In Association with

Geotechnical Engineering Report: Segment 2A Wall 9.05R-B FDC-054

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WSDOT I-405 Renton to Bellevue Design-Build

Renton to Bellevue, Washington

Project # PS19-20316-0

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List of acronyms

DLT	design load transfer
ESU	Engineering Stratigraphic Unit
Flatiron-Lane	Flatiron-Lane Joint Venture
Project GDM	Project Geotechnical Design Manual, consisting of WSDOT's 2015 *Geotechnical Design Manual*, along with project-specific Chapters 6 (Seismic) and 15 (Retaining Walls) from Request for Proposal Addendum 9
I-405	Interstate 405
plf	pounds per linear foot
Sta.	Station
Wood	Wood Environment & Infrastructure Solutions, Inc.
WSDOT	Washington State Department of Transportation

1.0 Description of Structure

This document presents our geotechnical engineering analysis for retaining wall 9.05R-B, located near northbound Interstate 405 (I-405) Station (Sta.) 7780+00; Wall Sta. 1+00 to 6+05, in support of the Washington State Department of Transportation (WSDOT) I-405 Renton to Bellevue Design-Build project. This report supersedes the original Released For Use version of this report (Wood 2020a). The changes to the report were due to the testing data collected during the soil nail verification tests.

During initial construction of the wall in 2021, test pit standup tests and soil nail verification tests were performed. The test pits demonstrated adequate standup for soil nail wall excavation (see Section 3.2). However, some of the soil nail verification tests did not pass, due to pullout occurring prior to reaching the maximum design load transfer (DLT) required (see Section 6.1). The verification tests were conducted in soils similar to the soils found in the borings and consistent with the Engineering Stratigraphic Units (ESUs) used for design. There were no errors in testing, such as the bond zone being measured incorrectly, poor grout, unsuitable testing equipment, incorrect procedures, etc. It appears that the low overburden pressure at the test nail elevations and auger drilling method resulted in lower DLTs than initially assumed. The initial pullout resistance was based on empirical guidelines and after receiving site-specific data, the pullout resistance was adjusted to be consistent with the site-specific conditions. Discussion of the soil types can be found in Sections 2.0 and 3.2, and further discussion of the soil-grout bond strength can be found in Section 6.1.

Due to the lower pullout resistance of the soil nail verification tests, the Flatiron-Lane Joint Venture (Flatiron-Lane) construction team directed Wood Environment & Infrastructure Solutions, Inc. (Wood) to revise the calculations and recommendations in the report to accommodate the actual verification test results. Wood was directed to engineer a soil nail wall design using the lowest pullout resistance achieved from the verification tests. Therefore, this report utilizes a soil-grout bond stress and recommends a DLT that was both achieved in the soil nail verification tests and that is lower than the DLT presented in the original report.

This report has been prepared in accordance with the requirements presented in the I-405 Renton to Bellevue Widening Project Request for Proposal, specifically Section 2.6.5.3, and the applicable sections of the Project Geotechnical Design Manual (GDM) which consists of the WSDOT *Geotechnical Design Manual* (WSDOT 2015), along with project-specific Chapters 6 (Seismic) and 15 (Retaining Walls) from the Request for Proposal Addendum 9.

1.1 Structure Location and Forward Compatibility

The retaining wall is located on the east side of I-405 near the Newport Hills park-and-ride. Wall 9.05R-B will be located on the new shoulder of the northbound lane of the off-ramp at 112th Avenue SE. The location of the retaining wall is shown in the Retaining Wall Plan and Profile (Appendix A) and described in detail in the structural plans. A soil nail wall is planned to support a cut into the existing slope.

Wall 9.05R-B will be designed for forward compatibility. Although the wall may not be excavated to the full future depth during construction of this project, the wall will be designed for the future condition. The construction plan for forward compatibility is that the soil nail wall will be constructed as deep as necessary to accommodate the current Request for Proposal requirements, and then in the future, construction can continue by excavating steps and installing soil nail rows until the future bottom of wall is complete. From the current design perspective, this means that the soil nails that are installed now must be compatible with the final future wall. To accomplish this design, the future compatible wall layout has been analyzed. Engineering analyses and design recommendations stated in this report are intended for the future-compatible wall. Table 1 summarizes the wall structure. Wood understands that only a portion of this wall will be constructed under the current contract.

Table 1: Summary of Wall 9.05R

Start Station	End Station	Design Station	Max. Exposed Height (feet)	Max. FC Exposed Height (feet)	Fore slope (degree	Back slope (degree)	Wall Type
1+00	6+06	1+40	9	19	24	22	Soil Nail Wall
		3+80	34	39	0	0	
		5+20	19	25	0	18	

Abbreviations:
FC= forward compatibility
Max. = maximum

1.2 Site Surface Conditions

Overall topography along this segment of I-405 has gentle sloping highway grade down to the north. The highway is located on the west slope of a hillside that slopes down to Lake Washington to the west. Most of the slope inclines at around 2.5H:1V (horizontal:vertical), but occasionally is as a steep as 2H:1V.

The wall is located south of the 112th Avenue SE interchange on the slope that rises from the highway shoulder. Lake Washington Boulevard SE is located behind the wall on top of the slope. Existing and new utilities along I-405 will be described in the project's utility management plan submittal (Submittal No. 013). The structural plans do not indicate any utility impacts related to the wall.

2.0 Exploration and Laboratory Testing

Geotechnical explorations were performed as part of Subsurface Investigation Plan Nos. 2 and 3 (Wood 2020b and 2020c) to supplement exploration from the project Geotechnical Data Report (WSDOT 2018a). Soil boring logs can be found in Appendix B. Results of soil laboratory testing performed for this report are included in Appendix C. The exploration locations are also shown on the Retaining Wall Plan and Profile (Appendix A).

Wood explored surface and subsurface conditions at the project site between April 15 and May 19, 2020. The exploration and testing program comprised the following elements:

- Four borings with Standard Penetration Test samples taken at 5-foot intervals were advanced at the approximate locations shown on the Retaining Wall Plan and Profile (Appendix A). The borings are summarized in Appendix B.
- Laboratory testing consisted of grain-size analyses, hydrometer analyses, 200 washes, moisture content determinations, and plasticity testing. These are summarized in Appendix C.
- Two borings and associated laboratory testing from the project Geotechnical Data Report (WSDOT 2018a) are included in the investigation for this wall. They are included in the appendices.

Table B-1 in Appendix B summarizes the locations, surface elevations, and termination depths of the subsurface explorations used for designing this wall. Explorations W-117-20 and W-118-20 provide information supporting the interpreted consistent soil conditions at the wall face. Explorations W-64mw-20, R2B-65-17, and R2B-66-17 are located east of the face and allow interpretation of ESU stratigraphy in the bond zone; in addition, explorations W-64mw-20 and R2B-65-17 are positioned to allow interpretation at both the wall face and bond zone. ESU soil properties are included in Appendix D. Given the dense, consistent soil conditions, these six borings are sufficient to characterize this wall, which is 500 feet long. Therefore, geotechnical investigation for wall 9.05R-B meets the requirements in Section 15.3.4 of the Project GDM. Table 2 outlines the exploration requirement for compliance.

Table 2: Wall 9.05R-B Exploration Compliance Summary

Critical Foreslope/ Backslope	Ground Condition	Explorations				Boring in Bond Zone?	Compliant?	Notes
		No. Req'd	Reference ID (Total #)	Spacing (feet)	Max. Depth			
Neither	Good	3	W-64-20, W-65-20, W-117-20, W-118-20, R2B-65-17, R2B-66-17 (6)	200	79.5	Yes	Yes	Test pits were completed and verified

Abbreviations:
Max. = maximum
Req'd = required

Test pits excavated prior to construction for evaluation of the facing stability are presented in Appendix E. These two test pits (W-TP5-21 and W-TP6-21) were excavated on March 16, 2021, to verify facing stability for construction as required by Section 15-3.4.2.1 of the Project GDM and project plans. The soils observed were consistent with the previous explorations and interpretation of ESUs.

The soil conditions observed during drilling of the verification test nails appeared to be consistent with the explorations; however, observing disturbed drill cuttings and drilling action is not as accurate as the other exploration performed for this report.

3.0 Subsurface Conditions

3.1 Geologic Setting

The project lies within the southern portion of the Puget Sound Lowland physiographic region. The Puget Sound Lowland has undergone physiographic and depositional changes due to at least five glacial episodes. The last glaciation that occurred in the region was the Vashon Stade of the Fraser Glaciation, which ended approximately 13,500 years ago.

The advance of the Vashon Glacier deepened and widened the north/south trending valleys situated between the Olympic Mountains and the Cascade Range in western Washington. In the Seattle area, the Vashon Stade is represented by four stratigraphic units (from oldest to youngest): Lawton Clay, Esperance Sand, Vashon Till, and Vashon recessional deposits, which make up the Vashon Drift (Galster and Laprade 1991).

As the Vashon glacial lobe advanced south and blocked the northern portion of the Puget Sound basin, a lake was formed, and fine-grained sediments were deposited. The glaciolacustrine deposit, known as the Lawton Clay, is reported to be present in the Seattle area as high as 150 feet above mean sea level. A fine-to-medium-grained sand unit was deposited above the Lawton Clay by meltwater streams issuing from the advancing ice sheet as it neared the Seattle area. That sand unit is called the Esperance Sand Member. The Lawton Clay and Esperance Sand are sometimes intermixed and interbedded, and the contact between the two soil types may be gradational. Both deposits were overridden by an estimated 3,000 feet of ice, which consolidated them into hard or dense layers. A mantle of the Vashon Till was deposited on top of the Esperance Sand and Lawton Clay. The Esperance Sand and Lawton Clay deposits were overlain by Vashon Till, also overridden by the ice sheet. These units are mantled by recessional deposits that were formed during the retreat of the ice sheet. Holocene modification of the glacial landscape in the last 11,700 years and recent activities helped sculpt the landform that is today.

The geologic unit descriptions and stratigraphy used by Wood are based on the mapped and structural geology (McKnight 1923, Waldron et al. 1962, Mullineaux 1965, Yount et al. 1993, Johnson et al. 1994, Liberty and Pratt 2008, Troost 2012, and WSDOT 2018a and 2018b) and as described by others (Golder 1993, Shannon & Wilson 2000, and GeoEngineers 2008) in the project vicinity. Wood simplified the geologic units for converting them into ESUs, which were used for foundation design of the structure. These modifications to the geologic units consisted of combining the Quaternary period Pleistocene and Holocene epoch soils. The geologic units encountered at the subject site, along with a brief discussion of their descriptions used for the project geology are provided in Table 3.

Table 3: Wall 9.05R-B Geologic Unit Descriptions

Geologic Unit Name		Abbrev.	Geologic Unit Description
Quaternary	Fill	Af	Fill placed by humans, both engineered and uncontrolled fill consisting of various materials, including debris; typically dense or stiff if engineered, but very loose to dense or very soft to stiff if uncontrolled fill
	Vashon Glacial Till	Qvt	Lodgment till laid down along the base of the glacial ice and overridden by the weight of glacial ice, consisting of gravelly, silty sand, or gravelly, sandy silt (“hardpan”); boulders and cobbles common; gray and very dense, and in its weathered state may be oxidized brown and medium dense to dense. Sometimes referred to as a diamicton.
	Advance Outwash	Qva	Glaciofluvial sediments deposited as the glacial ice advanced through the Puget Lowland and overridden by the weight of glacial ice; typically stratified, light brown to gray, sand, gravelly sand, and sandy gravel; dense to very dense

3.2 Site Soil Conditions

Some explorations encountered fill from construction of the 112th Avenue SE interchange and the Newport Hills park-and-ride lot varying in thicknesses from 3 to 20 feet. The fill was divided into two strata: loose sand and gravel, and dense sand and

gravel. The underlying native soil consisted of glacially overridden Vashon-age glacial till and glacial outwash to the full depths explored. The two test pits excavated prior to wall construction disclosed conditions similar to those described above. The southernmost test pit, W-TP5-21, which was excavated near the south end of the wall, encountered medium dense sandy silt with scattered organics (rootlets) interpreted as fill; overlying dense, poorly graded sand with interbedded gravel that was interpreted as advance outwash. Test pit W-TP6-21, which was excavated near the central portion of the wall, also encountered fill soils which in turn mantled dense silty sand that was interpreted as glacial till. The glacial till in turn mantled dense, poorly graded sand with interbedded gravel that was interpreted as advance outwash.

The exploration logs included in Appendix B and Appendix E provide detailed descriptions of the soil stratigraphy encountered during the subsurface explorations. The ESU profile and cross sections in Appendix A depict our interpretations of the stratigraphy.

The soil types encountered during the soil nail verification tests were consistent with the explorations. Glacial till consisting of dense silty sand and advance outwash consisting of dense sand was observed during verification of the soil nails.

3.3 Site Groundwater Conditions

Groundwater was not encountered at the time of drilling the explorations. Measurements taken from the monitoring well installed in W-64mw-20 indicated no groundwater present. Given the soil stratigraphy, there is a possibility of perched groundwater to accumulate with the fill above the glacial till (presented in Appendix A as ESU 4C) during wet periods of the year (due to glacial till inhibiting the infiltration of rainfall). Note that fluctuations of groundwater conditions may occur due to seasonal variations in the amount of rainfall, runoff, construction activities, and other factors not evident at the time borings were performed.

4.0 Geologic Hazards

The only applicable geologic hazard relative to this retaining wall is seismic stability. The design calculation package presenting detailed evaluations according to WSDOT-specific project requirements for determining the seismic parameters can be found in Appendix F. The seismic parameters for the area are summarized in Table 4 and correspond to a return period of about 1,000 years for the Safety Evaluation Earthquake. Seismic overall stability was analyzed per the Project GDM, Section 6.1.2.1.

Table 4: Segment 2A Seismic Design Parameters

Parameter	Return Period
	1,000-year (SEE)
Site class	C
Peak ground acceleration (PGA)	0.431g
F_{PGA}	1.200
Site-adjusted peak ground acceleration (A_S)	0.517g
Short-period (0.2-second) spectral acceleration (S_S)	0.98g
Site coefficient (Fa)	1.200
Short-period design response acceleration (S_{DS}) = S_S x Fa	1.176g
1-second period spectral acceleration (S_1)	0.283g
Site coefficient (Fv)	1.500
1-second design response acceleration S_{D1} = S_1 x Fv	0.425g
Mean earthquake magnitude (Mw)	7.0

Abbreviations:
SEE = Safety Evaluation Earthquake

The seismic coefficient parameter procedures are summarized in Section 6.2.2, Limit Equilibrium Pseudo Static Stability Analysis, in *Geotechnical Engineering Circular No. 3* (Kavazanjian 2011). To briefly summarize, the procedure modifies the average peak acceleration to account for slope height effects, in accordance with equations as shown below:

$$k_{av} = \alpha \cdot k_{max}$$

$$\alpha = 1 + 0.01 \cdot H \cdot (0.5 \cdot \beta - 1)$$

Where:
H = slope height (feet) and β is a function of the shape of the acceleration response spectrum as given by:

$$\beta = F_v \cdot S_1 / k_{max}$$

The height effects parameter, α, were calculated for various wall heights as shown in Table 5.

Table 5: Height Effects Parameter Calculations

Wall Height (feet)	A_s (g)	S_{D1} (g)	α	k_h (g)	Station No.
20	0.517	0.425	0.88	0.23	1+40
25	0.517	0.425	0.85	0.22	5+20
40	0.517	0.425	0.76	0.20	3+80

Abbreviation(s)
$A_s = k_{max}$ = peak ground acceleration
α = height effects parameter
g = acceleration of gravity
k_h = horizontal seismic coefficient
$S_{D1} = F_v \cdot S_1$ = 1-second design response acceleration

Wood used the following values in our pseudo-static seismic analysis:

- $k_h = 0.5 \cdot \alpha \cdot A_s = 0.5 \times 0.88 \times 0.517 = 0.23$ for Sta. 1+40;
- $k_h = 0.5 \cdot \alpha \cdot A_s = 0.5 \times 0.85 \times 0.517 = 0.22$ for Sta. 5+20; and
- $k_h = 0.5 \cdot \alpha \cdot A_s = 0.5 \times 0.76 \times 0.517 = 0.20$ for Sta. 3+80.

5.0 Design Soil Properties

5.1 Description of Units

Table 6 summarizes encountered geological units and the assigned ESUs used to develop geotechnical engineering recommendations for the design of wall 9.05R-B.

Table 6: ESU Units and Descriptions

Geologic Unit Name	Assigned ESU	ESU Description
Recent Fill	1A	All man-made (artificial) fill deposits; includes coarse- and fine-grained granular deposits. Typically, medium dense.
Recent Fill	1B	All man-made (artificial) fill deposits; includes coarse-grained granular deposits. Typically dense.
Glacial Till (Qvt)	4C	Dense to very dense silty SAND and GRAVEL, and hard, SILT and silty CLAY with sand and gravel; commonly containing cobbles or boulders; sorted or unsorted, may grade to clean sand over a relatively short distance.
Advance Outwash (Qva)	4A	Dense to very dense SAND and GRAVEL; may contain cobbles and varying amounts of silt; includes fluvial and outwash deposits.

5.2 Soil Properties

The project ESU soil properties were assigned based on the Geotechnical Soil Properties Methodology report (Wood 2020d). The methodology is consistent with Chapter 5 of the Project GDM. The soil properties for wall 9.05R-B are listed in Table 7. Calculations of these ESU soil properties are included in Appendix D.

Table 7: Wall 9.05R-B Design Soil Properties

ESU	Soil Type (USCS)	Average $(N_1)_{60}$ (blows per foot)	Moist Unit Weight (pcf)	Effective Friction Angle (deg)	Effective Cohesion (psf)
1A	SM	12	110	32	NA
1B	SM	25	120	35	NA
4A	SP-SM	81	135	42	NA
4C	SM	97	135	43	500

Abbreviation(s)

deg = degrees
ESU = Engineering Stratigraphic Unit
$(N_1)_{60}$ = SPT N-value corrected for effective overburden stress
NA = not applicable
pcf = pounds per cubic foot
psf = pounds per square foot
SPT = standard penetration test
USCS = Unified Soil Classification System

6.0 Engineering Analyses

The following sections describe results of geotechnical engineering analyses for soil nail wall 9.05R-B. As required by the Project GDM, the soil nail wall was analyzed in accordance with *Geotechnical Engineering Circular No. 7, Soil Nail Walls – Reference Manual* (FHWA 2015). The recommendations are based on interpretation of the subsurface condition shown in the ESU profile and cross sections, elevation and/or geometry of the structures as shown in the structural plan and profile sheets in Appendix A, and Flatiron-Lane's requested soil nail DLT based on the verification test results. The engineering analyses have been revised to align with the lower DLT of 1,700 pounds per linear foot (plf) for soil nails in the upper portion of the wall. If different subsurface conditions are encountered during the construction, the Project Geotechnical Engineer shall review the subsurface conditions and revise the recommendations as appropriate.

6.1 Soil-Grout Bond Strength

The soil-grout bond strength of the ESUs was originally estimated based on the upper bound values presented in Table 4.4a: Estimated Bond Strength for Soil Nails in Coarse-Grained Soils in *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015). As a result of the soil nail verification testing, the soil-grout bond strength has been reduced. Some of the verification tests resulted in pullout prior to achieving the maximum test loads. See Appendix G for a summary of the six verification tests and the detailed testing reports.

Since the soils observed during drilling of the test nails appeared to be consistent with the ESUs, proper materials (grout, bar, jack, etc.) were used, and the testing procedures were correct, the reason for the lower-than-expected pullout capacity is most likely the lower overburden pressure at the test elevations and the auger drilling method with gravity grouting. The drilling contractor plans to use this drilling method to prevent caving of the drill hole in the event of uniform sands. With this in mind, for constructability purposes, Flatiron-Lane directed us to use a DLT of 1,700 plf for the upper three rows of soil nails. This DLT represents the lowest of all six verification tests. In order to convert the DLT to ultimate soil-grout bond stress, we reduced the value for ESU 4C to 15 pounds per square inch. This is in agreement with the soil nail verification tests shown in Appendix G and is within the lower bound values presented in Table 4.4a in *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015). Note that the values provided in *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015) are based on empirical testing and the selection of the value should be based on actual testing when available.

Epoxy-coated soil nails will be installed in pre-drilled holes that will be a minimum of 6 inches in diameter and grouted with Type 4 Grout per WSDOT Standard Specification 9-20.3 (WSDOT 2018c). The soil-grout bond strength of the ESUs is shown in Table 8.

Table 8: ESU Ultimate Bond Strength

ESU	Soil Type (USCS)	Soil-Grout Bond Strength (psi)
1A	SM	15
1B	SM	18
4A	SP-SM	22
4C	SM	15

Abbreviations
ESU = Engineering Stratigraphic Unit
psi = pounds per square inch
USCS = Unified Soil Classification System

6.2 Surcharge Pressure Considerations

Lake Washington Boulevard SE is 42 feet wide and is located behind wall 9.05R-B at varying distances. The roadway traffic loading was modeled as a uniform surcharge of 250 pounds per square foot per Section 3.11.6.4 and the Extreme event live load was modeled as 0.5*LL per Section 3.4.1 of the *LRFD Bridge Design Specifications* (AASHTO 2017). Distances between the edge of the roadway and the soil nail wall faces at Sta. 03+80 and Sta. 05+20 are approximately 15 feet and 28 feet, respectively. The roadway traffic surcharge has little effect on the global stability of the soil nail wall section at Sta. 01+40, because the distance from the edge of the roadway to the face of the wall is as far as 280 feet, which is 15 times the height of the wall.

6.3 Resistance Factors

The resistance factors used for the soil nail wall external and internal stability evaluation summarized in Table 9 are based on *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015).

Table 9: Wall Design Resistance Factors

Design Parameter	Static Loading	Seismic Loading
Overall Stability	0.65	0.90
Nail Pullout	0.65	0.65
Tensile Resistance (Grades 60/75)	0.75	0.75

6.4 Stability of Soil Nail Walls

Two-dimensional, limit-equilibrium analyses based on the method of slices according to Morgenstern-Price & Spencer method for static condition and Morgenstern-Price & Bishop method for seismic condition were performed by using Snail-Plus Software Program (2019 version), developed by Deep Excavation LLC. This program employs limit-equilibrium methods in accordance with the Project GDM Chapter 7 and Section 15.4.12. This program analyzes overall stability, both internal (slip surface through some soil nails) and external (slip surface around all soil nails) stability, unlike older soil nail software described in *Geotechnical Engineering Circular No. 7, Soil Nail Walls – Reference Manual* (FHWA 2015). SnailPlus performs slope stability analysis and soil nail wall design. SnailPlus checks the global stability of slip surfaces (simple or reinforced with soil nails). SnailPlus can calculate and report the most critical slip surface and the slope stability safety factor with the use of various methods, such as Bishop, Morgenstern-Price, and Spencer (Deep Excavation 2021).

Global stability was checked and the results are included in Appendix F; however, they are not repeated in this section as they do not control the design. Due to the high frictional strength of the soils, the critical slip surface will exit at the toe of the wall, not beyond; therefore, internal stability controls the design. The analyses also provide estimated tensile forces for each of the nails supporting the wall. Results of estimated soil nail force (maximum tensile force) and nail force at the facing are included in Appendix F.

The revised overall stability analysis (using the lower soil-grout bond stress) resulted in the need for slightly higher nail head strength in order to keep the soil nail lengths and spacing the same. The revised values have been confirmed with the structural engineer and are less than or equal to the actual design strengths. The structural engineers will design the nail head connection and wall facing, taking into account the minimum strength assumed in the stability design.

The following three design conditions were considered:

- ***Permanent Static:*** Static stability after construction has been completed;
- ***Temporary Static:*** Static stability during construction, particularly the period of time after excavation of a new step but before installation of the soil nails for that step; and
- ***Seismic:*** Seismic stability after construction has been completed, based on the Safety Evaluation Earthquake.

Revised results of the overall stability analyses for the project wall heights are summarized in Table 10, and details can be found in Appendix F. The minimum required factors of safety are based on Project GDM Sections 15.5.7 and 7.4.5. Results of the overall stability analyses for the forward compatible wall heights are summarized in Table 11.

Table 10: Design Factors of Safety – Project Wall

Condition	Minimum Required FS	Analysis Method	Project Wall Height Design Section[1]		
			9.05R-B Sta. 01+40	9.05R-B Sta. 03+80	9.05R-B Sta. 05+20
Permanent Static	1.5	M-P	2.1	1.9	1.8
		Spencer	2.2	2.0	1.8
Temporary Static	1.2	M-P	1.3	1.6	1.5
		Spencer	1.4	1.7	1.5
Seismic	1.1	M-P	1.3	1.6	1.4
		Bishop	1.2	1.7	1.4

Notes:
1. Calculations are included in Appendix F.

Abbreviations:
FS = factor of safety
M-P = Morgenstern-Price
Sta. = station

Table 11: Design Factors of Safety – Future Wall

Condition	Minimum Required FS	Analysis Method	Future Wall Height Design Section[1]		
			9.05R-B Sta. 01+40	9.05R-B Sta. 03+80	9.05R-B Sta. 05+20
Permanent Static	1.5	M-P	1.7	1.6	1.5
		Spencer	1.7	1.9	1.6
Temporary Static	1.2	M-P	1.4	1.6	1.3
		Spencer	1.3	1.6	1.4
Seismic	1.1	M-P	1.3	1.4	1.3
		Bishop	1.4	1.5	1.4

Notes:
1. Calculations are included in Appendix F.

Abbreviations:
FS = factor of safety
M-P = Morgenstern-Price
Sta. = station

Soil Nail Wall Displacements: Soil nail reinforcement is mobilized through lateral wall deflections as the cut wall construction proceeds downward in stages. Typical wall deflections during construction are estimated to be 0.2 percent of the excavation depth as stated in Section 5.9.2 of *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015). It is estimated that vertical and horizontal deflections of the wall may approach 1 inch during or shortly after construction for the highest wall segment, with the greatest deflections occurring near the top of the wall. Due to the very dense glacially over-consolidated soils (ESUs 4A and 4C), lateral and vertical soil nail wall displacement and settlement could be less than what is typically estimated.

7.0 Soil Nail Wall Design

Soil nail wall design followed the requirements in Sections 15-5.2.3 and 15-5.7 of the Project GDM and *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015). The design of the soil nail wall, soil nail lengths, spacing, size, etc., followed the *Geotechnical Engineering Circular No. 7, Soil Nail Walls – Reference Manual* (FHWA 2015) and verified that the calculated factor of safety for the critical slip surface was greater than the minimum required factor of safety.

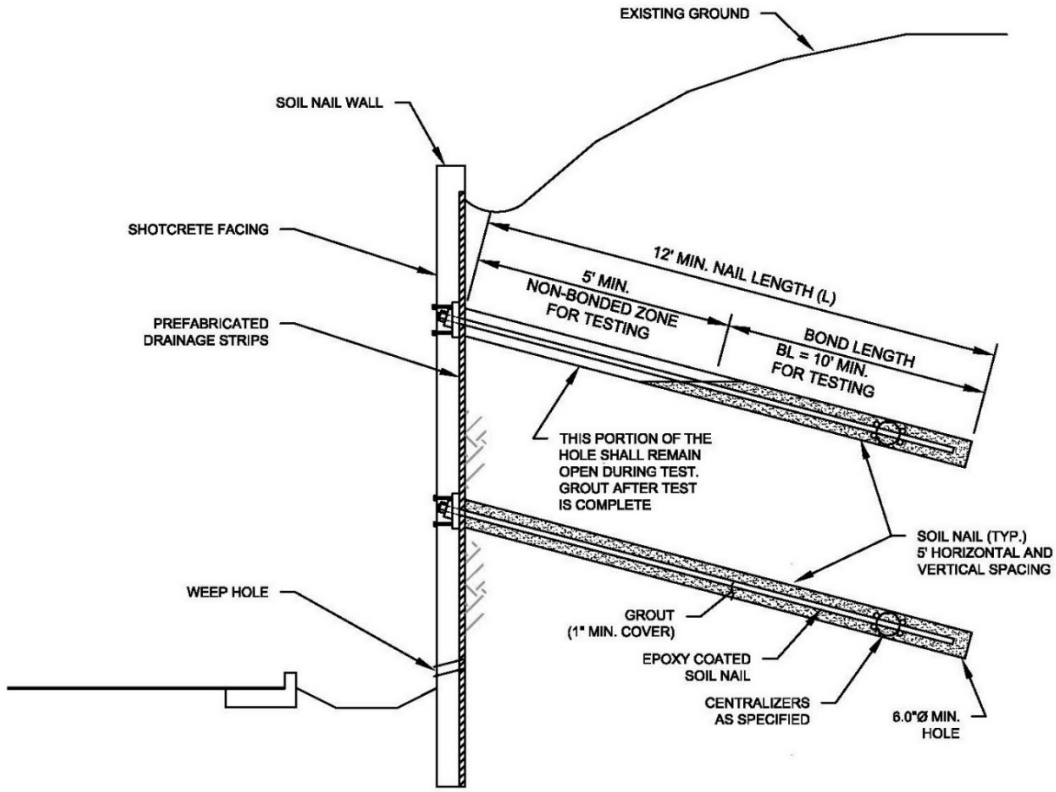
7.1 Design Wall Sections

Wall 9.05R-B was evaluated at three different sections of the wall, based on the variation of the wall height, soil conditions, and geometry. The soil conditions varied at Sta. 01+40 (cross section A–A') with lower strength properties in the upper 10 feet. The wall height was the greatest at Sta. 03+80 (cross section B–B'). The geometry of the backslope and foreslope varied at Sta. 05+20 (cross section C–C'), so an additional section at Sta. 05+40 was required to confirm the design of the soil nail wall. The design criteria are highlighted for each critical cross section in Table 12.

Table 12: Design Sections

Cross Section	Wall Station	Start Station	End Station	Selection Criteria
A–A'	01+40	1+00	2+00	Different soils
B–B'	03+80	2+00	5+20	Maximum wall height
C–C'	05+20	5+20	6+06	Backslope

Recommendations for design and layout that apply to the entire wall are discussed in Section 7.5. Figure 1 displays a typical/general soil nail wall cross-section. Soil nail wall design calculations are presented in Appendix F.



Verify adhesion with verification tests and proof tests, as specified.

Figure 1: Soil Nail Design Criteria

7.2 Cross-Section A–A' Sta. 01+40

Interpreted subsurface conditions at this location along the wall are displayed on ESU cross section A–A at Sta. 1+40 in Appendix A. The ESU soil properties and the soil-grout bond stress are presented in Table 13. Groundwater was not encountered in the explorations.

Table 13: Cross Section A–A' Sta. 01+40 ESUs

Elevation (feet)		ESU	Soil Type (USCS)	Ymoist (pcf)	Phi (deg)	Cohesion[1] (psf)	Ultimate Soil-Grout Bond (psi)
From	To						
152	148	1A	SM	110	32	NA	15
148	145	1B	SM	120	35	NA	18
145	145	4C	SM	135	43	500[1]	15[2]
145	90	4A	SP-SM	135	42	NA	22

Notes:
1. Cohesion not used for the stability modeling of the soil nail wall.
2. Revised based on verification testing and test pit observations.
3. Groundwater elevation: not encountered.

Abbreviations:
deg = degree
ESU = Engineering Stratigraphic Unit
NA = not applicable
pcf = pounds per cubic foot
Phi = effective friction angle
psf = pounds per square foot
psi = pounds per square inch
USCS = Unified Soil Classification System
Ymoist = moist unit weight

Wall Design Summary:

- Analyses were performed using a 19-foot-high wall with a 3H:1V backslope and a soil nail length of 15 feet.
- Top of wall is assumed at elevation 152 feet and bottom of wall is assumed at elevation 133 feet considering future expansion. Elevations referenced in this report are based on the North American Vertical Datum of 1988.
- The upper (first and second) soil nail rows will be installed during this construction. The lower (third and fourth) soil nail rows will be installed during forward compatibility construction in the future.
- Table 14 provides detailed design information.

Table 14: Cross Section A–A' Sta. 01+40 Design Information

Soil Nail Location	Total Length (feet)	Spacing (V x H in feet)	Bar Size (#)	DLT (lbs/ft)	Nail Head Force[1]	
					Static (kips)	Seismic (kips)
1st row from top	15	5 x 6	8	1,700	16	22
Lower rows	15	5 x 6	8	2,500	18	36

Note:
1. Estimated maximum nail tensile force at the wall face (T_o).

Abbreviations:
DLT = design load transfer using a resistance factor of 0.5
H = horizontal
lbs/ft = pounds per foot
V = vertical

7.3 Cross-Section B–B' Sta. 03+80

The critical section at Sta. 03+80 represents the design section for the soil nail wall from northbound Sta. 7779+59 to Sta. 7782+54. Interpreted subsurface conditions are displayed on ESU cross section B–B' at Sta. 3+80 in Appendix A. The ESU soil properties and soil-grout bond stress are presented in Table 15. Groundwater was not encountered in the explorations.

Table 15: Cross Section B–B' Sta. 03+80 ESUs

Elevation (feet)		ESU	Soil Type (USCS)	Ymoist (pcf)	Phi (deg)	Cohesion[1] (psf)	Ultimate Soil-Grout Bond (psi)
From	To						
178	171	4C	SM	135	43	500[1]	15[2]
171	93	4A	SP-SM	135	42	NA	22

Notes:
1. Cohesion not used for the stability modeling of the soil nail wall.
2. Revised based on verification testing.
3. Groundwater elevation: not encountered.

Abbreviations:
deg = degree
ESU = Engineering Stratigraphic Unit
NA = not applicable
pcf = pounds per cubic foot
Phi = effective friction angle
psf = pounds per square foot
psi = pounds per square inch
USCS = Unified Soil Classification System
Ymoist = moist unit weight

Wall Design Summary:

- Analyses were performed using a 39-foot-high wall with a live load of 250 pounds per square foot and a soil nail length of 25 feet.
- Top of wall is assumed at elevation 177 feet and bottom of wall is assumed at elevation 138 feet considering future expansion.
- The upper (first to seventh) soil nail rows will be installed during this construction. The bottom (eighth) soil nail rows will be installed during forward compatibility construction in the future.
- Table 16 provides detailed design information.

Table 16: Cross Section B–B' Sta. 03+80 Design Information

Soil Nail Location	Total Length (feet)	Spacing (V x H in feet)	Bar Size (#)	DLT (lbs/ft)	Nail Head Force[1]	
					Static (kips)	Seismic (kips)
First Three Rows From Top	25	5 x 5	10	1,700[2]	29	32
Lower Rows	25	5 x 5	10	2,500	33	31

Note:
1. Estimated maximum nail tensile force at the wall face (To).
2. Revised based on verification testing.

Abbreviations:
DLT = design load transfer using a resistance factor of 0.5
H = horizontal
lbs/ft = pounds per foot
V = vertical

7.4 Cross-Section C–C' Sta. 05+20

The critical section at Sta. 05+20 represents the design section for the soil nail wall from northbound Sta. 7782+54 to Sta. 7784+04. Interpreted subsurface conditions are displayed on ESU cross section C–C' at Sta. 5+20 in Appendix A. The ESU soil properties and soil-grout bond stress are presented in Table 17. Groundwater was not encountered in the explorations.

Table 17: Cross Section C–C' Sta. 05+20 ESUs

Elevation (feet)		ESU	Soil Type (USCS)	Ymoist (pcf)	Phi (deg)	Cohesion (psf)	Ultimate Soil-Grout Bond (psi)
From	To						
172	93	4A	SP-SM	135	42	NA	22

Notes:
1. Groundwater elevation: not encountered.

Abbreviations:
deg = degree
ESU = Engineering Stratigraphic Unit
NA = not applicable
pcf = pounds per cubic foot
Phi = effective friction angle
psf = pounds per square foot
psi = pounds per square inch
USCS = Unified Soil Classification System
Ymoist = moist unit weight

Wall Design Summary:

- Analyses were performed using a 25-foot-high wall with a 2H:1V backslope (10 feet in vertical), a live load of 250 pounds per square foot, and a soil nail length of 20 feet. Since various backslopes exist in the area, an additional cross section at Sta. 5+40 was checked to verify the soil nail length of 20 feet. Analyses confirmed that Sta 5+20 was the critical design section.
- Top of wall is assumed at elevation 163 feet and bottom of wall is assumed at elevation 143 feet considering future expansion.
- The upper (first to fourth) soil nail rows will be installed during this construction. The fifth soil nail row will be installed during forward compatibility construction in the future.
- Table 18 provides detailed design information.

Table 18: Cross Section C–C' Sta. 05+20 Design Information

Soil Nail Location	Total Length (feet)	Spacing (V x H in feet)	Bar Size (#)	DLT (lbs/ft)	Nail Head Force[1]	
					Static (kips)	Seismic (kips)
First Row From Top	20	5 x 6	8	1,700[2]	24	25
Lower Rows (Initial Construction)	20	5 x 6	8	2,500	27	27
Bottom Row (Forward Compatibility)	15	5 x 6	8	2,500	16	14

Note:
1. Estimated maximum nail tensile force at the wall face (To).
2. Revised based on verification testing.

Abbreviations:
DLT = design load transfer using a resistance factor of 0.5
H = horizontal
lbs/ft = pounds per foot
V = vertical

7.5 Soil Nail Wall General Recommendations

Recommendations for design of the soil nail walls that apply to all sections are described in this section.

Wall Batter: The design of the wall has assumed the facing will be vertical. A small batter to the wall face would increase stability.

Soil Nail Locations: The nails can be laid out using a squared pattern for construction simplicity, or a staggered pattern to reduce the total number of nails. The recommended spacing could be modified slightly to avoid utilities and other obstructions, as necessary. Where spacing is to be modified, the nail spacing must still meet minimum and maximum spacing requirements specified in Project GDM Section 15-5.7. The specific spacing for each design section is provided in Tables 14, 16, and 18.

