
FT.	S.Y.
105.8	0

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
19.5	777.3	0	0



BEL-NATIONAL RD. BIKEWAY

MODEL: 713+00 Soldier Wall Ahead - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:04 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

BEL - NATIONAL ROAD BIKEWAY
STA. 713+00 - BEGIN SOLDIER PILE WALL (SOUTH)

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
32	36
SHEET	TOTAL
62	83

PLATE 27

SEEDING	
WIDTH	AREA
FT.	S.Y.
140.7	0

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
363.7	439.0	177	563

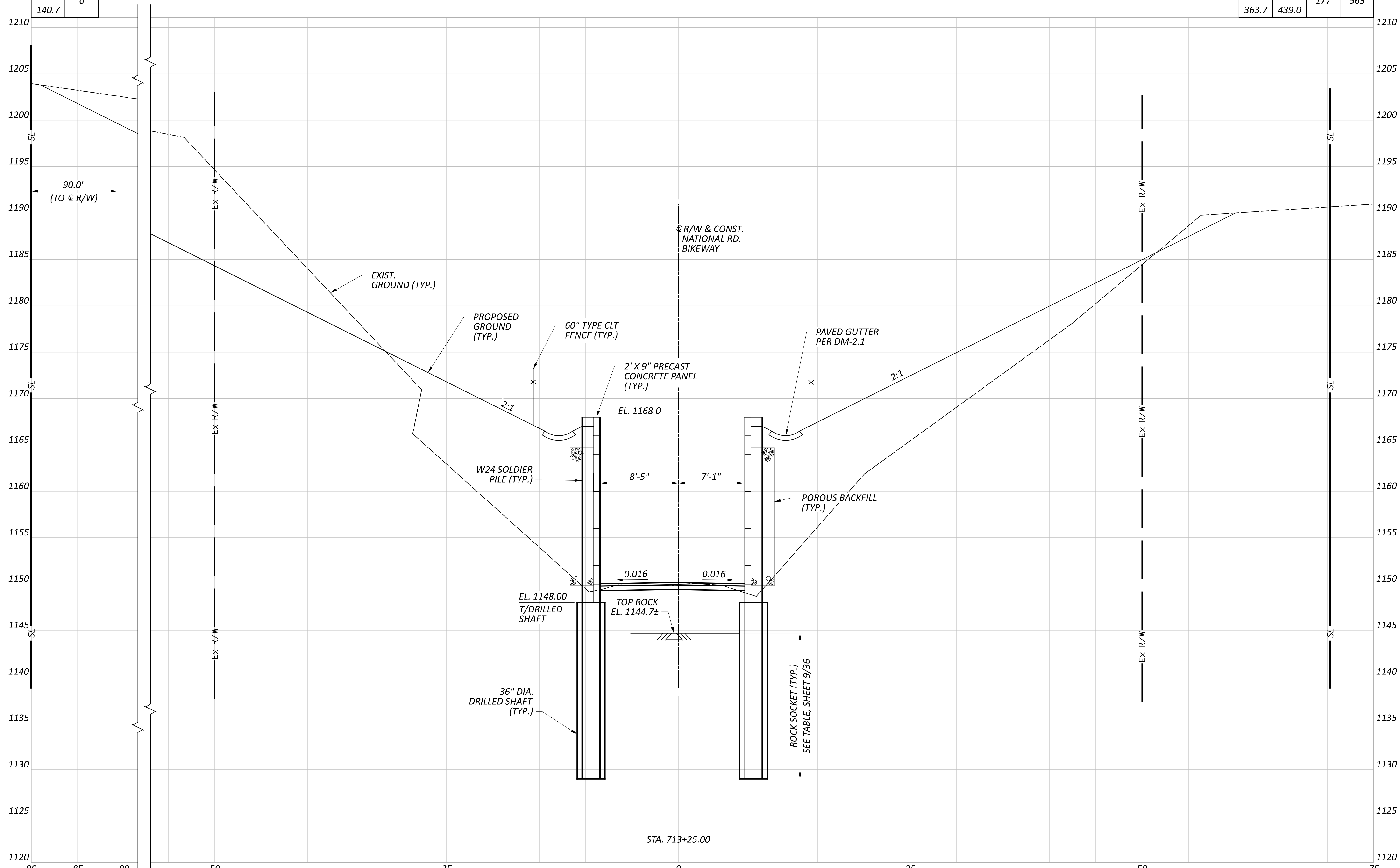


PLATE 28

BEL - NATIONAL ROAD BIKEWAY
STA. 713+25 - SOLDIER PILE WALL (SOUTH)

BEL-NATIONAL RD. BIKEWAY

MODEL: 713+25 Soldier Wall - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:05 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
33	36
SHEET	TOTAL
63	83

SEEDING	
WIDTH	AREA
FT.	S.Y.
179.6	0

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
1009.3	119.3	585	238

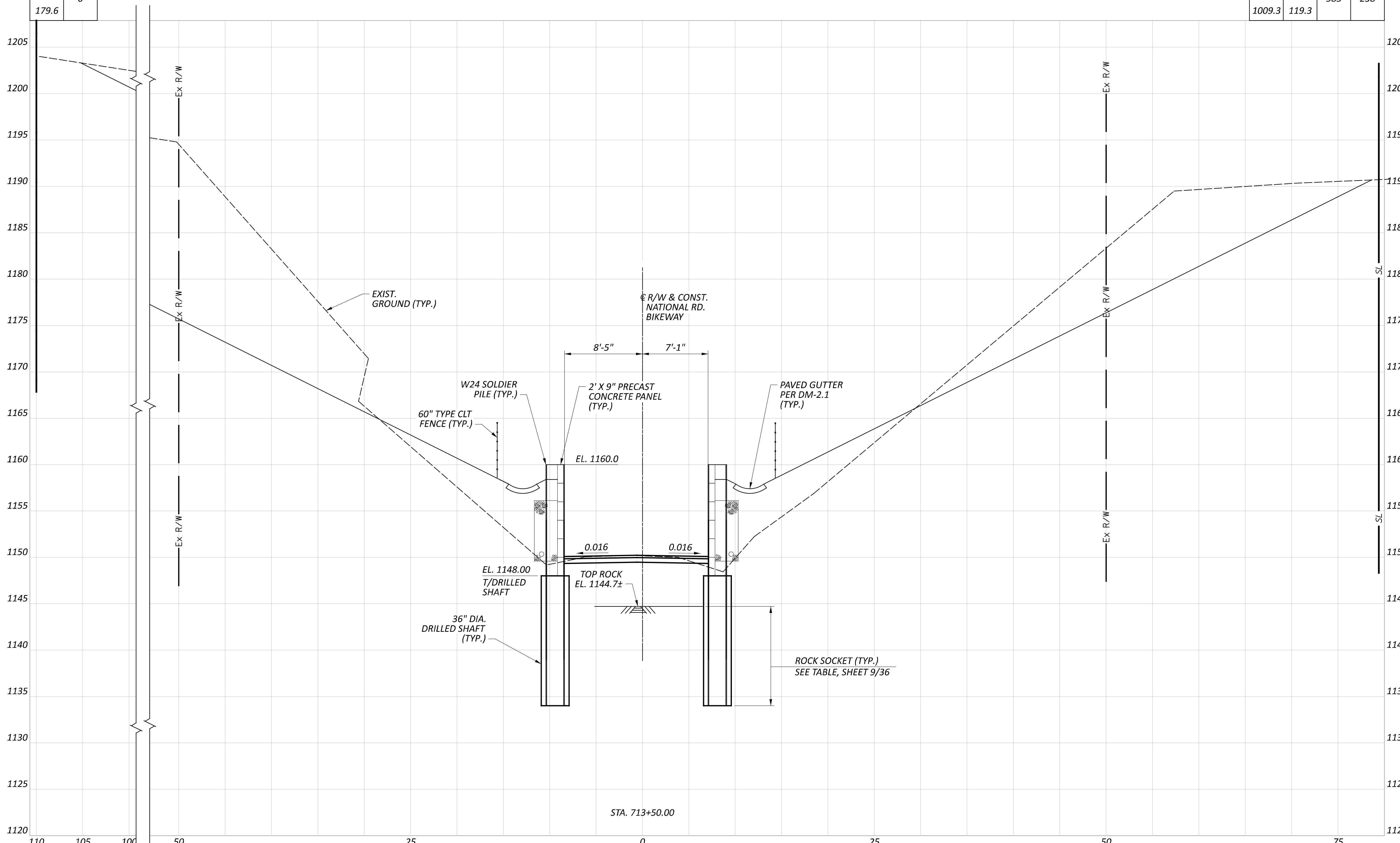


PLATE 29

BEL-NATIONAL RD. BIKEWAY

MODEL: 713+50 Soldier Wall - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:06 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

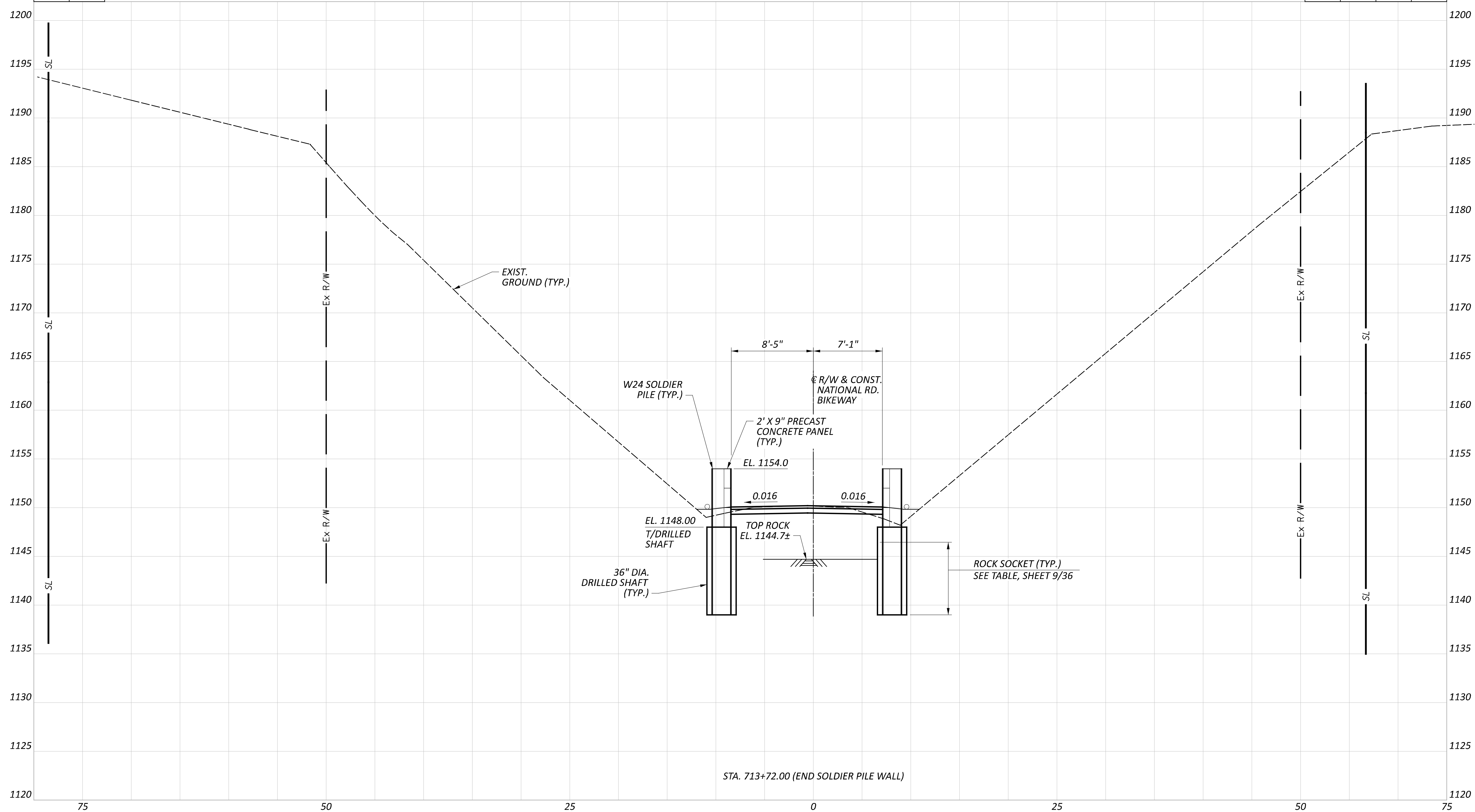
BEL - NATIONAL ROAD BIKEWAY
STA. 713+50 - END SOLDIER PILE WALL (SOUTH)

SFN 0701572
DESIGN AGENCY
ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER JDH	2-27-23
PROJECT ID 108774	
SUBSET 34	TOTAL 36
SHEET 64	TOTAL 83

SEEDING	
WIDTH	AREA
FT.	S.Y.
	249
7.4	

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
		449	56
0	6.6		



BEL - NATIONAL ROAD BIKEWAY
STA. 713+72

BEL-NATIONAL RD. BIKEWAY

MODEL: 713+72 Soldier Wall - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:07 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
35	36
SHEET	TOTAL
65	83