Upper and Lower Nail Locations: When laying out the soil nails on the wall profile, ideally, the highest row of soil nails should be located no less than 2 and no more than 3 feet below the top of the temporary cut slope, to provide adequate soil cover and to avoid excessive facing cantilever distances. The lowest nail should be at least 2 feet above the lowest excavation level to allow adequate spacing for the drilling rig; and not more than 3 feet above the bottom of temporary excavations.

Nail Declinations: Soil nails should be installed at a 15-degree angle below horizontal. However, per WSDOT Standard Specifications (WSDOT 2018c), a tolerance of 3 degrees is allowable to avoid obstructions or structures.

Nail Hole Diameters: A minimum diameter of 6 inches shall be specified to maintain grout cover over the soil nail tendons. Regardless of the nail diameter or installation method selected by the contractor, all soil nails need to provide the minimum DLT stated in Tables 14, 16, and 18, and shall be verified by verification testing and proof testing.

Nail Tendon Types and Sizes: The design is based on all nail tendons consisting of minimum Grade 75 deformed steel reinforcing rods, threaded at the proximal end (closest to the face). The specific bar sizes have been provided in Tables 14, 16, and 18.

Corrosion Protection: The retained soil at the wall location was sampled for corrosion testing. Sample S-9 at 35 feet deep in boring W-65-20 was tested for pH and resistivity per method SW-846 9045D and ASTM G-187, respectively. The test results showed a pH of 7.0 and resistivity of 11,000 ohms-cm and are included in Appendix C. Per Section 15-5.7 of the Project GDM, the soil is not classified with strong corrosion potential; therefore, the permanent soils nails may be epoxy coated.

Nail Tendon Centralizer: Centralizers shall be installed along the tendons at a maximum spacing of 7 feet, including one centralizer within 3 feet of the distal (furthest from the face) end of the tendon. The centralizers shall be stiff and large enough to provide at least 1 inch of grout cover over the tendon. Openings between the centralizer support arms shall allow unobstructed tremie pipe insertion and grout flow.

Completed Verification Testing: Verification tests have already been completed for the upper rows of nails (upper row for cross sections A–A' and C–C', and upper three rows for cross section B–B'). The results of these test were incorporated into the engineering analyses and recommendations in this report.

Verification Testing: Prior to installing any production nails in the lower rows of soil nails, sacrificial nails shall be installed and tested to verify the higher DLT of 2,500 plf. The lower rows will only be one soil type (ESU 4A), so the number of verification tests will depend on the other considerations listed in the WSDOT Standard Specifications (WSDOT 2018c). We recommend a minimum of two verification tests near the elevation of the fourth row of soil nails distributed between Sta. 2+00 and Sta. 5+20 (cross section B–B').

Proof Testing: During construction of the walls, sacrificial soil nails shall be tested to prove the required pullout resistance (DLT). At least one soil nail in each row shall be tested and at least 5 percent of all nails shall be tested. Test nails will need to be selected prior to installation so that the grouting is stopped short to create an unbonded zone for testing purposes. The WSDOT Standard Specifications (WSDOT 2018c) outline the testing procedure for soil nails.

Facing Design Parameters: Wood has coordinated the facing design with the wall structural engineers. Although the structural engineers will be designing the facing, several design parameters are needed as inputs to the Soil Nail Plus software, which are then used to check the nail loads, especially the nail head load at the face. After confirming the facing parameters and analyzing the walls with Soil Nail Plus, Wood included the maximum nail head load in the calculation package in Appendix F.

Wall Drainage: Drainage during and after construction will be important to prevent hydrostatic pressure. Perched groundwater might be encountered from the cut slope through the soil. To reduce hydrostatic pressures on the wall facing, prefabricated drainage strips shall be placed between the cut slope and shotcrete facing. At least one vertical strip with a minimum width of 12 inches will be placed between each column of soil nails. Drainage material shall be connected to weep holes using a drain grate or shall be wrapped around an underdrain.

Wall Deflections: Soil nail reinforcement is mobilized through lateral wall deflections as the cut wall construction proceeds downward in stages. Typical wall deflections during construction are estimated to be 0.2 percent of the excavation depth as stated in Section 5.9.2 of *Geotechnical Engineering Circular No 7: Soil Nail Walls Reference Manual* (FHWA 2015). It is estimated that vertical and horizontal deflections of the wall may approach 1 inch during or shortly after construction for the highest wall segment, with the greatest deflections occurring near the top of the wall.

8.0 Construction and Maintenance Considerations

8.1 Construction

Test Pit Exploration: Test pits have been excavated to evaluate the unsupported wall facing stand-up time in accordance with Section 15-3.4.2.1 of the Project GDM. The soils observed in the test pits were consistent with the design ESUs and the sidewalls demonstrated adequate standup time. See Appendix E for detailed observations of the test pits.

Drilling Conditions: The soils include fill, glacial till, and advance outwash; these soils are expected to have a wide variety of grain size, including the possibility of gravel and boulders. Gravel, cobbles, and boulders are known to exist in the ESU 4A and 4C materials and while cobbles were only encountered in one boring (W-65-20) near the north end of the wall, there is a possibility that they could be present in other areas as well. Soil nail drilling may encounter caving ground conditions, in which case the soil nails may need to be inserted into a temporary cased hole. Glacial till and boulders could present difficult, slow drilling conditions. Although no groundwater was encountered in the explorations, perched groundwater could accumulate on top of the glacial till during the wet season.

Verification and Proof Testing of the Soil Nails: For simplicity during construction, the soil-grout bond stress stated in the report will be converted to a DLT on the construction plan sheets, consistent with WSDOT standard plans and specifications. The DLT will represent the allowable (resistance factor applied) force per foot of nail (in pounds per foot). The testing procedure in the WSDOT Standard Specifications (WSDOT 2018c) lists testing steps in proportion to the DLT. Follow the WSDOT Standard Specifications for verification and proof testing of soil nails. Some verification nails have been completed already and the resulting DLT has been applied to the design of the upper soil nail rows. Additional verification soil nails will be needed for the lower rows of soil nails where a higher DLT has been assumed. We recommend two verification tests near the elevation of the fourth row of soil nails distributed between Sta. 2+00 and Sta. 5+20 (cross section B–B').

Forward Compatibility: Forward compatibility allows for road expansion on I-405 in the future. The lower soil nails (third and fourth row from the top) at cross section A–A', bottom soil nail row (eight rows from the top) at cross section B–B', and bottom soil nail row (fifth row from the top) at cross section C–C' will be installed during future construction. They will not be installed during this construction project.

8.2 Maintenance

The retaining wall structure will require typical maintenance throughout its lifetime. The walls will have drainage through the wall to prevent hydrostatic pressure build-up behind the wall. These drainage systems need to be maintained.

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In Association with

Appendix A
Wall Design Plan Sheets and
ESU Cross Sections and Profiles

ESU CLASSIFICATION

ESU GROUP #1	FILL MATERIAL			
DESCRIPTION	DENSITY/CONSISTENCY	PRIMARY CONSITIUENT	ESU #	COLOR
UNCONTROLLED FILL	LOOSE TO MEDIUM DENSE	SAND/GRAVEL	1A	
UNCONTROLLED FILL	MEDIUM DENSE TO DENSE	SAND/GRAVEL	1B	

ESU GROUP #4	GLACIALLY OVERRIDDEN DEPOSITS			
DESCRIPTION	DENSITY/CONSISTENCY	PRIMARY CONSITIUENT	ESU #	COLOR
ADVANCE OUTWASH	DENSE TO VERY DENSE	SAND	4A	
GLACIAL TILL	DENSE TO VERY DENSE	SAND	4C	

BORE LOCATIONS

- PROJECT BORE LOCATIONS
- HISTORIC BORE LOCATIONS
- PREVIOUS EXPLORATION LOCATIONS
- CURRENT EXPLORATION LOCATIONS
- CURRENT TEST PIT LOCATIONS

WETLAND

- SHORELINES
- WETLAND PATTERN AND BOUNDARY
- OHW — ORDINARY HIGH WATER LINE
- WETLAND MITIGATION BUFFER
- STREAM MITIGATION BUFFER
- PERMANENT WETLAND BUFFER
- TEMPORARY WETLAND BUFFER
- PERMANENT STREAM BUFFER
- TEMPORARY STREAM BUFFER
- TEMPORARY STREAM IMPACT
- PERMANENT WETLAND IMPACT
- TEMPORARY WETLAND IMPACT
- STREAM CENTERLINE
- CONVERT WETLAND TO STREAM

UTILITIES

- OP — ABOVE GROUND POWER
- S — SEWER LINE
- W — WATER LINE
- BP — UNDER GROUND POWER LINJE
- BT — UNDER GROUND TELEPHONE CABLE
- OT — ABOVE GROUND TELEPHONE LINE
- O — OIL LINE
- G — GAS LINE
- BF — UNDER GROUND FIBRE OPTIC
- BTV — UNDER GROUND TV CABLE
- W — UNDER GROUND WATER VAULT
- P — UNDER GROUND POWER VAULT

DRAINAGE

- DITCH BOTTOM
- ST — ST — STORM SEWER LINE
- DETENTION POND
- CATCH BASIN
- CULVERT
- BOX CULVERT NEW
- BIO FILTRATION SWALE

EXISTING TOPOGRAPHY

- TREE
- BRUSH LINE
- TREE LINE
- FENCE
- PROPOSED RETAINING WALL
- STD METAL LIGHT OR SIGNAL

RIGHT OF WAY

- EXISTING RIGHT OF WAY
- PROPOSED RIGHT OF WAY
- IMPACT PERMIT LINE NEW

- PROPOSED WALL LOCATION
- GROUNDWATER LEVEL

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ENTERED BY	P. MCCARTHY
CHECKED BY	A. ANDERSON
PROJ. ENGR.	T. WENTWORTH
REGIONAL ADM.	T. NETTLETON

REVISION	DATE	BY

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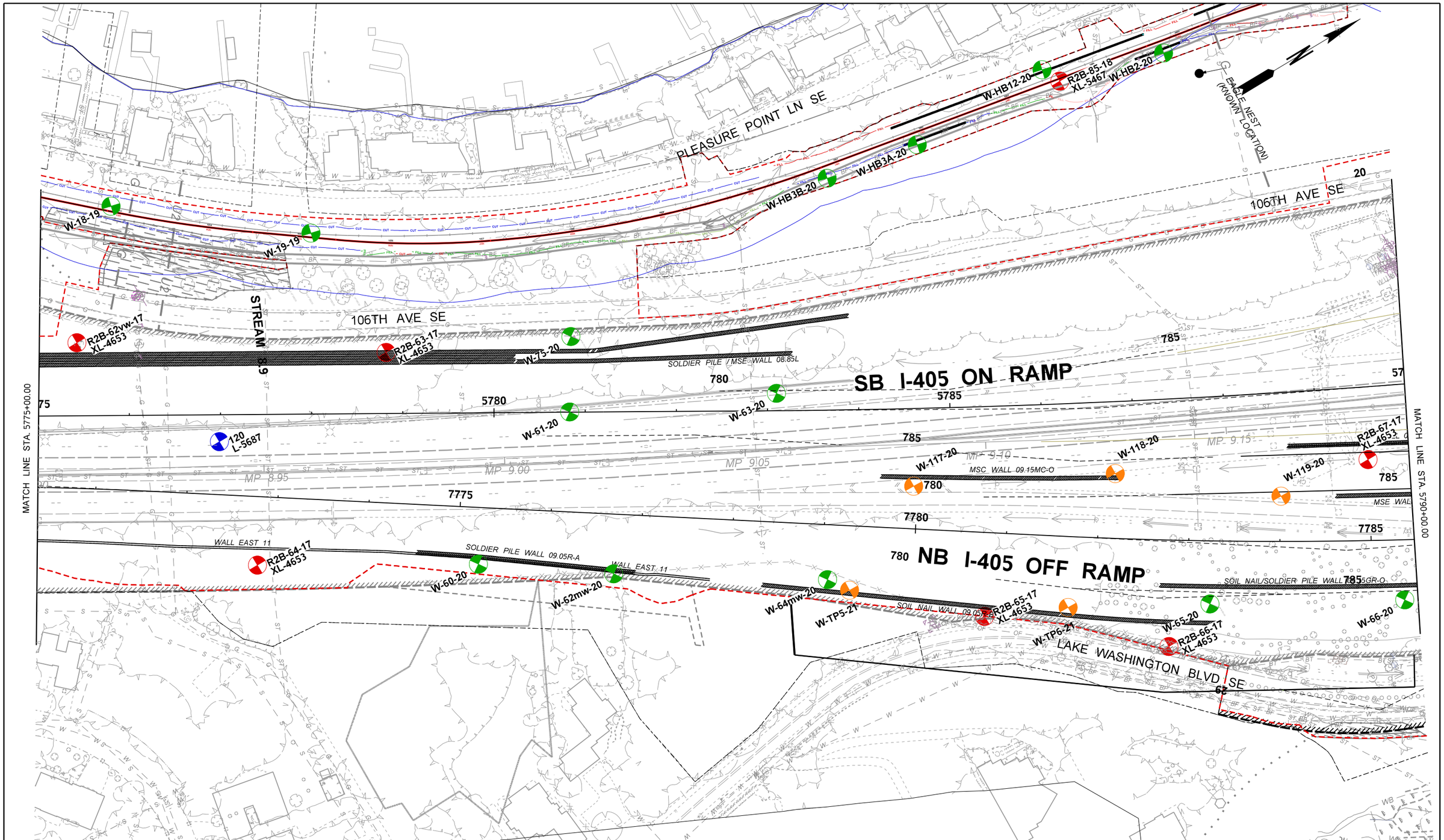
I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

SHEET LEGEND

SHEET 2 OF 9 SHEETS



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I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

SIP-4 SHEET STA 5775+00 TO STA 5790+00

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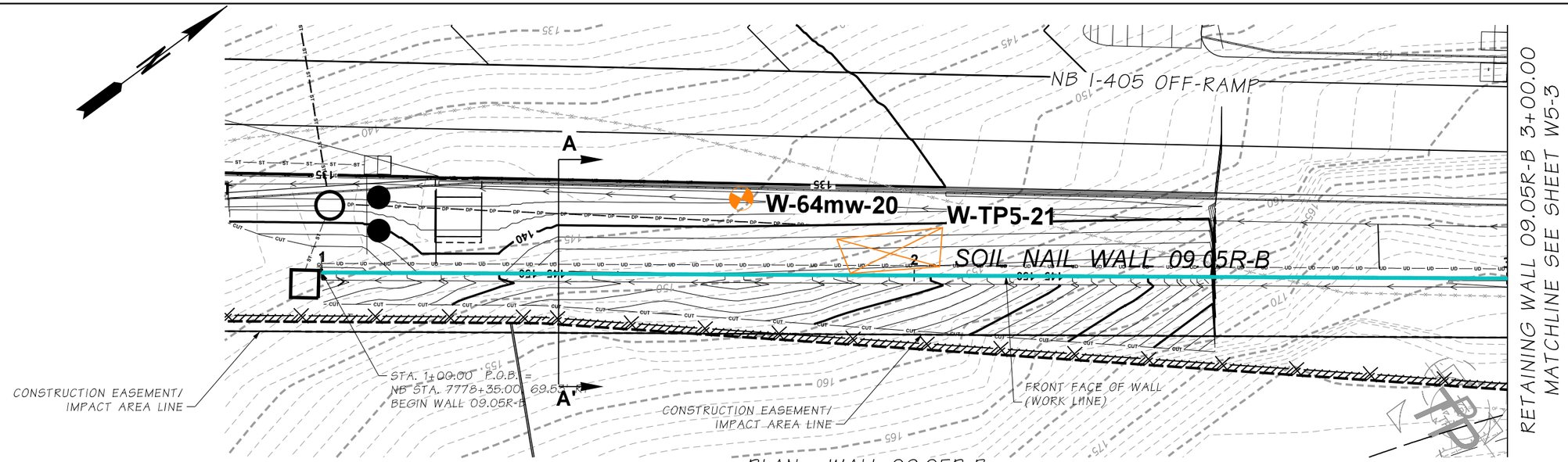
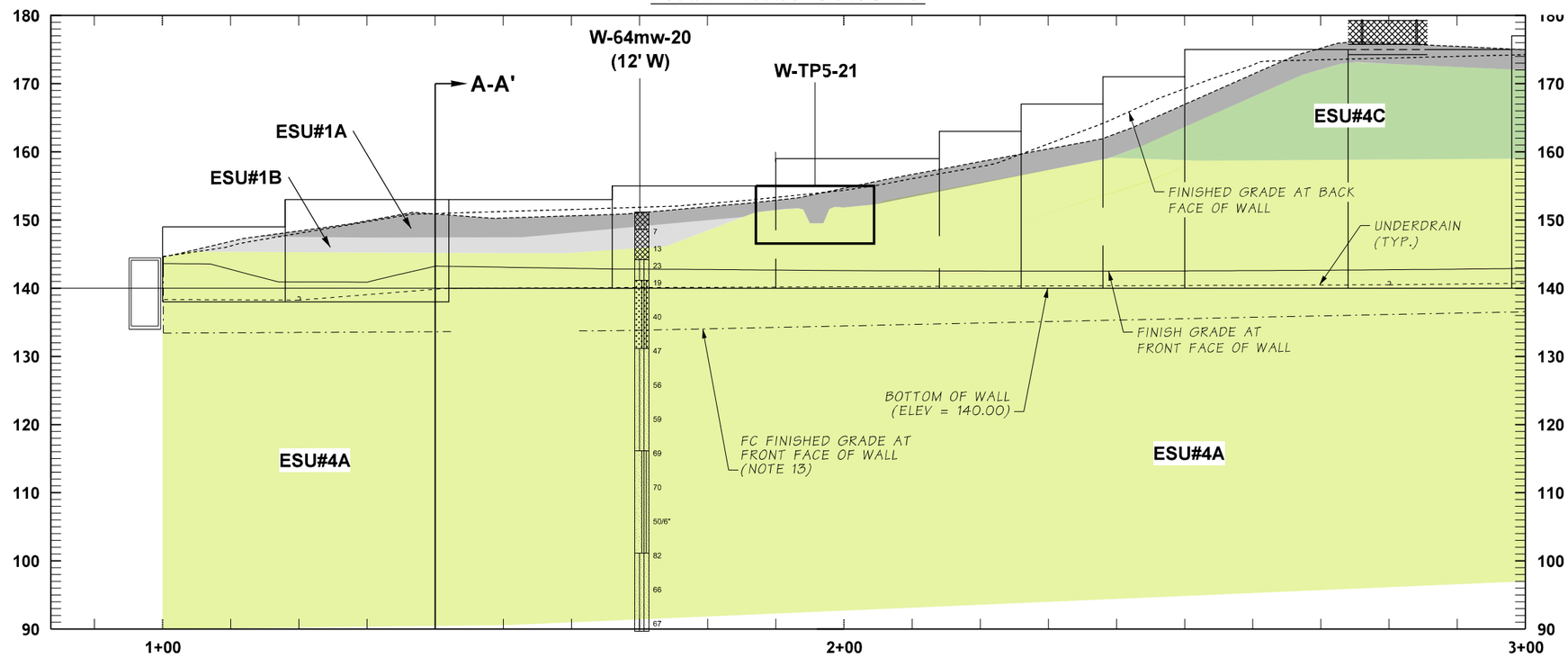


PLAN - WALL 09.05R-B



REFLECTIVE ELEVATION - WALL 09.05R-B

THE ESU STRATIFICATION HAVE BEEN INTERPRETED, INTERPOLATED BETWEEN EXPLORATIONS, AND EXTRAPOLATED BEYOND EXPLORATIONS FOR ENGINEERING DESIGN PURPOSES. THE STRATA MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. SEE THE EXPLORATION LOGS FOR DETAILED SUBSURFACE CONDITIONS AT THE LOCATION EXPLORED.

WALL TYPE: SOIL NAIL

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PROJ. ENGR.	T. WENTWORTH						
REGIONAL ADM.	T. NETTLETON	REVISION	DATE	BY			

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Washington State Department of Transportation

FLATIRON LANE

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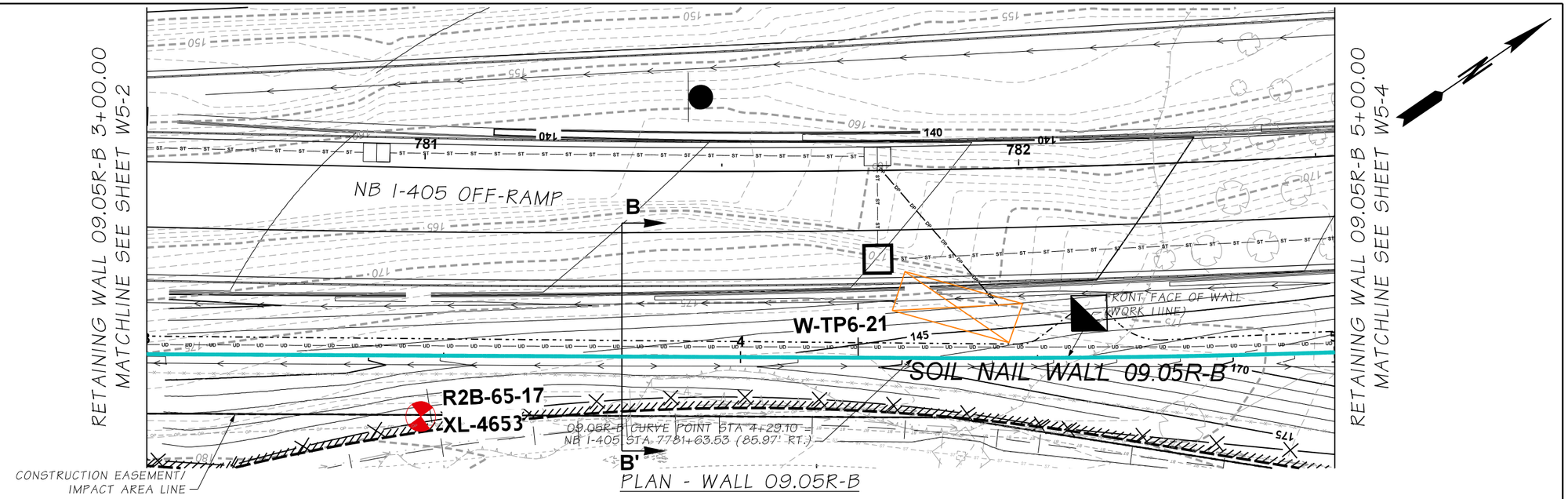
I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

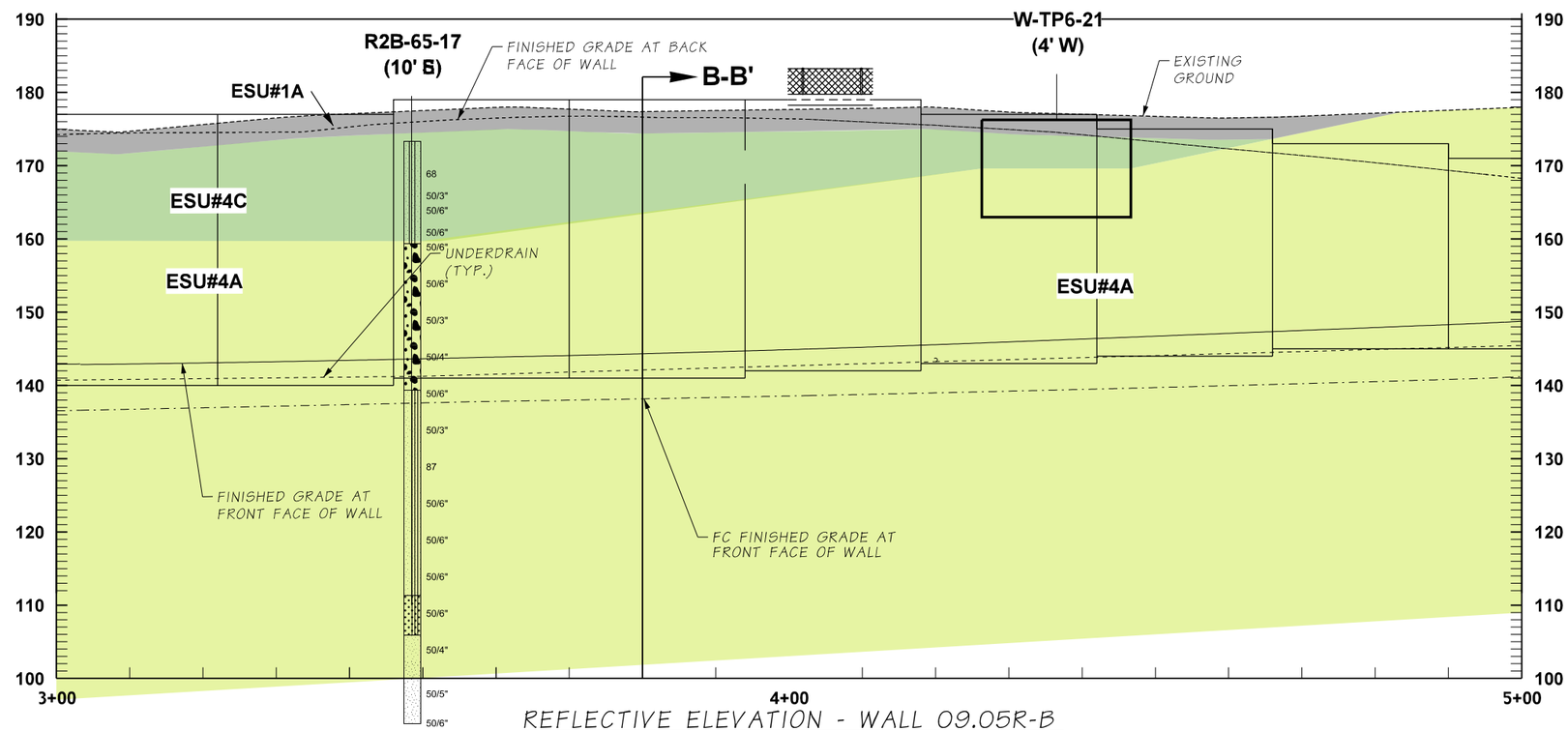
RETAINING WALL PLAN AND PROFILE
WALL 09.05R-B (1 OF 3)

PLAN REF NO
W5-2

SHEET 4 OF 9 SHEETS



PLAN - WALL 09.05R-B



REFLECTIVE ELEVATION - WALL 09.05R-B

THE ESU STRATIFICATION HAVE BEEN INTERPRETED, INTERPOLATED BETWEEN EXPLORATIONS, AND EXTRAPOLATED BEYOND EXPLORATIONS FOR ENGINEERING DESIGN PURPOSES, THE STRATA MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. SEE THE EXPLORATION LOGS FOR DETAILED SUBSURFACE CONDITIONS AT THE LOCATION EXPLORED.

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DATE	12/1/2021
PLOTTED BY	patrick.mccarthy
DESIGNED BY	D. LEE
ENTERED BY	P. MCCARTHY
CHECKED BY	A. ANDERSON
PROJ. ENGR.	T. WENTWORTH
REGIONAL ADM.	T. NETTLETON

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER

CONTRACT NO. | LOCATION NO.

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

FLATIRON LANE

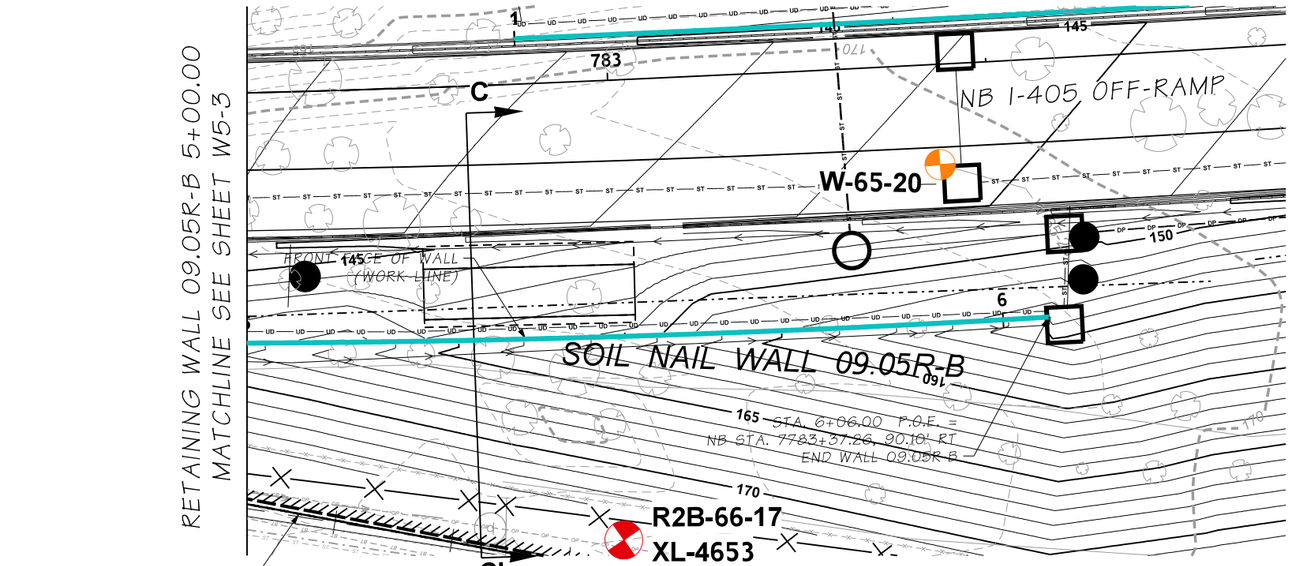
wood.

I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

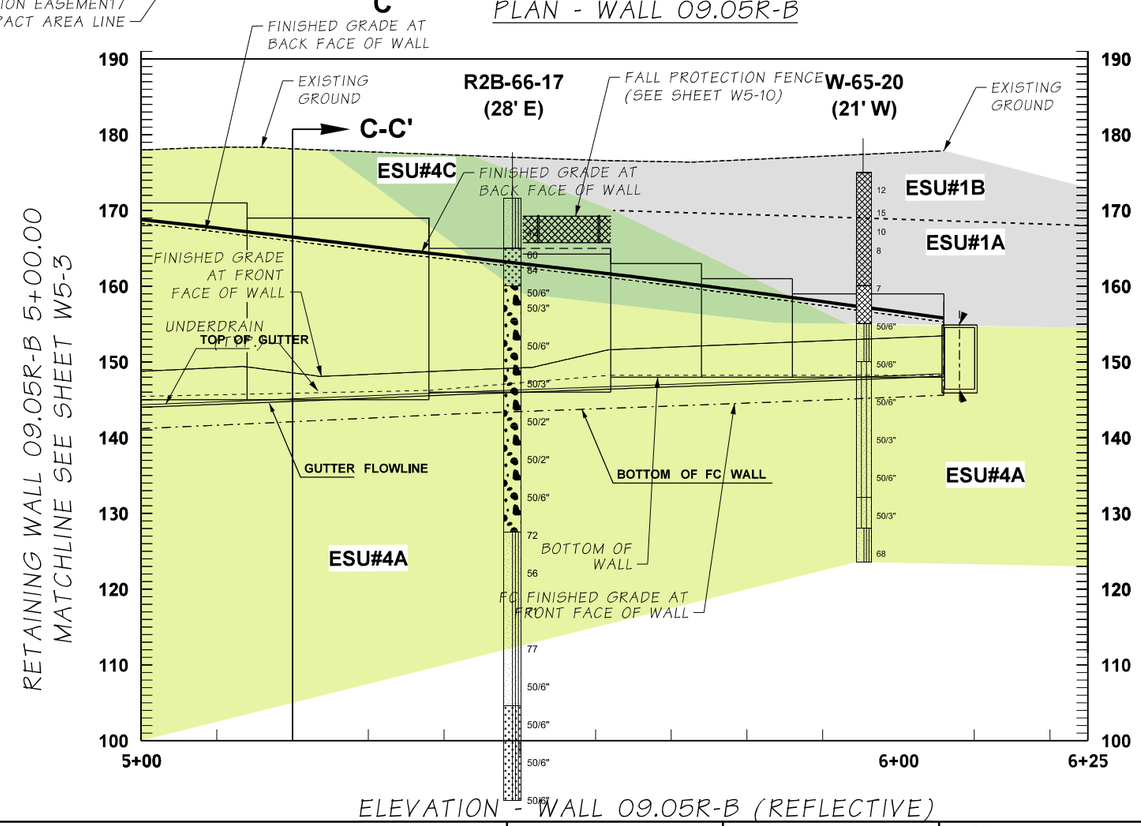
RETAINING WALL PLAN AND PROFILE
WALL 09.05R-B (2 OF 3)

PLAN REF NO

SHEET 5 OF 9 SHEETS



PLAN - WALL 09.05R-B



ELEVATION - WALL 09.05R-B (REFLECTIVE)

THE ESU STRATIFICATION HAVE BEEN INTERPRETED, INTERPOLATED BETWEEN EXPLORATIONS, AND EXTRAPOLATED BEYOND EXPLORATIONS FOR ENGINEERING DESIGN PURPOSES. THE STRATA MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. SEE THE EXPLORATION LOGS FOR DETAILED SUBSURFACE CONDITIONS AT THE LOCATION EXPLORED.

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DATE	11/15/2021				JOB NUMBER		
PLOTTED BY	patrick.mccarthy						
DESIGNED BY	D. LEE						
ENTERED BY	P. MCCARTHY						
CHECKED BY	A. ANDERSON				CONTRACT NO.		LOCATION NO.
PROJ. ENGR.	T. WENTWORTH						
REGIONAL ADM.	T. NETTLETON	REVISION	DATE	BY			

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

FLATIRON LANE

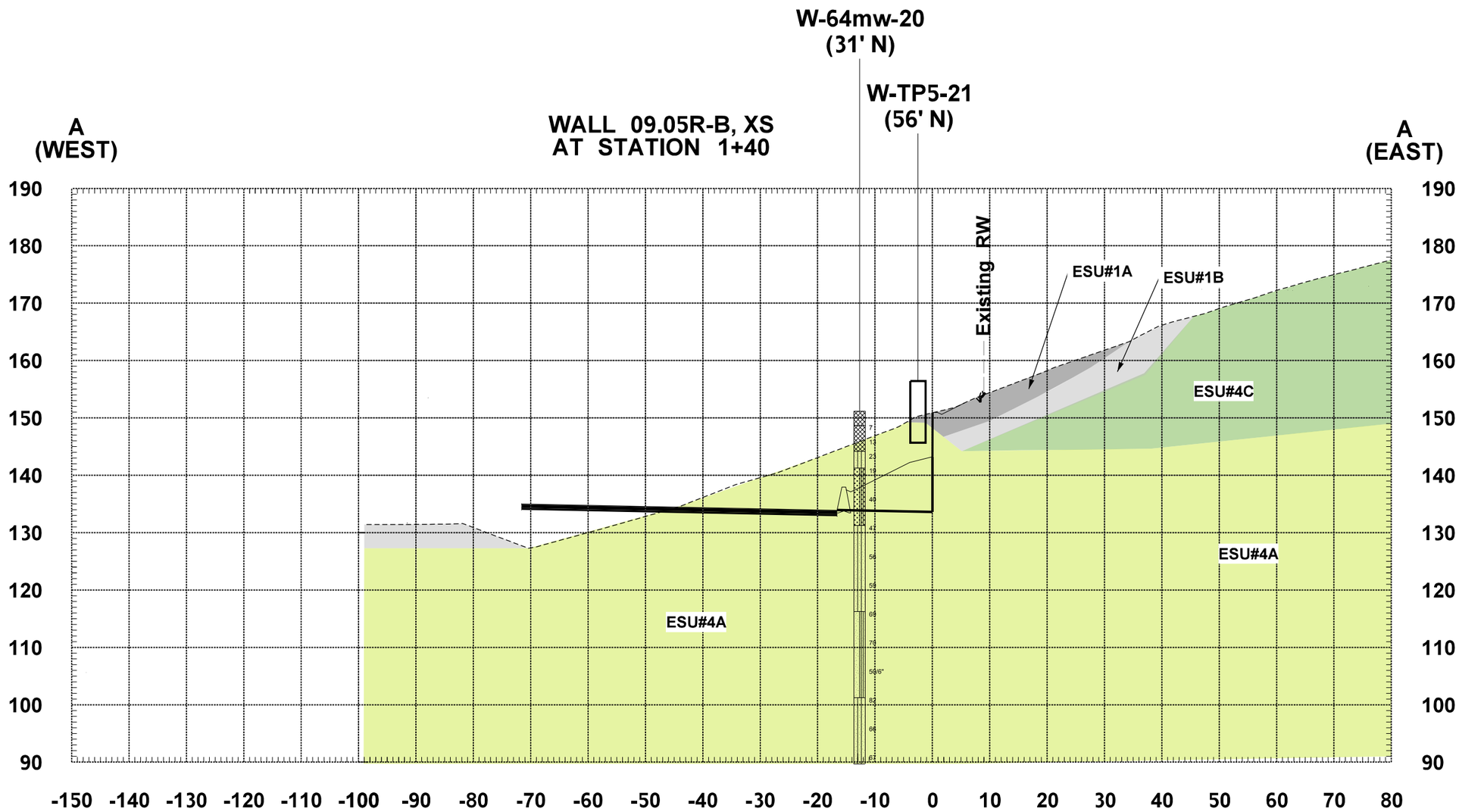
wood.

I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

RETAINING WALL PLAN AND PROFILE
WALL 09.05R-B (3 OF 3)

PLAN REF NO

SHEET 6 OF 9 SHEETS



THE ESU STRATIFICATION HAVE BEEN INTERPRETED, INTERPOLATED BETWEEN EXPLORATIONS, AND EXTRAPOLATED BEYOND EXPLORATIONS FOR ENGINEERING DESIGN PURPOSES. THE STRATA MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. SEE THE EXPLORATION LOGS FOR DETAILED SUBSURFACE CONDITIONS AT THE LOCATION EXPLORED.

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DATE	11/15/2021				JOB NUMBER		
PLOTTED BY	patrick.mccarthy						
DESIGNED BY	D. LEE						
ENTERED BY	P. MCCARTHY						
CHECKED BY	A. ANDERSON				CONTRACT NO.		LOCATION NO.
PROJ. ENGR.	T. WENTWORTH						
REGIONAL ADM.	T. NETTLETON	REVISION	DATE	BY			

P.E. STAMP BOX DATE

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Washington State Department of Transportation

FLATIRON LANE

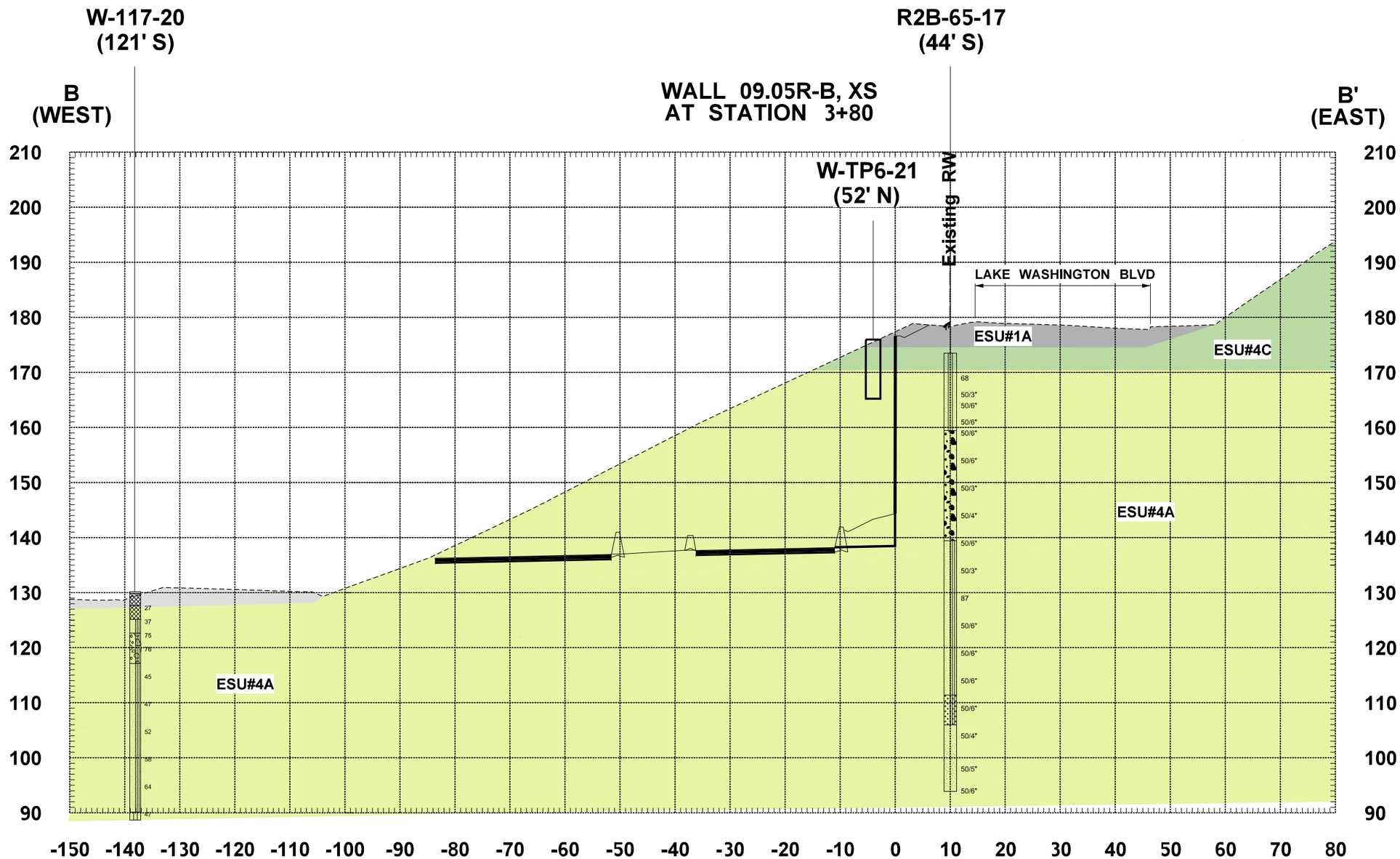
wood.

I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

WALL 09.05R-B
CROSS-SECTION A-A', STA 1+40

PLAN REF NO

SHEET 7 OF 9 SHEETS



PROFILE

SCALE: 1H:1V

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0 10 20 VERTICAL SCALE IN FEET

THE ESU STRATIFICATION HAVE BEEN INTERPRETED, INTERPOLATED BETWEEN EXPLORATIONS, AND EXTRAPOLATED BEYOND EXPLORATIONS FOR ENGINEERING DESIGN PURPOSES. THE STRATA MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. SEE THE EXPLORATION LOGS FOR DETAILED SUBSURFACE CONDITIONS AT THE LOCATION EXPLORED.

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DATE	12/1/2021
PLOTTED BY	patrick.mccarthy
DESIGNED BY	D. LEE
ENTERED BY	P. MCCARTHY
CHECKED BY	A. ANDERSON
PROJ. ENGR.	T. WENTWORTH
REGIONAL ADM.	T. NETTLETON

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER

CONTRACT NO. | LOCATION NO.

P.E. STAMP BOX DATE

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FLATIRON LANE

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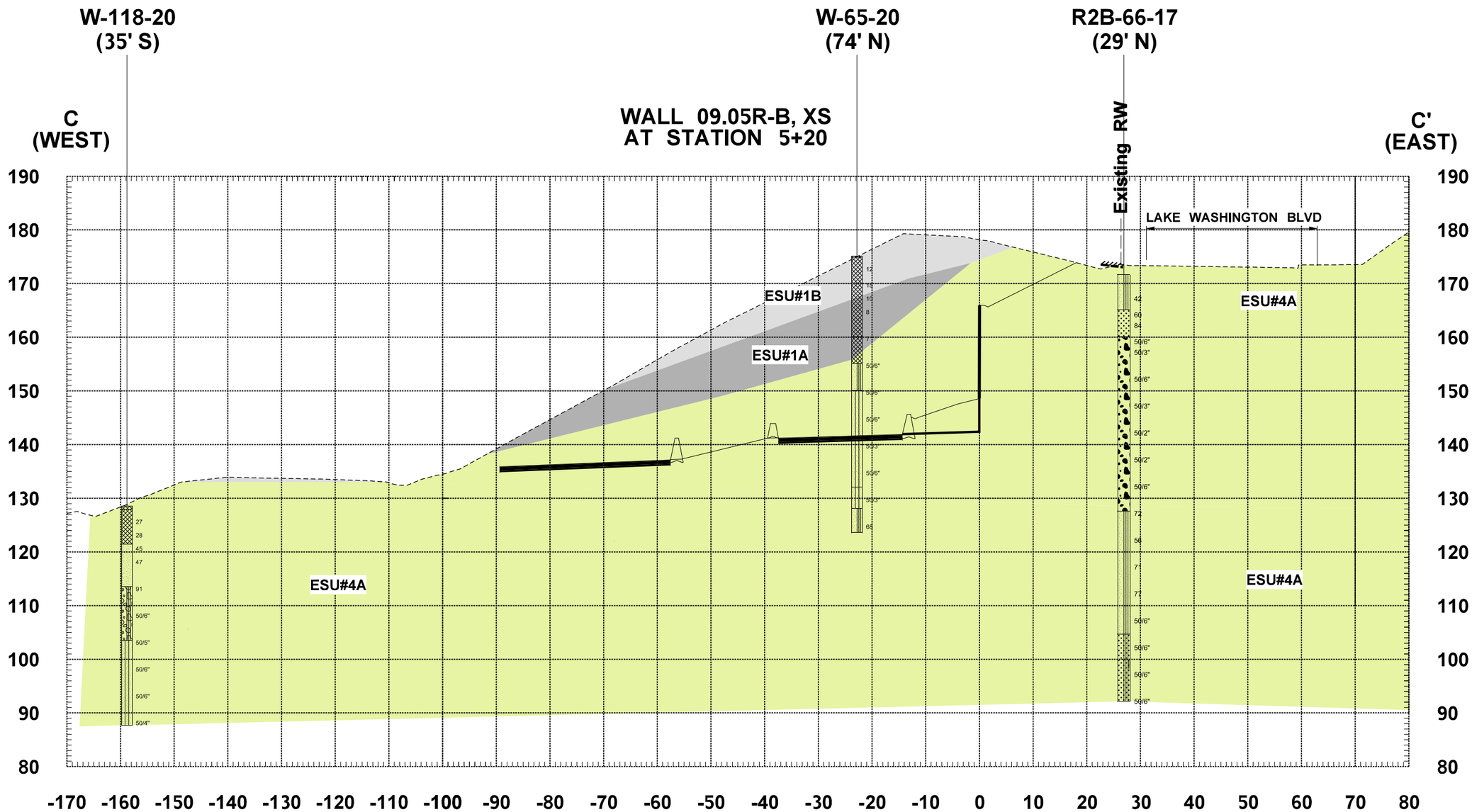
I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

WALL 09.05R-B
CROSS-SECTION B-B', STA 3+80

PLAN REF NO

SHEET 8 OF 9 SHEETS



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DATE	11/17/2021								
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DESIGNED BY	D. LEE								
ENTERED BY	P. MCCARTHY								
CHECKED BY	A. ANDERSON				CONTRACT NO.		LOCATION NO.		
PROJ. ENGR.	T. WENTWORTH								
REGIONAL ADM.	T. NETTLETON	REVISION	DATE	BY					

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

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I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

WALL 09.05R-B
CROSS-SECTION C-C', STA 5+20

PLAN REF NO

SHEET 9 OF 9 SHEETS

In Association with

Appendix B
Field Exploration Procedures and Logs

Appendix B –Field exploration procedures and logs

The following paragraphs describe the procedures used for field explorations and field tests that Wood conducted for this project. Descriptive logs of our explorations are enclosed in this appendix.

Auger boring procedures

Exploratory borings were advanced with a hollow-stem auger using a track-mounted drill rig operated by an independent drilling firm working under subcontract to Wood. An engineering geologist from Wood continuously observed the borings, logged the subsurface conditions, and collected representative soil samples. All samples were stored in watertight containers and later transported to the laboratory for further visual examination and testing. After each boring was completed, the borehole was backfilled with a mixture of bentonite chips and soil cuttings, and the surface was patched with asphalt or concrete (where appropriate).

Throughout the drilling operation, soil samples were obtained at 2.5- or 5-foot depth intervals by means of the Standard Penetration Test (SPT) per ASTM D-1586. This testing and sampling procedure consists of driving a standard 2-inch-diameter steel split-spoon sampler 18 inches into the soil with a 140-pound hammer free-falling 30 inches. The number of blows required to drive the sampler through each 6-inch interval was counted, and the total number of blows struck during the final 12 inches was recorded as the Standard Penetration Resistance, or "SPT blow count." If a total of 50 blows were struck within any 6-inch interval, the driving was stopped and the blow count was recorded as 50 blows for the actual penetration distance. The resulting Standard Penetration Resistance values indicate the relative density of granular soils and the relative consistency of cohesive soils.

The enclosed boring logs describe the vertical sequence of soils and materials encountered in each boring, based primarily on field classifications and supported by subsequent laboratory examination and testing. Where a soil contact was observed to be gradational, boring logs indicate the average contact depth. Where a soil type changed between sample intervals, we inferred the contact depth. The boring logs also graphically indicate the blow count, sample type, sample number, and approximate depth of each soil sample obtained from the borings, as well as any laboratory tests performed on these soil samples. If any groundwater was encountered in a borehole, the approximate groundwater depth is depicted on the boring log. Groundwater depth estimates are typically based on the moisture content of soil samples, the wetted height on the drilling rods, and the water level measured in the borehole after the auger has been extracted.

Well Installation Procedures

A groundwater observation well consisting of a 2-inch diameter polyvinyl chloride pipe with the lower 10 feet of the pipe finely slotted was installed. The annular space around the slotted segment was backfilled with clean sand, and the upper portion of the annulus was sealed with bentonite chips and concrete. A flush-mounted monument was placed over the top of the wellhead for protection. The as-built configuration of the observation well is illustrated on the boring log.

TABLE B-1: LIST OF BORINGS

Location ID	Date Completed	State Plane Coordinates (WA SPC North NAD 83; Survey Feet)		Ground Elevation	Termination Depth
		Northing	Easting	(NAVD 88)	(feet bgs)
W-64mw-20	5/19/2020	205277.597	1305164.897	151.2	61.5
W-65-20	4/16/2020	205623.3864	1305403.804	175.1	51.5
W-117-20	5/12/2020	205411.398	1305125.712	130.1	41.5
W-118-20	5/13/2020	205608.067	1305227.686	128.5	40.8
R2B-65-17	3/17/2017	205404.475	1305288.216	173.44	79.5
R2B-66-17	3/15/2017	205560.787	1305420.642	171.63	79.5

wood.
4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-64mw-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

DATE STARTED 5/18/20 **COMPLETED** 5/19/20 **GROUND ELEVATION** 151.2 ft NAVD88 **HOLE SIZE** 8 inches

DRILLING CONTRACTOR Gregory Drilling **DRILL RIG** CME 55 ID: #310 **SPT HAMMER EFFICIENCY** 88%

DRILLING METHOD HSA **Well Tag #** BLE-769 **STATION (FT)** 5783+65.34 **OFFSET (FT)** 170.0 R

LOGGED BY Carlos Mendoza **CHECKED BY** H Brenniman **NORTHING** 205277.597 **EASTING** 1305164.897

NOTES Soil Nail Wall 09.05R **GW LEVEL (ATD)** Dry **GW LEVEL (6/4/2020)** Dry

ELEVATION (ft) / DEPTH	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	SPT N VALUE (20 40 60 80) / PL MC LL / FINES CONTENT (%)	TESTS AND REMARKS
0	Poorly graded SAND with silt and gravel, loose, reddish brown, moist, [Fill] (SP-SM)				
150	Silty SAND, loose, yellowish brown, moist, [Fill] (SM)	11	SPT-1 1 1 6	7	MC = 13%
5 / 145	Becomes medium dense at 5 feet	33	SPT-2 3 6 7	13	
	Silty SAND with gravel, medium dense, light olive brown, moist, with scattered reddish brown mottling and scattered rootlets, [Qvt] (SM)	61	SPT-3 8 9 14	23	MC = 11% Fines = 29%
10 / 140	Well graded SAND with silt, medium dense, yellowish brown, moist, [Qva] (SW-SM)	39	SPT-4 7 11 8	19	MC = 7% Fines = 11%
15 / 135	Becomes dense at 15 feet	78	SPT-5 6 17 23	40	
20					

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wood. 4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-64mw-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

ELEVATION (ft) / DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	WELL DIAGRAM	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80	TESTS AND REMARKS
20		Silty SAND, dense, yellowish brown, moist, [Qva] (SM)	67	SPT-6 9 23 24		● ▲ 47	MC = 10%
130							
25		Becomes very dense at 25 feet	83	SPT-7 12 26 30		▲ 56	
125							
30			89	SPT-8 13 28 31		▲ 59	
120							
35		Poorly graded SAND, very dense, yellowish brown, moist, [Qva] (SP-SM)	83	SPT-9 16 28 41		■ ▲ 69	MC = 6% Fines = 7%
115							
40			67	SPT-10 16 30 40		▲ 70	
110							

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4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-64mw-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

ELEVATION (ft) / DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	WELL DIAGRAM	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80	TESTS AND REMARKS
		Poorly graded SAND, very dense, yellowish brown, moist, [Qva] (SP-SM) *(continued)*					
45 / 105			89	SPT-11 17 40 50		50/6"	
50		Silty SAND, very dense, yellowish brown, moist, [Qva] (SM)	89	SPT-12 17 45 37		● ▲ 82	MC = 5%
100							
55 / 95			89	SPT-13 17 33 33		▲ 66	
60 / 90			67	SPT-14 16 30 37		● ▲ 67	MC = 5%

Bottom of borehole at 61.5 feet.

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wood. 4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-65-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

DATE STARTED 4/15/20 **COMPLETED** 4/16/20 **GROUND ELEVATION** 175.1 ft NAVD88 **HOLE SIZE** 8 inches

DRILLING CONTRACTOR Gregory Drilling **DRILL RIG** CME 55 ID: #310 **SPT HAMMER EFFICIENCY** 88%

DRILLING METHOD HSA **STATION (FT)** 5787+76.45 **OFFSET (FT)** 205.2 R

LOGGED BY Carlos Mendoza **CHECKED BY** H. Brenniman **NORTHING** 205623.3864 **EASTING** 1305403.804

NOTES Soil Nail Wall 09.05 R & Soldier Pile Wall 09.15 GR-0 **GW LEVEL (ATD)** Dry

ELEVATION (ft)	DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	SPT N VALUE (20 40 60 80) / PL MC LL / FINES CONTENT (%)	TESTS AND REMARKS
175	0		Mulch (straw) over				
			Silty SAND with gravel, medium dense, grayish brown, dry to moist, with organics and oxidized mottles, [FILL] (SM)				
				39	SPT-1 3 5 7	12	MC = 7% Fines = 18% Organic content = 2.4%
170	5			50	SPT-2 5 6 9	15	MC = 11% LL = NP PL = NP
				50	SPT-3 4 5 5	10	MC = 11% Fines = 31%
165	10		Becomes loose at 10 feet	39	SPT-4 5 3 5	8	MC = 12%
160	15		Clayey SAND with gravel, loose, grayish brown, moist, [FILL] (SC)	28	SPT-5 7 4 3	7	MC = 16% LL = 33 PL = 19 Fines = 29%
	20						

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wood.
4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-65-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

ELEVATION (ft)	DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80	TESTS AND REMARKS
155	20		Silty SAND with silt, gravel and cobbles, very dense, olive brown, moist, [Qva] (SM)	42	SPT-6 18 50	50/6"	MC = 3% Fines = 11%
150	25			42	SPT-7 22 50	50/6"	MC = 5% Fines = 13%
145	30			42	SPT-8 24 50	50/6"	
140	35			56	SPT-9 24 50/3"	50/3"	Resistivity: 11,000 ohms cm, pH: 7.0
135	40			33	SPT-10 23 50	50/6"	

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wood.
4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-65-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

ELEVATION (ft)	DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80	TESTS AND REMARKS
			Silty SAND with gravel and cobbles, very dense, moist, [Qva] (SM)				
130	45			44	SPT-11 9 50/3"	50/3"	
			Poorly graded SAND with silt, very dense, yellowish brown, moist, [Qva] (SP-SM)				
125	50			89	SPT-12 6 27 41	▲ 68	

Bottom of borehole at 51.5 feet.

WSDOT GEOTECH DRILLING - I405 WSDOT.GDT - 8/3/20 13:42 - C:\USERS\CHELSEA.FOSTER\DOCUMENTS\PROJECTWISE\WORKINGDIR\WSDOT\DMS08721\I405 WSDOT - SEG. 1.GPJ

wood.
4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-117-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

DATE STARTED 5/11/20 **COMPLETED** 5/12/20 **GROUND ELEVATION** 130.1 ft NAVD88 **HOLE SIZE** 8 inches

DRILLING CONTRACTOR Holt Services **DRILL RIG** CME 85 ID: #7 **SPT HAMMER EFFICIENCY** 88%

DRILLING METHOD HSA **STATION (FT)** 5784+59.16 **OFFSET (FT)** 67.9 R

LOGGED BY Patricia Reed **CHECKED BY** H Brenniman **NORTHING** 205411.398 **EASTING** 1305125.712

NOTES Wall 09.15 MC-O **GW LEVEL (ATD)** Dry

ELEVATION (ft)	DEPTH	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	SPT N VALUE / PL MC LL / FINES CONTENT (%)	TESTS AND REMARKS
130	0	Asphalt (3 inches) over Well graded SAND with silt and gravel, dense, yellowish brown, moist, with clasts of gray CLAY (CL), [Fill] (SW-SM)				
		Well graded SAND with silt, dense, yellowish brown, moist, with clasts of gray CLAY (CL), [Fill] (SW-SM)	83	SPT-1 10 12 15	27	MC = 5% Fines = 10%
125	5	Poorly graded SAND with silt, dense, yellowish brown, moist, [Qva] (SP-SM)	89	SPT-2 11 17 20	37	
		Silty SAND with gravel, very dense, yellowish brown, dry to moist, [Qva] (SM)	94	SPT-3 13 31 44	75	
120	10		67	SPT-4 26 35 41	76	MC = 3%
		Poorly graded SAND with silt, dense, yellowish brown, moist, [Qva] (SP-SM)				
115	15		78	SPT-5 15 16 29	45	
	20					

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wood.
4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-117-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

ELEVATION (ft)	DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	SPT N VALUE (20 40 60 80) / PL MC LL (20 40 60 80) / FINES CONTENT (%) (20 40 60 80)	TESTS AND REMARKS
110	20		Poorly graded SAND with silt, dense, yellowish brown, moist, [Qva] (SP-SM) *(continued)*	78	SPT-6 15 21 26	47	
105	25		Becomes very dense at 25 feet	100	SPT-7 16 20 32	52	MC = 6% Fines = 8%
100	30			100	SPT-8 22 29 29	58	
95	35			100	SPT-9 28 29 35	64	
90	40		Silty SAND, dense, yellowish brown, moist, [Qva] (SM)	78	SPT-10 26 22 25	47	MC = 4%

Bottom of borehole at 41.5 feet.

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Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-118-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

DATE STARTED 5/12/20 **COMPLETED** 5/13/20 **GROUND ELEVATION** 128.5 ft NAVD88 **HOLE SIZE** 8 inches

DRILLING CONTRACTOR Holt Services **DRILL RIG** CME 85 ID: #7 **SPT HAMMER EFFICIENCY** 88%

DRILLING METHOD HSA **STATION (FT)** 5786+79.10 **OFFSET (FT)** 58.5 R

LOGGED BY Patricia Reed **CHECKED BY** H. Brenniman **NORTHING** 205608.067 **EASTING** 1305227.686

NOTES Wall 09.15 MC-O **GW LEVEL (ATD)** Dry

ELEVATION (ft) / DEPTH	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	SPT N VALUE (20 40 60 80) / PL MC LL / FINES CONTENT (%)	TESTS AND REMARKS
0	Sod, soft, black brown, moist, [Fill]				
	Poorly graded SAND with gravel, dense, reddish brown, moist, [Fill] (SP-SM)				
125		89	SPT-1 6 12 15	27	
5		89	SPT-2 6 18 10	28	MC = 7% Fines = 6%
	Poorly graded SAND with gravel, dense, yellowish brown, moist, [Qva] (SP)				
120		83	SPT-3 13 23 22	45	
10		78	SPT-4 4 15 32	47	MC = 7% Fines = 5%
115					
15	Poorly graded GRAVEL with silt and sand, very dense, yellowish brown, moist, [Qva] (GP-GM)	78	SPT-5 33 46 45	91	
110					Rough drilling at 17 feet
20					

(Continued Next Page)

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wood. 4020 Lake Washington Blvd Suite 200
Kirkland, WA 98033

PROJECT NAME I-405 Renton to Bellevue Widening **PROJECT NUMBER** 20316 **BORING NUMBER** W-118-20

CLIENT WSDOT **PROJECT LOCATION** Renton, WA

ELEVATION (ft) / DEPTH	GRAPHIC LOG	SOIL & ROCK DESCRIPTION	RECOVERY % (RQD)	SAMPLE TYPE NUMBER	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80	TESTS AND REMARKS
20		Poorly graded GRAVEL with silt and sand, very dense, yellowish brown, moist, [Qva] (GP-GM) *(continued)*	0	SPT-6 50	50/6"	Blow counts overstated, gravel in tip of driving shoe at 20.5 feet
105						Rough drilling at 23 feet
25		Silty SAND with gravel, very dense, yellowish brown, moist, [Qva] (SM)	33	SPT-7 50	50/5"	MC = 4%
100						
30			42	SPT-8 44 50	50/6"	
						Blew hydraulic hose; shut down for mechanical repair at 31 feet Resumed drilling 5/13/2020
95						
35			100	SPT-9 50	50/6"	MC = 4%
90						
40			80	SPT-10 29 50/4"	50/4"	

Bottom of borehole at 40.8 feet.

WSDOT GEOTECH DRILLING - I405 WSDOT.GDT - 7/9/20 11:37 - C:\USERS\CHELSEA.FOSTER\DOCUMENTS\PROJECTWISE\WORKINGDIR\WSDOT\DMS08721\I405 WSDOT - SEG. 1.GPJ

LOG OF TEST BORING

WSDOT

Start Card SE-61019 / AE-41349

HOLE No. R2B-65-17

Sheet 1 of 4

Job No. XL-4653 SR 405 Elevation 173.4 ft

Project I-405 Renton to Bellevue - ETL - Envir & Traff

Driller Henderson, Danny Lic# 2742

Component Cut Wall 09.05R

Inspector Harvey, Thomas #2599

Start March 16, 2017 Completion March 17, 2017 Well ID# N/A

Equipment CME 45C (9A4-7)

Station NB405 7780+92.392 Offset 92.1 feet right Hole Dia (inches) 4

Historical SPT Efficiency 88.4%

Northing 205404.475 Easting 1305288.216 Collected by Region Survey Crew

Method Casing Advancer

Lat 47.5550028 Long -122.1905913 Datum NAD 83/91 HARN, NAVD88, SPN (ft)

Drill Fluid Bentonite

Depth (ft)	Elevation (ft)	Profile	SPT Efficiency / Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	170.0									
5				19 28 40 (68)		D-1		Silty SAND with gravel, sub-rounded, very dense, grayish brown, moist, stratified. HCl not tested. Recovered: 1.5 ft Retained: 1.5 ft		
			>>	44 50/3" (REF)		D-2		Silty SAND, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.8 ft Retained: 0.8 ft		
	165.0									
10			>>	50/6" (REF)		D-3		Silty SAND with gravel, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
			>>	20 50/6" (REF)		D-4	MC GS AL	SM, MC=9%, PI=2 Silty SAND with gravel, sub-rounded, very dense, grayish brown, moist, stratified. HCl not tested. Recovered: 0.9 ft Retained: 0.9 ft		
	160.0									
15			>>	24 50/6" (REF)		D-5		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
	155.0									
20			>>	50/6" (REF)		D-6		Well graded GRAVEL with sand, sub-rounded, very dense, gray, moist, homogeneous. HCl not tested.		

LOG OF TEST BORING

WSDOT

Job No. XL-4653 SR 405 Elevation 173.4 ft

HOLE No. R2B-65-17

Sheet 2 of 4

Project I-405 Renton to Bellevue - ETL - Envir & Traff

Driller Henderson, Danny

SPT Efficiency
Field SPT (N)
Moisture Content
RQD

Depth (ft)	Elevation (ft)	Profile	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
							Recovered: 0.4 ft Retained: 0.4 ft		
	150		>> 50/3" (REF)		D-7		Well graded GRAVEL with sand, sub-rounded, very dense, gray, moist, homogeneous. HCl not tested. Recovered: 0.3 ft Retained: 0.3 ft		
25									
	145		>> 50/4" (REF)		D-8		Well graded GRAVEL with sand, sub-rounded, very dense, gray, moist, homogeneous. HCl not tested. Recovered: 0.4 ft Retained: 0.4 ft		
30									
	140		>> 37 50/6" (REF)		D-9		Poorly graded SAND with silt, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
35									
	135		>> 30 43 50/3" (REF)		D-10	MC GS	MC=13% Poorly graded SAND with silt, very dense, gray, moist, homogeneous. HCl not tested. Recovered: 1.3 ft Retained: 1.3 ft		
40									
	130		32 43		D-11		Poorly graded SAND with silt, very dense, gray, moist, homogeneous. HCl not tested.		
45									

ENTERPRISE BORING LOG XL-5467 (OLD XL-4653) 405 RENTON TO BELLEVUE ETL - ENVIRO AND TRAFF.GPJ ENTERPRISE DATA TEMPLATE.GDT 5/11/18

LOG OF TEST BORING

WSDOT

Job No. XL-4653 SR 405 Elevation 173.4 ft

HOLE No. R2B-65-17

Sheet 3 of 4

Project I-405 Renton to Bellevue - ETL - Envir & Traff

Driller Henderson, Danny

SPT Efficiency
Field SPT (N)
Moisture Content
RQD

Depth (ft)	Elevation (ft)	Profile	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
			44 (87)				Recovered: 1.0 ft Retained: 1.0 ft		
	125		>> 36 50/6" (REF)		D-12		Poorly graded SAND with silt, very dense, gray, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
50									
	120		>> 50/6" (REF)		D-13		Poorly graded SAND with silt, very dense, gray, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
55									
	115		>> 46 50/6" (REF)		D-14		Poorly graded SAND, very dense, gray, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
60									
	110		>> 45 50/6" (REF)		D-15	MC GS	MC=15% Well graded SAND with silt, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
65									
							Drilling behavior indicated gravel at 67.5 ft.		
	105		>> 50/4" (REF)		D-16		Poorly graded SAND with gravel, sub-angular, very dense, grayish brown, moist, homogeneous. HCl not		
70									

ENTERPRISE BORING LOG XL-5467 (OLD XL-4653) 405 RENTON TO BELLEVUE ETL - ENVIRO AND TRAFF.GPJ ENTERPRISE DATA TEMPLATE.GDT 5/11/18

LOG OF TEST BORING

WSDOT

Job No. XL-4653 SR 405 Elevation 173.4 ft

HOLE No. R2B-65-17

Sheet 4 of 4

Project I-405 Renton to Bellevue - ETL - Envir & Traff

Driller Henderson, Danny

Depth (ft)	Elevation (ft)	Profile	SPT Efficiency / Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
								tested. Recovered: 0.4 ft Retained: 0.4 ft		
	100									
75			>>	50/5" (REF)		D-17		Poorly graded SAND, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.3 ft Retained: 0.3 ft		
	95		>>	50/6" (REF)		D-18		Poorly graded SAND with gravel, sub-angular, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
80										
	90							The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Office and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew.		
85										
	85							End of test hole boring at 79.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Note: REF = SPT Refusal		
90								Bail/Recharge test: Hole Diameter: 4 inches Depth of boring during bail test: 79.5 ft. Depth of casing during bail test: 79 ft. Water depth before bailing: 10 ft. Bailed bore hole water level to 37.1 ft. Recharge after 5 minutes: 36.9 ft. Recharge after 10 minutes: 36.9 ft. Recharge after 15 minutes: 37 ft. Recharge after 20 minutes: 37.1 ft. Recharge after 30 minutes: 37.2 ft.		
	80									
95										

ENTERPRISE BORING LOG XL-5467 (OLD XL-4653) 405 RENTON TO BELLEVUE ETL - ENVIRO AND TRAFF.GPJ ENTERPRISE DATA TEMPLATE.GDT 5/11/18

LOG OF TEST BORING

WSDOT

Start Card SE-61019 / AE-41349

HOLE No. R2B-66-17

Sheet 1 of 4

Job No. XL-4653 SR 405 Elevation 171.6 ft

Project I-405 Renton to Bellevue - ETL - Envir & Traff

Driller Henderson, Ted Lic# 2902

Component Cut Wall 09.05R

Inspector Harvey, Thomas #2599

Start March 14, 2017 Completion March 15, 2017 Well ID# N/A

Equipment CME 45C (9A4-7)

Station NB405 7782+95.961 Offset 116.0 feet right Hole Dia (inches) 4

Historical SPT Efficiency 88.4%

Northing 205560.787 Easting 1305420.642 Collected by Region Survey Crew

Method Casing Advancer

Lat 47.5554377 Long -122.1900662 Datum NAD 83/91 HARN, NAVD88, SPN (ft)

Drill Fluid Bentonite

SPT Efficiency / Field SPT (N) / Moisture Content / RQD

20 40 60 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	170.0							
5		15 20 22 (42)		D-1	MC GS	MC=12% Poorly graded SAND with silt, dense, brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
	165.0							
		24 20 40 (60)		D-2		Well graded SAND with gravel, sub-rounded, very dense, brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
10		20 36 48 (84)		D-3		Well graded SAND with gravel, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 1.5 ft Retained: 1.5 ft		
	160.0							
		>> 50/6" (REF)		D-4		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
15		>> 43 50/3" (REF)		D-5		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
	155.0							
20		>> 50/6" (REF)		D-6		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not		

LOG OF TEST BORING

WSDOT

Job No. XL-4653 SR 405 Elevation 171.6 ft HOLE No. R2B-66-17

Sheet 2 of 4

Project I-405 Renton to Bellevue - ETL - Envir & Traff Driller Henderson, Ted

SPT Efficiency / Field SPT (N) / Moisture Content / RQD — 20 40 60 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
						tested. Recovered: 0.3 ft Retained: 0.3 ft		
25	150	22 50/3" (REF)		D-7	MC GS	GW, MC=8% Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.8 ft Retained: 0.8 ft		
30	145	30 50/2" (REF)		D-8		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.7 ft Retained: 0.7 ft		
35	140	42 50/2" (REF)		D-9		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, wet, homogeneous. HCl not tested. Recovered: 0.5 ft Retained: 0.5 ft		
40	135	50/6" (REF)		D-10		Well graded GRAVEL with sand, sub-rounded, very dense, grayish brown, wet, homogeneous. HCl not tested. Recovered: 0.4 ft Retained: 0.4 ft		
45	130	33 30		D-11	MC GS	MC=17% Poorly graded SAND with silt, very dense, brown, moist,		

ENTERPRISE BORING LOG XL-5467 (OLD XL-4653) 405 RENTON TO BELLEVUE ETL - ENVIRO AND TRAFF.GPJ ENTERPRISE DATA TEMPLATE.GDT 5/11/18

LOG OF TEST BORING

WSDOT

Job No. XL-4653 SR 405 Elevation 171.6 ft HOLE No. R2B-66-17

Sheet 3 of 4

Project I-405 Renton to Bellevue - ETL - Envir & Traff Driller Henderson, Ted

SPT Efficiency / Field SPT (N) / Moisture Content / RQD — 20 40 60 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
		42 (72)				homogeneous. HCl not tested. Recovered: 1.5 ft Retained: 1.5 ft		
	125							
		20 26 30 (56)		D-12		Poorly graded SAND with silt, very dense, brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
50								
	120							
		26 30 41 (71)		D-13		Poorly graded SAND with silt, very dense, brown, moist, homogeneous. HCl not tested. Recovered: 1.5 ft Retained: 1.5 ft		
55								
	115							
		25 36 41 (77)		D-14		Poorly graded SAND with silt, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
60								
	110							
		>> 28 50/6" (REF)		D-15		Poorly graded SAND with silt, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
65								
	105							
		>> 32 50/6"		D-16	MC GS	MC=14% Well graded SAND with silt, very dense, grayish brown,		
70								

ENTERPRISE BORING LOG XL-5467 (OLD XL-4653) 405 RENTON TO BELLEVUE ETL - ENVIRO AND TRAFF.GPJ ENTERPRISE DATA TEMPLATE.GDT 5/11/18

LOG OF TEST BORING

WSDOT

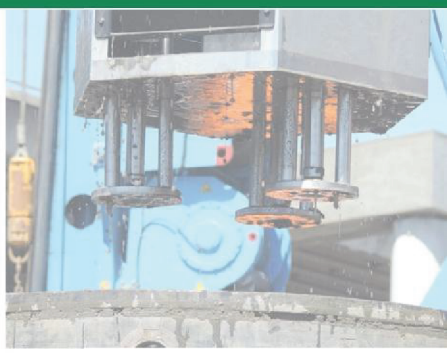
Job No. XL-4653 SR 405 Elevation 171.6 ft HOLE No. R2B-66-17

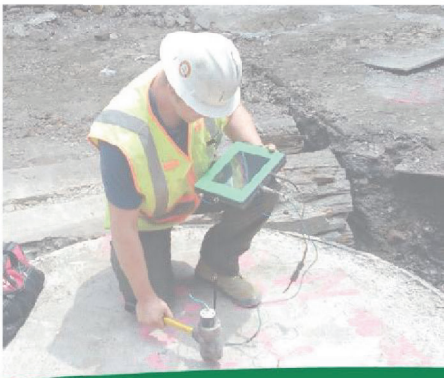
Sheet 4 of 4

Project I-405 Renton to Bellevue - ETL - Envir & Traff Driller Henderson, Ted

SPT Efficiency
Field SPT (N)
Moisture Content
RQD

Depth (ft)	Elevation (ft)	Profile	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
			(REF)				moist, homogeneous. HCl not tested. Recovered: 1.0 ft Retained: 1.0 ft		
	100								
			>>◆ 50/6" (REF)		D-17		Well graded SAND with silt, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
75									
	95								
			>>◆ 50/6" (REF)		D-18		Well graded SAND with silt, very dense, grayish brown, moist, homogeneous. HCl not tested. Recovered: 0.6 ft Retained: 0.6 ft		
80									
	90								
							The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Office and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew.		
85									
	85						End of test hole boring at 79.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Note: REF = SPT Refusal		
90							Bail/Recharge test: Hole Diameter: 4 inches Depth of boring during bail test: 79.5 ft. Depth of casing during bail test: 74 ft. Water depth before bailing: 22.4 ft. Bailed bore hole water level to 49.9 ft. Recharge after 5 minutes: 50.4 ft. Recharge after 10 minutes: 50.7 ft. Recharge after 15 minutes: 50.9 ft. Recharge after 20 minutes: 50.9 ft. Recharge after 30 minutes: 51 ft.		
	80								
95									





Job No. 196013-1

Report on:
Dynamic Energy Measurements
SPT Rig Calibration Project
Puyallup, Washington

Prepared for Holt Services, Inc.
By Marty Bixler and Diego Campos

August 19, 2019

GRL engineers, inc.
Dynamic Measurements and Analyses

www.GRLengineers.com info@GRLengineers.com

August 19, 2019

Travis Stephens
Holt Services, Inc.
10621 Todd Road E
Puyallup, WA 98372

Re: Energy Measurement for Dynamic Penetrometers
Standard Penetration Tests (SPT)
Puyallup, Washington GRL Job No. 196013-1

Dear Mr. Stephens:

This report transmits our findings from energy measurements and related data analysis conducted by GRL Engineers, Inc. (GRL) for your CME 85 truck-rig operating in Puyallup, Washington. One automatic hammer and penetrometer system was monitored during Standard Penetration Tests. Dynamic testing summarized in this report was conducted on August 16, 2019.