SEEDING	
WIDTH	AREA
FT.	S.Y.
0	0

AREA		VOLUME	
CUT	FILL	CUT	FILL
S.F.	S.F.	C.Y.	C.Y.
0	0	0	0

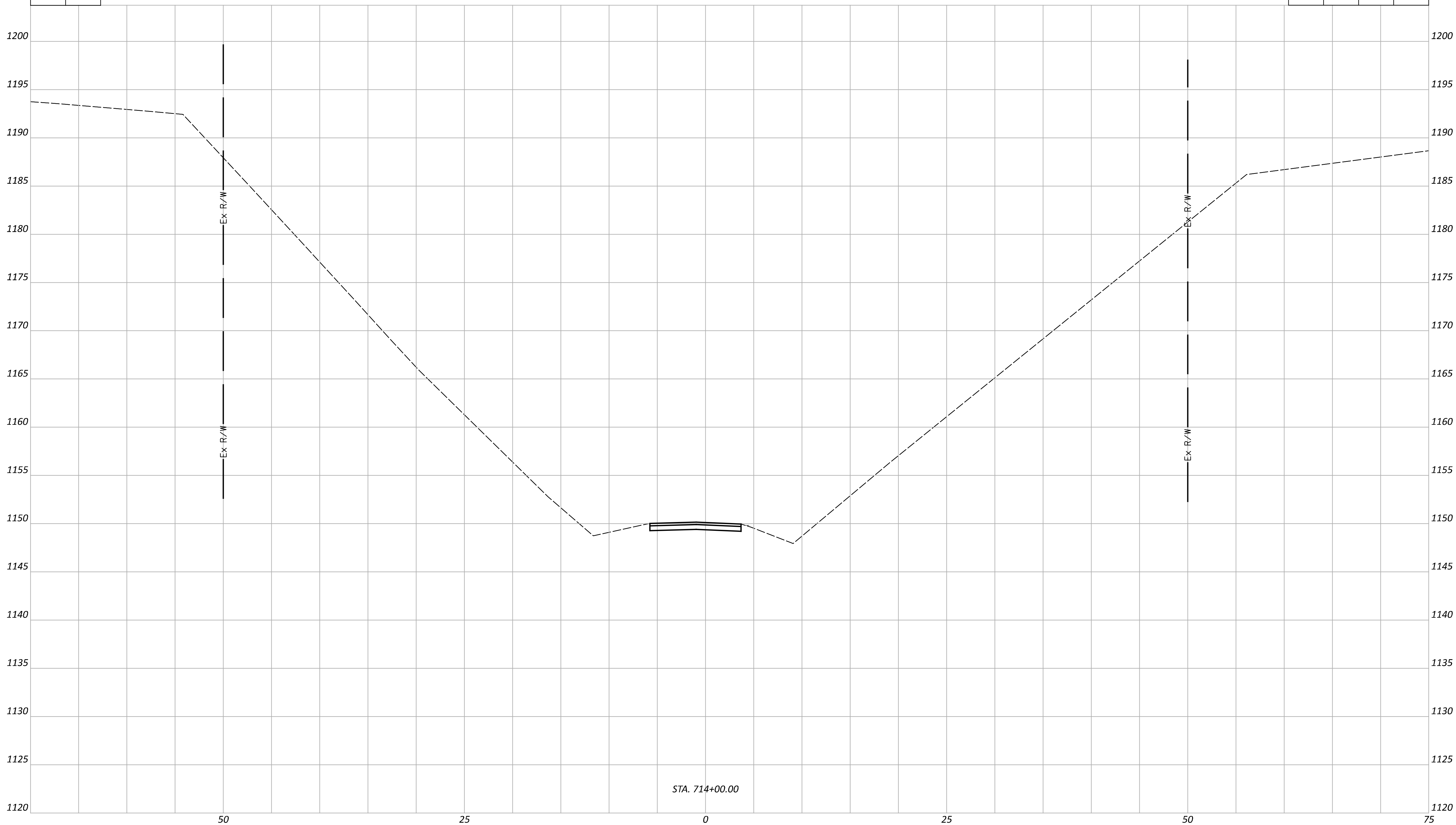


PLATE 31

BEL-NATIONAL RD. BIKEWAY

MODEL: 714+00 Soldier Wall - Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:07 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Roadway\Sheets\108774_XS000.dgn

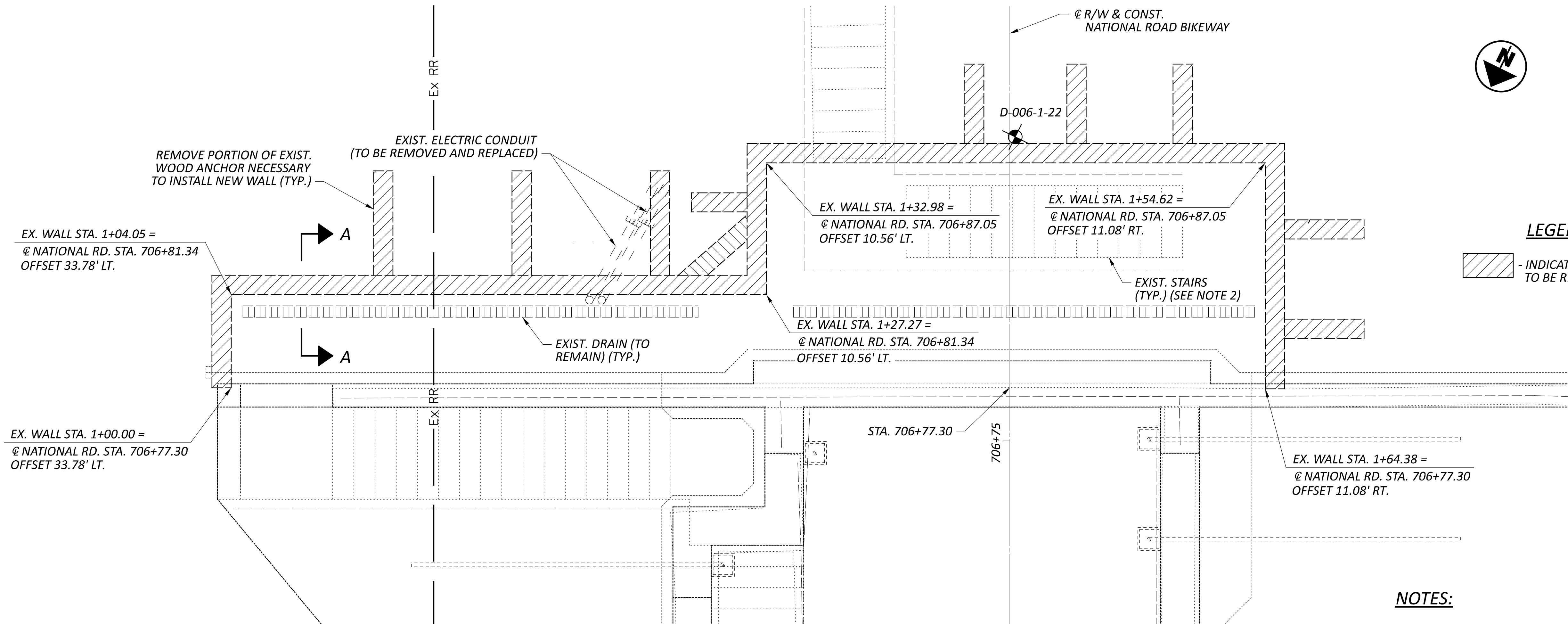
BEL - NATIONAL ROAD BIKEWAY
STA. 714+00

SFN 0701572

DESIGN AGENCY

ms consultants, inc.

DESIGNER	CHECKER
SJR	WER
REVIEWER	
JDH	2-27-23
PROJECT ID	
108774	
SUBSET	TOTAL
36	36
SHEET	TOTAL
66	83



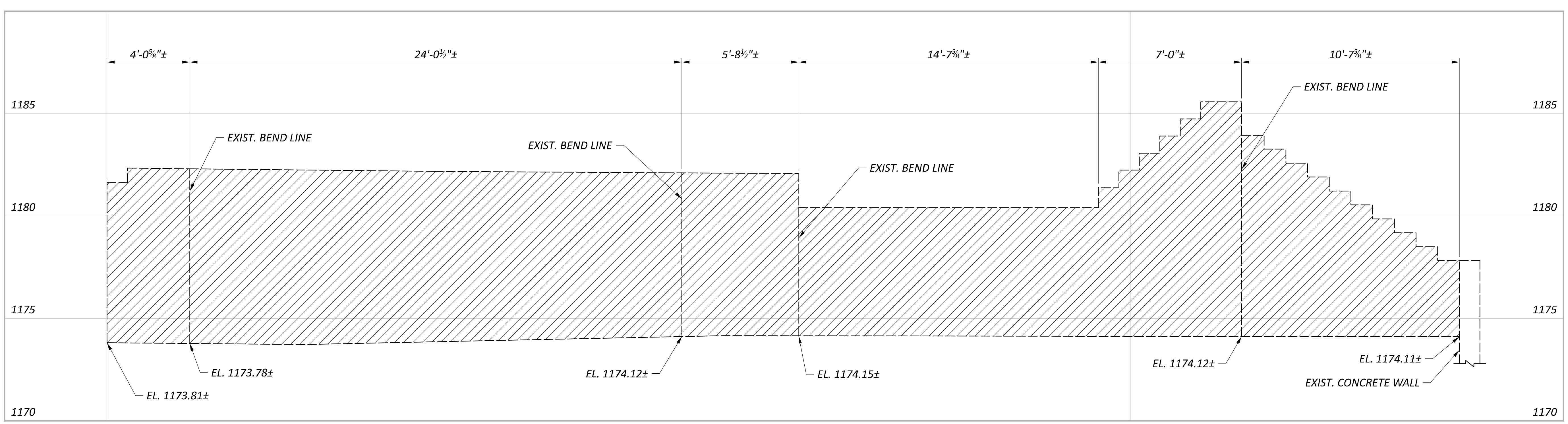
LEGEND:

- INDICATES EXISTING TIMBER RETAINING WALL TO BE REMOVED

PLAN

NOTES:

1. FOR SECTION A-A, SEE SHEET 5/7.
2. EXISTING STAIRS ARE TO BE REMOVED, PAINTED AND RE-INSTALLED TO FACILITATE THE REMOVAL OF THE EXISTING TIMBER RETAINING WALL AND INSTALLATION OF THE NEW PREFABRICATED MODULAR RETAINING WALL.



ELEVATION
(DEVELOPED)

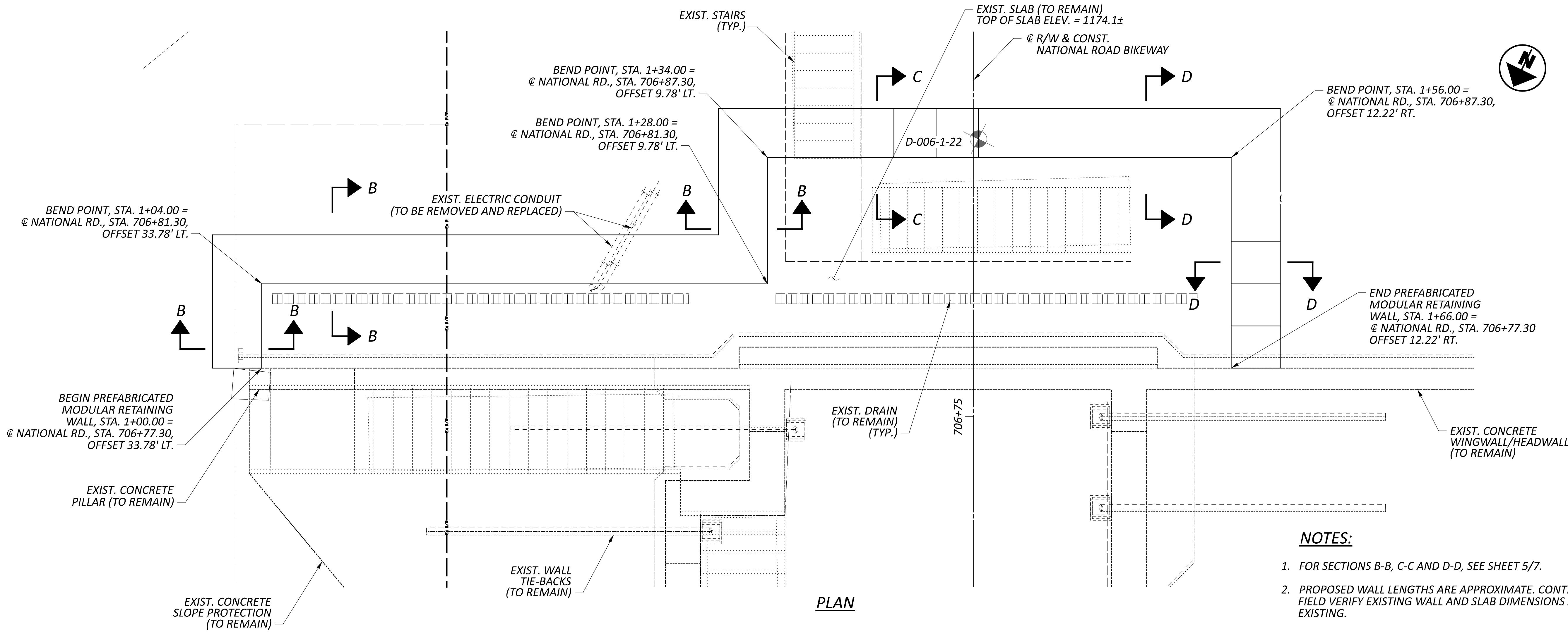
PLAN AND ELEVATION (EXISTING)
BEL-NATIONAL ROAD BIKEWAY
LOWER PLAZA OVERLOOK AND STAIR RENOVATION

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER	JDH 2-27-23
PROJECT ID	108774
SUBSET 3	TOTAL 7
SHEET 69	TOTAL 83

PLATE 32

BEL-NATIONAL RD. BIKEWAY

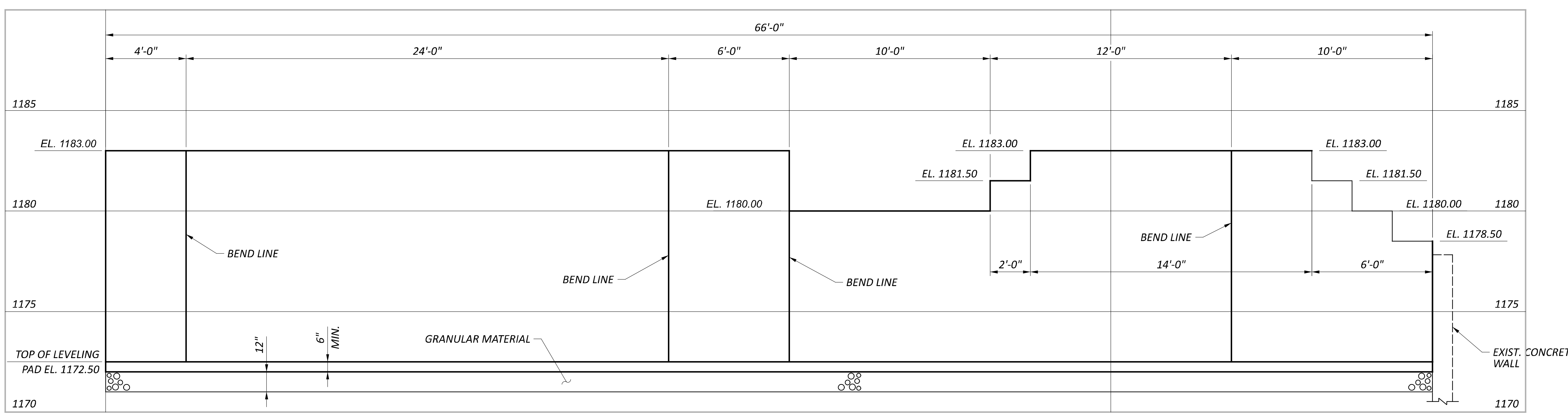
MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:13 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SG001.dgn



PLAN

NOTES:

1. FOR SECTIONS B-B, C-C AND D-D, SEE SHEET 5/7.
2. PROPOSED WALL LENGTHS ARE APPROXIMATE. CONTRACTOR SHALL FIELD VERIFY EXISTING WALL AND SLAB DIMENSIONS AND MATCH EXISTING.