A Pile Driving Analyzer® Model 8G recorded, processed and displayed the dynamic data to meet the objectives of the hammer system calibration. Discussions on the test methods, limitations and implementation are provided in Appendix A. The energy measurement results are summarized in the appended table with the average and standard deviation provided in Appendix B together with representative plots of force and normalized velocity.

EQUIPMENT

Hammer and Penetrometer System

Energy measurements were recorded during standard penetration tests conducted for one automatic hammer and the following drill rig type.

Drill Rig Type
CME 85 Truck-rig
SN 372726

Measurements were recorded for one boring location; reported as F-1 and located at your property at the above address. Holt Services, Inc. advanced the penetrometer to a depth of approximately 66½ feet at five feet increments with uncorrected N-values less than 20 throughout, and most uncorrected N-values less than 10. The instrumented subassembly was connected to the top of the drill rod string and measurements recorded at intervals for each depth of data.

Selected data presented in this report is from depths of approximately 15, 25, 60, and 65 feet for boring F-1.

Measurements were recorded for each blow required to advance the sampler. Results are provided for 12 inches of the sampler advancement (i.e., excluding the initial 6 inches of advancement) for the averaging of results. Please refer to ASTM D4633 regarding recommendations on blow counts and instrumented drill rod lengths, as well as other details of the test method.

The following drill rod dimensions, of rod size NWJ, were employed during testing.

Drill Rod Area sq. inch	Outside Diameter Inch	Inside Diameter inch
1.45	2.63	2.25

Note that these are the rod size dimensions for the instrumented section used for the testing, as well as the drill rod string. A split spoon sampler was used as the penetrometer.

Instrumentation

A Pile Driving Analyzer was employed for recording, processing, and displaying the dynamic data. An instrumented subassembly, inserted at the top of the drill rod string below the hammer and anvil system and above the drill rods, was used to record force and acceleration data. The subassembly was instrumented with two foil strain gages in a full bridge circuit and two piezoresistive accelerometers attached on diametrically opposite sides of the subassembly. Data sampling frequency was 50.0 kHz.

The 8G utilizes a digital system, and with the employed sampling frequency of 50.0 kHz, the signal conditioning conforms to ASTM D4633. Results for the maximum hammer operating rate, rod top force and velocity, and transferred energy are provided in Appendix B and summarized in the appended table. Discussions on the test method and its limitations can be found in Appendix A.

MEASUREMENTS AND CALCULATIONS

The primary objective of testing was the measurement of the energy transmitted from the hammer impact through the anvil into the instrumented subassembly and drill rods. Strain transducers and accelerometers were employed for the calculation of the transferred energy using force, F(t) and velocity v(t), records as follows:

$$EFV = \int_b^a F(t)v(t)dt$$

where time "b" is to the beginning of the energy transfer and time "a" is to the time at which the energy transfer reaches a maximum. Force is calculated as the product of the measured strain, elastic modulus and cross-sectional area, and measured acceleration is integrated to velocity.

Integrated over the complete impact event and calculated from measured force and velocity, the energy transferred to the top of the drill rod was calculated as a function of time. The maximum transferred energy (i.e., EFV) is used as an indicator of the energy content of the event. The described method is the only theoretically correct method of measuring energy transfer and automatically corrects for rod non-uniformities such as connector masses or loose joints.

TEST RESULTS

Result Discussion

Dynamic data was evaluated for the hammer operating rate, rod top force and velocity, and transferred energy. Appendix B provides the evaluated quantities for blows making up the SPT N-value, with their averages and standard deviation, plotted and printed as a function of depth for the monitored sequences of the standard penetration tests. Measurements collected for relevant samples are presented herein.

The tables in Appendix B include:

- FMX – the maximum measured rod top force
- VMX – the maximum measured rod top velocity
- BPM – the hammer operating rate in blows per minute
- EFV – the maximum calculated energy (EMX) transferred to the rod top
- ETR – ratio of transferred energy (EFV) to the maximum theoretical potential energy

The maximum theoretical potential energy is the product of the standard 140 lb hammer impact mass dropped the standard 30 inches.

A representative plot of force and normalized velocity versus time for a typical blow from each data set is provided in Appendix B to demonstrate the data quality.

Summary of Results

I. The automatic hammer was monitored during standard penetration tests conducted on August 16, 2019. The average energy transfer ratio calculated with the EFV method for the monitored sequence for the drill rig is tabulated below together with the corresponding, average hammer operating rate.

Drill Rig	Energy Transfer Ratio percent	Operating Rate bpm
CME 85 Rig	**88.0**	53.3

.

II. The uncorrected N-values encountered during the sequence ranged from 11 to 19.

III. To convert the uncorrected N-values for the employed hammer and penetrometer system and operators, the Schmertman correction for adjustment to 60 percent transfer efficiency is

$$N_{60} = \left(\frac{e_m}{60}\right) N_m$$

where N_{60} is the corrected hammer N-value, e_m is the percent energy transfer efficiency (i.e., e_m = 100*ETR) and N_m is the measured SPT N-value. N_{60} values for the measurements and monitored depths meeting ASTM requirements are presented in the appended tables. The measured overall energy transfer ratio tabulated above for the drill rig produce an N_{60} equivalent of roughly $1.47N_m$. Further corrections due to overburden stresses in the soil may be made prior to use of the N-values for design purposes.

We appreciate the opportunity to be of assistance to you on this project. Please contact our offices should you have any questions regarding the contents of this report, or if we may be of further service.

Respectfully,
GRL ENGINEERS, INC.

MARTY G. BIXLER
STATE OF WASHINGTON
51806
REGISTERED
PROFESSIONAL ENGINEER

Marty G. Bixler
8-19-19

Marty G. Bixler, P.E. (Washington #51806)
Senior Engineer

Diego Campos, E.I.
Staff Engineer

APPENDIX A
AN INTRODUCTION INTO SPT DYNAMIC PILE TESTING

The following has been written by GRL Engineers, Inc. and may only be copied with its written permission.

1. BACKGROUND

The Standard Penetration Test is frequently conducted as an in-situ assessment of soil strength. This test requires that a 140 lb weight is dropped 30 inches onto a drive rod at whose bottom a sampler is usually installed. The sampler is driven for 18 inches; the number of blows required for the last 12 inches of driving is the so-called N-value. The N-value may be used as a strength indicator for foundation design or as a means of assessing the liquefaction potential of soils.

Obviously, the SPT hammer efficiency is an important consideration when using the N-values for design purposes. Measurements have indicated that the energy in the drive rod is sometimes only 30% and and may reach 90% of the potential or rated energy of the SPT hammer (E-rated = 0.35 kip-ft or 0.475 kJ). The type of hammer used to drive the rod is the main reason for these variations. On the average, the energy in the drive rod is 60% of the standard rated energy.

Because of the variability of energy, methods based on N-values are considered unreliable. However, measurements during SPT testing using the Case Method can be done on a routine basis and these measurements yield the transferred energy values. With measured energy, EMX, known, an adjustment of the measured N-value, N_m, can be made as follows.

$$N_{60} = N_m [E_m / (0.6E_r)] \qquad (1)$$

Thus, if the measured energy value is equal to the normally expected transferred energy of 60% of E-rated then the adjusted and measured N-values are identical. On the other hand, if the measured energy is only 30% then the adjusted blow count will be reduced by 50%.

2. DYNAMIC TESTING AND ANALYSIS METHODS APPLIED TO SPT

The Case Method of dynamic pile testing, named after the Case Institute of Technology where it was developed between 1964 and 1975, requires that a substantial ram mass (e.g. a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. Thus, the method is also referred to as a “High Strain Method”. The Case Method requires dynamic measurements on the pile or shaft under the ram impact and then a calculation of various quantities. Conveniently, for SPT applications, the measurements and analyses are done by a single piece of equipment: the SPT Analyzer. The Pile Driving Analyzer® (PDA) is also suitable to perform these measurements and data processing.

A related analysis method is the “Wave Equation Analysis” which calculates a relationship between bearing capacity, pile stresses, transferred energy and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data. This program can be used very effectively to simulate the SPT driving process.

3. MEASUREMENTS

GRL uses equipment manufactured by Pile Dynamics, Inc. The system includes either an SPT-Analyzer™ (SPTA) or a Pile Driving Analyzer® (PDA), an instrumented rod section and two accelerometers. SPT energy testing is very closely related to and borrows procedures from dynamic pile testing. Those interested in the basis of the SPT energy testing method may obtain extensive literature on dynamic pile testing from GRL Engineers, Inc.

3.1 SPT Analyzer or Pile Driving Analyzer

The basis for the results calculated by the SPTA or PDA are strain and acceleration measured in an instrumented rod section. These signals are converted to rod top force, F(t), and rod top velocity, v(t). The SPTA or PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. The product of these two

measurements is then integrated over time which yields the energy transferred to the instrumented section as a function of time (see Section 4.1).

For convenience and accuracy, strain measurements are usually taken on an instrumented section of SPT drive rod. Ideally, the section properties of the instrumented rod and those of the drive rod are the same, however, using subs, other sections can also be utilized.

For the instrumented section, PDI provides a force calibration in such a way that the output of the instrumented rod is directly calculated without the need for an accurate elastic modulus or cross sectional area of the rod section.

The acceleration measurements are often demanding in the SPT environment, because of high frequency and high acceleration motion components. An experienced measurement engineer, therefore, has to evaluate the quality of this data before final conclusions are drawn from the numerical results calculated by SPTA or PDA.

SPTA or PDA records are taken while the standard N-value is acquired in the conventional manner. This then allows a direct correlation between N-value and average transferred energy.

3.2 HPA

The SPT hammer's ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. The impact velocity results can be automatically processed with a PC or recorded on a strip chart. HPA measurements yield a hammer kinetic energy, but not the energy transferred to the drive rod.

4 RECORD EVALUATION BY SPTA OR PDA

4.1 HAMMER PERFORMANCE

The PDA calculates the energy transferred to the pile top from:

$$E(t) = \int_0^t F(\tau)v(\tau)\, d\tau \qquad (2)$$

The maximum of the E(t) curve is often called **ENTHRU or EMX;** it is the most important quantity for an overall evaluation of the performance of a hammer and driving system. **EMX** allows for a classification of the hammer's performance when presented as, e_T, the rated transfer efficiency, also called energy transfer ratio (**ETR**) or global efficiency.

$$e_T = EMX/E_R \qquad (3)$$

where E_R is the hammer manufacturer's rated energy value or 0.35 kip-ft (0.475 kJ) in the case of the SPT hammer.

Often in the SPT literature one finds also reference to the EF2 energy. This evaluation is based on assumed proportionality between force and velocity (see also Section 5):

$$v(t) = F(t) / Z \qquad (4)$$

where Z = EA/c is the pile impedance, E is the elastic modulus, A is the cross sectional area and c is the speed of the stress wave in the pile material..

Combining equations 2 and 4 leads to

$$EF(t) = \int_0^t F(\tau)^2 / Z\, d\tau \qquad (5)$$

The EF2 transferred energy value is the EF-value at the time t = 2L/c, where L is the drive rod length and c is the stress wave speed in steel (16,800 ft/s or 5,124 m/s). Since the force is easier to measure than both force and velocity, Equation 5 is preferred by some test engineers. However, the EF method is fraught with errors and certain correction factors have to be applied to make it approximately correct. Among the error sources are the following:

- Proportionality is often violated prior to time 2L/c. The proportionality between force and velocity in a downward traveling wave only holds if the wave does not encounter a disturbance prior to reflecting off the pile toe. Such disturbances include a change in cross sectional area, an open or loose splice or joint, or resistance along the shaft.

- Using only one force measurement precludes a data quality check based on the proportionality between force and velocity. Thus, a force measurement that is for some reason in error may not be detectable, which will lead to errors in the EF2 value. Data quality checks will be discussed further in Section 5.

The use if EF2 is therefore not recommended but it is often included in result presentations for the sake of completeness.

4.2 STRESSES

During SPT monitoring, it is also of interest to monitor compressive stresses at both the top of the drive rod and at its bottom.

At the pile top (location of sensors) the maximum compression stress averaged over the rod's cross section, **CSX**, is directly obtained from the measurements. Note that this stress value refers to the instrumented section. If the rod has a different cross sectional area then the stress in the rod will be different from CSX.

The SPTA or PDA can also calculate, in an approximate manner, the force at the rod bottom, **CFB**. To obtain the corresponding stress, this force value should be divided by the appropriate cross sectional area, e.g. by the rod area just above the sampler or by the sampler area itself. Of course, non-uniform stress components as they might occur at the sampler tip due to a sloping rock are not considered in this calculation.

5. DATA QUALITY CHECKS

Quality data is the first and foremost requirement for accurate dynamic testing results. It is therefore important that the measurement engineer performing SPTA or PDA tests has the experience necessary to recognize measurement problems and take appropriate corrective action should problems develop. Fortunately, dynamic pile testing allows for certain data quality checks because two independent measurements are taken that have to conform to the so-called proportionality relationship.

As long as there is only a wave traveling in one direction, as is the case during impact when only a downward traveling wave exists in the rod, force and velocity measured at its top are proportional

$$F = v\,Z \qquad (5)$$

where Z is again the pile impedance, Z = EA/c. This relationship can also be expressed in terms of stress

$$\sigma = F/A = v\,(E/c) \qquad (6)$$

or strain

$$\epsilon = \sigma/E = v / c \qquad (7)$$

This means that the early portion of strain times wave speed must be equal to the velocity unless the proportionality is affected by high friction near the pile top or by a pile cross sectional change not far below the sensors. Checking the proportionality is an excellent means of assuring meaningful measurements but is only truly meaningful for perfectly uniform rods. Open or loose splices, for example, will lead to a non-proportionality. For SPT rods it is fortunate that usually no soil resistance acts along the shaft and for that reason, proportionality can exist until the stress wave returns from sampler top or rod bottom unless connectors are not sufficiently tightened or have a significant mass.

Velocity data quality can also be checked by looking at the final displacement, DFN, which is calculated from the acceleration by double integration. If the calculated final displacement is much higher or lower than indicated by the N-value, the accelerometer attachment may be loose or the sensor may be faulty. If major drift in the velocity is observed, the EMX value may be in error, even though proportionality from impact to time 2L/c exists. In this case, it may be useful to evaluate the energy transferred to the drill rod at time 2L/c, which is calculated by the PDA or SPTA as the E2E quantity.

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Appendix B

Results of SPT Rig Calibration

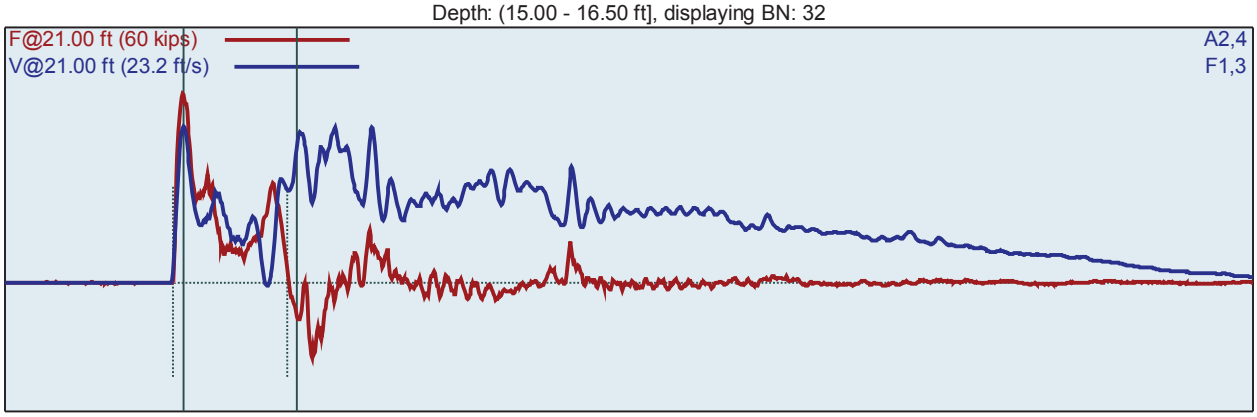
CME 85 RIG
mgb-grl
F-1

10
Test date: 8/16/2019

AR: 1.45 in^2
LE: 21.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (15.00 - 16.50 ft], displaying BN: 32



F1 : [292NWJ] 215.95 PDICAL (1) FF1
F3 : [292NWJ-2] 216.67 PDICAL (1) FF1

A2 (PR): [K4433] 318 mv/6.4v/5000g (1) VF1
A4 (PR): [K5523] 390 mv/6.4v/5000g (1) VF1

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute

EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

BL#	BC /6"	LP ft	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
17	6	15.08	42	14.3	1.9	283.0	80.9
18	6	15.17	43	14.1	50.3	293.9	84.0
19	6	15.25	43	14.1	49.6	293.9	84.0
20	6	15.33	45	14.7	50.7	318.4	91.0
21	6	15.42	43	14.3	56.1	300.9	86.0
22	6	15.50	45	14.4	55.7	311.8	89.1
23	8	15.56	44	14.3	55.6	309.8	88.5
24	8	15.63	43	14.7	55.8	311.7	89.1
25	8	15.69	45	14.6	55.4	317.3	90.7
26	8	15.75	46	14.6	55.9	312.7	89.3
27	8	15.81	43	14.0	55.8	300.8	86.0
28	8	15.88	45	14.9	55.8	319.7	91.3
29	8	15.94	44	14.9	55.4	309.8	88.5
30	8	16.00	44	15.1	56.2	321.1	91.7
31	4	16.13	43	14.2	55.1	302.9	86.5
32	4	16.25	44	14.2	56.0	309.1	88.3
33	4	16.38	47	15.1	55.4	320.2	91.5
34	4	16.50	44	14.1	55.3	303.9	86.8
		Average	44	14.6	55.6	311.6	89.0
		Std Dev	1	0.4	0.3	6.6	1.9
		Maximum	47	15.1	56.2	321.1	91.7
		Minimum	43	14.0	55.1	300.8	86.0

N-value: 12

Sample Interval Time: 18.69 seconds.

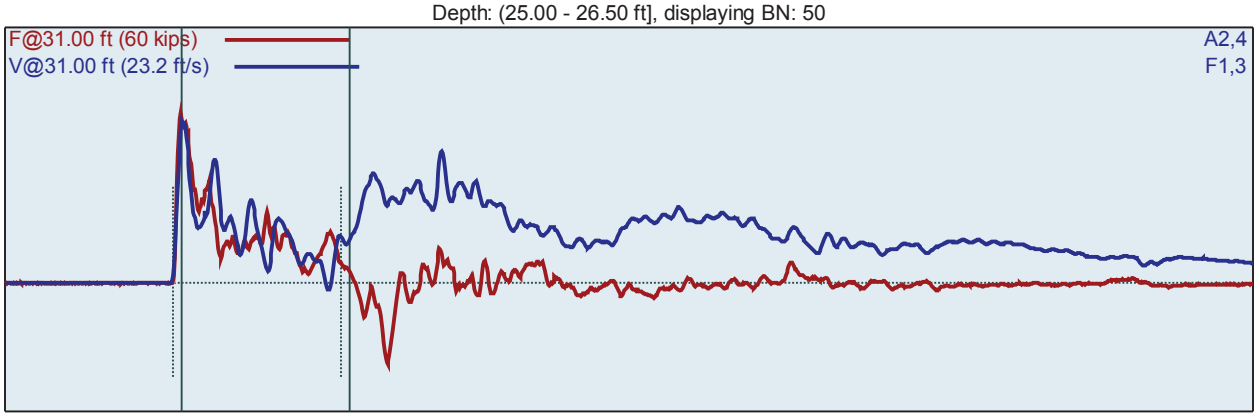
CME 85 RIG
mgb-grl
F-1

10
Test date: 8/16/2019

AR: 1.45 in^2
LE: 31.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (25.00 - 26.50 ft], displaying BN: 50



F1 : [292NWJ] 215.95 PDICAL (1) FF1
F3 : [292NWJ-2] 216.67 PDICAL (1) FF1

A2 (PR): [K4433] 318 mv/6.4v/5000g (1) VF1
A4 (PR): [K5523] 390 mv/6.4v/5000g (1) VF1

BL#	BC /6"	LP ft	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
35	7	25.07	44	14.5	1.9	317.0	90.6
36	7	25.14	45	14.3	55.0	320.5	91.6
37	7	25.21	47	15.2	55.4	335.7	95.9
38	7	25.29	47	15.1	55.0	327.9	93.7
39	7	25.36	44	14.3	55.1	318.3	90.9
40	7	25.43	45	15.1	55.2	327.1	93.5
41	7	25.50	42	14.4	55.1	318.4	91.0
42	5	25.60	42	14.6	55.1	320.6	91.6
43	5	25.70	44	15.2	55.0	330.0	94.3
44	5	25.80	47	15.3	55.0	328.1	93.7
45	5	25.90	46	15.3	54.8	322.3	92.1
46	5	26.00	44	15.6	55.5	323.1	92.3
47	6	26.08	45	15.9	54.7	320.1	91.5
48	6	26.17	40	14.9	54.9	310.3	88.6
49	6	26.25	42	15.0	55.0	317.6	90.7
50	6	26.33	40	14.7	55.0	307.3	87.8
51	6	26.42	40	15.0	55.0	314.3	89.8
52	6	26.50	43	15.9	54.9	328.6	93.9
		Average	43	15.2	55.0	320.2	91.5
		Std Dev	2	0.4	0.2	7.1	2.0
		Maximum	47	15.9	55.5	330.0	94.3
		Minimum	40	14.6	54.7	307.3	87.8
			N-value: 11				

Sample Interval Time: 18.49 seconds.

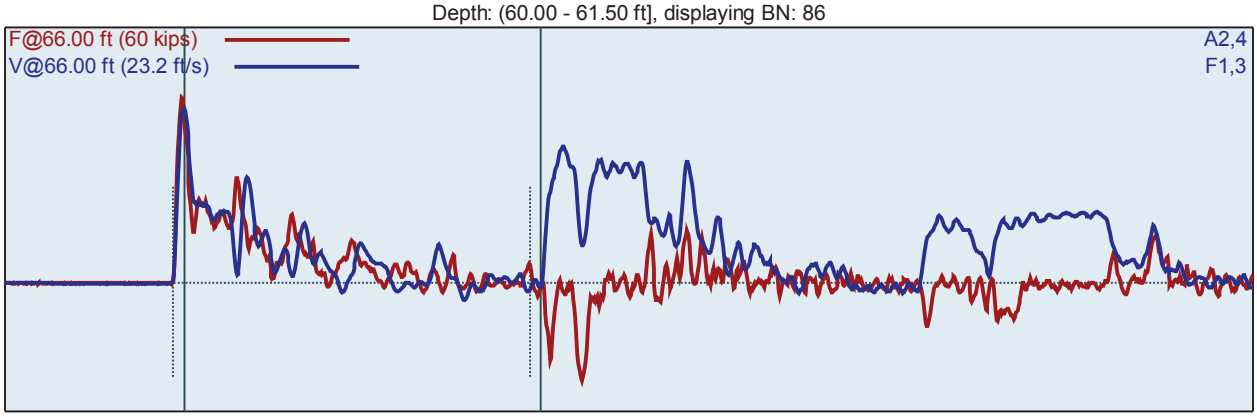
CME 85 RIG
mgb-grl
F-1

10
Test date: 8/16/2019

AR: 1.45 in^2
LE: 66.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (60.00 - 61.50 ft], displaying BN: 86



F1 : [292NWJ] 215.95 PDICAL (1) FF1
F3 : [292NWJ-2] 216.67 PDICAL (1) FF1

A2 (PR): [K4433] 318 mv/6.4v/5000g (1) VF1
A4 (PR): [K5523] 390 mv/6.4v/5000g (1) VF1

BL#	BC /6"	LP ft	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
69	9	60.06	42	16.9	1.9	326.0	93.1
70	9	60.11	43	16.9	52.7	331.0	94.6
71	9	60.17	42	16.9	53.1	328.8	93.9
72	9	60.22	39	16.5	53.5	317.0	90.6
73	9	60.28	42	16.3	53.2	315.9	90.3
74	9	60.33	41	16.5	53.3	320.3	91.5
75	9	60.39	44	16.1	53.5	318.2	90.9
76	9	60.44	45	16.0	53.1	320.7	91.6
77	9	60.50	43	16.6	53.4	323.0	92.3
78	5	60.60	42	15.5	53.2	307.6	87.9
79	5	60.70	46	16.2	53.3	326.8	93.4
80	5	60.80	44	15.1	53.2	308.6	88.2
81	5	60.90	42	15.5	53.3	313.4	89.5
82	5	61.00	40	15.2	53.4	315.8	90.2
83	6	61.08	41	15.5	53.4	317.4	90.7
84	6	61.17	41	15.5	53.4	311.5	89.0
85	6	61.25	36	15.2	53.1	298.1	85.2
86	6	61.33	43	15.7	53.2	315.2	90.1
87	6	61.42	42	15.7	53.3	318.9	91.1
88	6	61.50	35	15.8	53.3	299.5	85.6
		Average	41	15.5	53.3	312.1	89.2
		Std Dev	3	0.3	0.1	8.0	2.3
		Maximum	46	16.2	53.4	326.8	93.4
		Minimum	35	15.1	53.1	298.1	85.2
			N-value: 11				

Sample Interval Time: 21.42 seconds.

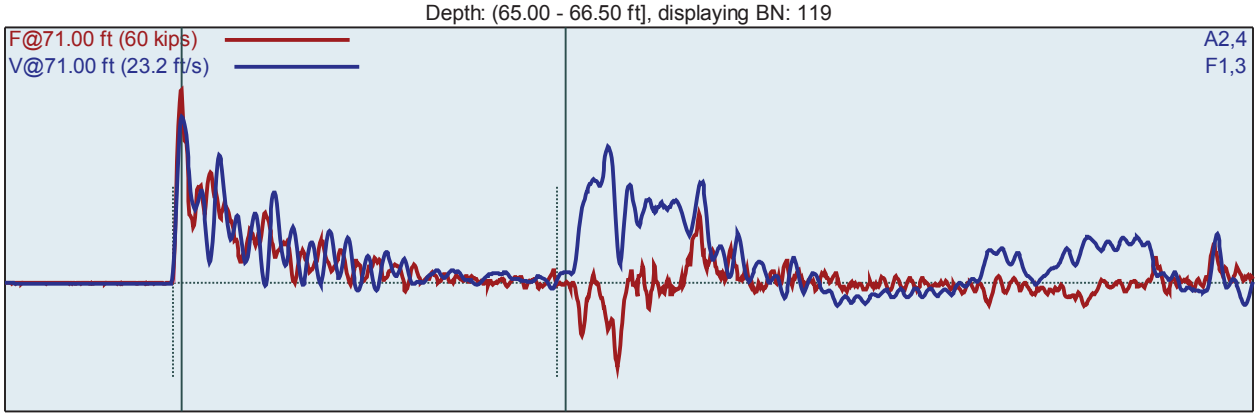
CME 85 RIG
mgb-grl
F-1

10
Test date: 8/16/2019

AR: 1.45 in^2
LE: 71.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (65.00 - 66.50 ft], displaying BN: 119



F1 : [292NWJ] 215.95 PDICAL (1) FF1
F3 : [292NWJ-2] 216.67 PDICAL (1) FF1

A2 (PR): [K4433] 318 mv/6.4v/5000g (1) VF1
A4 (PR): [K5523] 390 mv/6.4v/5000g (1) VF1

BL#	BC /6"	LP ft	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR %
89	14	65.04	44	15.7	12.1	305.4	87.3
90	14	65.07	44	15.5	44.5	296.2	84.6
91	14	65.11	44	15.7	44.7	289.6	82.7
92	14	65.14	46	15.7	49.4	302.4	86.4
93	14	65.18	47	15.8	50.7	308.7	88.2
94	14	65.21	47	16.2	50.8	317.0	90.6
95	14	65.25	44	15.6	50.8	298.7	85.3
96	14	65.29	47	15.8	51.0	301.3	86.1
97	14	65.32	46	15.5	50.9	303.6	86.7
98	14	65.36	47	15.3	50.9	305.9	87.4
99	14	65.39	44	14.9	50.8	291.4	83.3
100	14	65.43	46	14.8	50.9	305.3	87.2
101	14	65.46	44	14.8	51.1	292.1	83.5
102	14	65.50	43	14.8	51.0	293.3	83.8
103	10	65.55	45	14.8	50.7	298.4	85.3
104	10	65.60	43	14.6	51.1	290.6	83.0
105	10	65.65	44	14.7	50.8	295.7	84.5
106	10	65.70	44	14.6	50.8	305.9	87.4
107	10	65.75	40	14.7	51.1	289.7	82.8
108	10	65.80	42	14.6	51.0	287.5	82.1
109	10	65.85	40	14.4	50.9	292.0	83.4
110	10	65.90	42	14.8	50.9	293.0	83.7
111	10	65.95	43	14.4	51.0	284.1	81.2
112	10	66.00	41	14.6	50.9	282.0	80.6
113	9	66.06	44	15.1	51.0	289.2	82.6
114	9	66.11	43	14.7	50.9	310.3	88.7
115	9	66.17	43	14.4	50.8	298.7	85.3
116	9	66.22	45	14.6	50.9	307.7	87.9
117	9	66.28	41	14.7	50.8	293.8	83.9
118	9	66.33	41	14.6	51.0	293.7	83.9
119	9	66.39	45	15.1	51.1	310.4	88.7

120	9	66.44	43	14.8	50.7	311.3	88.9
121	9	66.50	40	14.5	51.0	303.5	86.7
		Average	43	14.7	50.9	296.7	84.8
		Std Dev	2	0.2	0.1	8.9	2.5
		Maximum	45	15.1	51.1	311.3	88.9
		Minimum	40	14.4	50.7	282.0	80.6

N-value: 19

Sample Interval Time: 38.08 seconds.

Summary of SPT Test Results

Project: CME 85 RIG, Test Date: 8/16/2019

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute

EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

Instr. Length ft	Blows Applied /6"	Start Depth ft	Final Depth ft	**N Value**	**N60 Value**	Average FMX kips	Average VMX ft/s	Average BPM bpm	Average EFV ft-lb	Average ETR %
21.00	**6-8-4**	15.00	16.50	**12**	**17**	44	14.6	55.6	311.6	89.0
31.00	**7-5-6**	25.00	26.50	**11**	**16**	43	15.2	55.0	320.2	91.5
66.00	**9-5-6**	60.00	61.50	**11**	**16**	41	15.5	53.3	312.1	89.2
71.00	**14-10-9**	65.00	66.50	**19**	**27**	43	14.7	50.9	296.7	84.8
				Overall Average Values:		43	14.9	53.3	308.1	88.0
				Standard Deviation:		2	0.5	2.0	12.0	3.4
				Overall Maximum Value:		47	16.2	56.2	330.0	94.3
				Overall Minimum Value:		35	14.0	50.7	282.0	80.6

Robert Miner Dynamic Testing, Inc.

Dynamic Measurements and Analyses for Deep Foundations

May 13, 2020

Mr. William Lockard, LEG
Wood Environment & Infrastructure Solutions, Inc.
4020 Lake Washington Blvd NE, Suite 200
Kirkland, WA 98033

Re: Penetration Test Energy Measurements
Gregory Drilling, CME-55 Rig No. 310, CME Auto Hammer
Bore Hole: W-63-20, May11, 2020
Lake Washington Blvd SE, SB I-405 On-ramp
Renton, Washington RMDT Job No. 20F21

Mr. Lockard:

This letter presents energy transfer measurements made during Standard Penetration Tests for the drill hole and drill rig referenced above. Robert Miner Dynamic Testing, Inc. (RMDT) made dynamic measurements with a Pile Driving Analyzer® as a hammer advanced AW rod during sampling with a split spoon sampler.

The purpose of RMDT's testing was the measurement of energy transferred to the drill rods. Measurements were made on a section of AW or NW gauge rod at the top of the drill string. Strain gages and accelerometers on the rod were connected to a Pile Driving Analyzer® (PDA) which generally processed acceleration and strain measurements from each hammer blow and stored both the measurements and computed results. Measurements and data processing generally followed the ASTM D4633 standard. Energy transfer past the gage location, EFV, was computed by the PDA using force and velocity records as follows:

$$EFV = \int_a^b F(t)\ v(t)\ dt$$

The value "a" corresponds to the start of the record which is when the energy transfer begins and *"b"* is the time at which energy transferred to the rod reaches a maximum value. Appendix A contains more information on our measurement equipment and methods of analysis. The EFV energy calculation is identical to the EMX energy result discussed in Appendix A. The EFV and EMX values apply to the sensor location near the top of the rod.

TEST DETAILS

On the evening of May 11, 2020, boring W-63-20 was advanced along Southbound I-405 near the Lake Washington Blvd SE on-ramp in Renton, Washington. The drill rig used during sampling was a track mounted CME-55 unit manufactured by Central Mine Equipment (CME)

Mailing Address: P.O. Box 340, Manchester, WA, 98353, USA **Phone:** 360-871-5480
Location: 2288 Colchester Dr. E., Ste A, Manchester, WA, 98353 **Fax:** 360-871-5483

and referred to as Rig No. 310 by the operator from Gregory Drilling. On May 11, 2020, the CME-55 unit drilled to predetermined sample depth intervals ranging from 15 to 60 ft below ground surface. The rod used to advance the split spoon at each sample depth had a diameter matching that of AW rod. The automatic hammer in use during our testing was manufactured by CME and appeared to use a chain drive powered by a hydraulic motor, with the ram and chain drive enclosed within an outer casing. Energy transfer measurements during the 25 ft sample interval used a instrumented section of NW gauge rod with an adapter to couple with the AW gauge drill string. All other sample depth intervals were measured using an instrumented section of AW gauge rod.

RESULTS

A summary of testing and monitoring results is given in Table 1. The tabulated results include the starting sample depth, the penetration resistance, the number of hammers blows in our data set, measured energy transfer, EFV, the computed transfer efficiency, ETR, and the hammer blow rate, BPM. Appendix B contains detailed numeric results for each individual test.

Energy measurements must be divided by the theoretical free fall energy of the hammer to obtain an efficiency. A 140 lb ram raised 30 inches above an impact surface has 350 lb-ft of potential energy. Thus, the transfer energy results for sampling with the 140 lb ram may be divided by 350 lb-ft to yield the ratio of the delivered energy to the nominal potential energy. This efficiency ratio, ETR, is given for each sample interval as a percent efficiency.

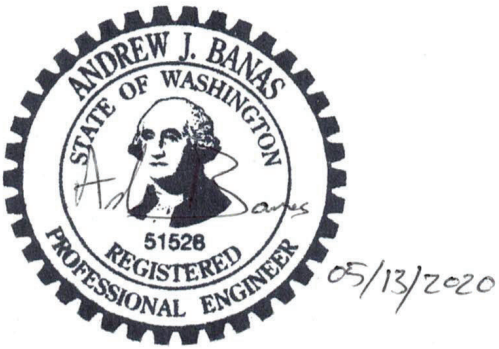
Table 1. Summary of Test Details and Results

Sample Name and Sample Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
25 ft Sample	8/1 ft	8	305	87	53
35 ft Sample	12/1 ft	12	302	86	54
40 ft Sample	14/1 ft	14	307	88	54
45 ft Sample	16/1 ft	16	309	88	54
50 ft Sample	23/1 ft	23	311	89	54
60 ft Sample	60/1 ft	60	310	89	54
Average for Split Spoon samples:			**307**	**88**	**54**

Six sample returns were monitored while the 140 lb ram and standard split spoon sampler were in use. The overall average ETR and hammer blow rate was 88 percent and 54 blows per minute, respectively. Results from the 25 ft sample using an instrumented section of NW gauge rod and adapter were within the range of those results using an instrumented AW gauge rod. It is our opinion that the results from the 25 ft sample interval may be included within the data set. However, if the 25 ft sample results are excluded from the data set, the overall average ETR and hammer blow rate remain at 88 percent and 54 blows per minute, respectively.

It was a pleasure to assist you and to participate on this project with the Wood and Gregory Drilling team. Please do not hesitate to contact us if you or other project participants have any questions about this report.

Sincerely,



Andrew J. Banas, P.E.

Robert Miner Dynamic Testing, Inc.

APPENDIX A
AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

The following has been written by Goble Rausche Likins and Associates, Inc. and may only be copied with its written permission.

BACKGROUND

Modern procedures of design and construction control require verification of bearing capacity and integrity of deep foundations during preconstruction test programs and also production installation. Dynamic pile testing methods meet this need economically and reliably, and therefore, form an important part of a quality assurance program when deep foundations are executed. Several dynamic pile testing methods exist; they have different benefits and limitations and different requirements for proper execution.

The Case Method of dynamic pile testing, named after the Case Institute of Technology where it was developed between 1964 and 1975, requires that a substantial ram mass (such as that of a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. The method is therefore also referred to as a "High Strain Method". The Case Method requires dynamic measurements on the pile or shaft under the ram impact and then an evaluation of various quantities based on closed form solutions of the wave equation, a partial differential equation describing the motion of a rod under the effect of an impact. Conveniently, measurements and analyses are done by a single piece of equipment: the Pile Driving Analyzer® (PDA). However, for bearing capacity evaluations an important additional method is CAPWAP® which performs a much more rigorous analysis of the dynamic records than the simpler Case Method.