ELEVATION
(DEVELOPED)

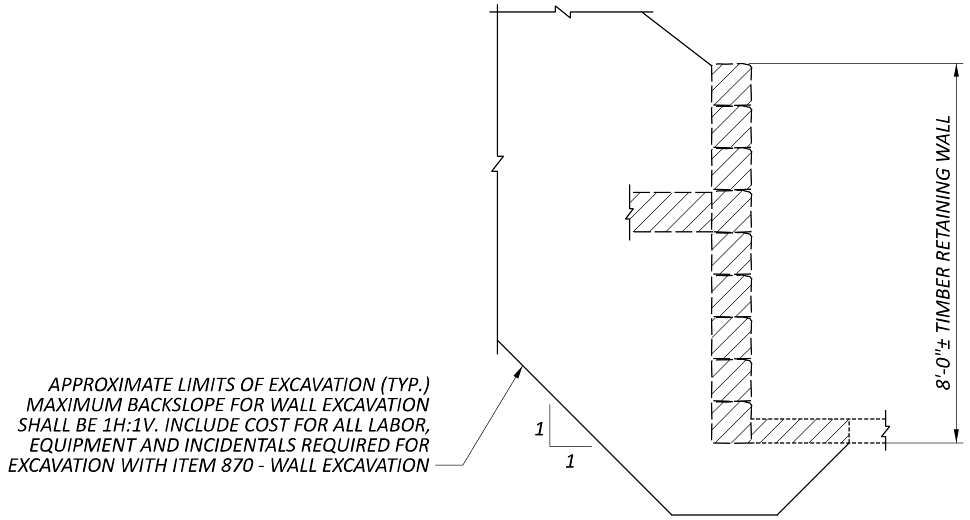
PLAN AND ELEVATION (PROPOSED)
BEL-NATIONAL ROAD BIKEWAY
LOWER PLAZA OVERLOOK AND STAIR RENOVATION

BEL-NATIONAL RD. BIKEWAY

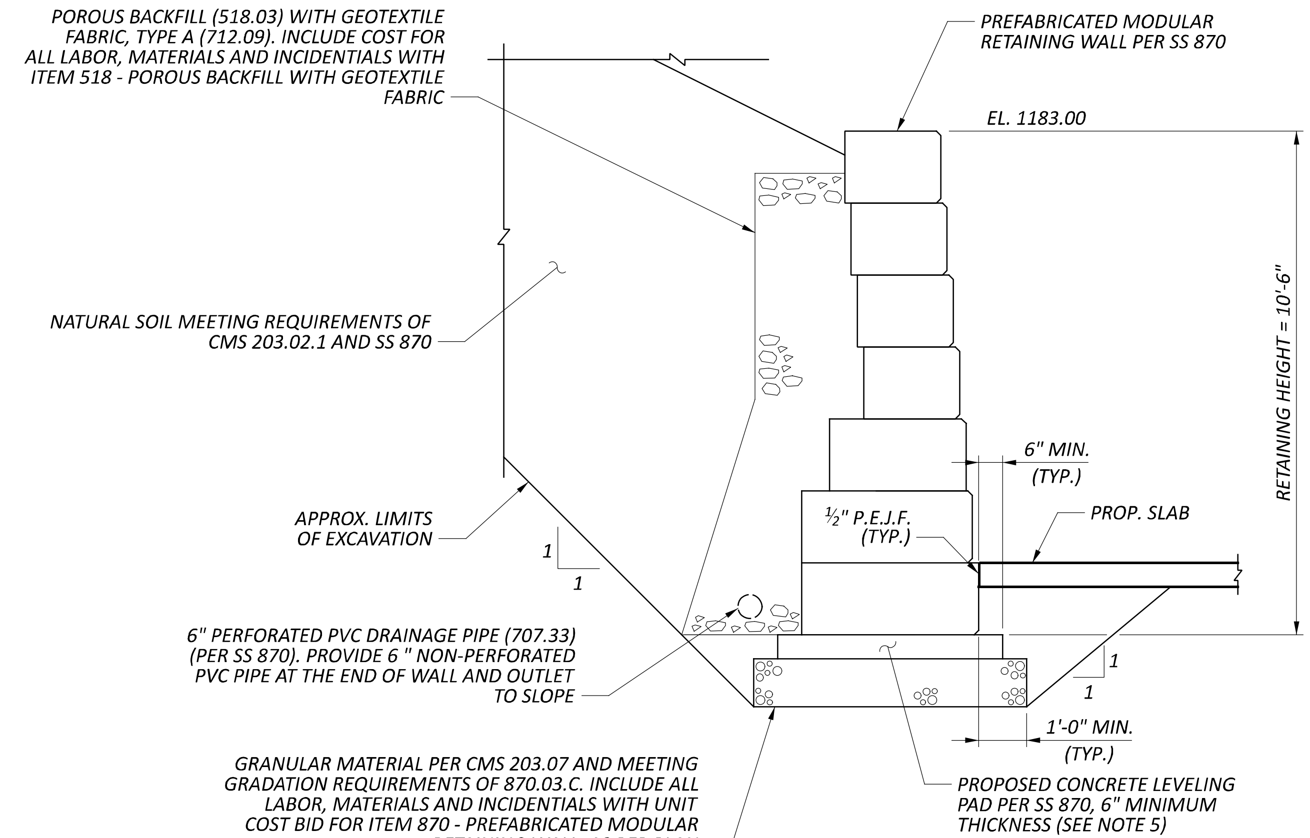
MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:14 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SG002.dgn

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER JDH	2-27-23
PROJECT ID	108774
SUBSET 4	TOTAL 7
SHEET 70	TOTAL 83

PLATE 33



SECTION A-A
(TYPICAL TIMBER WALL REMOVAL)



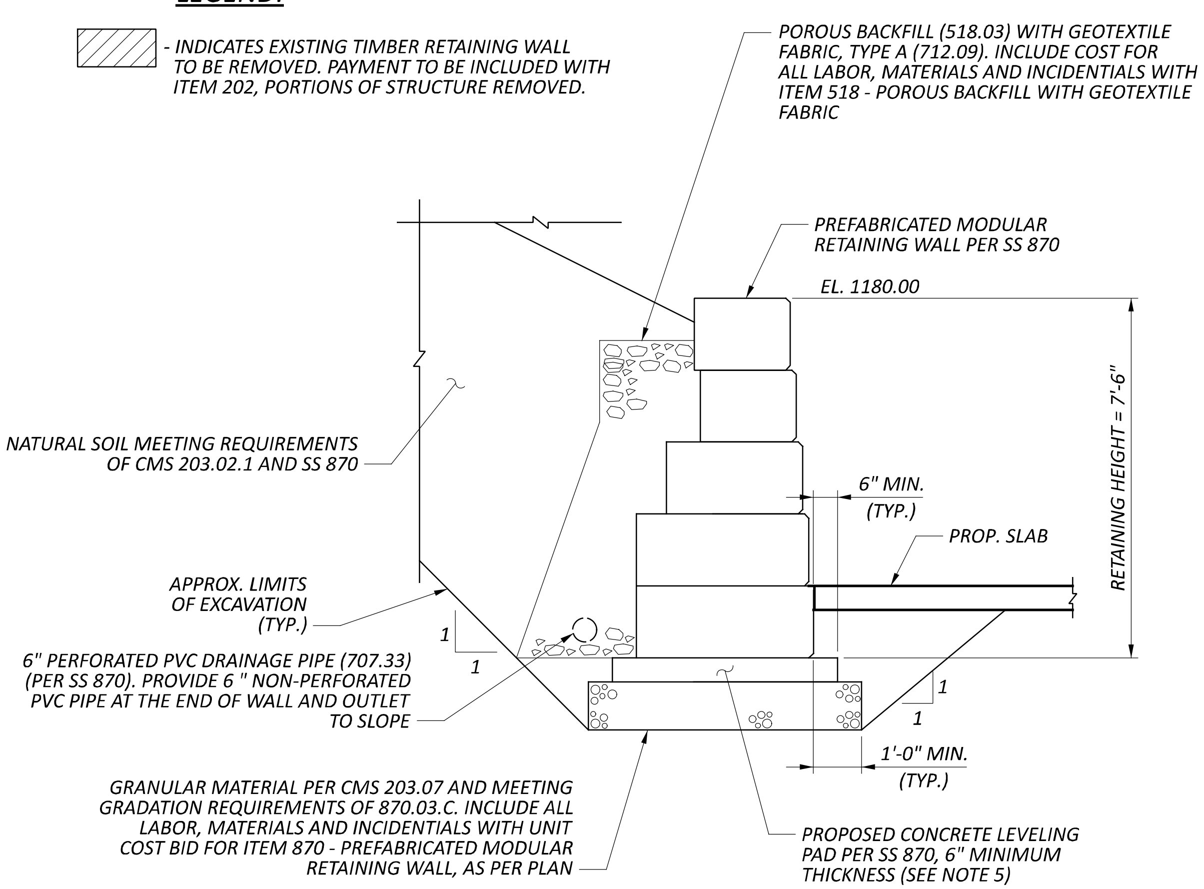
SECTION B-B

NOTES:

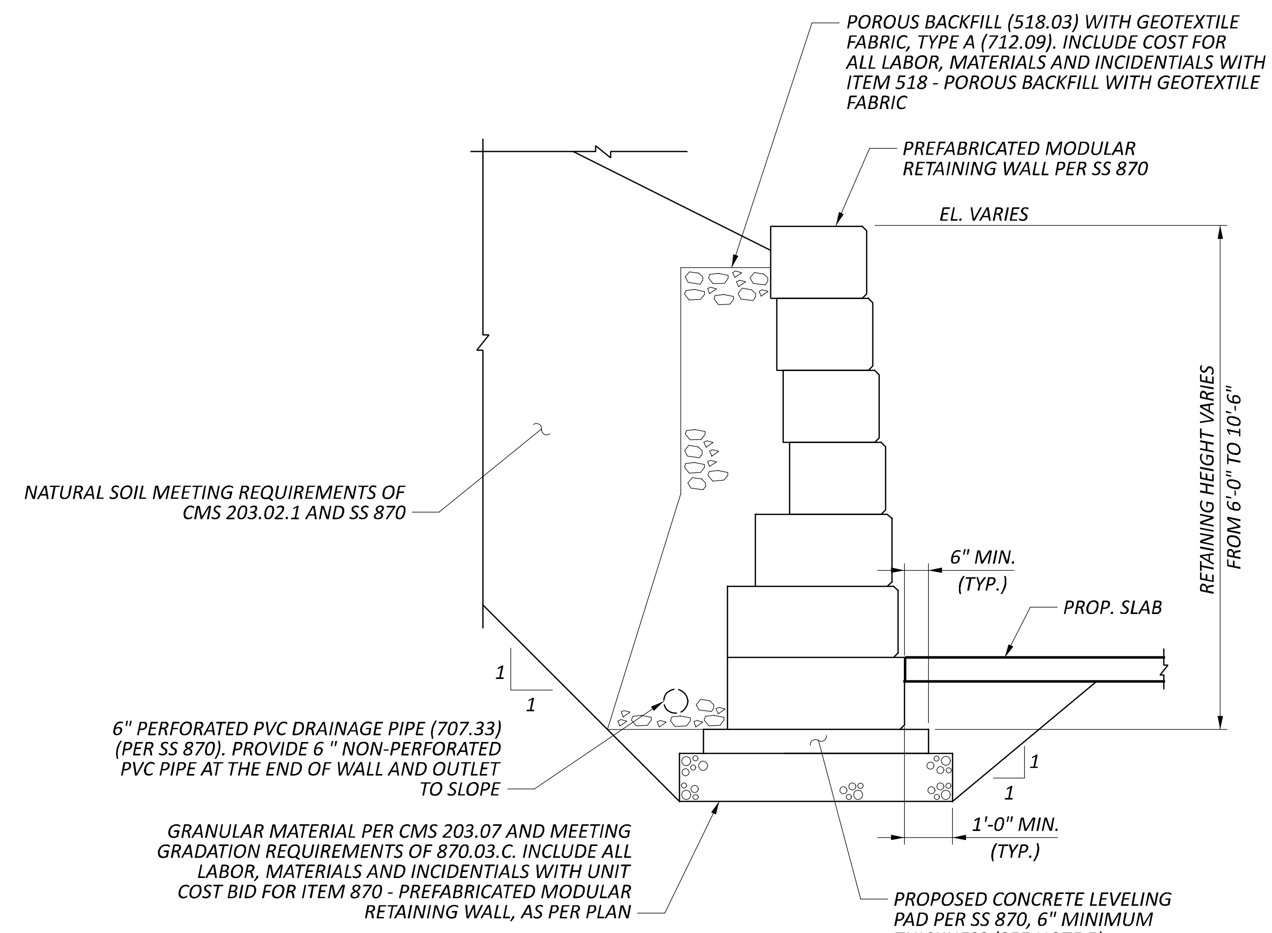
1. SEE SHEET 4/7 FOR PLAN OF PREFABRICATED MODULAR BLOCK RETAINING WALL.
2. SEE SHEET 3/7 FOR LOCATION OF SECTION A-A.
3. SEE SHEET 4/7 FOR LOCATION OF SECTIONS B-B, C-C AND D-D.
4. PREFABRICATED MODULAR BLOCK RETAINING WALL SYSTEM SHALL BE DESIGNED AND CONSTRUCTED IN ACCORDANCE WITH LRFD 11.11 AND SS870.
5. LEVELING PAD SHALL BE QC1 CONCRETE PER SS870. INCLUDE FOR PAYMENT WITH ITEM - PREFABRICATED MODULAR RETAILING WALL, AS PER PLAN.