A related analysis method is the "Wave Equation Analysis" which calculates a relationship between bearing capacity and pile stress and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data.

The following description deals primarily with the Case Method or "High Strain Test" Method of pile testing, however, for the sake of completeness, the "Low Strain Test" performed with the Pile Integrity Test™ (PIT), mainly for pile integrity evaluation, will also be described.

RESULTS FROM DYNAMIC TESTING

There are two main objectives of high strain dynamic pile testing:

- *Dynamic Pile Monitoring* and
- *Dynamic Load Testing*.

Dynamic pile monitoring is conducted during the installation of impact driven piles to achieve a safe and economical pile installation. Dynamic load testing, on the other hand, has as its primary goal the assessment of pile bearing capacity. It is applicable to both cast *insitu* piles or drilled shafts and impact driven piles during restrike.

Dynamic Pile Monitoring

During pile installation, the sensors attached to the pile measure pile top force and velocity. A PDA conditions and processes these signals and calculates or evaluates:

- Bearing capacity at the time of testing, including an assessment of shaft resistance development and driving resistance. This information supports formulation of a driving criterion.

- Dynamic pile stresses, axial and averaged over the pile cross section, both tensile and compressive, during pile driving to limit the potential of damage either near the pile top or along its length. Bending stresses can be evaluated at the point of sensor attachment.

- Pile integrity assessment by the PDA is based on the recognition of certain wave reflections from along the pile. If detected early enough, a pile may be saved from complete destruction. On the other hand, once damage is recognized measures can be taken to prevent reoccurrence.

- Hammer performance parameters including the energy transferred to the pile, the hammer speed in blows per minute and the stroke of open ended diesel hammers.

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Dynamic Pile Load Testing

Bearing capacity testing of either driven piles or drilled shafts applies the same basic measurement approach of dynamic pile monitoring. However, the test is done independent of the pile installation process and therefore a pile driving hammer or other dynamic loading device may not be available. If a special ram has to be mobilized then its weight should be between 0.8 and 2% of the test load (e.g. between 4 and 10 tons for a 500 ton test load) to assure sufficient soil resistance activation.

For a successful test, it most important that the test is conducted after a sufficient waiting time following pile installation for soil properties approaching their long term condition or concrete to properly set. During testing, PDA results of pile/shaft stresses and transferred energy are used to maintain safe stresses and assure sufficient resistance activation. For safe and sufficient testing of drilled shafts, ram energies are often increased from blow to blow until the test capacity has been activated. On the other hand, restrike tests on driven piles may require a warm hammer so that the very first blow produces a complete resistance activation. Data must be evaluated by CAPWAP for bearing capacity.

After the dynamic load test has been conducted with sufficient energy and safe stresses, the CAPWAP analysis provides the following results:

- Bearing capacity i.e. the mobilized capacity present at the time of testing
- Resistance distribution including shaft resistance and end bearing components
- Stresses in pile or shaft calculated for both the static load application and the dynamic test. These stresses are averages over the cross section and do not include bending effects or nonuniform contact stresses, e.g. when the pile toe is on uneven rock.
- Shaft impedance vs depth; this is an estimate of the shaft shape if it differs substantially from the planned profile
- Dynamic soil parameters for shaft and toe, i.e. damping factors and quakes (related to the dynamic stiffness of the resistance at the pile/soil interface.)

MEASUREMENTS

PDA

The basis for the results calculated by the PDA are pile top strain and acceleration measurements which are converted to force and velocity records, respectively. The PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. Using closed form Case Method solutions, based on the one-dimensional linear wave equation, the PDA calculates the results described in the analytical solutions section below.

HPA

The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. For this unit to be applicable, the ram must be visible. The impact velocity results can be automatically processed with a PC or recorded on a strip chart.

Saximeter™

For open end diesel hammers, the time between two impacts indicates the magnitude of the ram fall height or stroke. This information is not only measured and calculated by the PDA but also by the convenient, hand-held Saximeter.

PIT

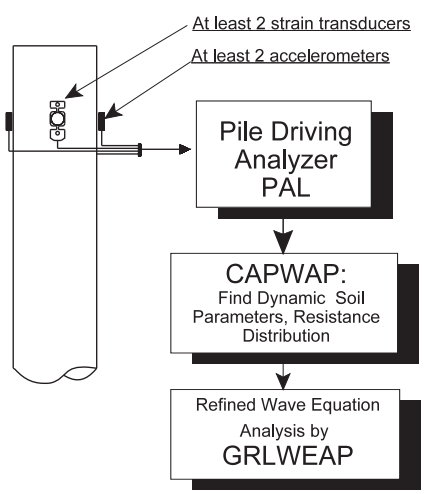
The Pile Integrity Tester™ (PIT) can be used to evaluate defects in concrete piles or shafts which may have occurred during driving or casting. Also timber piles of limited length can be tested in that manner. This so-called "Low Strain Method" or “Pulse-Echo Method” of integrity testing requires only the measurement of acceleration at the pile top. The stress wave producing impact is then generated by a small hand-held hammer and the records interpreted in the time domain. PIT also supports the so-called “Transient Response Method” which requires the additional measurement of the hammer force and an analysis in the frequency domain. This method may also be used to evaluate the unknown length of deep foundations under existing structures.

ANALYTICAL SOLUTIONS
BEARING CAPACITY

Wave Equation

GRL has written the GRLWEAP™ program which calculates a relationship between bearing capacity, pile stress and blow count. This relationship is often called the "bearing graph." Once the blow count is known from pile installation logs, the bearing graph yields the bearing capacity. This approach requires no measurements and therefore can be performed during the design stage of a project, for example for the selection of hammer, cushion and pile size.

After dynamic pile monitoring and/or dynamic load testing has been performed, the "Refined Wave Equation Analysis" or RWEA (see schematic below) is often performed by inputting the PDA and CAPWAP calculated parameters. Then the bearing graph from the RWEA is the basis for a safe and sufficient driving criteria.



Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil resistance is

$$R(t) = \tfrac{1}{2}\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

t = a point in time after impact
t_2 = time $t + 2L/c$
L = pile length below gages
c = $(E/\rho)^{1/2}$ is the speed of the stress wave
ρ = pile mass density
Z = EA/c is the pile impedance
E = elastic modulus of the pile ($\rho\, c^2$)
A = pile cross sectional area

The total soil resistance consists of a dynamic (R_d) and a static (R_s) component. The static component is therefore

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2.

There are a number of ways in which Eq. 1 through 3 can be evaluated. Most commonly, t_2 is set to that time at which the static resistance becomes maximum. The result is the so-called **RMX** capacity. Damping factors for RMX typically range between 0.5 for coarse grained materials to 1.0 for clays. The **RSP** capacity (this method is most commonly referred to in the literature, yet it is not very frequently used) requires damping factors between 0.1 for sand and 1.0 for clay. Another capacity, **RA2**, determines the capacity at a time when the pile is essentially at rest and thus damping is small; RA2

therefore requires no damping parameter. In any event, the proper Case Method and its associated damping parameter is most conveniently found after a CAPWAP analysis has been performed.

The static resistance calculated by Case Method or CAPWAP is the mobilized resistance at the time of testing. Consideration therefore has to be given to soil setup or relaxation effects and whether or not a sufficient set has been achieved under the test loading that would correspond to a full activation of the ultimate soil resistance.

The PDA also calculates an estimate of shaft resistance as the difference between force and velocity times impedance at the time immediately prior to the return of the stress wave from the pile toe. This shaft resistance is not reduced by damping effects and is therefore called the total shaft resistance **SFT**. A correction for damping effects produces the static shaft resistance estimate, **SFR**.

The Case Method solution is simple enough to be evaluated "in real time," i.e. between hammer blows, using the PDA. It is therefore possible to calculate all relevant results for all hammer blows and plot these results as a function of depth or blow number. This is done in the PDAPLOT program.

CAPWAP

The CAse Pile Wave Analysis Program combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the shaft resistance, end bearing, damping factors and soil stiffnesses. The method iteratively calculates a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

During pile monitoring, it is important that compressive stress maxima at pile top and toe and tensile stress maxima somewhere along the pile be calculated for each hammer blow.

At the pile top (location of sensors) both the maximum compression stress, **CSX**, and the maximum stress from individual strain transducers, **CSI**, are directly obtained from the measurements. Note that CSI is greater than or equal to CSX and the difference between CSI and CSX is a measure of bending in the plane of the strain transducers. Note also that all stresses calculated for locations below the sensors are averaged over the pile cross section and therefore do not include components from either bending or eccentric soil resistance effects.

The PDA calculates the compressive stress at the pile bottom, **CSB**, assuming (a) a uniform pile and (b) that the pile toe force is the maximum value of the total resistance R(t) minus the total shaft resistance, SFT. Again, for this stress estimation uniform resistance force are assumed (e.g. not a sloping rock.)

For concrete piles, the maximum tension stress, **TSX**, is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by finding the maximum tension wave (either traveling upward, W_U, or downward, W_d) and reducing it by the minimum compressive wave traveling in opposite direction.

$$W_u = ½[F(t) - Zv(t)] \quad (4)$$

$$W_d = ½[F(t) + Zv(t)] \quad (5)$$

CAPWAP also calculates tensile and compressive stresses along the pile and, in general, more accurately than the PDA. In fact, for non-uniform piles or piles with joints, cracks or other discontinuities, the closed form solutions from the PDA may be in error.

PILE INTEGRITY

High Strain Tests (PDA)

Stress waves in a pile are reflected wherever the pile impedance, $Z = EA/c = \rho cA = A \sqrt{(E \rho)}$, changes. Therefore, the pile impedance is a measure of the quality of the pile material (E, ρ, c) and the size of its cross section (A). The reflected waves arrive at the pile top at a time which is greater the farther away from the pile top the reflection occurs. The

magnitude of the change of the upward traveling wave (calculated from the measured force and velocity, Eq. 4) indicates the extent of the cross sectional change. Thus, with β_i (**BTA**) being a relative integrity factor which is unity for no impedance change and zero for the pile end, the following is calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \quad (6)$$

with

$$\alpha_i = ½(W_{UR} - W_{UD})/(W_{Di} - W_{UR}) \quad (7)$$

where

W_{UR} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.

W_{UD} is the upwards traveling wave due to the damage reflection.

W_{Di} is the maximum downward traveling wave due to impact.

It can be shown that this formulation is quite accurate as long as individual reflections from different pile impedance changes have no overlapping effects on the stress wave reflections.

Without rigorous derivation, it has been proposed to consider as slight damage when β is above 0.8 and a serious damage when β is less than 0.6.

Low Strain Tests (PIT)

The pile top is struck with a held hand hammer and the resulting pile top velocity is measured, displayed and interpreted for signs of wave reflections. In general, a comparison of the reflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the reflection. PIT records can also be interpreted by the β-Method. However, low strain tests do not activate much resistance which simplifies Eq. 7 since W_{UR} is then equal to zero.

For drilled shafts and PIT records that clearly show a toe reflection, an approximate shaft profile can be calculated from low strain records using the PITSTOP program's PROFILE routine.

HAMMER PERFORMANCE

The PDA calculates the energy transferred to the pile top from:

$$E(t) = \int_0^t F(t)v(t)\,dt \quad (8a)$$

The maximum of the E(t) curve is the most important information for an overall evaluation of the performance of a hammer and driving system. This **EMX** value allows for a classification of the hammer's performance when presented as the rated transfer efficiency, also called energy transfer ratio (**ETR**) or global efficiency

$$e_T = EMX/E_R \quad (8b)$$

where

E_R is the manufacturer's rated energy value.

Both Saximeter and PDA calculate the stroke (**STK**) of an open end diesel hammer using

$$STK = (g/8)\,T_B^2 - h_L \quad (9)$$

where

g is the earth's gravitational acceleration,
T_B is the time between two hammer blows,
h_L is a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

DETERMINATION OF WAVE SPEED

An important facet of dynamic pile testing is an assessment of pile material properties. Since in general force is determined from strain by multiplication with elastic modulus, E, and cross sectional area, A, the dynamic elastic modulus has to be determined for pile materials other than steel. In general, the records measured by the PDA clearly indicate a pile toe reflection as long as pile penetration per blow is greater than 1 mm or .04 inches. The time between the onset of the force and velocity records at impact and the onset of the reflection from the toe (usually apparent by a local maximum of the wave up curve) is the so-called wave travel time, T. Dividing 2L (L is here the length of the pile below sensors) by T leads to the stress wave speed in the pile:

$$c = 2L/T \quad (10)$$

The elastic modulus of the pile material is related to the wave speed according to the linear elastic wave equation theory by

$$E = c^2\rho \tag{11}$$

Since the mass density of the pile material, ρ, is usually well known (an exception is timber for which samples should be weighed), the elastic modulus is easily found from the wave speed. Note, however, that this is a dynamic modulus which is generally higher than the static one and that the wave speed depends to some degree on the strain level of the stress wave. For example, experience shows that the wave speed from PIT is roughly 5% higher than the wave speed observed during a high strain test.

Other Notes:

- If the pile material is nonuniform then the wave speed c, according to Eq. 10, is an average wave speed and does not necessarily reflect the pile material properties of the location where the strain sensors are attached to the pile top. For example, pile driving often causes fine tension cracks some distance below the top of concrete piles. Then the average c is slower than that at the pile top. It is therefore recommended to determine E in the beginning of pile driving and not adjust it when the average c changes.

- If the pile has such a high resistance that there is no clear indication of a toe reflection then the wave speed of the pile material must be determined either by assumption or by taking a sample of the concrete and measuring its wave speed in a simple free column test. Another possibility is to use the proportionality relationship, discussed under "DATA QUALITY CHECKS" to find c as the ratio between the measured velocity and measured strain.

DATA QUALITY CHECKS

Quality data is the first and foremost requirement for accurate dynamic testing results. It is therefore important that the measurement engineer performing PDA or PIT tests has the experience necessary to recognize measurement problems and take appropriate corrective action should problems develop. Fortunately, dynamic pile testing allows for certain data quality checks because two independent measurements are taken that have to conform to certain relationships.

Proportionality

As long as there is only a wave traveling in one direction, as is the case during impact when only a downward traveling wave exists in the pile, force and velocity measured at the pile top are proportional

$$F = v\,Z = v\,(EA/c) \tag{12a}$$

This relationship can also be expressed in terms of stress

$$\sigma = v\,(E/c) \tag{12b}$$

or strain

$$\epsilon = v / c \tag{12c}$$

This means that the early portion of strain times wave speed must be equal to the velocity unless the proportionality is affected by high friction near the pile top or by a pile cross sectional change not far below the sensors. Checking the proportionality is an excellent means of assuring meaningful measurements.

Measurements are always taken at opposite sides of the pile as a means of calculating the average force and velocity in the pile. The velocity on the two sides of the pile is very similar even when high bending exists. Thus, an independent check of the velocity measurements is easy and simple.

Strain measurements may differ greatly between the two sides of the pile when bending exists. It is even possible that tension is measured on one side while very high compression exists on the other side of the pile. In extreme cases, bending might be so high that it leads to a nonlinear stress distribution. The averaging of the two strain signals does then not lead to the average pile force and proportionality will not be achieved.

When testing drilled shafts, measurements of strain may also be affected by local concrete quality variations. It is then often necessary to use four strain transducers spaced at 90 degrees around the pile for an improved strain data quality. The use of four transducers is also recommended for large pile

diameters, particularly when it is difficult to mount the sensors at least two pile widths or diameters below the pile top.

LIMITATIONS, ADDITIONAL CONSIDERATIONS

Mobilization of capacity

Estimates of pile capacity from dynamic testing indicate the **mobilized pile capacity at the time of testing**. At very high blow counts (low set per blow), dynamic test methods tend to produce lower bound capacity estimates as not all resistance (particularly at and near the toe) is fully activated.

Time dependent soil resistance effects

Static pile capacity from dynamic method calculations provide an estimate of the axial pile capacity. Increases and decreases in the pile capacity with time typically occur (soil setup/relaxation). Therefore, **restrike testing usually yields a better indication of long term pile capacity than a test at the end of pile driving**. Often a wait period of one or two days between end of driving and restrike is satisfactory for a realistic prediction of pile capacity but this waiting time depends, among other factors, on the permeability of the soil.

(A) Soil setup

Because excess positive pore pressures often develop during pile driving in fine grained soil (clays, silts or even fine sands), the capacity of a pile at the time of driving may often be less than the long term pile capacity. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and thus the pile capacity at the time of driving. As these pore pressures dissipate, the soil resistance acting on the pile increases as does the axial pile capacity. This phenomena is routinely called soil setup or soil freeze.

(B) Relaxation

Relaxation (capacity reduction with time) has been observed for piles driven into weathered shale, and may take several days to fully develop. Pile capacity estimates based upon initial driving or short term restrike tests can significantly overpredict long term pile capacity. Therefore, piles driven into shale should be tested after a minimum one week wait either statically or dynamically (with particular emphasis than on the first few blows). Relaxation has also been observed for displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe. Again, restrike tests should be used, with great emphasis on early blows.

Capacity results for open pile profiles

Larger diameter open ended pipe piles (or H-piles which do not bear on rock) may behave differently under dynamic and static loading conditions. Under dynamic loads the soil inside the pile or between its flanges may slip and produce internal friction while under static loads the plug may move with the pile, thereby creating end bearing over the full pile cross section. As a result both friction and end bearing components may be different under static and dynamic conditions.

CAPWAP Analysis Results

A portion of the soil resistance calculated on an individual soil segment in a CAPWAP analysis can usually be shifted up or down the shaft one soil segment without significantly altering the match quality. Therefore, use of the CAPWAP resistance distribution for uplift, downdrag, scour, or other geotechnical considerations should be made with an understanding of these analysis limitations.

Stresses

PDA and CAPWAP calculated stresses are average values over the cross section. Additional allowance has to be made for bending or non-uniform contact stresses. To prevent damage it is therefore important to maintain good hammer-pile alignment and to protect the pile toes using appropriate devices or an increased cross sectional area.

In the United States is has become generally acceptable to limit the dynamic installation stresses of driven piles to the following levels:

90% of yield strength for steel piles

85% of the concrete compressive strength - after subtraction of the effective prestress - for concrete piles in compression

100% of effective prestress plus ½ of the concrete's tension strength for prestressed piles in tension

70% of the reinforcement strength for regularly reinforced concrete piles in tension

300% of the static design allowable stress for timber

Note that the dynamic stresses may either be directly measured at the pile top by the PDA or calculated by the PDA for other locations along the pile based on the pile top measurements.

Additional design considerations

Numerous factors have to be considered in pile foundation design. Some of these considerations include

- additional pile loading from downdrag or negative skin friction,
- lateral and uplift loading requirements
- effective stress changes (due to changes in water table, excavations, fills or other changes in overburden),
- long term settlements in general and settlement from underlying weaker layers and/or pile group effects,

These factors have not been evaluated by GRL and have not been considered in the interpretation of the dynamic testing results. The foundation designer should determine if these or any other considerations are applicable to this project and the foundation design.

Wave equation analysis results

The results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Although attempts have been made to base the analysis on the best available information, actual field conditions may vary and therefore stresses and blow counts may differ from the predictions reported. Capacity predictions derived from wave equation analyses should use restrike information. However, because of the uncertainties associated with restrike blow counts and restrike hammer energies, correlations of such results with static test capacities with have often displayed considerable scatter.

As for PDA and CAPWAP, the theory on which GRLWEAP is based is the one-dimensional wave equation. For that reason, stress predictions by the wave equation analysis can only be averages over the pile cross section. Thus, bending stresses or stress concentrations due to non-uniform impact or uneven soil or rock resistance are not considered in these results. Stress maxima calculated by the wave equation are usually subjected to the same limits as those measured directly or calculated from measurements by the PDA.

Appendix B

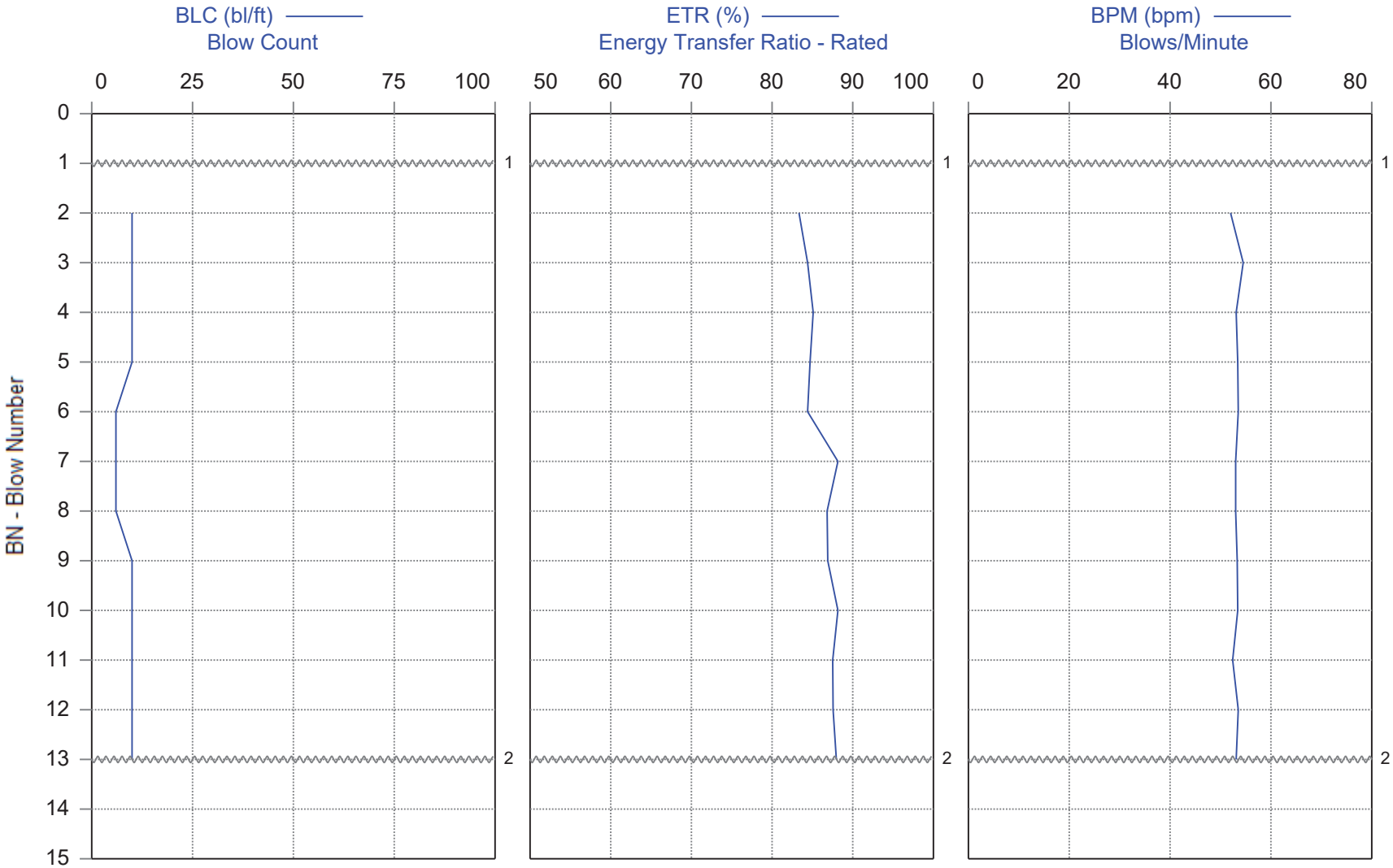
Summary of Case Method Results

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2017.2.58.5 - Case Method & iCAP® Results

Printed: 13-May-2020

Test started: 11-May-2020

WOOD, W-63-20, RIG 310, SPT - 25 FT SAMPLE



1 - Start of test on 5/11/2020 at 10:30 PM

2 - End of test on 5/11/2020 at 10:30 PM

WOOD, W-63-20, RIG 310, SPT - 25 FT SAMPLE RIG 310, CME 55, 140LB, SPT
OP: RMDT Date: 11-May-2020

AR: 1.43 in² SP: 0.492 k/ft³
LE: 29.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

EFV: Maximum Energy FMX: Maximum Force
ETR: Energy Transfer Ratio - Rated VMX: Maximum Velocity
BPM: Blows/Minute RAT: Length Ratio for SPT
CSX: Compression Stress Maximum DMX: Maximum Displacement
CSI: Compression Stress Maximum - Individual Sensor

BL#	Depth	BLC	EFV	ETR	BPM	CSX	CSI	FMX	VMX	RAT	DMX
	ft	bl/ft	k-ft	(%)	bpm	ksi	ksi	kips	f/s		in
6	25.67	6	295.4	84.4	53.5	28.8	29.3	41	13.8	1.1	2.00
7	25.83	6	308.5	88.2	53.0	29.1	29.6	42	14.2	1.1	2.00
8	26.00	6	303.9	86.8	53.0	29.3	29.8	42	14.5	1.1	2.00
9	26.10	10	304.2	86.9	53.3	28.9	29.5	41	15.5	1.1	1.48
10	26.20	10	308.6	88.2	53.4	28.9	29.2	41	15.6	1.1	1.58
11	26.30	10	306.3	87.5	52.4	28.8	29.2	41	15.5	0.8	1.62
12	26.40	10	306.4	87.6	53.5	28.3	28.5	40	15.6	1.2	1.77
13	26.50	10	307.9	88.0	53.1	28.9	29.3	41	15.8	0.8	1.37
		Average	305.1	87.2	53.2	28.9	29.3	41	15.1	1.1	1.73
		Std. Dev.	4.1	1.2	0.3	0.3	0.4	0	0.7	0.1	0.24
		Maximum	308.6	88.2	53.5	29.3	29.8	42	15.8	1.2	2.00
		Minimum	295.4	84.4	52.4	28.3	28.5	40	13.8	0.8	1.37

Total number of blows analyzed: 8

BL# Sensors

2-13 F1: [62NWJ-1] 215.0 (1.00); F2: [62NWJ-2] 216.9 (1.00); A1: [K2448] 290.0 (1.00);
A2: [K3260] 357.0 (1.00)

BL# Comments

1 Start of test on 5/11/2020 at 10:30 PM
13 End of test on 5/11/2020 at 10:30 PM

Time Summary

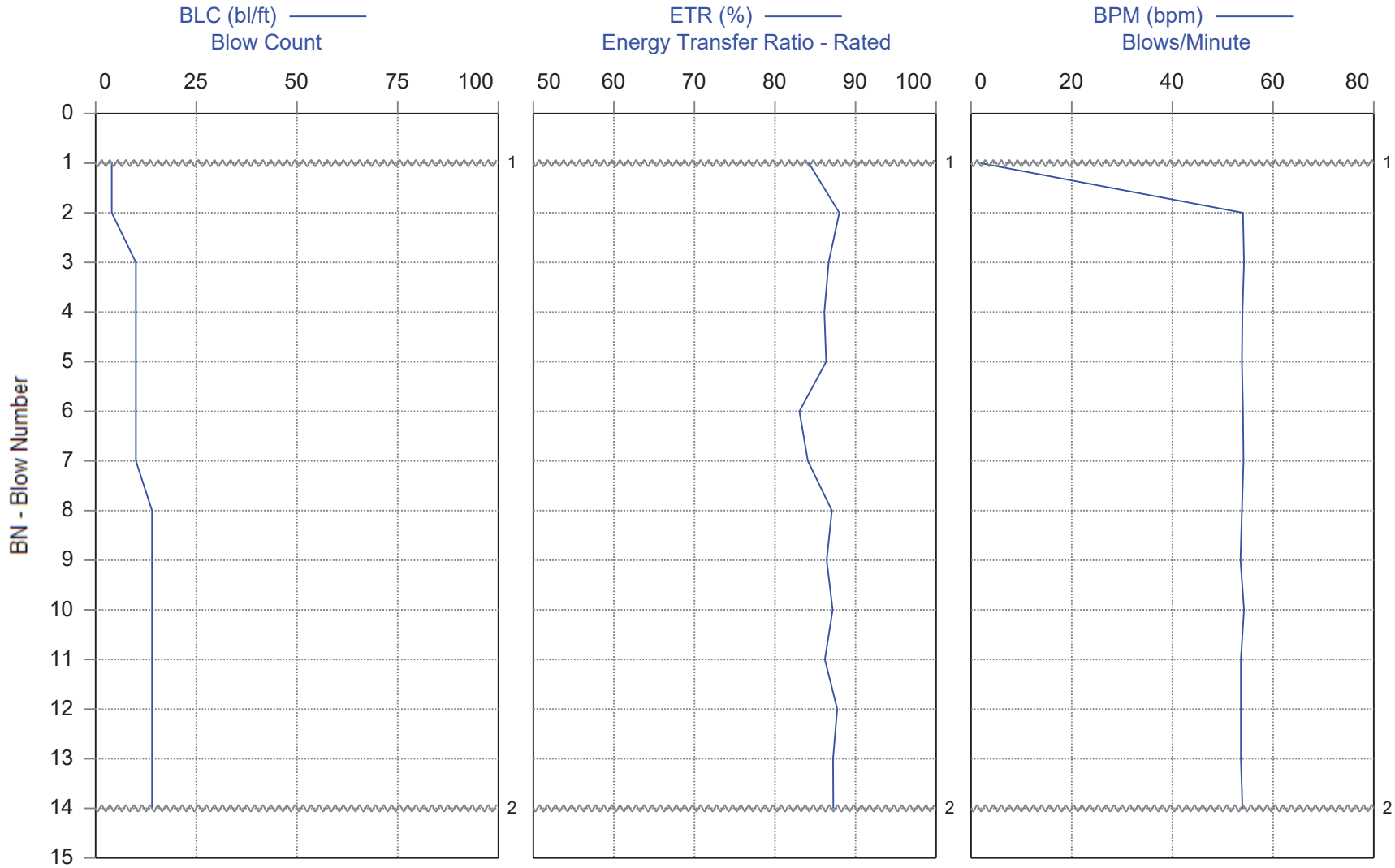
Drive 13 seconds 10:30 PM - 10:30 PM BN 1 - 13

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2017.2.58.5 - Case Method & iCAP® Results

Printed: 13-May-2020

Test started: 11-May-2020

WOOD, W-63-20,RIG 310, SPT - 35 FT SAMPLE



1 - Start of test on 5/11/2020 at 11:31 PM

2 - End of test on 5/11/2020 at 11:32 PM

WOOD, W-63-20,RIG 310, SPT - 35 FT SAMPLE RIG 310, CME 55, 140LB, SPT
OP: RMDT Date: 11-May-2020

AR: 1.19 in² SP: 0.492 k/ft³
LE: 39.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

EFV: Maximum Energy FMX: Maximum Force
ETR: Energy Transfer Ratio - Rated VMX: Maximum Velocity
BPM: Blows/Minute RAT: Length Ratio for SPT
CSX: Compression Stress Maximum DMX: Maximum Displacement
CSI: Compression Stress Maximum - Individual Sensor

BL#	Depth	BLC	EFV	ETR	BPM	CSX	CSI	FMX	VMX	RAT	DMX
	ft	bl/ft	k-ft	(%)	bpm	ksi	ksi	kips	f/s		in
3	35.60	10	303.3	86.7	54.2	24.8	24.8	30	15.6	1.0	1.81
4	35.70	10	301.4	86.1	53.9	24.8	24.8	29	15.7	1.1	1.68
5	35.80	10	302.2	86.3	53.8	24.9	24.9	30	15.6	1.1	1.48
6	35.90	10	290.6	83.0	54.0	25.0	25.0	30	15.6	1.1	1.21
7	36.00	10	294.2	84.1	54.1	25.0	25.0	30	15.6	1.1	1.20
8	36.07	14	304.7	87.1	53.8	24.9	24.9	30	15.7	1.1	1.17
9	36.14	14	302.4	86.4	53.5	25.0	25.0	30	15.7	1.0	1.42
10	36.21	14	305.0	87.2	54.2	25.0	25.0	30	15.6	1.1	1.45
11	36.29	14	301.7	86.2	53.6	24.6	24.6	29	15.8	1.1	1.25
12	36.36	14	307.0	87.7	53.6	24.6	24.6	29	16.2	1.1	1.22
13	36.43	14	305.2	87.2	53.6	25.0	25.0	30	16.2	1.1	1.12
14	36.50	14	305.3	87.2	53.9	24.9	24.9	30	16.1	1.1	1.15
		Average	301.9	86.3	53.9	24.9	24.9	30	15.8	1.1	1.35
		Std. Dev.	4.6	1.3	0.2	0.1	0.1	0	0.2	0.0	0.21
		Maximum	307.0	87.7	54.2	25.0	25.0	30	16.2	1.1	1.81
		Minimum	290.6	83.0	53.5	24.6	24.6	29	15.6	1.0	1.12

Total number of blows analyzed: 12

BL# Sensors

1-14 F1: [459 AWJ-1] 206.2 (1.00); F2: off; ; A1: [K3252] 336.0 (1.00); A2: off

BL# Comments

1 Start of test on 5/11/2020 at 11:31 PM
14 End of test on 5/11/2020 at 11:32 PM

Time Summary

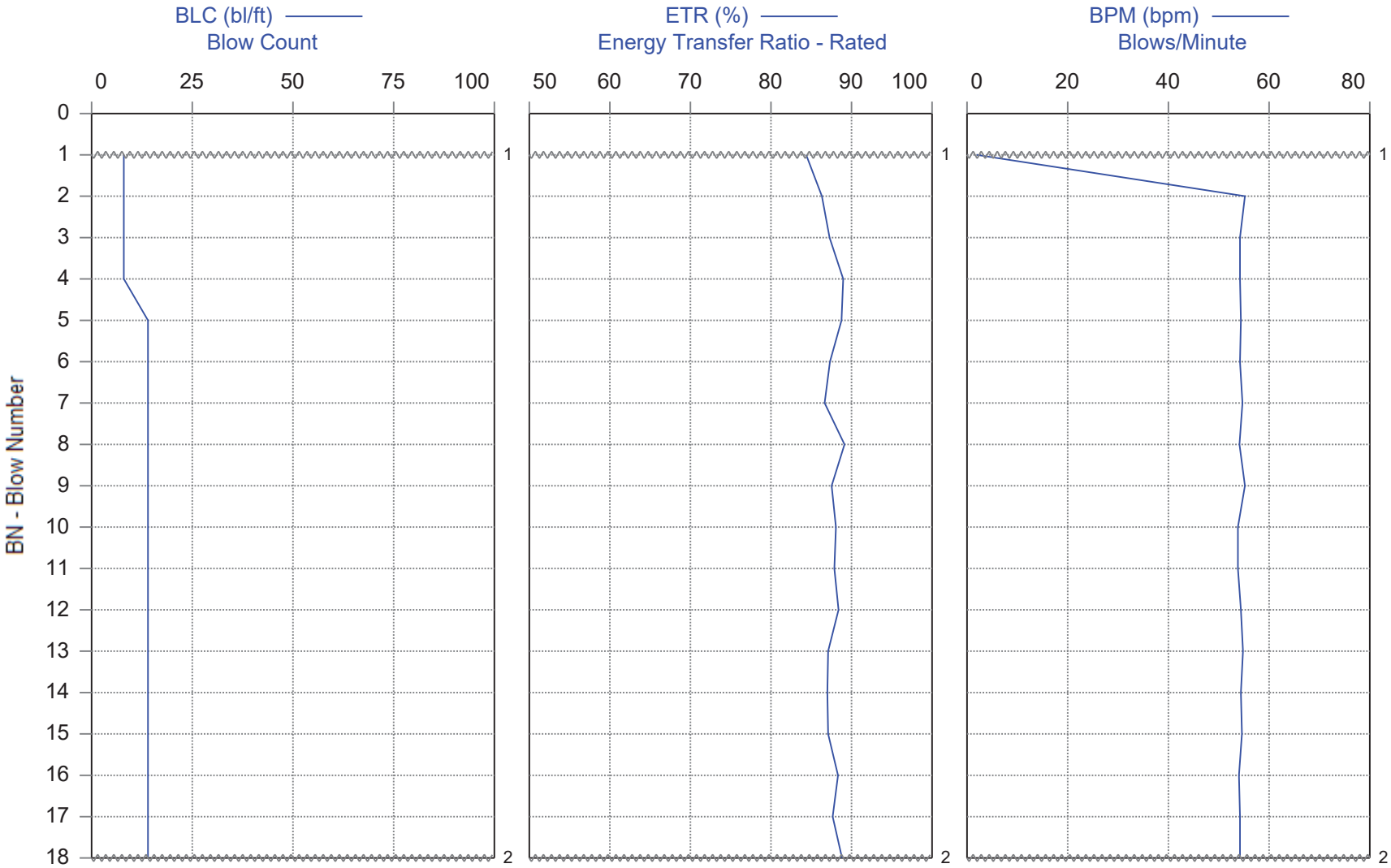
Drive 14 seconds 11:31 PM - 11:32 PM BN 1 - 14

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2017.2.58.5 - Case Method & iCAP® Results

Printed: 13-May-2020

Test started: 11-May-2020

WOOD, W-63-20,RIG 310, SPT - 40 FT SAMPLE



1 - Start of test on 5/11/2020 at 11:46 PM

2 - End of test on 5/11/2020 at 11:46 PM

WOOD, W-63-20,RIG 310, SPT - 40 FT SAMPLE RIG 310, CME 55, 140LB, SPT
OP: RMDT Date: 11-May-2020

AR: 1.19 in² SP: 0.492 k/ft³
LE: 44.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

EFV: Maximum Energy FMX: Maximum Force
ETR: Energy Transfer Ratio - Rated VMX: Maximum Velocity
BPM: Blows/Minute RAT: Length Ratio for SPT
CSX: Compression Stress Maximum DMX: Maximum Displacement
CSI: Compression Stress Maximum - Individual Sensor

BL#	Depth	BLC	EFV	ETR	BPM	CSX	CSI	FMX	VMX	RAT	DMX
	ft	bl/ft	k-ft	(%)	bpm	ksi	ksi	kips	f/s		in
5	40.57	14	310.6	88.8	54.4	25.6	25.9	30	16.1	1.1	1.08
6	40.64	14	305.6	87.3	54.2	25.6	25.7	30	15.9	1.1	1.11
7	40.71	14	303.3	86.7	54.7	25.7	25.9	31	16.0	1.1	0.98
8	40.79	14	311.9	89.1	54.1	25.9	26.0	31	16.2	1.1	1.28
9	40.86	14	306.3	87.5	55.2	25.5	25.6	30	16.0	1.1	1.32
10	40.93	14	308.2	88.1	53.8	25.7	25.7	31	16.4	1.0	1.27
11	41.00	14	307.5	87.9	53.8	25.3	25.4	30	16.4	1.0	1.22
12	41.07	14	309.4	88.4	54.4	25.3	25.5	30	16.5	1.1	1.29
13	41.14	14	304.8	87.1	54.8	25.4	25.5	30	16.5	1.0	1.44
14	41.21	14	304.5	87.0	54.4	25.4	25.6	30	16.7	1.0	1.32
15	41.29	14	304.8	87.1	54.6	25.0	25.3	30	16.6	1.0	1.35
16	41.36	14	309.1	88.3	54.0	24.9	24.9	30	16.5	1.1	1.50
17	41.43	14	306.8	87.7	54.2	25.5	25.7	30	16.6	1.0	1.36
18	41.50	14	310.8	88.8	54.2	25.8	25.9	31	16.9	1.0	1.30
		Average	307.4	87.8	54.3	25.5	25.6	30	16.4	1.1	1.27
		Std. Dev.	2.6	0.7	0.4	0.3	0.3	0	0.3	0.0	0.13
		Maximum	311.9	89.1	55.2	25.9	26.0	31	16.9	1.1	1.50
		Minimum	303.3	86.7	53.8	24.9	24.9	30	15.9	1.0	0.98

Total number of blows analyzed: 14

BL# Sensors

1-18 F1: [459 AWJ-1] 206.2 (1.02); F2: [459 AWJ-2] 206.5 (1.02); A1: [K3252] 336.0 (0.97);
A2: [K2448] 290.0 (0.94)

BL# Comments

1 Start of test on 5/11/2020 at 11:46 PM
18 End of test on 5/11/2020 at 11:46 PM

Time Summary

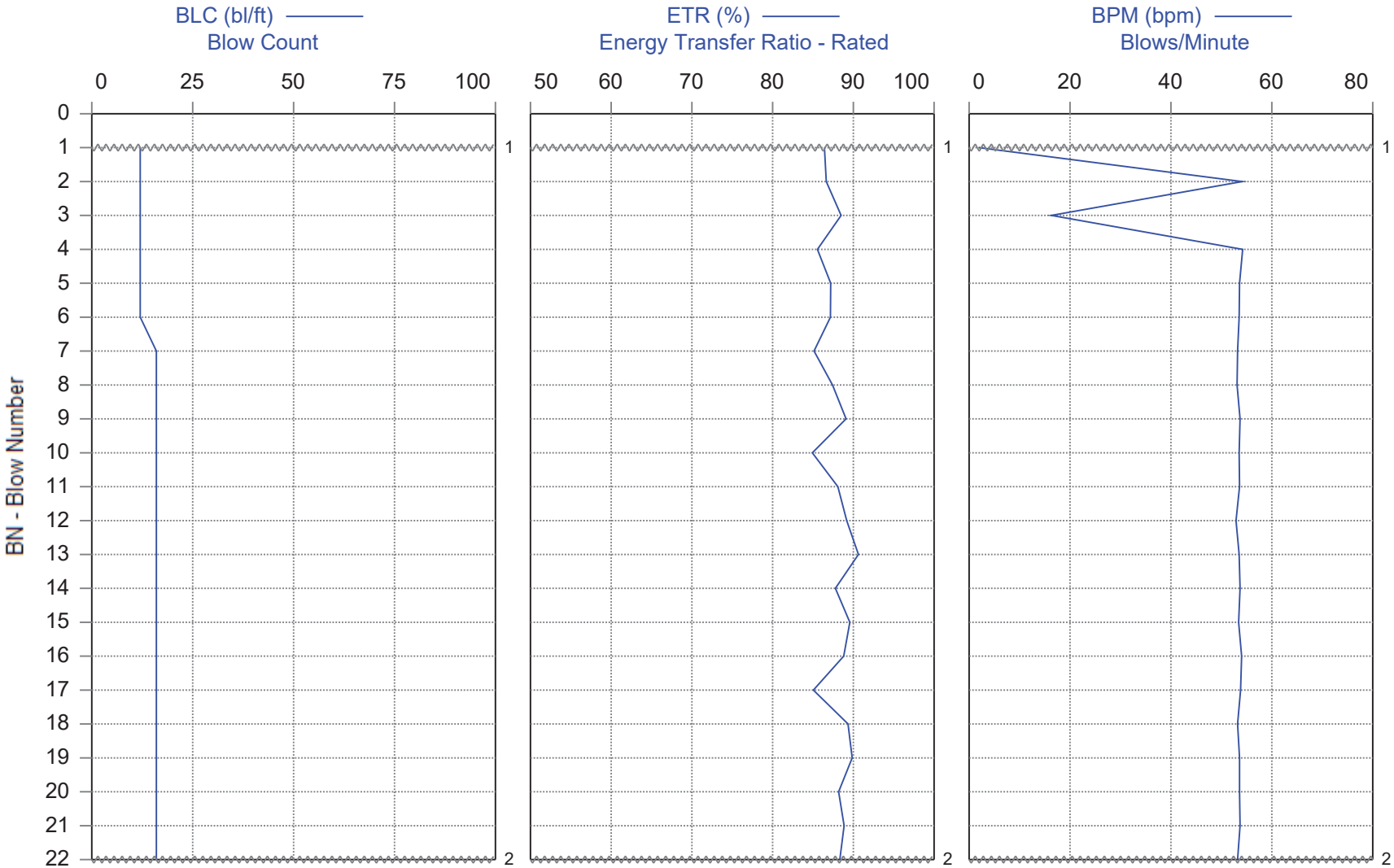
Drive 18 seconds 11:46 PM - 11:46 PM BN 1 - 18

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2017.2.58.5 - Case Method & iCAP® Results

Printed: 13-May-2020

Test started: 12-May-2020

WOOD, W-63-20,RIG 310, SPT - 45 FT SAMPLE



1 - Start of test on 5/12/2020 at 12:05 AM

2 - End of test on 5/12/2020 at 12:06 AM

In Association with

Appendix C
Laboratory Testing Procedures and Results

Appendix C – Laboratory testing procedures and results

This appendix describes procedures associated with the laboratory tests Wood assigned for this project. Geotechnical laboratory testing was performed by a local, accredited geotechnical testing laboratory, subcontracted to Wood. Results of certain laboratory tests are enclosed in this appendix.

Visual classification procedures

Visual soil classifications were conducted on all samples in the field and on selected samples in the laboratory. All soils were classified in general accordance with the Unified Soil Classification System, which includes color, relative moisture content, primary soil type (based on grain size), and any accessory soil types. The resulting soil classifications are presented on the exploration logs contained in Appendix B.

Moisture content determination procedures

Moisture content determinations were performed on representative samples to aid in identification and correlation of soil types. All determinations were made in general accordance with ASTM D-2216. The results of these tests are shown on the exploration logs contained in Appendix B.

Grain-size analysis procedures

A grain-size analysis indicates the range of soil particle diameters included in a particular sample. Grain-size analyses were performed on representative samples in general accordance with ASTM D-422. The results of these tests are presented on the enclosed grain-size distribution graphs and were used in soil classifications shown on the exploration logs contained in Appendix B.

Atterberg limit determination procedures

Atterberg limits are used primarily for classifying and indexing cohesive soils. The liquid and plastic limits, which are defined as the moisture contents of a cohesive soil at arbitrarily established limits for liquid and plastic behavior, were determined for selected samples in general accordance with ASTM D-4318. The results of these tests are presented on the enclosed Atterberg limit graphs and on the boring logs contained in Appendix B.

No. “200-Wash” analysis procedures

A “200-wash” is a procedure in which the fine-grained soil fraction is separated from the sand and gravel by washing the soil on a U.S. No. 200 sieve. A “200-wash” analysis was performed on selected soil samples obtained from our explorations in general accordance with ASTM D-1140. The results of these analyses is presented in the enclosed grain size graphs and were used in our soil classifications shown on the exploration logs contained in Appendix B.

Organic content procedures

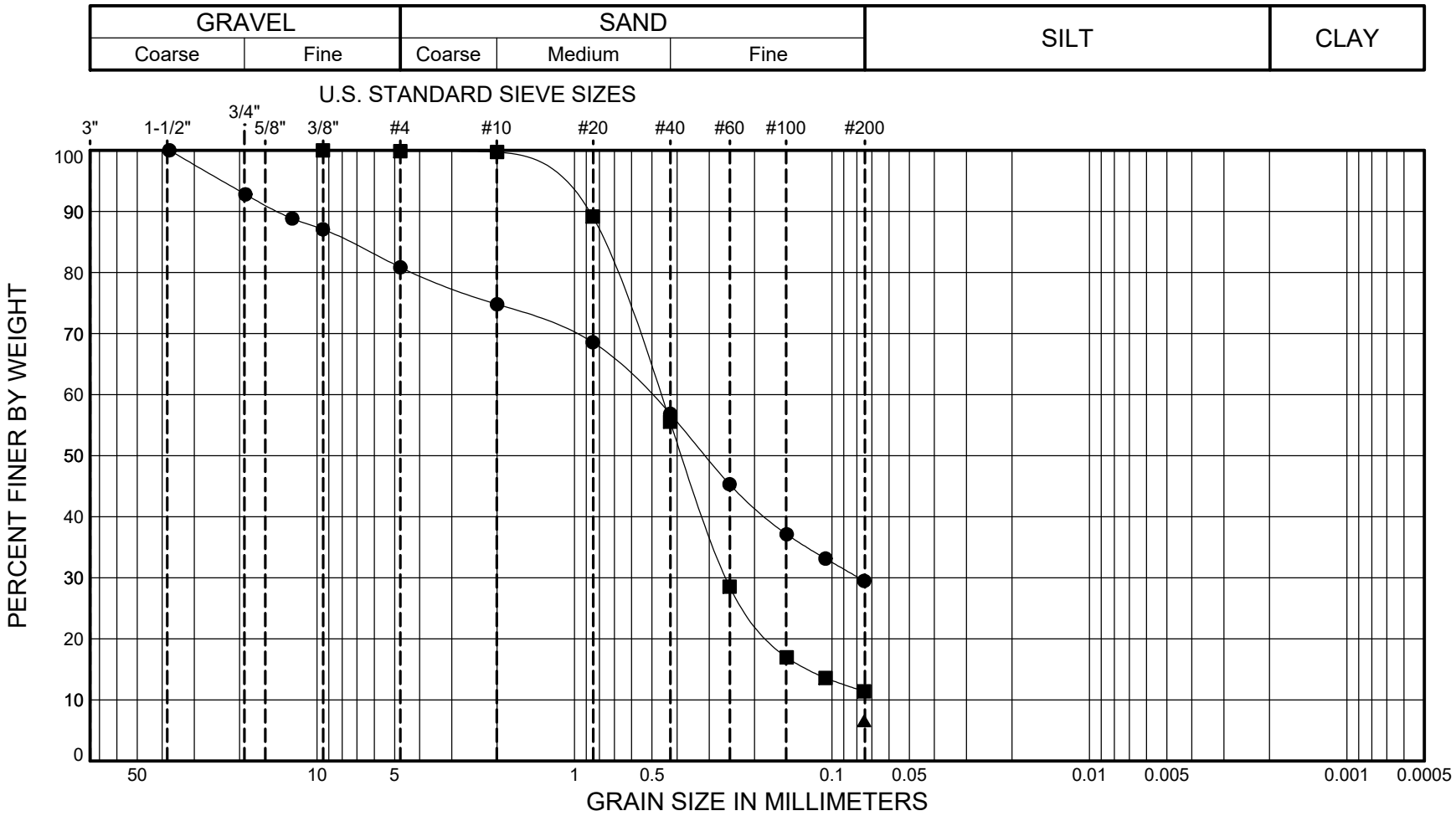
The organic content of soil samples was determined in accordance with ASTM D2974-14, Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils, Test Method C (440 degrees Celsius). The result of testing is shown on the exploration log in Appendix B.

Corrosion testing procedure

Corrosion testing of soil samples consists of pH and resistivity testing. pH values were determined in accordance with EPA SW-846 Test Method 9045D. The resistivity values were determined in accordance with ASTM G-187. The results of testing are shown on the exploration log in Appendix B.

Table C-1 Wall 9.05R-B South Laboratory Testing

Sample Information				Soil Index & Other											Soil Strength	Consolidation	Soil Corrosivity			
					Sieve Analysis (%)					Atterberg Limit (%)										
Boring Designation	Sample Number	Top Depth for Soil/Testing Depth Range for Rock (ft)	Sample Type	Water Content (%)	Percent Gravel	Percent Sand	Percent Fines	Wet Unit	Specific Gravity of Soil	Liquid Limit	Plastic Limit	Plastic Index	Organic Content (%)	Slake Test	Direct Shear Undisturbed	Incremental Load Consolidation	Soil pH	Soil Resistivity (Ohm-cm)	Plastic Index	Soil/Rock Description (USCS)
W-64mw-20	SPT-1	2.5	SPT	13.1																Yellowish-brown, silty SAND (SM)
W-64mw-20	SPT-3	7.5	SPT	11.0	19.2	51.3	29.5													Olive-brown, silty SAND with gravel (SM)
W-64mw-20	SPT-4	10.0	SPT	6.7	0.1	88.5	11.4													Olive-brown, well-graded SAND with silt (SW-SM)
W-64mw-20	SPT-6	20.0	SPT	10.5																Olive-brown, silty SAND (SM)
W-64mw-20	SPT-9	35.0	SPT	6.3			6.6													Olive-brown, poorly graded SAND with silt (SP-SM)
W-64mw-20	SPT-12	50.0	SPT	5.0																Olive-brown, silty SAND (SM)
W-64mw-20	SPT-14	60.0	SPT	5.5																Olive-brown, silty SAND (SM)
W-65-20	SPT-1	2.5	SPT	7.3									2.4							Dark grayish-brown, silty SAND with gravel (SM)
W-65-20	SPT-2	5.0	SPT	1.8						NP	NP	NP								Dark grayish-brown, silty SAND (SM)
W-65-20	SPT-3	7.5	SPT	11.0	19.6	49.6	30.7													Dark grayish-brown, silty SAND with gravel (SM)
W-65-20	SPT-4	10.0	SPT	11.7									2.1							Dark grayish-brown, silty SAND (SM)
W-65-20	SPT-5	15.0	SPT	15.6			29.4			33.0	19.0	14.0								Dark grayish-brown, clayey SAND (SC)
W-65-20	SPT-6	20.0	SPT	2.9			11.2													Olive-brown, poorly graded SAND with silt and gravel (SP-SM)
W-65-20	SPT-7	25.0	SPT	4.7	29.6	57.5	12.9													Olive-brown, silty SAND with gravel (SM)
W-65-20	SPT-9	35.0	SPT														7.0	11000		
W-117-20	SPT-1	2.5	SPT	5.2	9.7	80.2	10.2													Yellowish-brown, well-graded SAND with silt (SW-SM)
W-117-20	SPT-4	10.0	SPT	3.2																Light olive-brown, silty SAND with gravel (SM)
W-117-20	SPT-7	25.0	SPT	6.2		91.6	8.4													Light olive-brown, poorly graded SAND with silt (SP-SM)
W-117-20	SPT-10	40.0	SPT	4.3																Light olive-brown, silty SAND (SM)
W-118-20	SPT-2	5.0	SPT	7.3	16.7	77.8	5.5													Olive-brown, poorly graded SAND with silt and gravel (SP-SM)
W-118-20	SPT-4	10.0	SPT	7.3			4.6													Grayish-brown, poorly graded SAND with gravel (SP)
W-118-20	SPT-7	25.0	SPT	4.4																Gray, silty SAND with gravel (SM)
W-118-20	SPT-9	35.0	SPT	3.7																Grayish-brown, silty SAND with gravel (SM)
W-119-20	SPT-2	5.0	SPT	4.3	50.6	42.0	7.4													Grayish-brown, well-graded GRAVEL with silt and sand (GW-GM)
W-119-20	SPT-4	10.0	SPT	5.2																Grayish-brown, silty SAND with gravel (SM)
W-119-20	SPT-6	20.0	SPT	3.8																Grayish-brown, silty SAND with gravel (SM)
W-119-20	SPT-10	40.0	SPT	6.1			8.6													Grayish-brown, poorly graded SAND with silt (SP-SM)
R2B-65-17	D-4	12.0	SPT	9.0	18.3	50.3	31.4			17.0	15.0	3.0								Silty SAND with gravel (SM)
R2B-65-17	D-10	39.0	SPT	13.0	3.1	87.6	9.2													Poorly graded SAND with silt
R2B-65-17	D-15	64.0	SPT	15.0	0.6	91.8	7.5													Well graded SAND with silt
R2B-66-17	D-1	4.0	SPT	12.0	3.4	89.5	7.1													Poorly graded SAND with silt
R2B-66-17	D-7	24.0	SPT	8.0	49.7	45.9	4.4													Well graded GRAVEL with sand (GW)
R2B-66-17	D-11	44.0	SPT	17.0	5.4	85.8	8.7													Poorly graded SAND with silt
R2B-66-17	D-16	69.0	SPT	14.0	0.0	90.8	9.2													Well graded SAND with silt



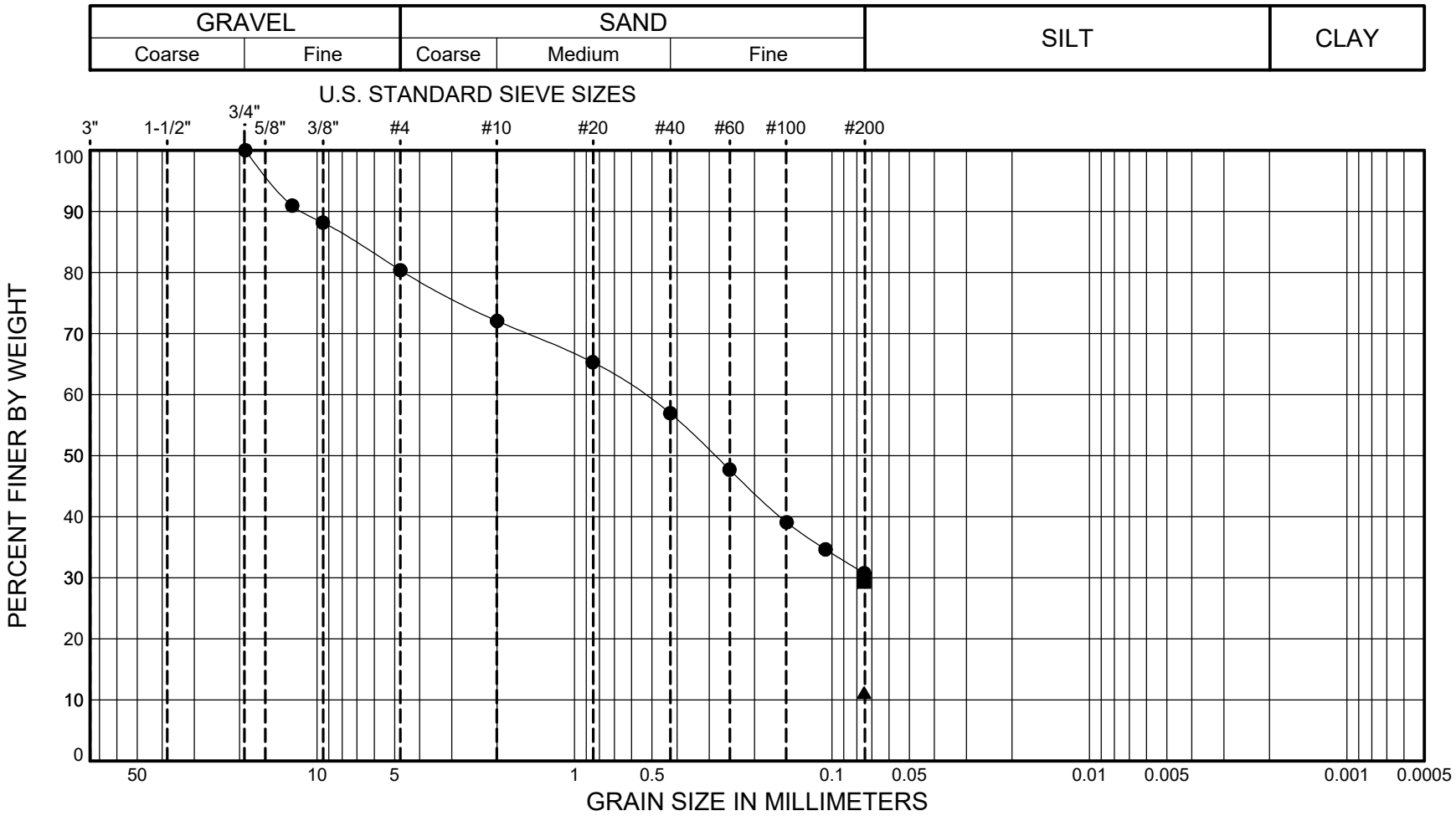
SYMBOL	SAMPLE		DEPTH (ft.)	ASTM SOIL CLASSIFICATION	% MC	LL	PL	PI	Gravel %	Sand %	Silt %	Clay %	Fines %
●	W-064mw-20	S-3	7.5 - 9.0	(SM) Olive-brown, silty SAND with gravel	11				19.2	51.3			29.5
■	W-064mw-20	S-4	10.0 - 11.5	(SW-SM) Olive-brown, well-graded SAND with silt	7				0.1	88.5			11.4
▲	W-064mw-20	S-9	35.0 - 36.5	(SP-SM) Olive-brown, poorly graded SAND with silt	6								6.6

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2019-015-21 T200 FIGURE: 4



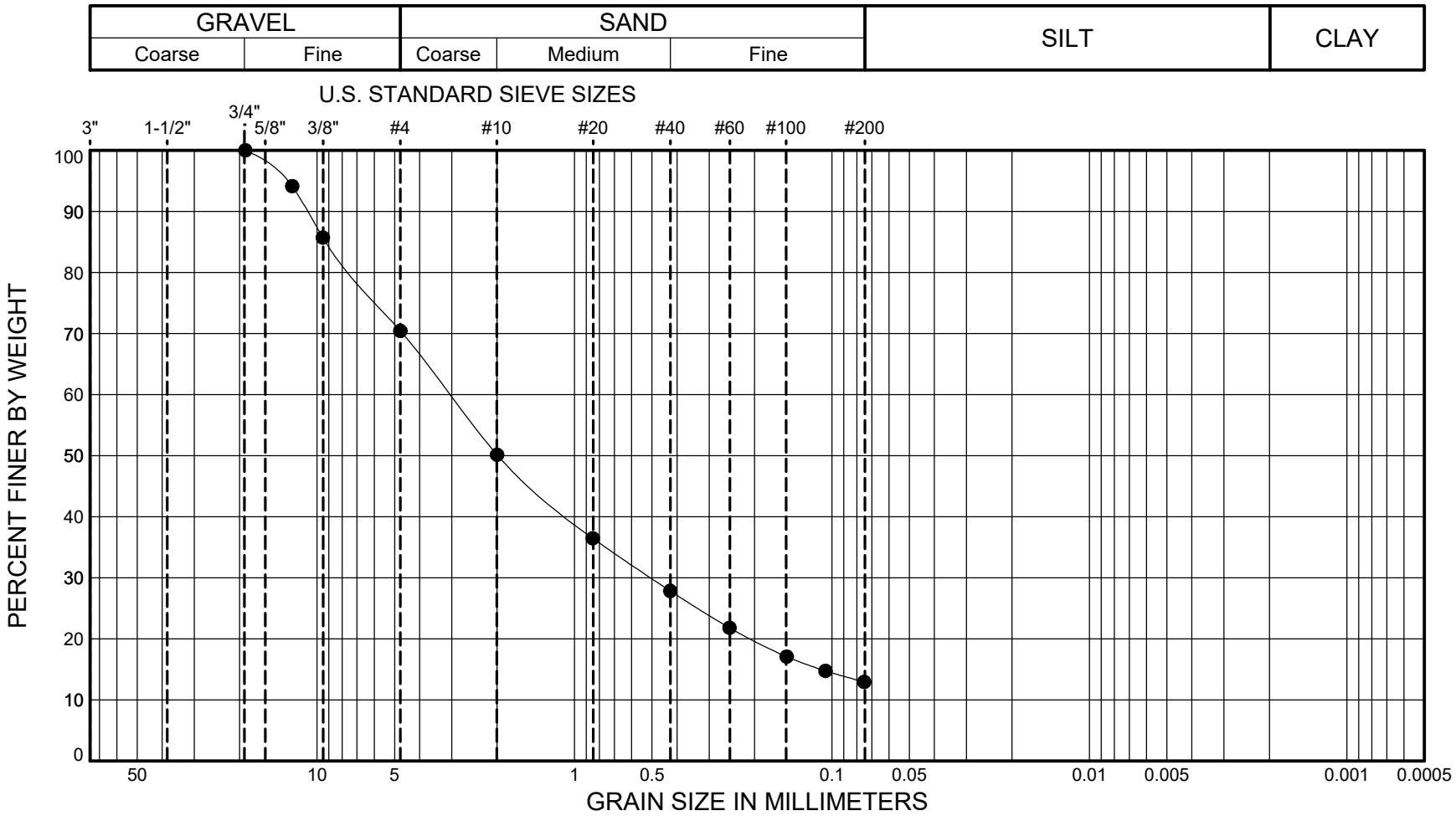
SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	W-065-20	S-3	7.5 - 9.0	(SM) Dark grayish-brown, silty SAND with gravel	11				19.6	49.6	30.7
■	W-065-20	S-5	15.0 - 16.5	(SC) Dark grayish-brown, clayey SAND	16	33	19	14			29.4
▲	W-065-20	S-6	20.0 - 21.0	(SP-SM) Olive-brown, poorly graded SAND with silt and gravel	3						11.2

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2019-015-21 T200 FIGURE: 5



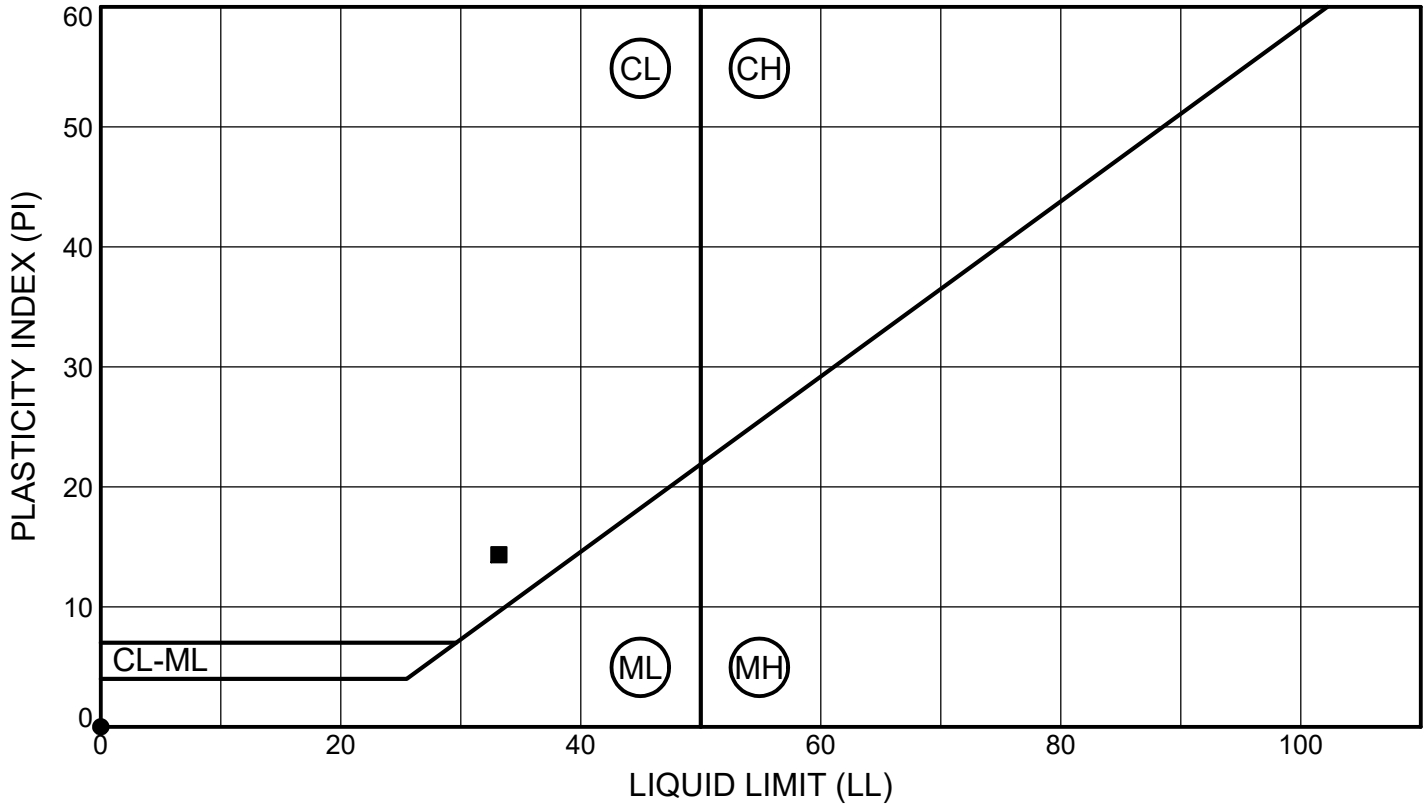
SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	W-065-20	S-7	25.0 - 26.0	(SM) Olive-brown, silty SAND with gravel	5				29.6	57.5	12.9

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2019-015-21 T200 FIGURE: 6



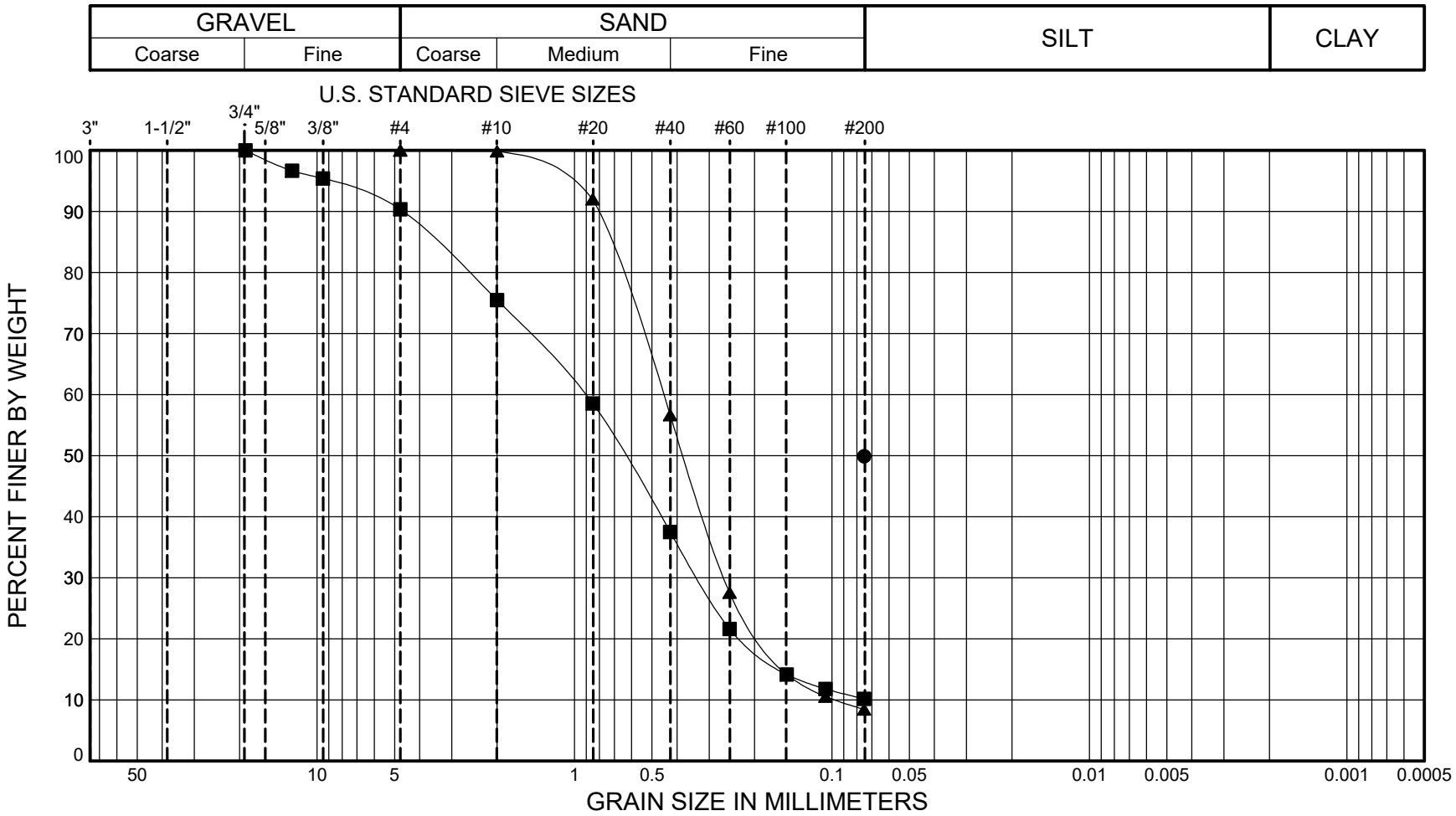
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	W-065-20	S-2	5.0 - 6.5	(SM) Dark grayish-brown, silty SAND	11	NP	NP	NP	
■	W-065-20	S-5	15.0 - 16.5	(SC) Dark grayish-brown, clayey SAND	16	33	19	14	29.4

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

LIQUID LIMIT, PLASTIC LIMIT AND
PLASTICITY INDEX OF SOILS
METHOD ASTM D4318

PROJECT NO.: 2019-015-21 T200 FIGURE: 7



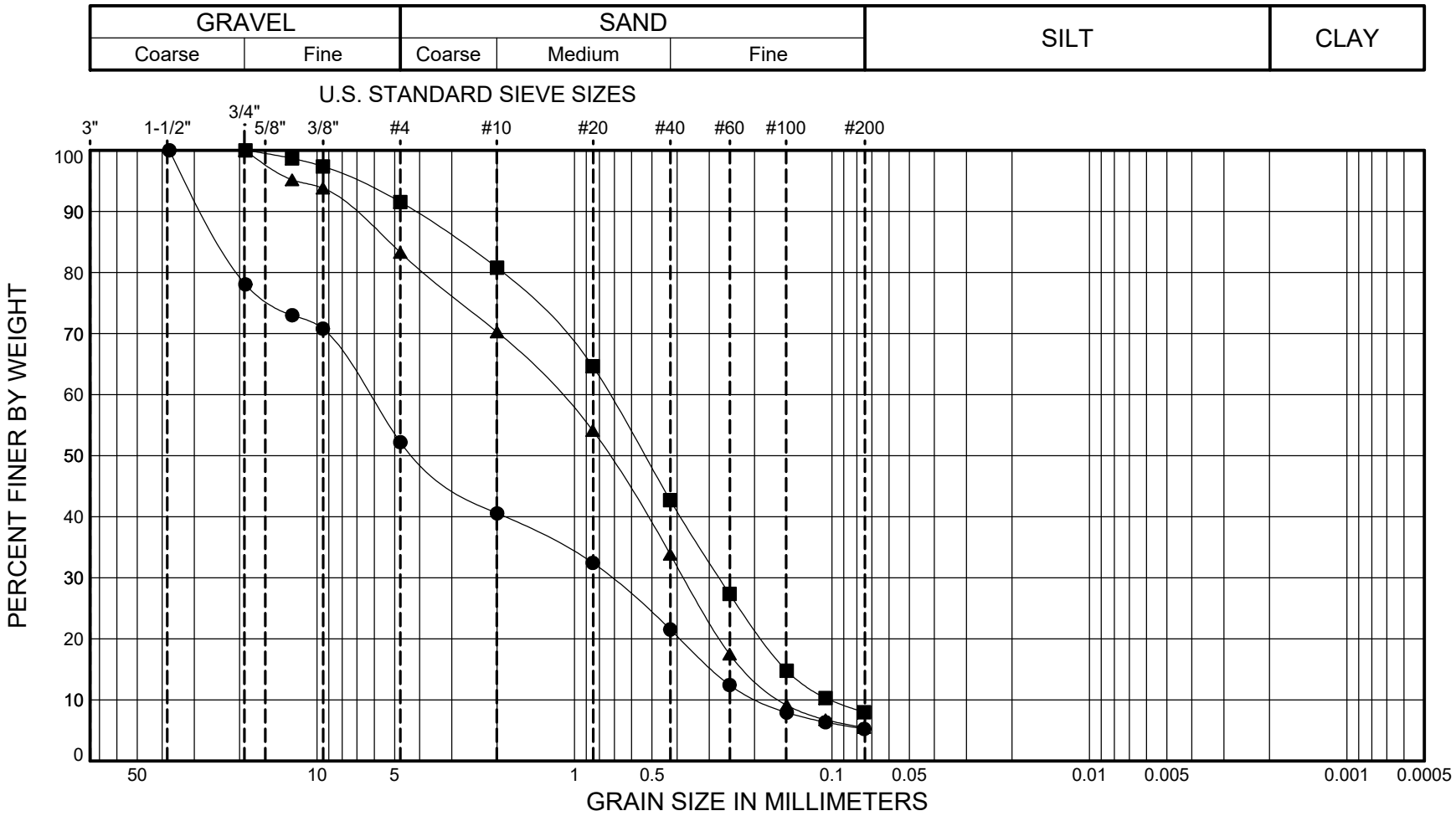
SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	W-100-20	S-11	45.0 - 46.5	(SM) Gray, silty SAND	25						49.9
■	W-117-20	S-1	2.5 - 4.0	(SW-SM) Yellowish-brown, well-graded SAND with silt	5				9.7	80.2	10.2
▲	W-117-20	S-7	25.0 - 26.5	(SP-SM) Light olive-brown, poorly graded SAND with silt	6					91.6	8.4

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2019-015-21 T200 FIGURE: 10



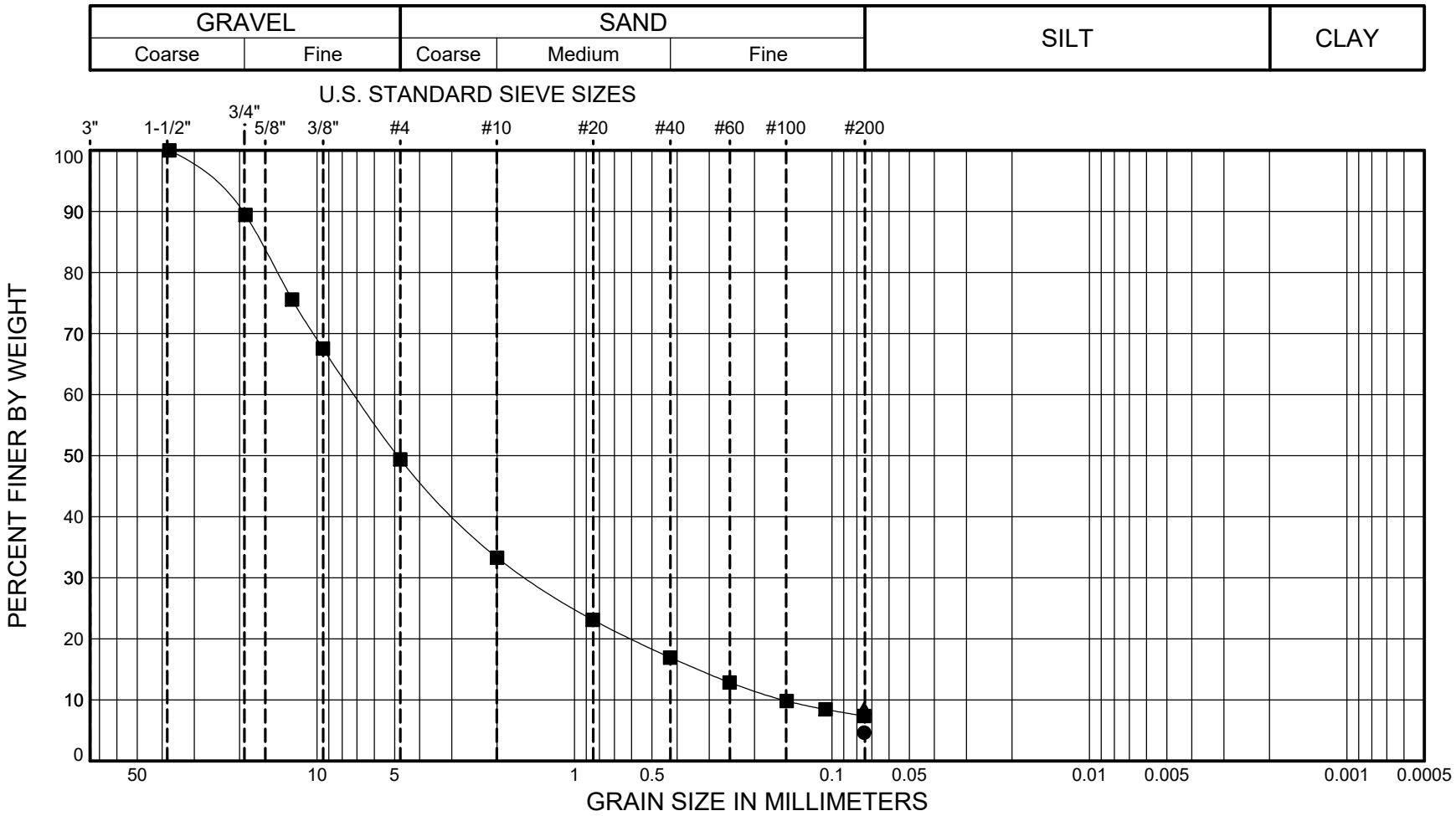
SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	W-115-20	S-2	5.0 - 6.5	(GP-GM) Dark olive-brown, poorly graded GRAVEL with silt and sand	5				47.8	47.0	5.2
■	W-115-20	S-8	30.0 - 31.0	(SW-SM) Olive-brown, well-graded SAND with silt	4				8.5	83.6	8.0
▲	W-118-20	S-2	5.0 - 6.5	(SP-SM) Olive-brown, poorly graded SAND with silt and gravel	7				16.7	77.8	5.5

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2019-015-21 T200 FIGURE: 4



SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	W-118-20	S-4	10.0 - 11.5	(SP) Grayish-brown, poorly graded SAND with gravel	7						4.6
■	W-119-20	S-2	5.0 - 6.5	(GW-GM) Grayish-brown, well-graded GRAVEL with silt and sand	4				50.6	42.0	7.4
▲	W-119-20	S-10	40.0 - 41.5	(SP-SM) Grayish-brown, poorly graded SAND with silt	6						8.6

HWA GEOSCIENCES INC.