LEGEND:

- INDICATES EXISTING TIMBER RETAINING WALL TO BE REMOVED. PAYMENT TO BE INCLUDED WITH ITEM 202, PORTIONS OF STRUCTURE REMOVED.



SECTION C-C



SECTION D-D

PLATE 34

RETAINING WALL SECTIONS
BEL-NATIONAL ROAD BIKEWAY
LOWER PLAZA OVERLOOK AND STAIR RENOVATION

SFN	0701572
DESIGN AGENCY	ms consultants, inc.
DESIGNER SJR	CHECKER WER
REVIEWER JDH	2-27-23
PROJECT ID	108774
SUBSET 5	TOTAL 7
SHEET 71	TOTAL 83

BEL-NATIONAL RD. BIKEWAY

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 7/18/2023 TIME: 11:33:15 AM USER: JPenman
\\msconsultants.com\files\Production\01\60\08388-00\108774\400-Engineering\Structures\SFN_0701572\Sheets\108774_SFN_0701572_SM001.dgn

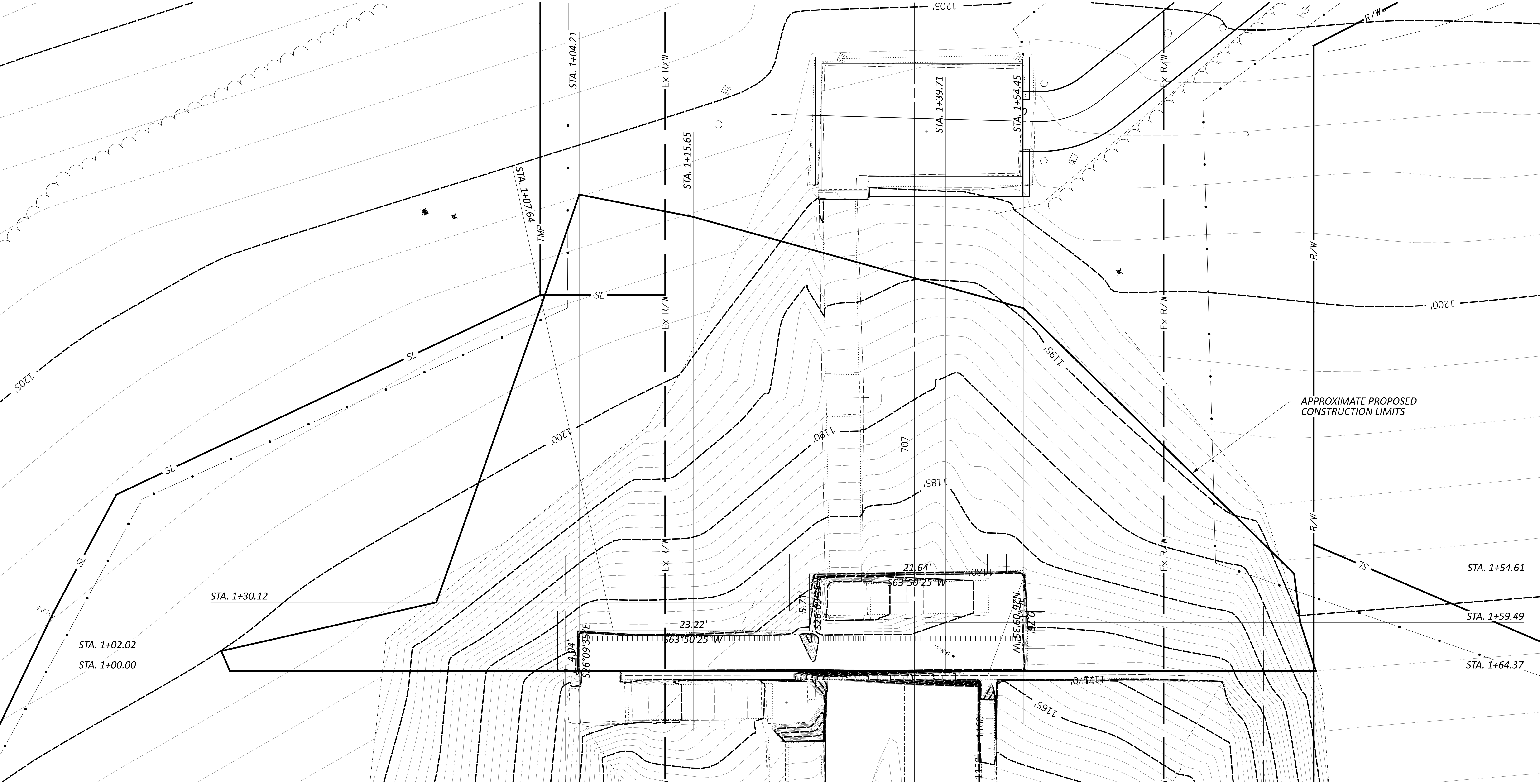
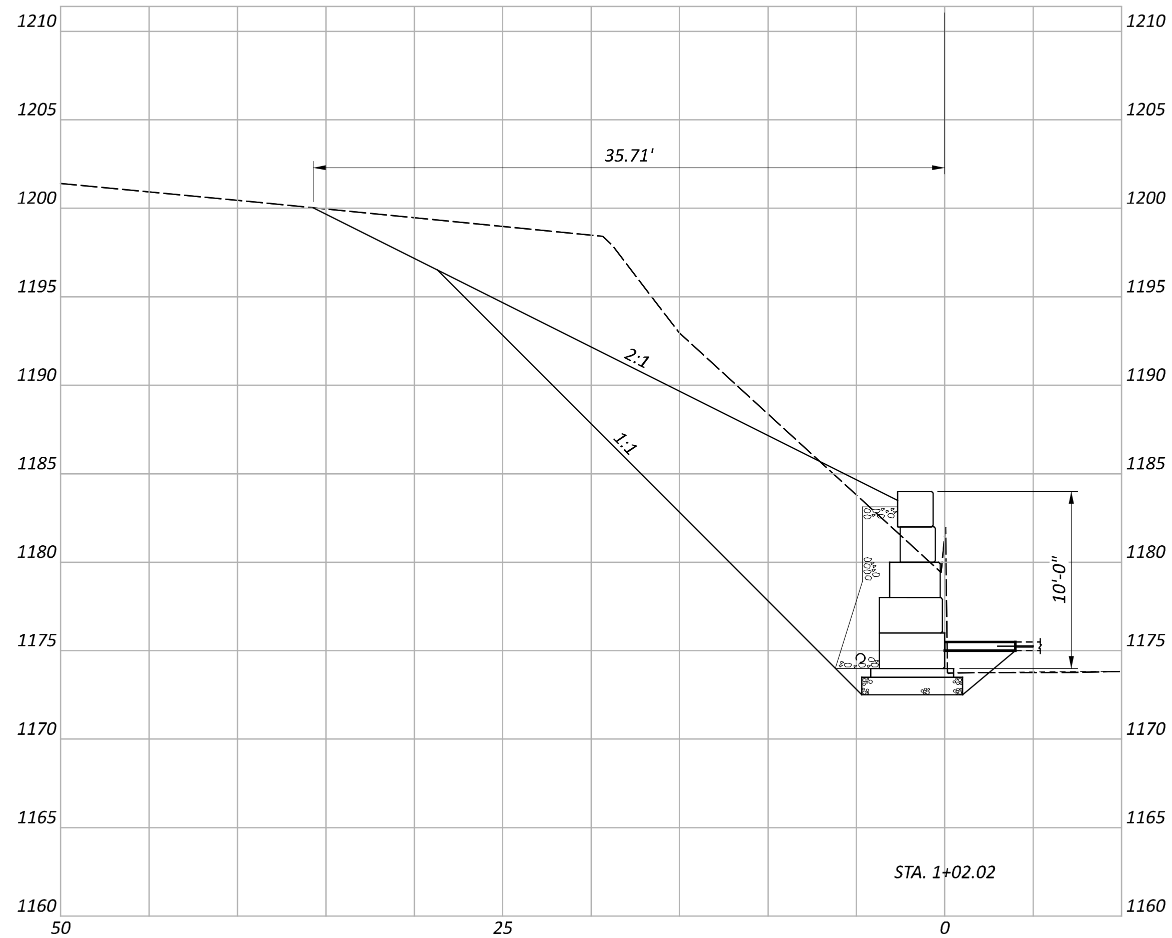
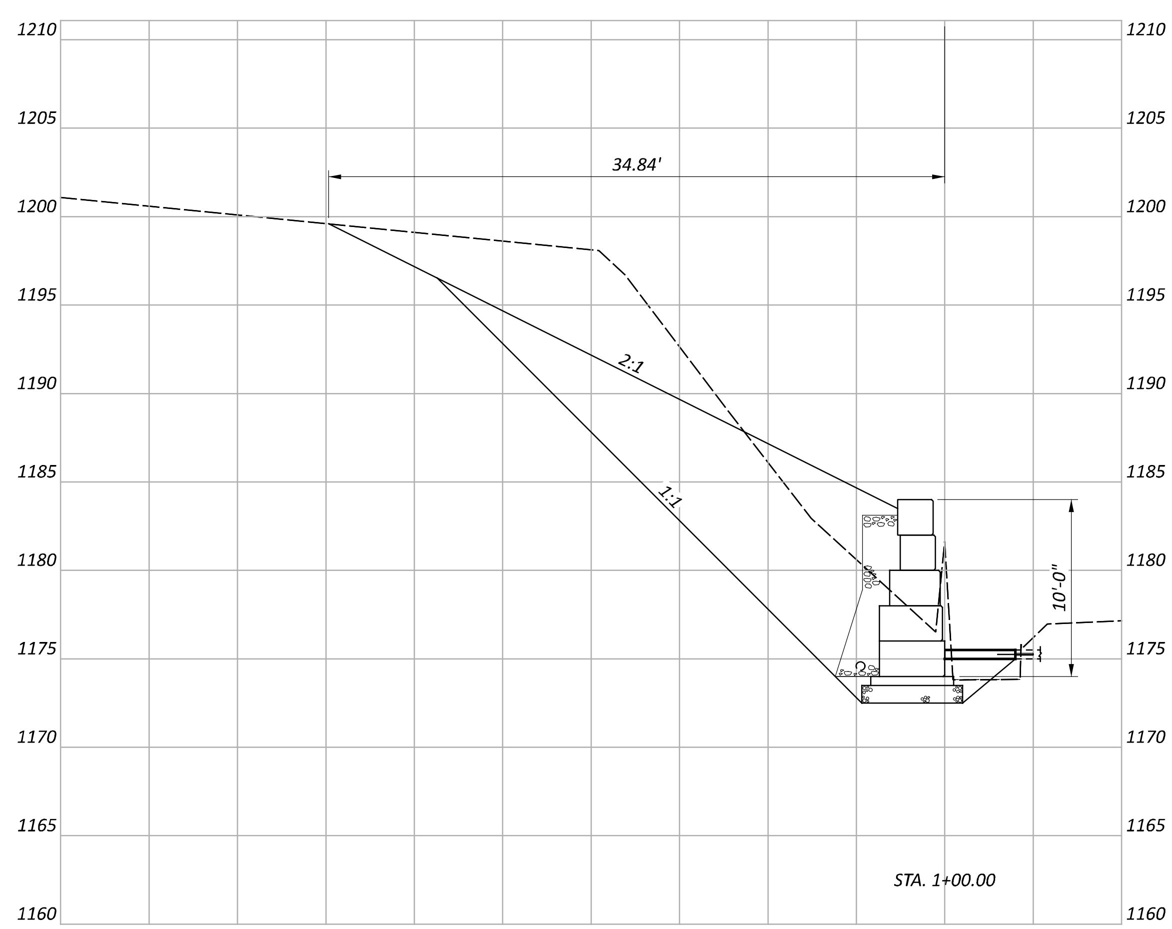

STA. 1+04.21
STA. 1+07.64
STA. 1+15.65
STA. 1+39.71
STA. 1+54.45
Ex R/W
R/W
TMP
SL
1205'
1200'
1195'
1190'
1185'
1180'
1170'
1165'
1160'
1150'
707
APPROXIMATE PROPOSED
CONSTRUCTION LIMITS
STA. 1+30.12
STA. 1+02.02
STA. 1+00.00
STA. 1+54.61
STA. 1+59.49
STA. 1+64.37
21.64'
S63°50'25"W
23.22'
S63°50'25"W
S26°09'35"E
4.04'
5.71'
S26°09'35"E
9.12'
N26°09'35"W