I-405 Renton to Bellevue
Widening and Express Toll Lanes
Client Project No.: PS19203160

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2019-015-21 T200 FIGURE: 5

Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664

Professional Analytical Services

Aug 3 2020
WOOD ENVIRONMENT & INFRASTRUCT
4020 LAKE WASHINGTON BLVD NE
SUITE 200
KIRKLAND, WA 98033
Attention: ALEC ANDERSON

Dear ALEC ANDERSON:

Enclosed please find the analytical data for your I-405 R2B project.

The following is a cross correlation of client and laboratory identifications for your convenience.

CLIENT ID	MATRIX	AMTEST ID	TEST
W-65-20 S-9	Soil	20-A010844	CONV

Your sample was received on Thursday, July 23, 2020. At the time of receipt, the sample was logged in and properly maintained prior to the subsequent analysis.

The analytical procedures used at AmTest are well documented and are typically derived from the protocols of the EPA, USDA, FDA or the Army Corps of Engineers.

Following the analytical data you will find the Quality Control (QC) results.

Please note that the detection limits that are listed in the body of the report refer to the Practical Quantitation Limits (PQL's), as opposed to the Method Detection Limits (MDL's).

If you should have any questions pertaining to the data package, please feel free to contact me.

Sincerely,

Aaron W. Young
Vice President

Project #: PS19-20316-0

BACT = Bacteriological
CONV = Conventionals
MET = Metals
ORG = Organics
NUT=Nutrients
DEM=Demand
MIN=Minerals

Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664
www.amtestlab.com

Professional Analytical Services

ANALYSIS REPORT

WOOD ENVIRONMENT & INFRASTRUCT
4020 LAKE WASHINGTON BLVD NE
KIRKLAND, WA 98033
Attention: ALEC ANDERSON
Project Name: I-405 R2B
Project #: PS19-20316-0
All results reported on an as received basis.

Date Received: 07/23/20
Date Reported: 8/ 3/20

AMTEST Identification Number **20-A010844**
Client Identification **W-65-20 S-9**
Sampling Date

Conventionals

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
pH	7.0	unit		1	SW-846 9045D	KW	07/29/20
Resistivity	11000	ohms cm		100	ASTM G-187	KF	08/01/20

Aaron W. Young
Vice President

Am Test Inc.
13600 NE 126th PL
Suite C
Kirkland, WA, 98034
(425) 885-1664
www.amtestlab.com

Professional Analytical Services

QC Summary for sample number: 20-A010844

DUPLICATES

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	DUP VALUE	RPD
20-A010844	pH	unit	7.0	6.9	1.4
20-A010844	Resistivity	ohms cm	11000	13000	17.

AmTest Chain of Custody Record

13600 NE 126th PL, Suite C, Kirkland, WA 98034
Ph (425) 885-1664 Fx (425) 820-0245
www.amtestlab.com

Chain of Custody No. 36763

Client Name & Address:	Invoice To:
Alec Anderson Wood PLC	
Contact Person: Alec Anderson	Invoice Contact:
Phone No: 425-638-9883	PO Number:
Fax No:	Invoice Ph/Fax:
E-mail: alec.anderson@woodplc.com	Invoice E-mail:
Report Delivery: (Choose all that apply) Mail / Fax / Email / Posted Online	Data posted to online account: YES / NO Web Login ID:

Special Instructions:

Requested TAT: **(Rush must be pre-approved by lab)**
Standard RUSH (5 Day / 3 Day / 48 HR / 24 HR)

Temperature upon Receipt: 24.8

Project Name: I-405 R2B

Project Number: P519-20316-0

AmTest ID	Client ID (35 characters max)	Date Sampled	Time Sampled	Matrix	No. of containers	Analysis Requested: Corrosivity	Resistivity	Ph							QA/QC
10844	W-65-20 S-9					X	X	X							
	W-65-20 S-10					X									
	W-65-20 S-11					X									
	W-65-20 S-12					X									

Collected/Relinquished By:	Date	Time	Received By:	Date	Time
Chelsea Foster	7/23/20	1329	[signature]	7/23/20	1329
Relinquished By:	Date	Time	Received By:	Date	Time
Relinquished By:	Date	Time	Received By:	Date	Time

COMMENTS:

Job No. **XL-4653** Date **May 7, 2018**

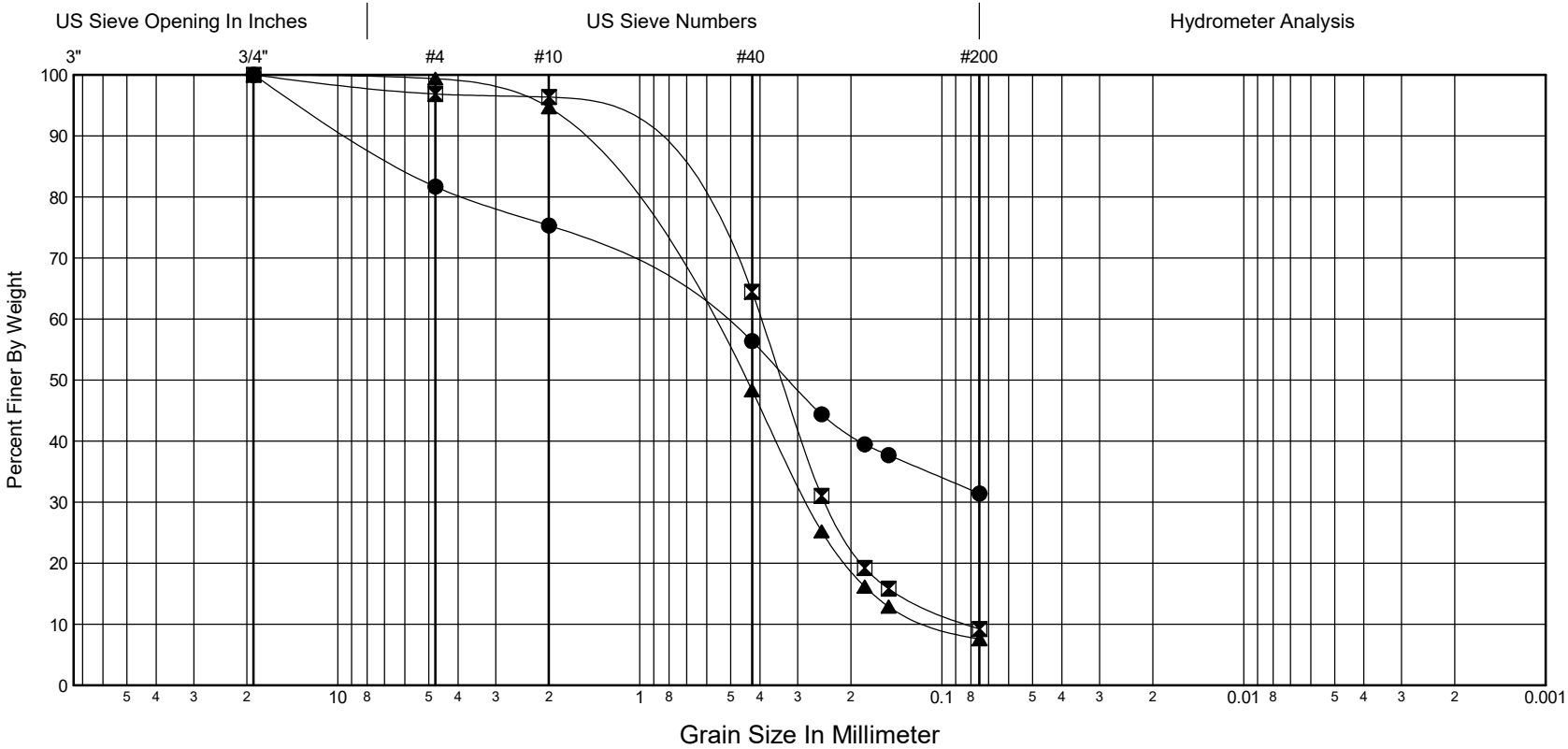
Hole No. **R2B-65-17** Sheet **1**

Project **I-405 Renton to Bellevue - ETL - Envir & Traff**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft³)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	12.0	D-4	SM	SILTY SAND with GRAVEL	9	17	15	2			18.3	50.3	31.4			0.571	0.32			
⊠	39.0	D-10		MC & Sieve Only	13						3.1	87.6	9.2	1.8	4.9	0.396	0.34	0.24	0.18	0.081
▲	64.0	D-15		MC & Sieve Only	15						0.6	91.8	7.5	1.2	6.1	0.628	0.45	0.28	0.21	0.103



XL-5467 (OLD XL-4653) 405 RENTON TO BELLEVUE ETL - ENVIRO AND TRAFF.GPJ PUBLIC-COMMON LIBRARY.GLB 5/7/18

Job No. **XL-4653** Date **May 7, 2018**

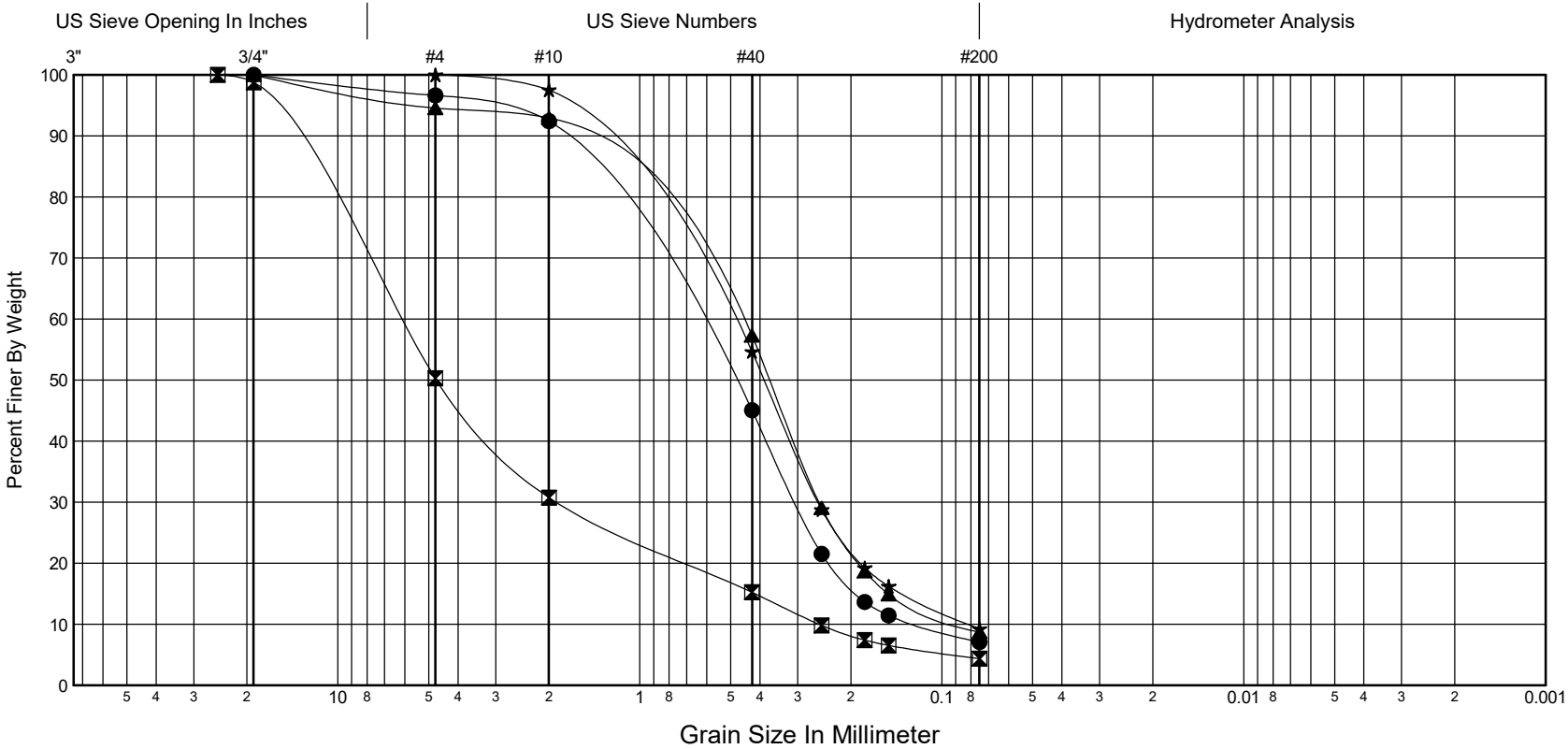
Hole No. **R2B-66-17** Sheet **1**

Project **I-405 Renton to Bellevue - ETL - Envir & Traff**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft³)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	4.0	D-1		MC & Sieve Only	12						3.4	89.5	7.1	1.1	5.8	0.693	0.50	0.30	0.23	0.119
⧗	24.0	D-7	GW	WELL-GRADED GRAVEL with SAND	8						49.7	45.9	4.4	2.2	24.6	6.272	4.69	1.86	0.68	0.255
▲	44.0	D-11		MC & Sieve Only	17						5.4	85.8	8.7	1.6	5.5	0.478	0.37	0.25	0.19	0.087
★	69.0	D-16		MC & Sieve Only	14						0.0	90.8	9.2	1.6	6.4	0.515	0.39	0.26	0.18	0.081



Gravel	Sand			Silt			Clay
	Coarse	Medium	Fine	Coarse	Medium	Fine	

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In Association with

Appendix D
ESU Soil Properties

Appendix D – ESU Soil Properties

This appendix describes procedures associated with the assignment of soil properties based on laboratory tests, field exploration, and soil property methodology. The data from the borehole logs and laboratory tests were imported into our spreadsheet and associated $(N_1)_{60}$ values were calculated.

Stratigraphic unit grouping

Geologic strata as defined in Section 5.2 of the Project GDM were identified based on review of the available borehole logs, laboratory testing and published geologic maps. Geologic cross sections were initially developed using the interpreted geologic strata. A geotechnical engineer then assigned Engineering Stratigraphic Units (ESUs) based on review of the geologic cross sections, grouping geologic strata with similar engineering properties.

Evaluate Statistical Analysis

The $(N_1)_{60}$ parameters were accumulated for each ESU. The average, geomean, and standard deviation were calculated for $(N_1)_{60.}$ The blow count values were evaluated for outliers that are associated with mislabeling, testing errors, and statistics. The outliers were either reassigned to another ESU, remained in the statistical evaluation, or were removed from the statistical valuation. The blow counts vs depth chart, standard deviations, and covariance were utilized to make these assessments. The covariance was verified to be between 15 and 45 percent per the *LRFD Bridge Design Specifications* (AASHTO 2017).

Review Soil Property Values

Soil properties were assigned per the Geotechnical Soil Properties Methodology report (Wood 2020d).

In most cases, the effective friction angle was assigned to the ESU group in accordance with Table 5-1 in the Project GDM using the average $(N_1)_{60}$ value. Within the range of values presented in Table 5-1, information on the fines content and soil plasticity was also considered to assign the effective friction angle. Values at or near the Upper limit of Table 5-1 were selected when fines content was determined as below 5 percent passing US sieve No.200. Values at or near the Lower Limit were selected for soil with “significant” fines, taken as soil with fines content greater than 30 percent passing US No.200 sieve, based on the 2014 Caltrans *Geotechnical Manual*. For samples where the fines content was between 5 and 30 percent, interpolation was used between the upper and lower limit to select the effective friction angle. For low plasticity fine grained material, material with a plasticity index less than 5, Table 5-1 was used to determine the effective friction angle using lower limit in comparison with the value that was derived based on the plasticity index value as referenced in the Geotechnical Soil Properties Methodology report (Wood 2020d). In circumstances where the ESU has high covariance and outside the soil parameters for the referenced volume of *Engineering Geology in Washington*, then the lower or higher value will be chosen.

The unit weight for each ESU was determined based on the Caltrans (2014) method of USCS classification with blow counts. The value for unit weight was compared to the ranges in Coduto (2001) and the Project GDM for verification. If the unit weight is outside the range of the reference documents, then the value will be adjusted to fit within the range.

Other soil engineering properties were determined based on results of Cone Penetrometer Test probes, laboratory testing and correlations as described in the Geotechnical Soil Properties Methodology report (Wood 2020d).

Tab	Description
Summary	Input available information on historic boring log ID, location, elevation, drill rig ID and hammer efficiency
Summary	Correct to NAVD88 vertical datum
Samples	Input each SPT sample and 6-inch interval blow count; formula calculates N Field
Samples	Input available lab test data and USCS classification from Lab
Samples	For R2B borings, this is all listed in Table B-1 of the GDR
Samples	Use lab data and boring log information to estimate USCS for all samples
Calc $(N_1)_{60}$	Use Coduto (2001) to estimate Unit weight for all samples (Unless we have Unit weight measurements)
Calc $(N_1)_{60}$	Use GDM to estimate Unit weight for organic/peat samples (Unless we have Unit weight measurements)
Calc $(N_1)_{60}$	Input for other fields in yellow highlight
Calc $(N_1)_{60}$	Input for fields in yellow highlight (input only known fines contents at this time)
Assign ESU	based on review of geologic cross sections and other information, assign ESUs
ESU 1, 2, etc.	1 - List data with $(N_1)_{60}$ values; give justification for deleting any values.
ESU 1, 2, etc.	2 - Check COV is within limits (15 to 45% for N values); consider if ESU needs subdividing or if OK
ESU 1, 2, etc.	3 - Plot Histogram and visually compare to GEOMEAN
ESU 1, 2, etc.	4 - Correlate $(N_1)_{60}$ with friction angle; use average unless other factors

CHECK UNIT WEIGHTS AGAINST CODUTO (2001)

TABLE 3.2 TYPICAL UNIT WEIGHTS

Soil Type and Unified Soil Classification (See Figure 3.3)	Typical Unit Weight, γ: Above Groundwater Table (lb/ft³)	Above Groundwater Table (kN/m³)	Below Groundwater Table (lb/ft³)	Below Groundwater Table (kN/m³)
GP—Poorly-graded gravel	110–130	17.5–20.5	125–140	19.5–22.0
GW—Well-graded gravel	110–140	17.5–22.0	125–150	19.5–23.5
GM—Silty gravel	100–130	16.0–20.5	125–140	19.5–22.0
GC—Clayey gravel	100–130	16.0–20.5	125–140	19.5–22.0
SP—Poorly-graded sand	95–125	15.0–19.5	120–135	19.0–21.0
SW—Well-graded sand	95–135	15.0–21.0	120–145	19.0–23.0
SM—Silty sand	80–135	12.5–21.0	110–140	17.5–22.0
SC—Clayey sand	85–130	13.5–20.5	110–135	17.5–21.0
ML—Low plasticity silt	75–110	11.5–17.5	80–130	12.5–20.5
MH—High plasticity silt	75–110	11.5–17.5	75–130	11.5–20.5
CL—Low plasticity clay	80–110	12.5–17.5	75–130	11.5–20.5
CH—High plasticity clay	80–110	12.5–17.5	70–125	11.0–19.5

CHECK UNIT WEIGHTS AGAINST CODUTO (2001)

	Above GW			Below GW		
USCS	Min (pcf)	Max (pcf)	Average	Min (pcf)	Max (pcf)	Average
GP	110	130	120	125	140	133
GW	110	140	125	125	150	138
GM	100	130	115	125	140	133
GC	100	130	115	125	140	133
SP	95	125	110	120	135	128
SW	95	135	115	120	145	133
SM	80	135	108	110	140	125
SC	85	130	108	110	135	123
ML	75	110	93	80	130	105
MH	75	110	93	75	130	103
CL	80	110	95	75	130	103
CH	80	110	95	70	125	98

REFERENCES:

Coduto, D.P. 2001. *Foundation Design Principles and Practices* . 2nd Edition. Prentice-Hall, Inc., New Jersey.

Washington State Department of Transportation (WSDOT). 2019. *Geotechnical Design Manual.* Publication M46-03.12.

BOREHOLE SUMMARY

PointID	Hole Depth	Elevation	Northing	Easting	Source	Hole Size	Contractor	Method	Equipment	Historical Efficiency	Date Start	Date End
R2B-61-17	61.5	162.637	203350.96	1304232.593	Note 1	4	Region Survey Crew	Casing Advancer	CME 45C	88	7/11/2017	7/11/2017
R2B-74-17	49.5	149.54	206489.55	1306007.215	Note 1	6	Region Survey Crew	Casing Advancer	CME 850	86	3/10/2017	3/10/2017
W-70-20	46.5	157	206584.011	1306044.102	Survey	8	Gregory Drilling	HSA	CME 55 ID: #310	88	6/11/2020	6/12/2020

Note 1 - Information not available

SAMPLE SUMMARY

PointID	Top Depth (ft)	Sample Number	Blow Counts[1]			Length[1]			Field N	USCS from Lab	Lab Description	Estimated USCS	Water Content (%)	Atterberg Limits			Total Wet Unit Weight	Estimated Total Unit Weight (pcf)	Dry Density (pcf)	Specific Gravity	Sieve analysis					% Organics
			1	2	3	1	2	3						Liquid Limit	Plastic Limit	Plasticity Index					% Gravel	% Sand	Fines Content From Lab	% Silt	% Clay	
R2B-61-17	5	D-1	9	15	21	6	6	6	36	SP-SM	Poorly graded SAND with silt	SP-SM	12	--	--	--	--	--	--	--	0	90.1	9.9	--	--	--
R2B-61-17	7.5	D-2	5	17	17	6	6	6	34	SP-SM		SP-SM					--	--	--					--	--	
R2B-61-17	10	D-3	11	16	18	6	6	6	34	SP-SM	Poorly graded SAND with silt	SP-SM	16	--	--	--	--	--	--	--	0	92.2	7.8	--	--	--
R2B-61-17	12.5	D-4	5	18	20	6	6	6	38	SP-SM		SP-SM					--	--	--					--	--	
R2B-61-17	15	D-5	14	18	25	6	6	6	43	SP-SM		SP-SM					--	--	--					--	--	
R2B-61-17	20	D-6	1	21	38	6	6	6	59	SM	Silty SAND	SM	13	--	--	--	--	--	--	--	0.1	87.3	12.6	--	--	--
R2B-61-17	25	D-7	16	29	32	6	6	6	61	SM		SM					--	--	--					--	--	
R2B-61-17	30	D-8	18	27	40	6	6	6	67	SM		SM					--	--	--					--	--	
R2B-61-17	35	D-9	14	26	31	6	6	6	57	SP-SM	Poorly graded SAND with silt	SP-SM	21	--	--	--	--	--	--	--	0	91.6	8.4	--	--	--
R2B-61-17	40	D-10	10	18	26	6	6	6	44	CL-ML	Sandy silty CLAY (CL-ML)	CL-ML	21	23	19	4	--	--	--	--	3.3	34.4	62.3	--	--	--
R2B-61-17	45	D-11	8	15	27	6	6	6	42	CL-ML	Sandy silty CLAY with organics (CL-ML)	CL-ML	20	26	19	7	--	--	--	--	10.2	30.3	59.5	--	--	--
R2B-61-17	50	D-12	11	19	29	6	6	6	48	CL-ML		CL-ML					--	--	--					--	--	
R2B-61-17	55	D-13	14	21	31	6	6	6	52	CL-ML		CL-ML					--	--	--					--	--	
R2B-61-17	60	D-14	15	20	29	6	6	6	49	CL	Sandy lean CLAY with organics (CL)	CL	17	30	18	12	--	--	--	--	2.5	30.2	67.2	--	--	--
R2B-74-17	3	D-1	5	7	10	6	6	6	17	ML		ML					--	--	--					--	--	
R2B-74-17	6	D-2	3	5	5	6	6	6	10	CH		CH					--	--	--					--	--	
R2B-74-17	8	D-3	3	4	4	6	6	6	8	CH	Fat CLAY	CH	56	71	33	38	--	--	--	--	--	--	--	--	--	--
R2B-74-17	11	D-4	3	4	4	6	6	6	8	CH	Fat CLAY (CH)	CH	41	72	31	41	--	--	--	2.68	0.1	0.1	99.8	--	--	--
R2B-74-17	13	P-5				6	6			CH		CH					--	--	--					--	--	
R2B-74-17	15	D-6	3	4	5	6	6	6	9	CH		CH					--	--	--					--	--	
R2B-74-17	18	D-7	5	7	9	6	6	6	16	CH	Fat CLAY	CH	38	57	27	30	--	--	--	--	--	--	--	--	--	--
R2B-74-17	23	D-8	4	4	6	6	6	6	10	CH		CH					--	--	--					--	--	
R2B-74-17	28	D-9	3	5	5	6	6	6	10	CH	Fat CLAY	CH	35	57	29	28	--	--	--	--	--	--	--	--	--	--
R2B-74-17	33	D-10	4	5	10	6	6	6	15	CH		CH					--	--	--					--	--	
R2B-74-17	38	D-11	5	6	8	6	6	6	14	CH	Fat CLAY	CH	37	51	27	24	--	--	--	--	--	--	--	--	--	--
R2B-74-17	43	D-12	4	7	8	6	6	6	15	CH		CH					--	--	--					--	--	
R2B-74-17	48	D-13	5	7	9	6	6	6	16	CH	Fat CLAY (CH)	CH	40	56	27	29	--	--	--	2.69	0	0	100	--	--	--
W-70-20	2.5	SPT-1	3	8	13	6	6	6	21	CL	lean CLAY	CL	19.2	--	--	--	--	--	--	--	--	--	--	--	--	
W-70-20	5.0	SPT-2	8	12	15	6	6	6	27	CL		CL	--	--	--	--	--	--	--	--	--	--	--	--	--	--
W-70-20	7.5	SPT-3	7	12	14	6	6	6	26	SC	clayey SAND	SC	14.4	23.9974	15.8801	8.11735	--	--	--	--	--	--	47.7	--	--	
W-70-20	10.0	SPT-4	8	10	9	6	6	6	19	SC		SC	--	--	--	--	--	--	--	--	--	--	--	--	--	--
W-70-20	15.0	SPT-5	3	7	8	6	6	6	15	CH	fat CLAY	CH	33.2	74.6886	31.71	42.9786	--	--	--	--	--	--	90.3	--	--	
W-70-20	17.5	ST-1								CH		CH	--	--	--	--	--	--	--	--	--	--	--	--	--	--
W-70-20	20.0	SPT-6	2	5	5	6	6	6	10	CH		CH	--	--	--	--	--	--	--	--	--	--	--	--	--	--
W-70-20	25.0	SPT-7	3	4	5	6	6	6	9	CH	fat CLAY	CH	36.5	67.3707	27.7763	39.5945	--	--	--	--	--	--	99.9	--	--	
W-70-20	30.0	SPT-8	4	4	6	6	6	6	10	CH		CH	--	--	--	--	--	--	--	--	--	--	--	--	--	--
W-70-20	35.0	SPT-9	3	6	6	6	6	6	12	CH	lean CLAY	CH	38.1	--	--	--	--	--	--	--	--	--	--	--	--	
W-70-20	40.0	SPT-10	3	4	5	6	6	6	9	CH		CH	--	--	--	--	--	--	--	--	--	--	--	--	--	--
W-70-20	45.0	SPT-11	4	6	11	6	6	6	17	CH	lean CLAY	CH	--	--	--	--	--	--	--	--	--	--	--	--	--	

Notes:

1. Blank cells in the Blow Counts and Length columns signify that eiter no SPT was performed, that refusal was encountered, or that only an overall "blows per foot" N value was recorded.

-- = not tested

STANDARD PENETRATION TEST DATA [1]

Boring Number	Sample Top Depth (ft)	Field Blowcounts	Sampler Type (spt = standard penetrometer w/ 1.375-inch I.D., m = Modified California)	Samplers Have Space for Liners But didn't Use?	Borehole Diameter (in)	C_R, Rod Length Correction Factor	C_s, Sampling Method Correction Factor	C_S, Correction for Sampler without Liners	Hammer efficiency (%)	C_E, Energy Ratio Correction	C_B, Boring Dia Correction	N_{60}, Blowcount Corrected for All Factors except Overburden	Groundwater Depth (ft)	Avg Unit Wt of Sample (pcf) [or corrleation based on Coduto and USCS info or GDM for Peats]	Total Overburden Stress (psf)	Effective Overburden Stress (psf)	C_N, Over-burden Correction (Eq 41, Idriss & Boulanger, 2008[2]) = (pa/σvo')^0.5	$(N_1)_{60}$, Corrected Blowcount for All Factors	Limit $(N_1)_{60}$ to 46	C_N, Over-burden Correction (Eq 39, Idriss & Boulanger, 2008[2]) = $f(N_1)_{60}$	$(N_1)_{60}$, Corrected Blowcount for All Factors refined for relative density	Estimated USCS Classification
		N	Sampler Type	(y/n)		C_R	C_s	C_S	ER(%)	C_E	C_B	N_{60}	gwt (ft)	γ (pcf)	σ (psf)	σ' (psf)	C_N	$(N_1)_{60}$	Limit $(N_1)_{60}$ to 46	C_N refined	$(N_1)_{60}$ refined	USCS
R2B-61-17	5.0	36	SPT	n	4	0.8	1	1.0	88	1.47	1.00	42	-	109	545.0	545.0	1.7	72	46	1.4	60	SP-SM
R2B-61-17	7.5	34	SPT	n	4	0.8	1	1.0	88	1.47	1.00	40	-	109	817.5	817.5	1.6	64	46	1.3	51	SP-SM
R2B-61-17	10.0	34	SPT	n	4	0.85	1	1.0	88	1.47	1.00	42	-	109	1090.0	1090.0	1.4	59	46	1.2	50	SP-SM
R2B-61-17	12.5	38	SPT	n	4	0.85	1	1.0	88	1.47	1.00	47	-	109	1362.5	1362.5	1.2	59	46	1.1	53	SP-SM
R2B-61-17	15.0	43	SPT	n	4	0.95	1	1.0	88	1.47	1.00	60	-	109	1635.0	1635.0	1.1	68	46	1.1	64	SP-SM
R2B-61-17	20.0	59	SPT	n	4	0.95	1	1.0	88	1.47	1.00	82	-	108	2175.0	2175.0	1.0	81	46	1.0	82	SM
R2B-61-17	25.0	61	SPT	n	4	0.95	1	1.0	88	1.47	1.00	85	-	108	2715.0	2715.0	0.9	75	46	0.9	80	SM
R2B-61-17	30.0	67	SPT	n	4	1	1	1.0	88	1.47	1.00	98	-	108	3255.0	3255.0	0.8	79	46	0.9	88	SM
R2B-61-17	35.0	57	SPT	n	4	1	1	1.0	88	1.47	1.00	84	-	109	3800.0	3800.0	0.7	62	46	0.9	72	SP-SM
R2B-61-17	40.0	44	SPT	n	4	1	1	1.0	88	1.47	1.00	65	-	94	4270.0	4270.0	0.7	45	45	0.8	53	CL-ML
R2B-61-17	45.0	42	SPT	n	4	1	1	1.0	88	1.47	1.00	62	-	94	4740.0	4740.0	0.7	41	41	0.8	49	CL-ML
R2B-61-17	50.0	48	SPT	n	4	1	1	1.0	88	1.47	1.00	70	-	94	5210.0	5210.0	0.6	45	45	0.8	55	CL-ML
R2B-61-17	55.0	52	SPT	n	4	1	1	1.0	88	1.47	1.00	76	-	94	5680.0	5680.0	0.6	47	46	0.8	59	CL-ML
R2B-61-17	60.0	49	SPT	n	4	1	1	1.0	88	1.47	1.00	72	-	95	6155.0	6155.0	0.6	42	42	0.7	53	CL
R2B-74-17	3.0	17	SPT	n	6	0.75	1	1.0	86	1.43	1.05	19	-	93	279.0	279.0	1.7	33	33	1.7	33	ML
R2B-74-17	6.0	10	SPT	n	6	0.8	1	1.0	86	1.43	1.05	12	-	95	564.0	564.0	1.7	20	20	1.7	20	CH
R2B-74-17	8.0	8	SPT	n	6	0.8	1	1.0	86	1.43	1.05	10	-	95	754.0	754.0	1.7	16	16	1.6	16	CH
R2B-74-17	11.0	8	SPT	n	6	0.85	1	1.0	86	1.43	1.05	10	-	95	1039.0	1039.0	1.4	15	15	1.4	14	CH
R2B-74-17	15.0	9	SPT	n	6	0.95	1	1.0	86	1.43	1.05	13	-	95	1419.0	1419.0	1.2	16	16	1.2	16	CH
R2B-74-17	18.0	16	SPT	n	6	0.95	1	1.0	86	1.43	1.05	23	-	95	1704.0	1704.0	1.1	26	26	1.1	25	CH
R2B-74-17	23.0	10	SPT	n	6	0.95	1	1.0	86	1.43	1.05	14	-	95	2179.0	2179.0	1.0	14	14	1.0	14	CH
R2B-74-17	28.0	10	SPT	n	6	0.95	1	1.0	86	1.43	1.05	14	-	95	2654.0	2654.0	0.9	13	13	0.9	13	CH
R2B-74-17	33.0	15	SPT	n	6	1	1	1.0	86	1.43	1.05	23	-	95	3129.0	3129.0	0.8	19	19	0.8	19	CH
R2B-74-17	38.0	14	SPT	n	6	1	1	1.0	86	1.43	1.05	21	-	95	3604.0	3604.0	0.8	16	16	0.8	16	CH
R2B-74-17	43.0	15	SPT	n	6	1	1	1.0	86	1.43	1.05	23	-	95	4079.0	4079.0	0.7	16	16	0.7	17	CH
R2B-74-17	48.0	16	SPT	n	6	1	1	1.0	86	1.43	1.05	24	-	95	4554.0	4554.0	0.7	16	16	0.7	17	CH
W-70-20	2.5	21	SPT	n	4	0.75	1	1.0	88	1.47	1.00	23	-	95	237.5	237.5	1.7	39	39	1.7	39	CL
W-70-20	5.0	27	SPT	n	4	0.8	1	1.0	88	1.47	1.00	32	-	95	475.0	475.0	1.7	54	46	1.5	47	CL
W-70-20	7.5	26	SPT	n	4	0.8	1	1.0	88	1.47	1.00	31	-	113	757.5	757.5	1.7	51	46	1.3	40	SC
W-70-20	10.0	19	SPT	n	4	0.85	1	1.0	88	1.47	1.00	24	-	113	1040.0	1040.0	1.4	34	34	1.3	30	SC
W-70-20	15.0	15	SPT	n	4	0.95	1	1.0	88	1.47	1.00	21	-	95	1515.0	1515.0	1.2	25	25	1.1	24	CH
W-70-20	20.0	10	SPT	n	4	0.95	1	1.0	88	1.47	1.00	14	-	95	1990.0	1990.0	1.0	14	14	1.0	14	CH
W-70-20	25.0	9	SPT	n	4	0.95	1	1.0	88	1.47	1.00	13	-	95	2465.0	2465.0	0.9	12	12	0.9	12	CH
W-70-20	30.0	10	SPT	n	4	1	1	1.0	88	1.47	1.00	15	-	95	2940.0	2940.0	0.8	12	12	0.8	12	CH
W-70-20	35.0	12	SPT	n	4	1	1	1.0	88	1.47	1.00	18	-	95	3415.0	3415.0	0.8	14	14	0.8	14	CH
W-70-20	40.0	9	SPT	n	4	1	1	1.0	88	1.47	1.00	13	-	95	3890.0	3890.0	0.7	10	10	0.7	9	CH
W-70-20	45.0	17	SPT	n	4	1	1	1.0	88	1.47	1.00	25	-	95	4365.0	4365.0	0.7	17	17	0.7	18	CH

Notes:

1. Yellow highlighting indicates fields where input data was required; green highlighting indicates samples for which no SPT blow counts were recorded, and consequently columns related to blowcounts are not filled in.
2. Source: Idriss, I.M. and R.W. Boulanger. 2008. *Soil Liquefaction During Earthquakes* . Earthquake Engineering Research Institute.