PLATE 35

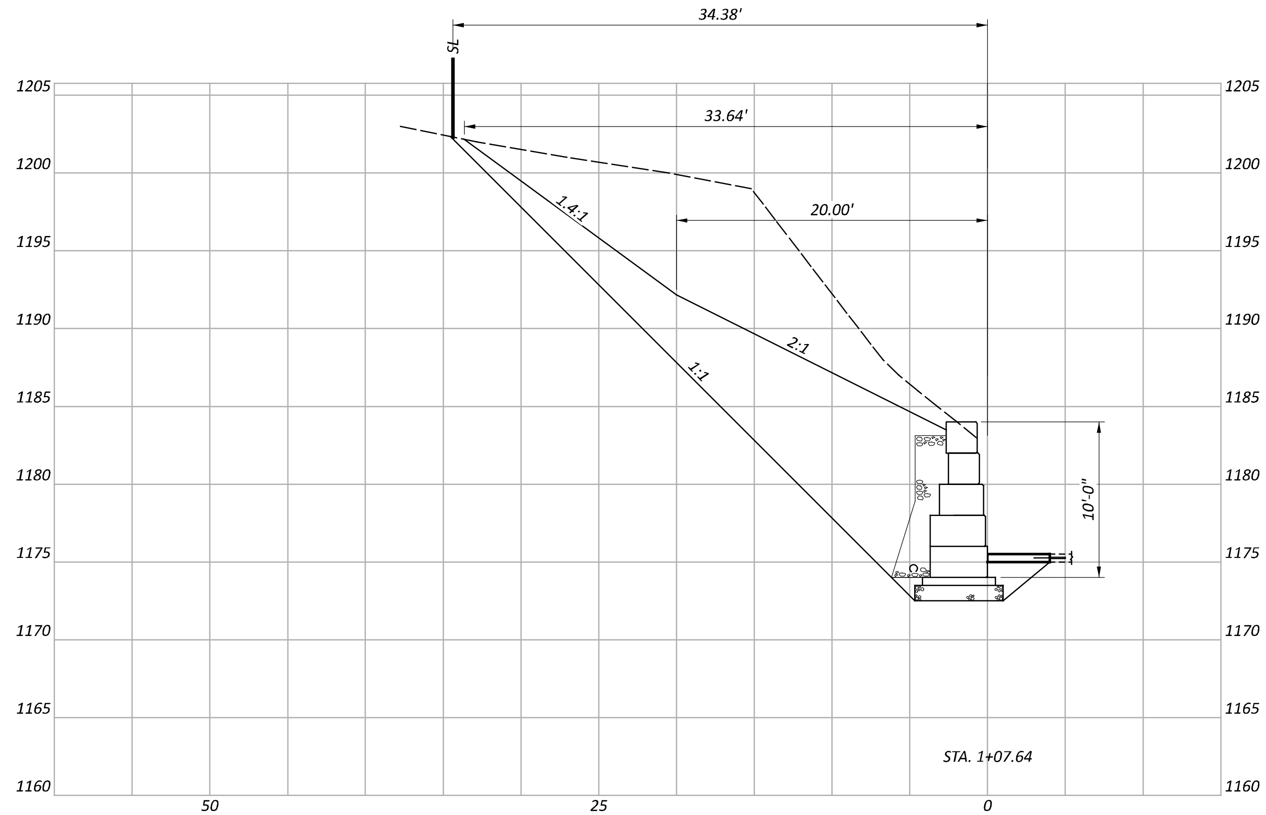


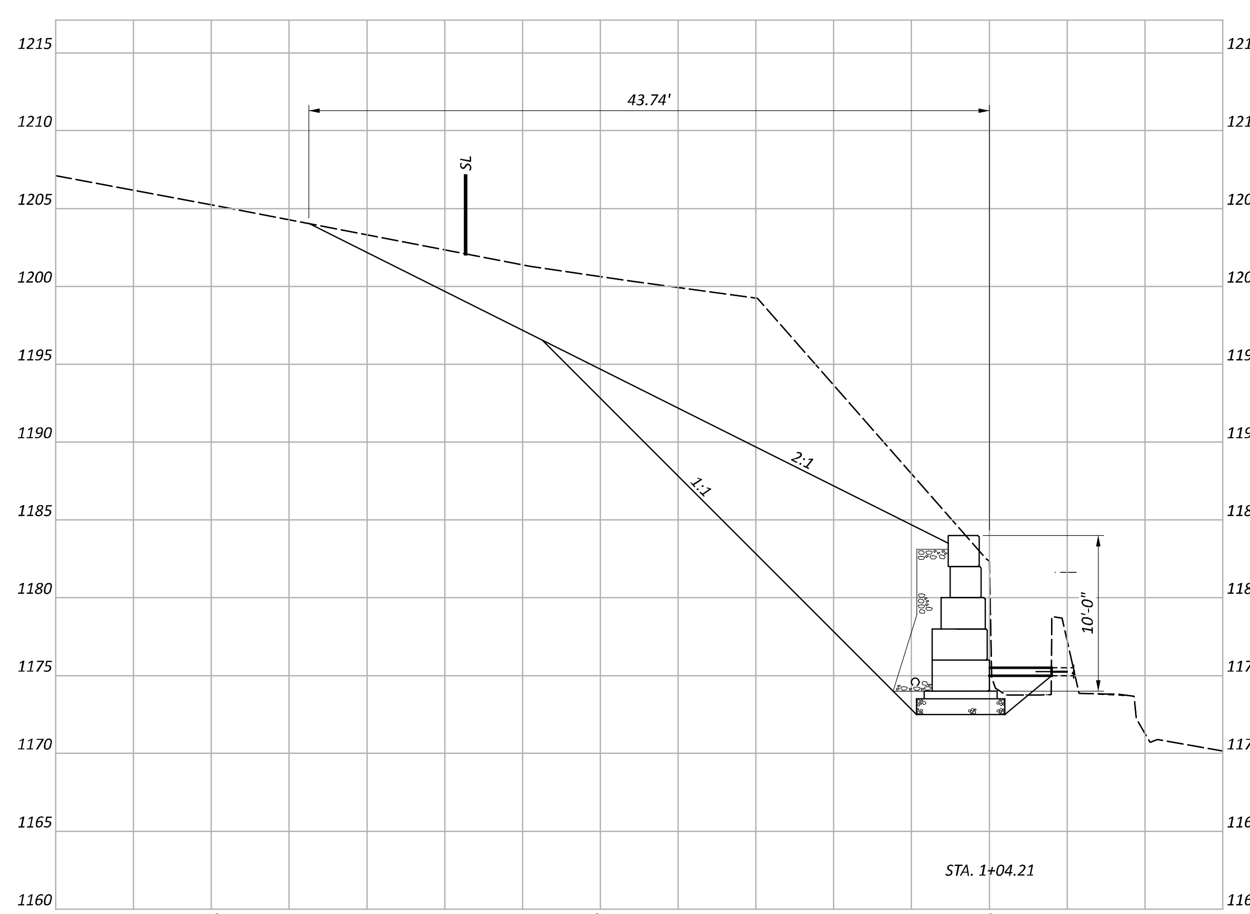
1210
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
35.71'
2:1
1:1
10'-0"
STA. 1+02.02
50
25
0

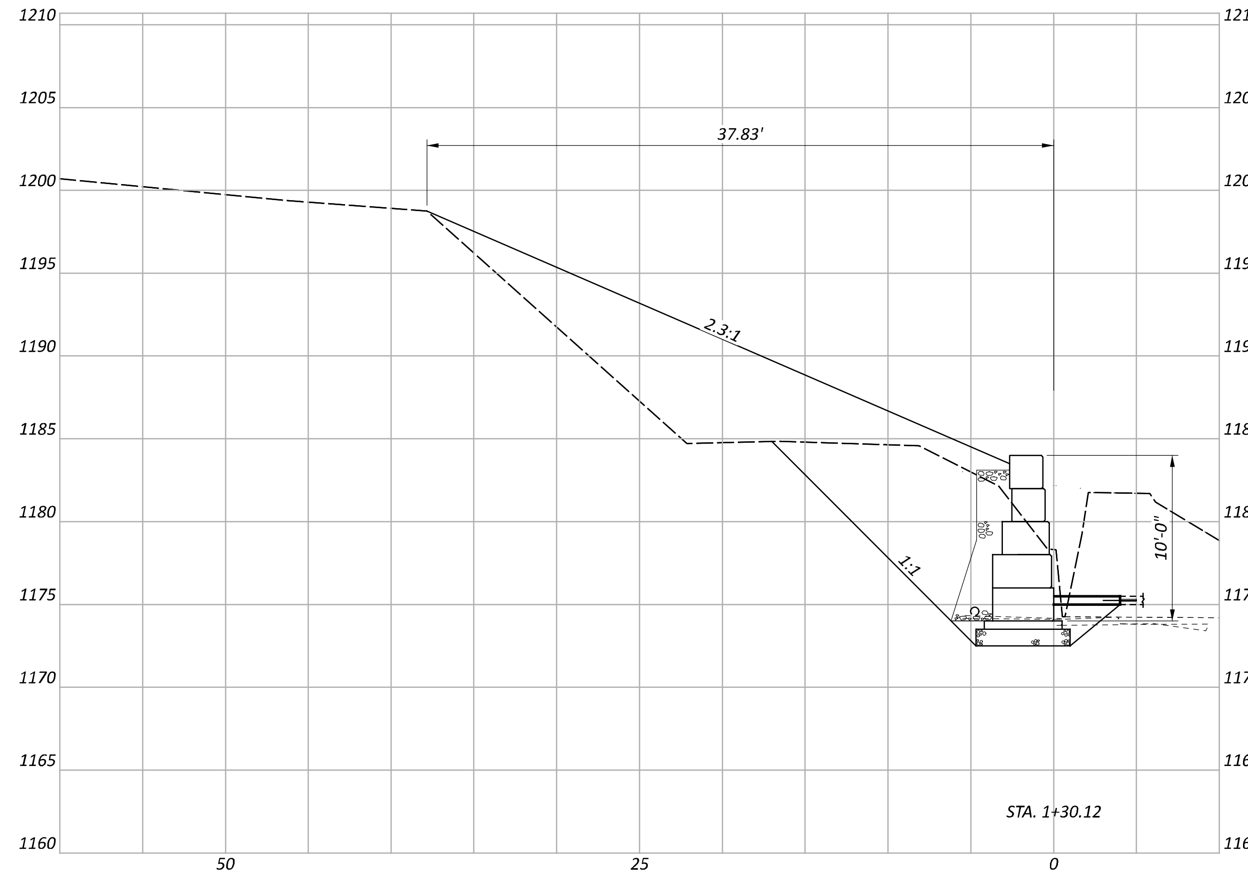


1210
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
34.84'
2:1
1:1
10'-0"
STA. 1+00.00
50
25
0

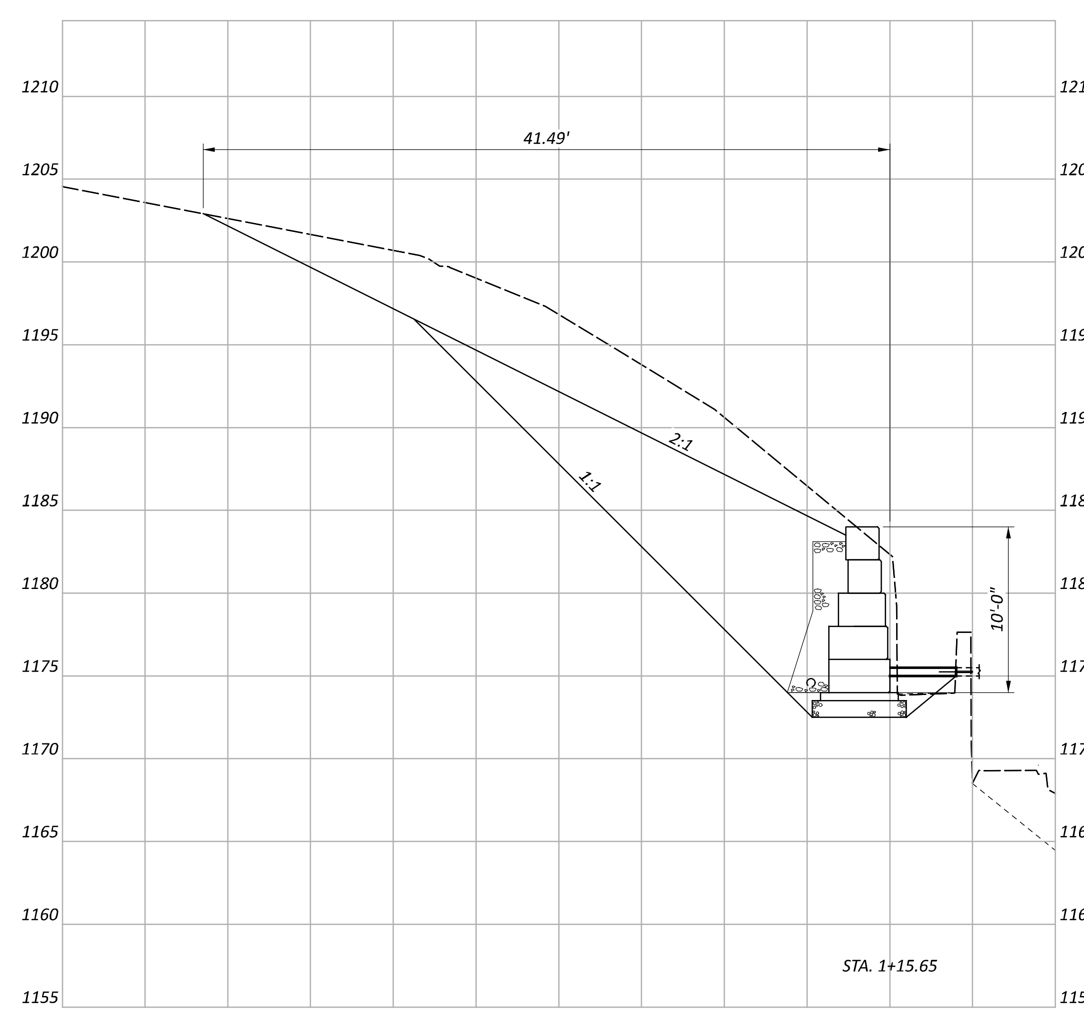
PLATE 36


34.38'
SL
33.64'
20.00'
1.4:1
2:1
1:1
10'-0"
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
STA. 1+07.64
50
25
0


43.74'
SL
2:1
1:1
10'-0"
1215
1210
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
STA. 1+04.21
50
25
0

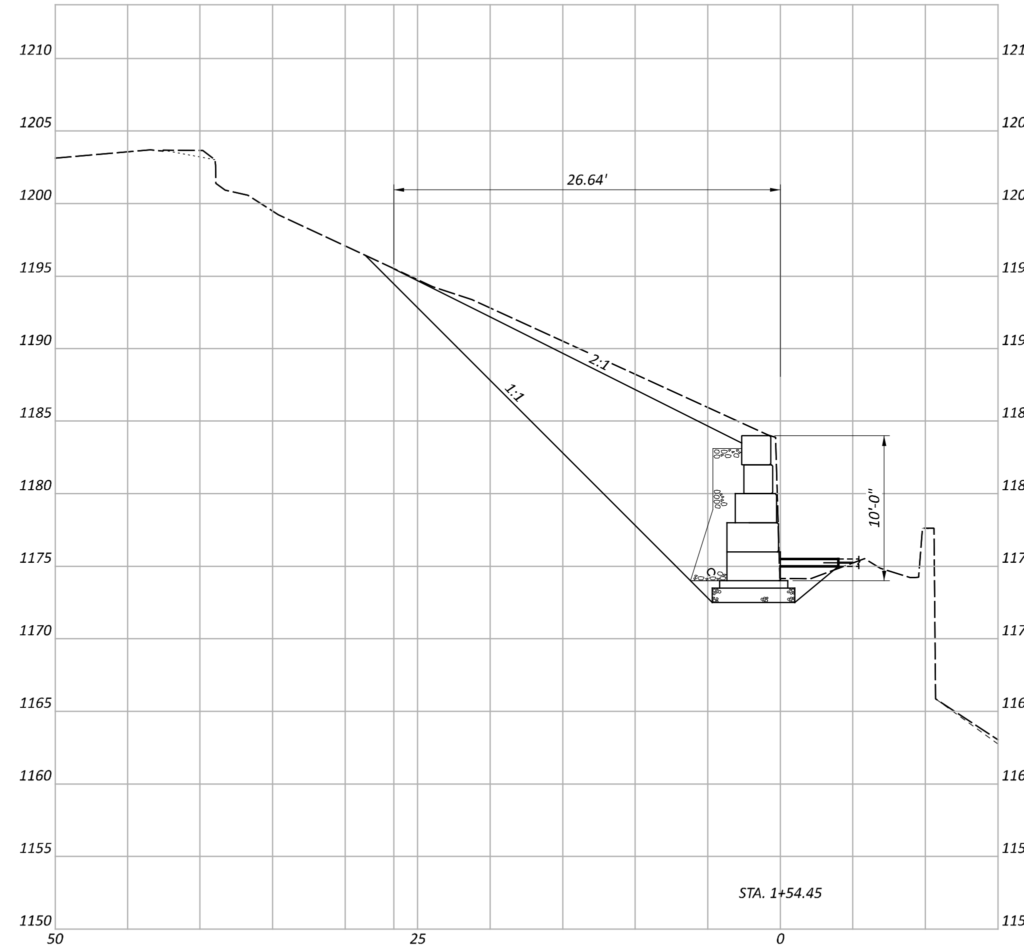


1210
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
37.83'
2.3:1
1:1
10'-0"
STA. 1+30.12
50
25
0

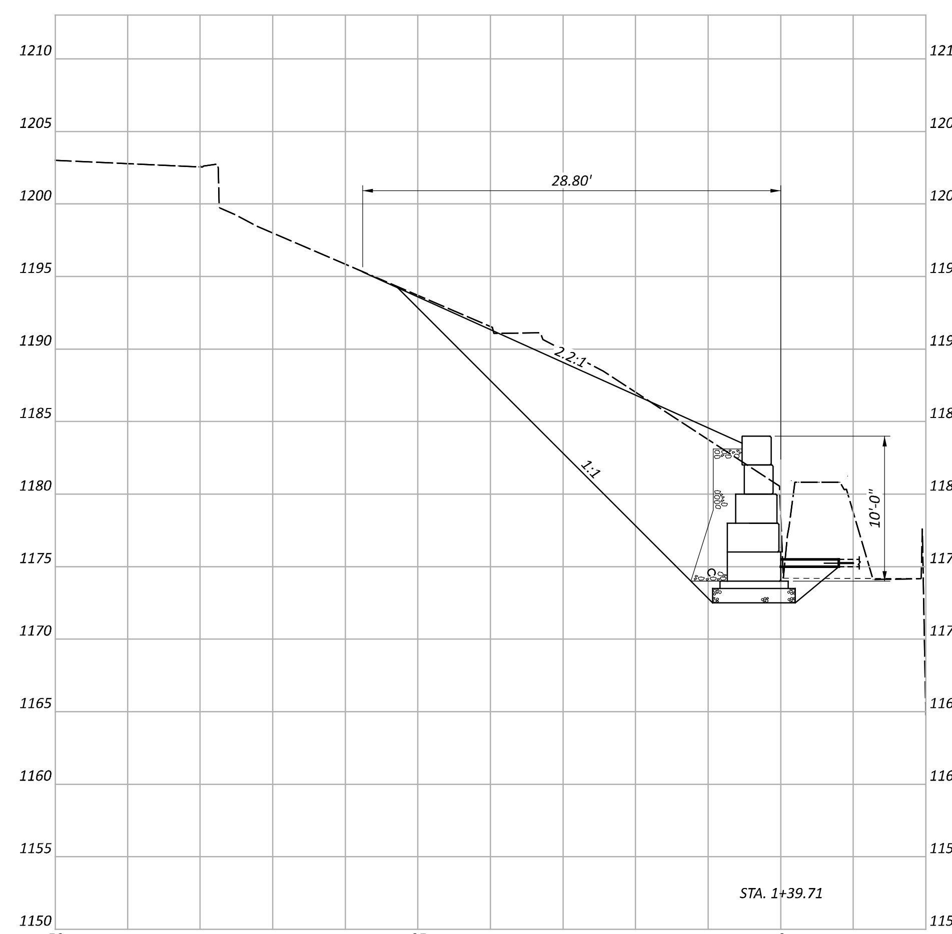


1210
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
1155
41.49'
2:1
1:1
10'-0"
STA. 1+15.65
50
25
0

PLATE 38

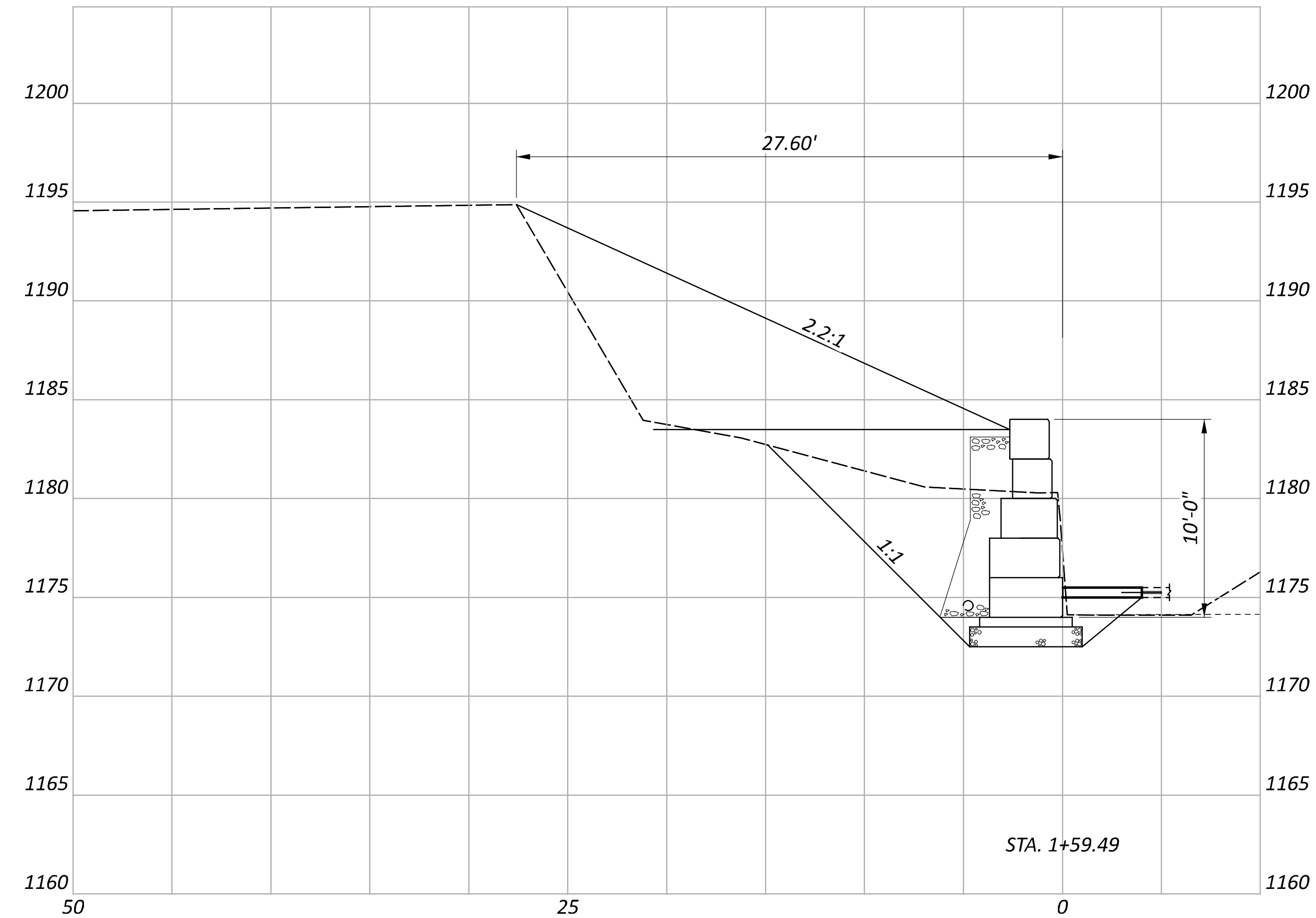


STA. 1+54.45

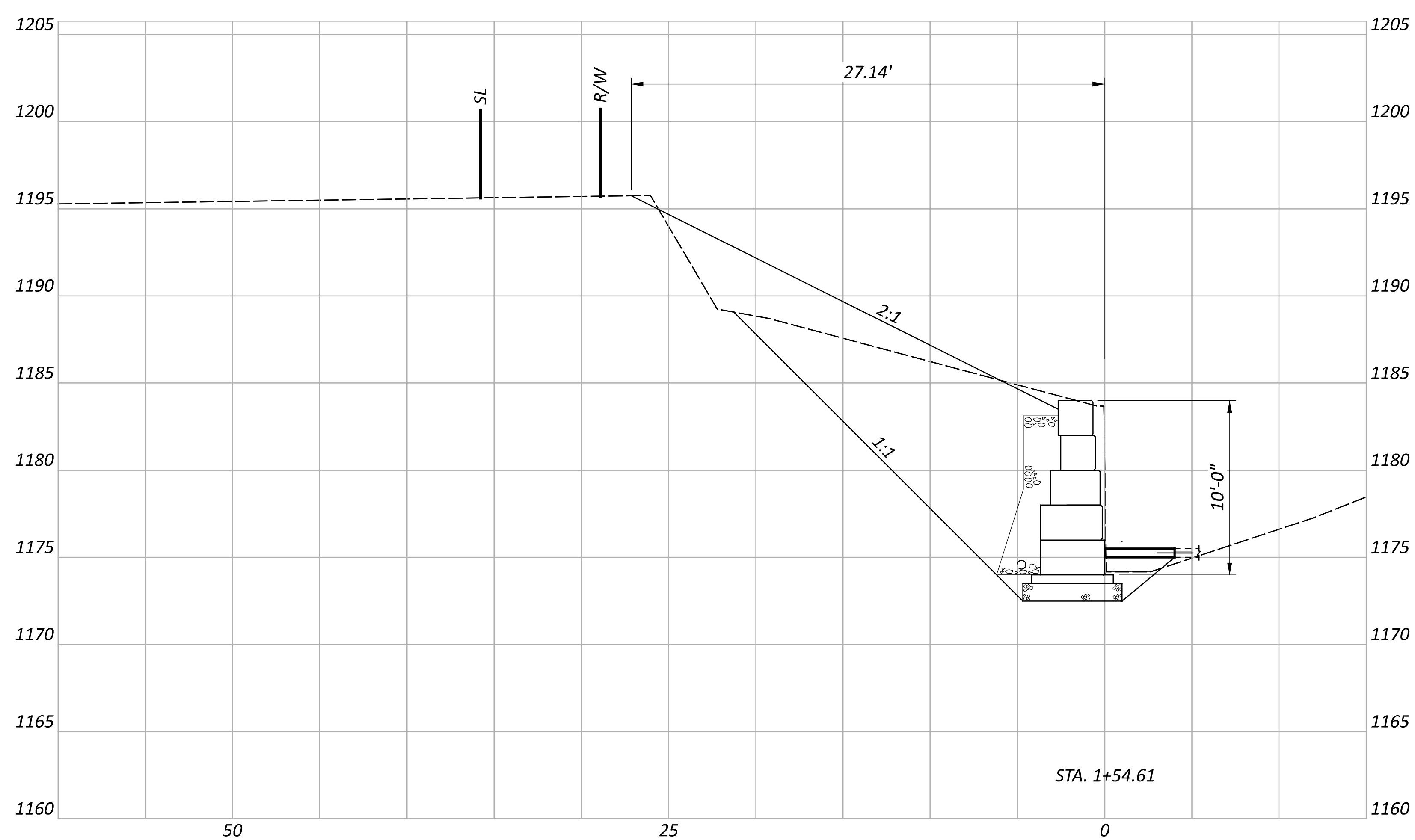


STA. 1+39.71

PLATE 39



1200
1195
1190
1185
1180
1175
1170
1165
1160
27.60'
2.2:1
1:1
10'-0"
STA. 1+59.49
50
25
0



1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
SL
R/W
27.14'
2:1
1:1
10'-0"
STA. 1+54.61
50
25
0

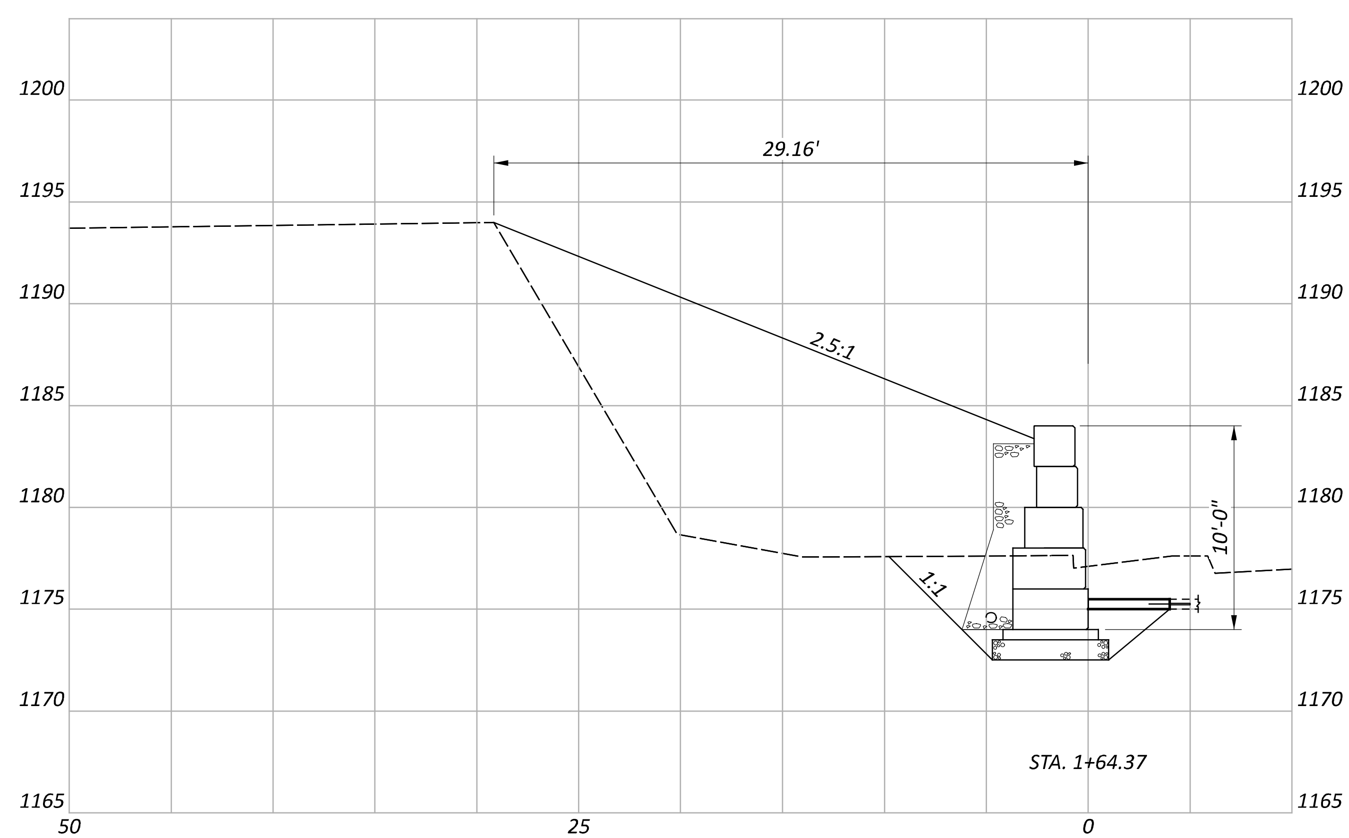
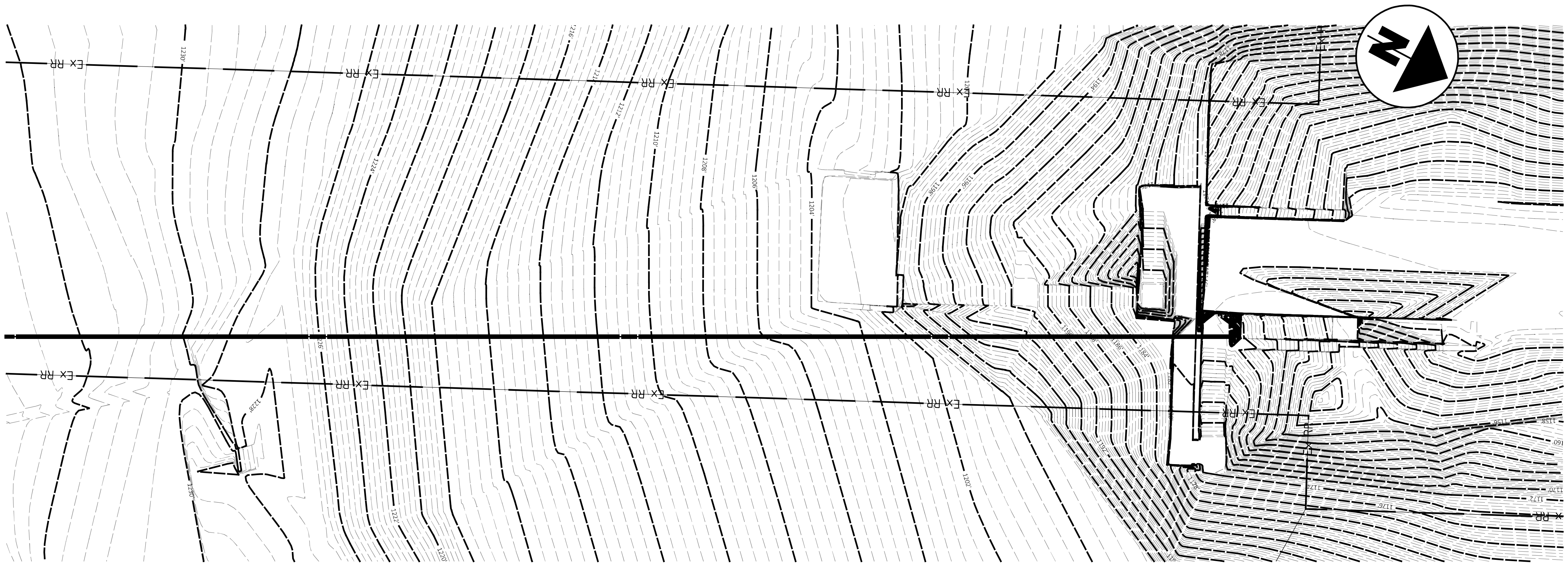
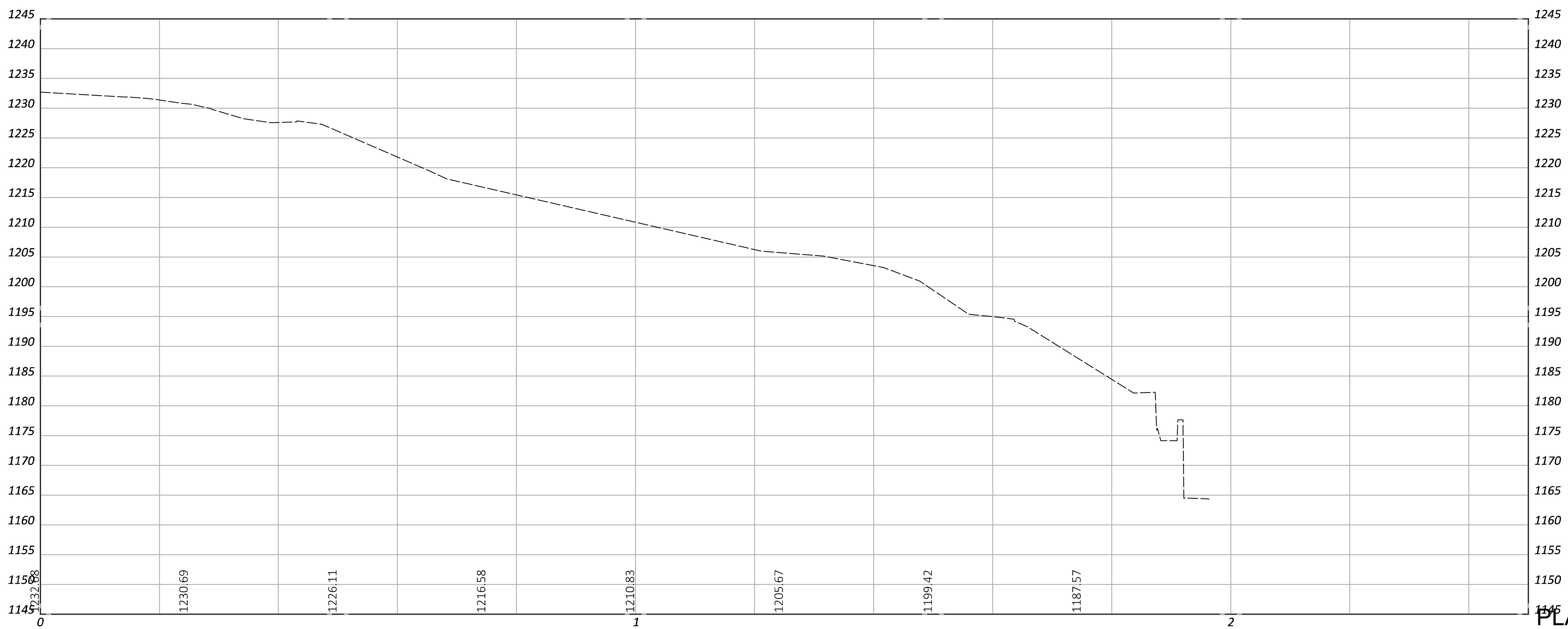

1200
1195
1190
1185
1180
1175
1170
1165
29.16'
2.5:1
1:1
10'-0"
STA. 1+64.37
50
25
0

PLATE 41





CTY-RTE-SECTION

MODEL: CLP_KMC - Plan 1 KMC-1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 10/10/2022 TIME: 3:59:35 PM USER: KCoville
N:\01\60\08388-00\108774\400-Engineering\Roadway\Basemaps\working\108774_Connector Trail_Conc Steps FOR BRIANS PROFILE.dgn

HORIZONTAL SCALE IN FEET
0 5 10 20

PLAN AND PROFILE STABILITY ANALYSES

DESIGN AGENCY
ms consultants, inc.

DESIGNER
KMC
REVIEWER
SSR 10-10-2022
PROJECT ID
108774
SHEET P.0 TOTAL 0

PLATE 42

Appendix V – OGE Geotechnical Checklists

I. Geotechnical Design Checklists

Project:	**BEL-National Rd Tunnel**	**PDP Path:**	
PID:	**108774**	**Review Stage:**	**3**

Checklist	**Included in This Submission**
II. Reconnaissance and Planning	✓
III. A. Centerline Cuts	
III. B. Embankments	
III. C. Subgrade	
IV. A. Foundations of Structures	✓
IV. B. Retaining Wall	✓
V. A. Landslide Remediation	
V. B. Rockfall Remediation	
V. C. Wetland or Peat Remediation	
V. D. Underground Mine Remediation	
V. E. Surface Mine Remediation	
V. F. Karst Remediation	
VI. A. Soil Profile	
VI. D. Geotechnical Reports	✓

II. Reconnaissance and Planning Checklist

C-R-S:	BEL-National Rd Tunnel	PID:	108774	Reviewer:	BKS	Date:	7/17/2023

Reconnaissance		(Y/N/X)	Notes:
1	Based on Section 302.1 in the SGE, have the necessary plans been developed in the following areas prior to the commencement of the subsurface exploration reconnaissance:	Y	
	Roadway plans		
	Structures plans	✓	
	Geohazards plans		
2	Have the resources listed in Section 302.2.1 of the SGE been reviewed as part of the office reconnaissance?	Y	
3	Have all the features listed in Section 302.3 of the SGE been observed and evaluated during the field reconnaissance?	Y	
4	If notable features were discovered in the field reconnaissance, were the GPS coordinates of these features recorded?	X	
Planning - General		(Y/N/X)	Notes:
5	In planning the geotechnical exploration program for the project, have the specific geologic conditions, the proposed work, and historic subsurface exploration work been considered?	Y	
6	Has the ODOT Transportation Information Mapping System (TIMS) been accessed to find all available historic boring information and inventoried geohazards?	X	No historic information was available.
7	Have the borings been located to develop the maximum subsurface information while using a minimum number of borings, utilizing historic geotechnical explorations to the fullest extent possible?	Y	
8	Have the topography, geologic origin of materials, surface manifestation of soil conditions, and any other special design considerations been utilized in determining the spacing and depth of borings?	Y	
9	Have the borings been located so as to provide adequate overhead clearance for the equipment, clearance of underground utilities, minimize damage to private property, and minimize disruption of traffic, without compromising the quality of the exploration?	Y	

II. Reconnaissance and Planning Checklist

Planning - General		(Y/N/X)	Notes:
10	Have the scaled boring plans, showing all project and historic borings, and a schedule of borings in tabular format, been submitted to the District Geotechnical Engineer?	Y	
	The schedule of borings should present the following information for each boring:		
a.	exploration identification number	Y	
b.	location by station and offset	Y	
c.	estimated amount of rock and soil, including the total for each for the entire program.	Y	
Planning – Exploration Number		(Y/N/X)	Notes:
11	Have the coordinates, stations and offsets of all explorations (borings, probes, test pits, etc.) been identified?	Y	
12	Has each exploration been assigned a unique identification number, in the following format X-ZZZ-W-YY, as per Section 303.2 of the SGE?	Y	
13	When referring to historic explorations that did not use the identification scheme in 12 above, have the historic explorations been assigned identification numbers according to Section 303.2 of the SGE?	X	

II. Reconnaissance and Planning Checklist

Planning – Boring Types		(Y/N/X)	Notes:
14	Based on Sections 303.3 to 303.7.6 of the SGE, have the location, depth, and sampling requirements for the following boring types been determined for the project?	Y	
	Check all boring types utilized for this project:		
	Existing Subgrades (Type A)		
	Roadway Borings (Type B)		
	Embankment Foundations (Type B1)		
	Cut Sections (Type B2)		
	Sidehill Cut Sections (Type B3)		
	Sidehill Cut-Fill Sections (Type B4)		
	Sidehill Fill Sections on Unstable Slopes (Type B5)		
	Geohazard Borings (Type C)		
	Lakes, Ponds, and Low-Lying Areas (Type C1)		
	Peat Deposits, Compressible Soils, and Low Strength Soils (Type C2)		
	Uncontrolled Fills, Waste Pits, and Reclaimed Surface Mines (Type C3)		
	Underground Mines (C4)		
	Landslides (Type C5)		
	Rockfall (Type C6)		
	Karst (Type C7)		
	Proposed Underground Utilities (Type D)		
	Structure Borings (Type E)	✓	
	Bridges (Type E1)		
	Culverts (Type E2 a,b,c)		
	Retaining Walls (Type E3 a,b,c)	✓	
	Noise Barrier (Type E4)		
	CCTV & High Mast Lighting Towers (Type E5)		
	Buildings and Salt Domes (Type E6)		

IV.A Foundations of Structures Checklist

C-R-S:	BEL-National Rd Tunnel	PID:	108774	Reviewer:	BKS	Date:	7/17/2023

If you do not have such a foundation or structure on the project, you do not have to fill out this checklist.

Soil and Bedrock Strength Data		(Y/N/X)	Notes:
1	Has the shear strength of the foundation soils been determined?	Y	
	Check method used:		
	laboratory shear tests		
	estimation from SPT or field tests	✓	
2	Have sufficient soil shear strength, consolidation, and other parameters been determined so that the required allowable loads for the foundation/structure can be designed?	Y	
3	Has the shear strength of the foundation bedrock been determined?	Y	
	Check method used:		
	laboratory shear tests	✓	
	other (describe other methods)		
Spread Footings		(Y/N/X)	Notes:
4	Are there spread footings on the project? If no, go to Question 11	Y	
5	Have the recommended bottom of footing elevation and reason for this recommendation been provided?	Y	
a.	Has the recommended bottom of footing elevation taken scour from streams or other water flow into account?	X	
6	Were representative sections analyzed for the entire length of the structure for the following:	Y	
a.	factored bearing resistance?	Y	
b.	factored sliding resistance?	X	Performed by others.
c.	eccentric load limitations (overturning)?	X	Performed by others.
d.	predicted settlement?	X	Bearing on bedrock
e.	overall (global) stability?	X	Bearing on bedrock
7	Has the need for a shear key been evaluated?	X	
a.	If needed, have the details been included in the plans?	X	
8	If special conditions exist (e.g. geometry, sloping rock, varying soil conditions), was the bottom of footing “stepped” to accommodate them?	X	
9	Have the Service I and Maximum Strength Limit States for bearing pressure on soil or rock been provided?	Y	

IV.A Foundations of Structures Checklist

Spread Footings		(Y/N/X)	Notes:
10	If weak soil is present at the proposed foundation level, has the removal / treatment of this soil been developed and included in the plans?	X	
a.	Have the procedure and quantities related to this removal / treatment been included in the plans?	X	
Pile Structures		(Y/N/X)	Notes:
11	Are there piles on the project? If no, go to Question 17	N	
12	Has an appropriate pile type been selected?		
	Check the type selected:		
	H-pile (driven)		
	H-pile (prebored)		
	Cast In-place Reinforced Concrete Pipe		
	Micropile		
	Continuous Flight Auger (CFA)		
	other (describe other types)		
13	Have the estimated pile length or tip elevation and section (diameter) based on either the Ultimate Bearing Value (UBV) or the depth to top of bedrock been specified? Indicate method used.		
14	If scour is predicted, has pile resistance in the scour zone been neglected?		
15	Has a wave equation drivability analysis been performed as per BDM 305.4.1.2 to determine whether the pile can be driven to either the UBV, the pile tip elevation, or refusal on bedrock without overstressing the pile?		
16	If required for design, have sufficient soil parameters been provided and calculations performed to evaluate the:		
a.	Nominal unit tip resistance and maximum settlement of the piles?		
b.	Nominal unit side resistance for each contributing soil layer and maximum deflection of the piles?		
c.	Downdrag load on piles driven through new embankment or compressible soil layers, as per BDM 305.4.2.2?		
d.	Potential for and impact of lateral squeeze from soft foundation soils?		

IV.A Foundations of Structures Checklist

Pile Structures		(Y/N/X)	Notes:
17	If piles are to be driven to strong bedrock (Q_u >7.5 ksi) or through very dense granular soils or overburden containing boulders, have "pile points" been recommended in order to protect the tips of the steel piling, as per BDM 305.4.5.6?		
18	If subsurface obstacles exist, has preboring been recommended to avoid these obstructions?		
19	If piles will be driven through 15 feet or more of new embankment, has preboring been specified as per BDM 305.4.5.7?		

IV.A Foundations of Structures Checklist

Drilled Shafts		(Y/N/X)	Notes:
20	Are there drilled shafts on the project? If no, go to the next checklist.	Y	Drilled shafts are for retaining wall supports
21	Have the drilled shaft diameter and embedment length been specified?	Y	
22	Have the recommended drilled shaft diameter and embedment been developed based on the nominal unit side resistance and nominal unit tip resistance for vertical loading situations?	Y	
23	For shafts undergoing lateral loading, have the following been determined:	Y	
a.	total factored lateral shear?	Y	Drilled shafts are for retaining wall supports
b.	total factored bending moment?	Y	Drilled shafts are for retaining wall supports
c.	maximum deflection?	Y	Drilled shafts are for retaining wall supports
d.	reinforcement design?	Y	Drilled shafts are for retaining wall supports
24	If a bedrock socket is required, has a minimum rock socket length equal to 1.5 times the rock socket diameter been used, as per BDM 305.5.2?	Y	
25	Generally, bedrock sockets are 6" smaller in diameter than the soil embedment section of the drilled shaft. Has this factor been accounted for in the drilled shaft design?	Y	
26	If scour is predicted, has shaft resistance in the scour zone been neglected?	✓	
27	Has the site been assessed for groundwater influence?	X	
a.	If yes, and if artesian flow is a potential concern, does the design address control of groundwater flow during construction?	X	
28	Have all the proper items been included in the plans for integrity testing?	X	Plans prepared by otheres
29	If special construction features (e.g., slurry, casing, load tests) are required, have all the proper items been included in the plans?	X	Plans prepared by otheres
30	If necessary, have wet construction methods been specified?	X	
General		(Y/N/X)	Notes:
31	Has the need for load testing of the foundations been evaluated?	X	
a.	If needed, have details and plan notes for load testing been included in the plans?	X	

IV.B. Retaining Wall Checklist

C-R-S:	BEL-National Rd Tunnel	PID:	108774	Reviewer:	BKS	Date:	7/17/2023
				PDP Path:			

If you do not have a retaining wall on the project, you do not have to fill out this checklist.

Soil Data and Preliminary Calculations		(Y/N/X)	Notes:
1	Has a justification study been performed to determine the necessity of a wall as opposed to ROW purchase or other project alternatives?	Y	Retaining wall type study was prepared by ms.
2	Have the necessary soil strength parameters and unit weights been determined?	Y	
	Check method used:		
	laboratory shear tests		
	estimation from SPT or field tests	✓	
3	Has the groundwater elevation been determined?	Y	
4	Have the proper loading conditions been determined?	Y	
a.	If yes, check which loading conditions apply:		
	Backfill (Active Earth Pressure Loading):	✓	
	Backfill (Apparent Earth Pressure (AEP) Loading for Ground Anchors):		
	Backfill (At-Rest Earth Pressure Loading):		
	Backfill (Flat, No Slope):		
	Backfill (Infinite Slope):	✓	
	Backfill (Broken Back Slope):	✓	
	Earth Surcharge:		
	Live Load Surcharge:		
	Other (describe):		
5	Have the correct Load Factors, Load Combinations, and Limit States been considered, per AASHTO LRFD 8th Ed. Articles 3.4.1, 10.5, and 11.5?	X	Walls being designed by ms. S&ME provided axial and lateral resistance parameter recommendations for drilled shafts and spread footings.
6	Are earth pressure loads inclined at the soil-structure interaction friction angle, δ and has δ been determined per BDM 307.1.1?	X	Walls being designed by ms.
7	Have the correct Resistance Factors been considered, per AASHTO LRFD 8th Ed. Articles 10.5 and 11.5?	X	Walls being designed by ms.
8	If applicable, has the influence of groundwater been taken into account with regards to soil unit weights and active pressures?	X	Walls being designed by ms.
9	Has the Coulomb method been utilized to determine the lateral earth pressure?	X	Walls being designed by ms.

IV.B. Retaining Wall Checklist

Design		(Y/N/X)	Notes:
10	For preliminary wall design, have the design criteria and wall type selection process been followed as instructed in BDM 201.2.5?	X	Walls being designed by ms.
11	Was an economic analysis performed to evaluate the cost benefits of the chosen wall type compared to others?	Y	Retaining wall type study was prepared by ms.
12	Were representative sections analyzed for the entire length of the retaining wall for the following:	X	Walls being designed by ms.
a.	bearing resistance?	X	Walls being designed by ms.
b.	sliding resistance?	X	Walls being designed by ms.
c.	limiting eccentricity and overturning resistance? Analyze moment equilibrium about toe for non-gravity cantilever walls.	X	Walls being designed by ms.
d.	total and differential settlement?	X	Walls bearing on intact rock.
e.	overall (global) stability?	X	Walls bearing on intact rock.
13	If poor foundation soils are present, has a solution been determined with respect to the following:	X	Walls bearing on intact rock.
a.	excessive settlement?	X	Walls bearing on intact rock.
b.	inadequate bearing resistance?	X	Walls bearing on intact rock.
c.	inadequate sliding resistance?	X	Walls bearing on intact rock.
d.	overall (global) instability?	X	Walls bearing on intact rock.
14	For non-proprietary walls, each wall type has design recommendations which need to be determined. For the wall type being evaluated, have the following design recommendations been determined by accepted design methods or, where applicable, FHWA design guidelines:	X	
a.	Rigid Gravity and Semigravity -- footing width and elevation, maximum factored Service and Strength Limit State bearing pressures, factored bearing resistance (BDM 307.1.5 & 307.2)	X	
b.	Drilled Shafts - diameter, spacing, embedment, arrangement and percent reinforcement, maximum moment and lateral shear, maximum deflection (see BDM 307.6)	X	
c.	Soldier Pile -pile size and type, drilled hole diameter, embedment, spacing, lagging design, facing, maximum moment and lateral shear, section modulus, maximum deflection	Y	S&ME provided design parameter recommendations and ms performed retaining wall analysis.

IV.B. Retaining Wall Checklist

Design		(Y/N/X)	Notes:
d.	Sheet Pile - pile size, embedment, maximum moment and lateral shear, section modulus, maximum deflection (BDM 307.7.1)	X	
e.	Cellular - type, maximum factored Service and Strength Limit State bearing pressures, factored bearing resistance, fill material (BDM 307.7.2)	X	
f.	Soil Anchor - load per anchor, number of rows, wale design, anchor inclination and minimum length, type of anchor, pile size, type, spacing, and embedment, maximum moment and lateral shear, section modulus, lagging design, facing (BDM 307.8)	X	
g.	Soil Nail - nail size, spacing, inclination, and length, loading per nail, facing (BDM 307.9)	X	
15	Has the need for load testing of the retaining wall elements been evaluated?	X	
a.	If needed, have details and plan notes for load testing been included in the plans?	X	
16	Proprietary wall designs require a special process for detail design, as outlined in BDM 307.3 and 307.4. Has this procedure been followed for this project?	X	Modular block walls planned at multiple locations. ms preparing plans.
17	Temporary walls - have the same design requirements as permanent walls of the same type been followed, except the design service life is no more than three years (BDM 307.10)?	X	
18	The presence and quality of water behind the wall structure and in the backfill can be a major source of overloading and failure.		Surface water only.
a.	Has the quality / chemistry of the groundwater been accounted for in the drainage system?	X	
b.	Has an adequate drainage system been included in the detail wall design?	X	Plans and design by ms.
c.	If there is a water source behind the wall, has additional drainage been added to control the effect of this water source on the wall?	X	Plans and design by ms.
19	Have the effects of the wall design and construction procedure been determined and accounted for on the construction schedule?	X	Plans and design by ms.

IV.B. Retaining Wall Checklist

Design		(Y/N/X)	Notes:
20	Has the effect of the wall design and construction been evaluated with regard to structures (e.g., bridges, culverts, buildings, utilities), which may be subject to unusual stresses or require special design or construction considerations?	X	
Plans and Contract Documents		(Y/N/X)	Notes:
21	Have all the necessary notes, specifications, special provisions, and details for the construction of the wall system been included in the plans?	X	Plans and design by ms.
22	Have the need, location, type, plan notes, and reading schedule for any instrumentation been determined and included in the plans?	X	
	Check the types of instrumentation specified:		
	settlement cells		
	settlement platforms		
	inclinometers		
	monitoring wells / piezometers		
	load cells		
	strain gages		
	other (describe other types)		

VI.B. Geotechnical Reports

C-R-S:	BEL-National Rd Tunnel	PID:	108774	Reviewer:	BKS	Date:	7/17/2023

General		(Y/N/X)	Notes:
1	Has an electronic copy of all geotechnical submissions been provided to the District Geotechnical Engineer (DGE)?	Y	
2	Has the first complete version of a geotechnical report being submitted been labeled as 'Draft'?	Y	
3	Subsequent to ODOT's review and approval, has the complete version of the revised geotechnical report being submitted been labeled 'Final'?	Y	
4	Has the boring data been submitted in a native format that is DIGGS (Data Interchange for Geotechnical and Geoenvironmental) compatable? gINT files may be used for this.	Y	
5	Does the report cover format follow ODOT's Brand and Identity Guidelines Report Standards found at http://www.dot.state.oh.us/brand/Pages/default.aspx ?	Y	
6	Have all geotechnical reports being submitted been titled correctly as prescribed in Section 705.1 of the SGE?	Y	
Report Body		(Y/N/X)	Notes:
7	Do all geotechnical reports being submitted contain the following:	Y	
a.	an Executive Summary as described in Section 705.2 of the SGE?	Y	
b.	an Introduction as described in Section 705.3 of the SGE?	Y	
c.	a section titled "Geology and Observations of the Project," as described in Section 705.4 of the SGE?	Y	
d.	a section titled "Exploration," as described in Section 705.5 of the SGE?	Y	
e.	a section titled "Findings," as described in Section 705.6 of the SGE?	Y	
f.	a section titled "Analyses and Recommendations," as described in Section 705.7 of the SGE?	Y	
Appendices		(Y/N/X)	Notes:
8	Do all geotechnical reports being submitted contain all applicable Appendices as described in Section 705.8 of the SGE?	Y	
9	Do the Appendices present a site Boring Plan showing all boring locations as described in Section 705.8.1 of the SGE?	Y	

VI.B. Geotechnical Reports

Appendices		(Y/N/X)	Notes:
10	Do the Appendices include boring logs and color pictures of rock, if applicable, as described in Section 705.8.2 of the SGE?	Y	
11	Do the Appendices include reports of undisturbed test data as described in Section 705.8.3 of the SGE?	Y	Rock core testing. Only unit weight determinations were performed on recovered Shelby tube samples.
12	Do the Appendices include calculations in a logical format to support recommendations as described in Section 705.8.4 of the SGE?	Y	