ASSIGNED ESUs

Point ID	Historic WSDOT R2B, WOOD	Sample ID	Sample Top Depth (ft)	Field N	N_{60}	$(N_1)_{60}$	Estimated USCS Classification	ESU	LL	PI	% Fines (Lab)
R2B-61-17	WSDOT R2B	D-1	5.0	36	42	72	SP-SM	4A	--	--	9.9
R2B-61-17	WSDOT R2B	D-2	7.5	34	40	64	SP-SM	4A			
R2B-61-17	WSDOT R2B	D-3	10.0	34	42	59	SP-SM	4A	--	--	7.8
R2B-61-17	WSDOT R2B	D-4	12.5	38	47	59	SP-SM	4A			
R2B-61-17	WSDOT R2B	D-5	15.0	43	60	68	SP-SM	4A			
R2B-61-17	WSDOT R2B	D-6	20.0	59	82	81	SM	4A	--	--	12.6
R2B-61-17	WSDOT R2B	D-7	25.0	61	85	75	SM	4A			
R2B-61-17	WSDOT R2B	D-8	30.0	67	98	79	SM	4A			
R2B-61-17	WSDOT R2B	D-9	35.0	57	84	62	SP-SM	4A	--	--	8.4
R2B-61-17	WSDOT R2B	D-10	40.0	44	65	45	CL-ML	4E	23	4	62.3
R2B-61-17	WSDOT R2B	D-11	45.0	42	62	41	CL-ML	4E	26	7	59.5
R2B-61-17	WSDOT R2B	D-12	50.0	48	70	45	CL-ML	4E			
R2B-61-17	WSDOT R2B	D-13	55.0	52	76	47	CL-ML	4E			
R2B-61-17	WSDOT R2B	D-14	60.0	49	72	42	CL	4E	30	12	67.2
R2B-74-17	WSDOT R2B	D-1	3.0	17	19	33	ML	4E			
R2B-74-17	WSDOT R2B	D-2	6.0	10	12	20	CH	4E-1			
R2B-74-17	WSDOT R2B	D-3	8.0	8	10	16	CH	4E-1	71	38	--
R2B-74-17	WSDOT R2B	D-4	11.0	8	10	15	CH	4E-1	72	41	99.8
R2B-74-17	WSDOT R2B	D-6	15.0	9	13	16	CH	4E-1			
R2B-74-17	WSDOT R2B	D-7	18.0	16	23	26	CH	4E-1	57	30	--
R2B-74-17	WSDOT R2B	D-8	23.0	10	14	14	CH	4E-1			
R2B-74-17	WSDOT R2B	D-9	28.0	10	14	13	CH	4E-1	57	28	--
R2B-74-17	WSDOT R2B	D-10	33.0	15	23	19	CH	4E-1			
R2B-74-17	WSDOT R2B	D-11	38.0	14	21	16	CH	4E-1	51	24	--
R2B-74-17	WSDOT R2B	D-12	43.0	15	23	16	CH	4E-1			
R2B-74-17	WSDOT R2B	D-13	48.0	16	24	16	CH	4E-1	56	29	100
W-70-20	WOOD	SPT-1	2.5	21	23	39	CL	4E	--	--	--
W-70-20	WOOD	SPT-2	5.0	27	32	54	CL	4E	--	--	--
W-70-20	WOOD	SPT-3	7.5	26	31	51	SC	4E	24.0	8.1	47.7
W-70-20	WOOD	SPT-4	10.0	19	24	34	SC	4E	--	--	--
W-70-20	WOOD	SPT-5	15.0	15	21	25	CH	4E-1	74.7	43.0	90.3
W-70-20	WOOD	SPT-6	20.0	10	14	14	CH	4E-1	--	--	--
W-70-20	WOOD	SPT-7	25.0	9	13	12	CH	4E-1	67.4	39.6	99.9
W-70-20	WOOD	SPT-8	30.0	10	15	12	CH	4E-1	--	--	--
W-70-20	WOOD	SPT-9	35.0	12	18	14	CH	4E-1	--	--	--
W-70-20	WOOD	SPT-10	40.0	9	13	10	CH	4E-1	--	--	--
W-70-20	WOOD	SPT-11	45.0	17	25	17	CH	4E-1	--	--	--

UNIT WEIGHT

$(N_1)_{60}$	SM	SC	GM	ML	MH	SP	GP	GW	GW	SP-SM	GP-GM	GW-GM	GW-GC	CL	CH
0	70	70	70	70	70	85	85	100	100	77.5	77.5	85	85	100	100
1	80	80	80	80	80	95	95	105	105	87.5	87.5	92.5	91.5	105	105
2	80	80	80	80	80	95	95	105	105	87.5	87.5	92.5	92.5	110	110
3	90	90	90	90	90	105	105	115	115	97.5	97.5	102.5	101.5	115	115
4	90	90	90	90	90	105	105	115	115	97.5	97.5	102.5	102.5	115	115
5	95	95	95	95	95	105	105	115	115	100	100	105	105	115	115
6	100	100	100	100	100	110	110	120	120	105	105	110	110	120	120
7	110	110	110	110	110	120	120	125	125	115	115	117.5	116.5	120	120
8	110	110	110	110	110	120	120	125	125	115	115	117.5	117.5	120	120
9	110	110	110	110	110	120	120	130	130	115	115	120	120	120	120
10	110	110	110	110	110	120	120	130	130	115	115	120	120	125	125
11	110	110	110	110	110	120	120	130	130	115	115	120	120	125	125
12	110	110	110	110	110	120	120	130	130	115	115	120	120	125	125
13	110	110	110	110	110	125	125	130	130	117.5	117.5	120	120	130	130
14	110	110	110	110	110	125	125	130	130	117.5	117.5	120	120	130	130
15	110	110	110	110	110	125	125	135	135	117.5	117.5	122.5	122.5	130	130
16	110	110	110	110	110	125	125	135	135	117.5	117.5	122.5	122.5	130	130
17	115	115	115	115	115	125	125	135	135	120	120	125	125	130	130
18	115	115	115	115	115	125	125	135	135	120	120	125	125	130	130
19	115	115	115	115	115	125	125	135	135	120	120	125	125	130	130
20	115	115	115	115	115	125	125	135	135	120	120	125	125	130	130
21	115	115	115	115	115	125	125	135	135	120	120	125	125	130	130
22	115	115	115	115	115	125	125	135	135	120	120	125	125	130	130
23	115	115	115	115	115	130	130	135	135	122.5	122.5	125	125	130	130
24	115	115	115	115	115	130	130	135	135	122.5	122.5	125	125	130	130
25	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
26	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
27	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
28	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
29	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
30	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
32	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
34	120	120	120	120	120	130	130	140	140	125	125	130	130	130	130
36	120	120	120	120	120	135	135	145	145	127.5	127.5	132.5	132.5	130	130
38	125	125	125	125	125	135	135	145	145	130	130	135	135	130	130
40	125	125	125	125	125	135	135	145	145	130	130	135	135	130	130
42	125	125	125	125	125	135	135	145	145	130	130	135	135	130	130
44	125	125	125	125	125	135	135	145	145	130	130	135	135	130	130
46	130	130	130	130	130	140	140	150	150	135	135	140	140	130	130
48	130	130	130	130	130	140	140	150	150	135	135	140	140	130	130
50	130	130	130	130	130	140	140	150	150	135	135	140	140	130	130

Note: CALTRANS

Coduto Table		
	Above GW	Below GW
GP	120	133
GW	125	137
GW-GM	120	135
GW-GC	118	135
GM	115	133
GP-GM	118	133
GC	115	133
SP	110	128
SP-SM	109	127
SP-SC	112	125
SW	115	133
SW-SM	112	129
SW-SC	114	128
SM	108	125
SC	113	123
ML	93	105
MH	93	103
CL	95	103
CH	95	98
OL	80	80
PT	80	80
CL-ML	94	104
SM-ML	101	115
SC-SM	110	124

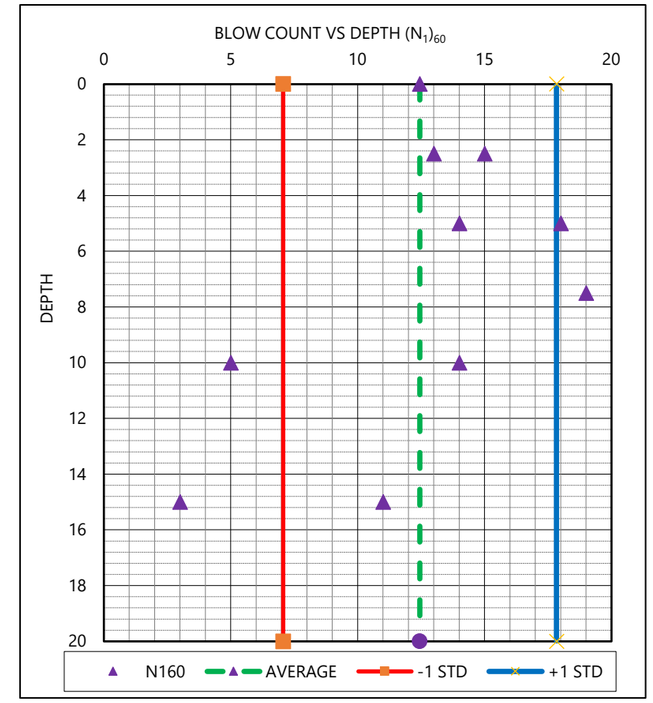
TABLE 3.2 TYPICAL UNIT WEIGHTS

Soil Type and Unified Soil Classification (See Figure 3.3)	Typical Unit Weight, γ			
	Above Groundwater Table		Below Groundwater Table	
	(lb/ft³)	(kN/m³)	(lb/ft³)	(kN/m³)
GP—Poorly-graded gravel	110–130	17.5–20.5	125–140	19.5–22.0
GW—Well-graded gravel	110–140	17.5–22.0	125–150	19.5–23.5
GM—Silty gravel	100–130	16.0–20.5	125–140	19.5–22.0
GC—Clayey gravel	100–130	16.0–20.5	125–140	19.5–22.0
SP—Poorly-graded sand	95–125	15.0–19.5	120–135	19.0–21.0
SW—Well-graded sand	95–135	15.0–21.0	120–145	19.0–23.0
SM—Silty sand	80–135	12.5–21.0	110–140	17.5–22.0
SC—Clayey sand	85–130	13.5–20.5	110–135	17.5–21.0
ML—Low plasticity silt	75–110	11.5–17.5	80–130	12.5–20.5
MH—High plasticity silt	75–110	11.5–17.5	75–130	11.5–20.5
CL—Low plasticity clay	80–110	12.5–17.5	75–130	11.5–20.5
CH—High plasticity clay	80–110	12.5–17.5	70–125	11.0–19.5

ESU #1A Fill (Loose to medium dense SAND/GRAVEL)

1 **REVIEW $(N_1)_{60}$ PARAMETERS AND CHECK FOR OUTLIERS**

Point ID	Depth	$(N_1)_{60}$	PI	USCS	Check $(N_1)_{60}$ data for outliers	
					deleted	why
W-66-20	5	14	6	SC-SM		
W-66-20	10	5		SC-SM		
W-66-20	15	3	15	SC-SM		
W-60-20	2.5	15		SP-SM		
W-60-20	5	18		SP-SM		
W-64mw-20	2.5	13		SM		
W-65-20	7.5	19		SM		
W-65-20	10	14		SM		
W-65-20	15	11	14	SM		
	AVERAGE	**12.4**				
	STD DEV	**5.4**				
	GEOMEAN	**10.9**				



Depth (ft)	A	B	C
0	12.4	17.8	7.1
20	12.4	17.8	7.1

A = Average $(N_1)_{60}$

B = Average $[(N_1)_{60}$ + (STD Dev $(N_1)_{60})]$

C = Average $[(N_1)_{60}$ - (STD Dev $(N_1)_{60})]$

2 **CHECK COV IS BETWEEN 15 AND 45%**

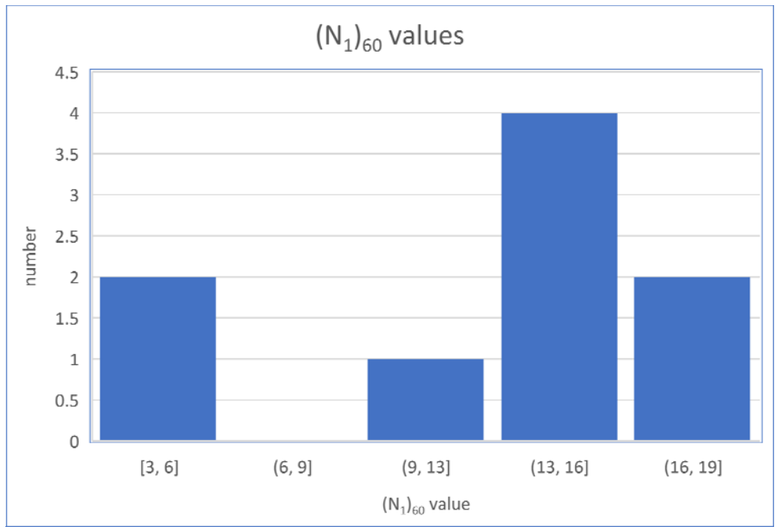
(consider revising ESU limits if outside range)

Coefficient of Variation (V) = standard deviation/average	43%
(V_{low}) from Table 52 in GEC 5 Sabatini (2002)	15%
(V_{high}) from Table 52 in GEC 5 Sabatini (2002)	45%

Explanation of Covariance:

Covariance is within the range provided by Duncan (2000) per the SPM.

3	**PLOT HISTOGRAM AND COMPARE TO GEOMEAN VALUE**



GEOMEAN	11

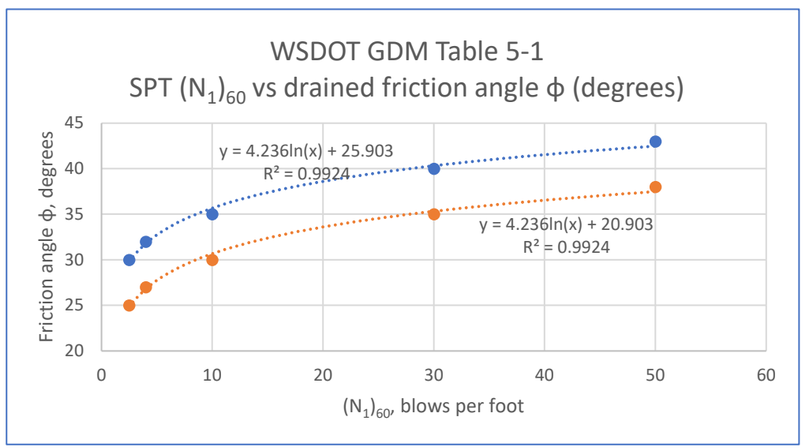
Explanation of Histogram:

Histogram represents a normal distribution curve.

4	**ESTIMATE PEAK FRICTION ANGLE (deg)**

Using WSDOT correlation

$(N_1)_{60}$ (blows per foot)	Friction angle ϕ (degrees)
2.5	25
2.5	30
4	27
4	32
10	30
10	35
30	35
30	40
50	38
50	43



	$(N_1)_{60}$	ϕ (high)	ϕ (low)	ϕ (avg)
Geomean	10.9	36	31	34
Average	12.4	37	32	34
Average minus one standard deviation	7.1	34	29	32

PEAK FRICTION ANGLE (deg) **32**

Explanation of Friction Angle:

The friction angle was selected based on the low $(N_1)_{60}$ with high level of covariance and an average fines content of 29%.

5	**USCS**	SM	USE PREDOMINANT USCS CLASSIFICATION
6	**Unit Weight (pcf)**	110	USE CALTRANS, verify with CODUTO (2001) or GDM for PEAT/ ORGANICS if no measurements.

Explanation of Unit Weight (pcf):

Unit weight was selected as SM based on the variation of fill material soil classifications from SP-SM to SC. The unit weight was selected using Figure 4 of the SPM and verified within the range of CODUTO (2001).

Notes:

= final selected soil design properties

REFERENCES:

California Department of Transportation (Caltrans). 2014. *Geotechnical Manual* .

Coduto, D.P. 2001. *Foundation Design Principles and Practices* . 2nd Edition. Prentice-Hall, Inc., New Jersey.

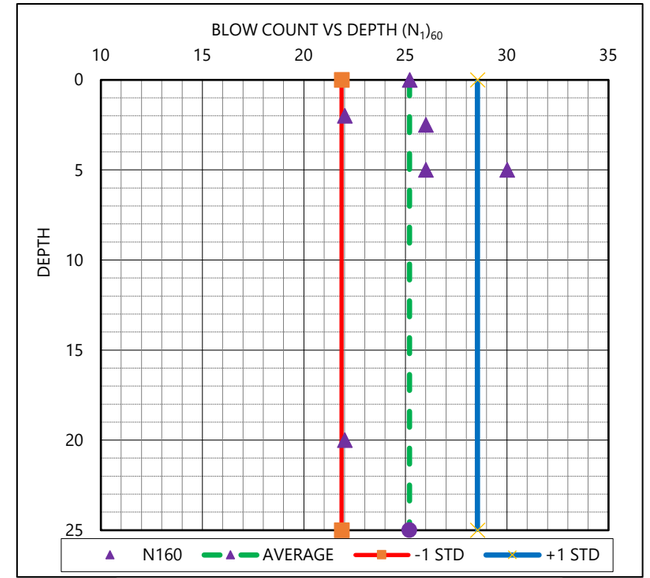
Duncan, J.M. 2000. “Factors of Safety and Reliability in Geotechnical Engineering.” ASCE *Journal of Geotechnical and Geoenvironmental Engineering* , Vol. 126, No.4, pp. 307-316.

Sabatini, P.J., R.C. Bachus, P.W. Mayne, T.E. Schneider, and T. E. Zettler. 2002. *Geotechnical Engineering Circular No. 5: Evaluation of Soil and Rock Properties* . FHWA-IF-02-034.

ESU #1B Fill (Medium dense to dense) SAND/GRAVEL)

1 **REVIEW $(N_1)_{60}$ PARAMETERS AND CHECK FOR OUTLIERS**

Point ID	Depth	$(N_1)_{60}$	PI	USCS	Check $(N_1)_{60}$ data for outliers	
					deleted	why
W-66-20	2.5	26		SC-SM		
W-66-20	20	22		SM		
W-64mw-20	5	26		SM		
W-65-20	5	30	0	SM		
W-65-20	2	22		SM		
	AVERAGE	**25.2**				
	STD DEV	**3.3**				
	GEOMEAN	**25.0**				



Depth (ft)	A	B	C
0	25.2	28.5	21.9
25	25.2	28.5	21.9

A = Average $(N_1)_{60}$

B = Average $[(N_1)_{60}$ + (STD Dev $(N_1)_{60})]$

C = Average $[(N_1)_{60}$ - (STD Dev $(N_1)_{60})]$

2 **CHECK COV IS BETWEEN 15 AND 45%**

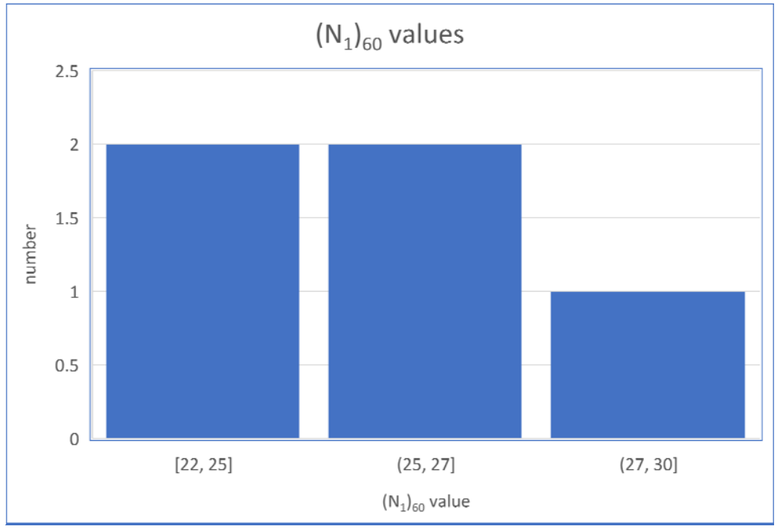
(consider revising ESU limits if outside range)

Coefficient of Variation (V) = standard deviation/average	13%
(V_{low}) from Table 52 in GEC 5 Sabatini (2002)	15%
(V_{high}) from Table 52 in GEC 5 Sabatini (2002)	45%

Explanation of Covariance:

Covariance is within the range provided by Duncan (2000) per the SPM.

3 **PLOT HISTOGRAM AND COMPARE TO GEOMEAN VALUE**



GEOMEAN	25

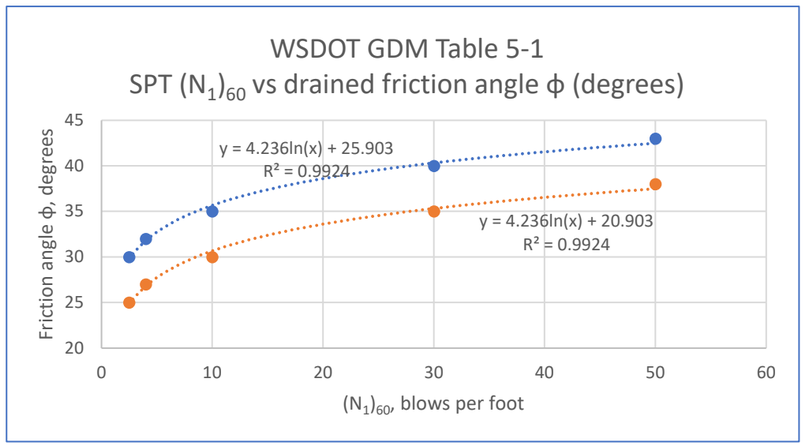
Explanation of Histogram:

It is difficult to determine the normal distribution for the histogram with the small sample size.

4 **ESTIMATE PEAK FRICTION ANGLE (deg)**

Using WSDOT correlation

$(N_1)_{60}$ (blows per foot)	Friction angle ϕ (degrees)
2.5	25
2.5	30
4	27
4	32
10	30
10	35
30	35
30	40
50	38
50	43



	$(N_1)_{60}$	ϕ (high)	ϕ (low)	ϕ (avg)
Geomean	25.0	40	35	37
Average	25.2	40	35	37
Average minus one standard deviation	21.9	39	34	36

PEAK FRICTION ANGLE (deg) **35**

Explanation of Friction Angle:

The friction angle was selected based on the low $(N_1)_{60}$ with high fines content of 29%.

5	**USCS**	SM	USE PREDOMINANT USCS CLASSIFICATION
6	**Unit Weight (pcf)**	120	USE CALTRANS, verify with CODUTO (2001) or GDM for PEAT/ ORGANICS if no measurements.

Explanation of Unit Weight (pcf):

Unit weight was selected as SM based on 80% of the samples classified as SM. The unit weight was selected using Figure 4 of the SPM and verified within the range of CODUTO (2001).

Notes:

= final selected soil design properties

REFERENCES:

California Department of Transportation (Caltrans). 2014. *Geotechnical Manual.*

Coduto, D.P. 2001. *Foundation Design Principles and Practices.* 2nd Edition. Prentice-Hall, Inc., New Jersey.

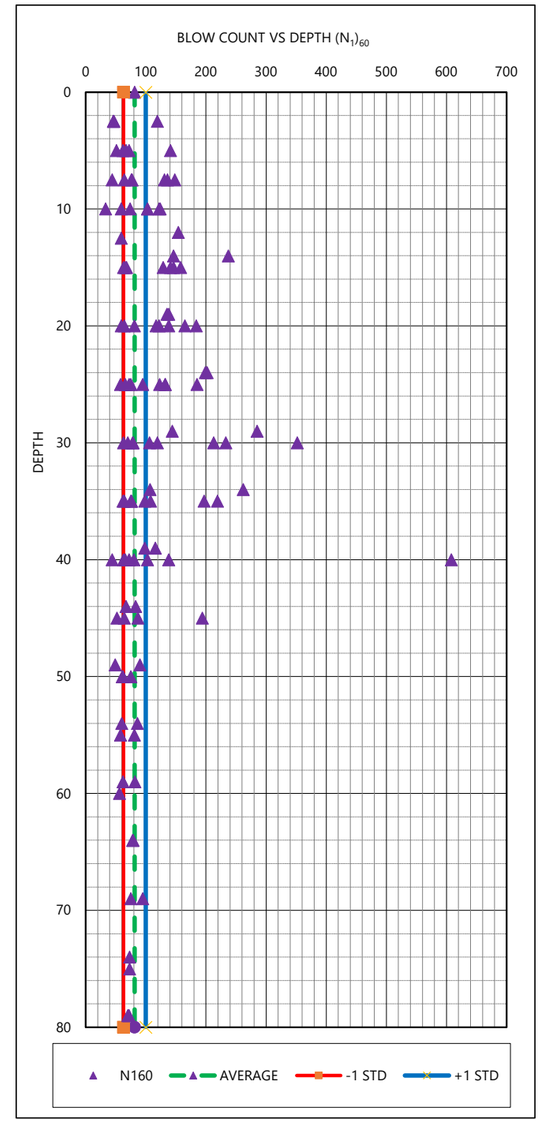
Duncan, J.M. 2000. "Factors of Safety and Reliability in Geotechnical Engineering." ASCE *Journal of Geotechnical and Geoenvironmental Engineering,* Vol. 126, No.4, pp. 307-316.

Sabatini, P.J., R.C. Bachus, P.W. Mayne, T.E. Schneider, and T. E. Zettler. 2002. *Geotechnical Engineering Circular No. 5: Evaluation of Soil and Rock Properties.* FHWA-IF-02-034.

ESU #4A Advance Outwash (Dense to very dense Sand/Gravel)

1	REVIEW $(N_1)_{60}$ PARAMETERS AND CHECK FOR OUTLIERS

Point ID	Depth	$(N_1)_{60}$ [1]	PI	USCS	Check $(N_1)_{60}$ data for outliers	
					deleted	why
W-66-20	25	72		SP-SM		
W-66-20	30	78		SP-SM		
W-66-20	35	76		SP-SM		
W-66-20	40	80		SP-SM		
W-66-20	45	64		SP-SM		
W-66-20	50	61		SP-SM		
W-66-20	55	81		SP-SM		
R2B-61-17	5	72		SP-SM		
R2B-61-17	7.5	64		SP-SM		
R2B-61-17	10	59		SP-SM		
R2B-61-17	12.5	59		SP-SM		
R2B-61-17	15	68		SP-SM		
R2B-61-17	20	81		SM		
R2B-61-17	25	75		SM		
R2B-61-17	30	79		SM		
R2B-61-17	35	62		SP-SM		
R2B-65-17	14	100		GW		
R2B-65-17	19	100		GW		
R2B-65-17	24	100		GW		
R2B-65-17	29	100		GW		
R2B-65-17	34	100		SP-SM		
R2B-65-17	39	100		SP-SM		
R2B-65-17	44	83		SP-SM		
R2B-65-17	49	90		SP-SM		
R2B-65-17	54	86		SP-SM		
R2B-65-17	59	82		SP-SM		
R2B-65-17	64	79		SW-SM		
R2B-65-17	69	95		SP		
R2B-65-17	79	72		SP		
R2B-65-17	75	73		SP		
R2B-66-17	12	100		GW		
R2B-66-17	14	100		GW		
R2B-66-17	19	100		GW		
R2B-66-17	24	100		GW		
R2B-66-17	29	100		GW		
R2B-66-17	34	100		GW		
R2B-66-17	39	98		GW		
R2B-66-17	44	67		SP-SM		
R2B-66-17	49	49		SP-SM		
R2B-66-17	54	60		SP-SM		
R2B-66-17	59	62		SP-SM		
R2B-66-17	64	78		SP-SM		
R2B-66-17	69	75		SW-SM		
R2B-66-17	74	73		SW-SM		
R2B-66-17	79	70		SW-SM		
W-60-20	7.5	76		SM		
W-60-20	10	100		SP-SM		
W-60-20	15	100		GP-GM		
W-60-20	20	100		SP-SM		
W-60-20	25	95		SP-SM		



Depth (ft)	A	B	C
0	81.4	100.0	62.8
80	81.4	100.0	62.8

A = Average $(N_1)_{60}$

B = Average $[(N_1)_{60}$ + (STD Dev $(N_1)_{60})]$

C = Average $[(N_1)_{60}$ - (STD Dev $(N_1)_{60})]$

W-60-20	30	100		GP-GM		
W-60-20	35	100		SM		
W-60-20	40	100		SM		
W-62mw-20	2.5	47		SP-SM		
W-62mw-20	5	62		SP-SM		
W-62mw-20	7.5	100		SP-SM		
W-62mw-20	10	100		SP-SM		
W-62mw-20	15	100		SP-SM		
W-62mw-20	20	100		SM		
W-62mw-20	25	100		SM		
W-62mw-20	30	100		GP-GM		
W-62mw-20	35	76		SM		
W-62mw-20	40	63		SM		
W-62mw-20	45	52		SM		
W-64mw-20	7.5	44		SM		
W-64mw-20	10	33		SW-SM		
W-64mw-20	15	63		SW-SM		
W-64mw-20	20	64		SM		
W-64mw-20	25	66		SM		
W-64mw-20	30	70		SM		
W-64mw-20	35	75		SP-SM		
W-64mw-20	40	72		SP-SM		
W-64mw-20	45	87		SP-SM		
W-64mw-20	50	75		SM		
W-64mw-20	55	58		SM		
W-64mw-20	60	56		SM		
W-65-20	20	100		SM		
W-65-20	25	100		SM		
W-65-20	30	100		SM		
W-65-20	35	100		SM		
W-65-20	40	100		SM		
W-65-20	45	100		SM		
W-65-20	50	62		SP-SM		
W-117-20	2.5	46		SW-SM		
W-117-20	5	67		SP-SM		
W-117-20	7.5	100		ML		
W-117-20	10	100		SM		
W-117-20	15	66		SP-SM		
W-117-20	20	59		SP-SM		
W-117-20	25	58		SP-SM		
W-117-20	30	63		SP-SM		
W-117-20	35	64		SP-SM		
W-117-20	40	44		SM		
W-118-20	2.5	46		SP-SM		
W-118-20	5	51		SP-SM		
W-118-20	7.5	77		SP		
W-118-20	10	74		SP		
W-118-20	15	100		GP-GM		
W-118-20	20	100		GP-GM		
W-118-20	25	100		SM		
W-118-20	30	100		SM		
W-118-20	35	98		SM		
W-118-20	40	100		SM		
W-119-20	2.5	100		GP-GM		
W-119-20	5	100		GW-GM		
W-119-20	7.5	100		GW-GM		
W-119-20	10	100		SM		

W-119-20	15	100		SM		
W-119-20	20	100		SM		
W-119-20	25	100		SM		
W-119-20	30	100		SM		
W-119-20	35	100		SM		
W-119-20	40	66		SP-SM		
	AVERAGE	**81.4**				
	STD DEV	**18.6**				
	GEOMEAN	**79.0**				

Notes:

1. Truncated blow counts at 100

2 **CHECK COV IS BETWEEN 15 AND 45%**

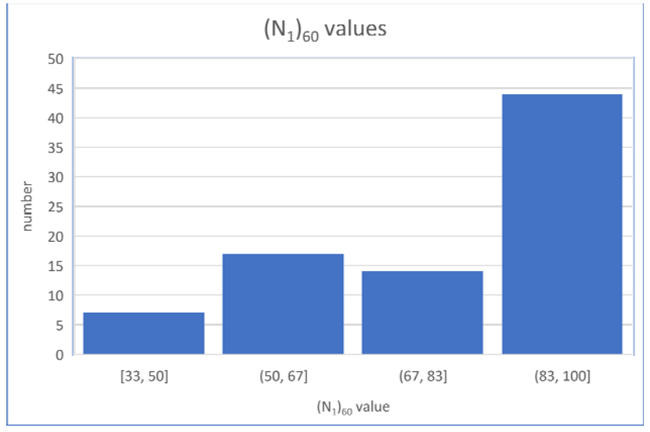
(consider revising ESU limits if outside range)

Coefficient of Variation (V) = standard deviation/average	23%
(V_{low}) from Table 52 in GEC 5 Sabatini (2002)	15%
(V_{high}) from Table 52 in GEC 5 Sabatini (2002)	45%

Explanation of Covariance:

Covariance is within the range provided by Duncan (2000) per the SPM.

3 **PLOT HISTOGRAM AND COMPARE TO GEOMEAN VALUE**



GEOMEAN	79

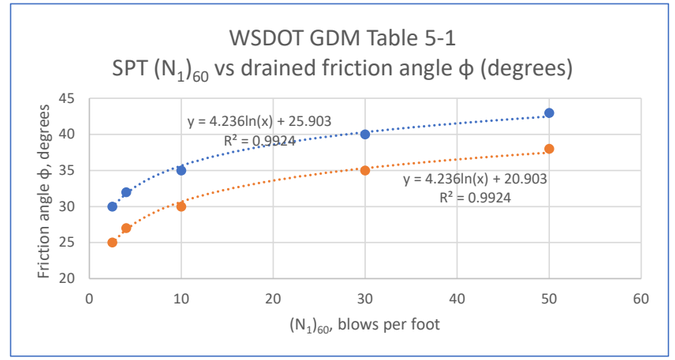
Explanation of Histogram:

Histogram represents a lognormal distribution curve.

4	ESTIMATE PEAK FRICTION ANGLE (deg)

Using WSDOT correlation

$(N_1)_{60}$ (blows per foot)	Friction angle ϕ (degrees)
2.5	25
2.5	30
4	27
4	32
10	30
10	35
30	35
30	40
50	38
50	43



	$(N_1)_{60}$	ϕ (high)	ϕ (low)	ϕ (avg)
Geomean	79.0	44	39	42
Average	81.4	45	40	42
Average minus one standard deviation	62.8	43	38	41

PEAK FRICTION ANGLE (deg) **42**

Explanation of Friction Angle:

The friction angle was selected based on the average $(N_1)_{60}$ with predominantly granular soil type, over-consolidated, and an average fines content of 9%. The selected friction angle is within a reasonable range in GDM section 15.13.3, Outwash 40-45. The friction angle is above the range in the En*gineering Geology in Washington* , Vol. 1, Outwash 30-40.

5	**USCS**	SP-SM	USE PREDOMINANT USCS CLASSIFICATION
6	**Unit Weight (pcf)**	135	USE CALTRANS, verify with CODUTO (2001) or GDM for PEAT/ ORGANICS if no measurements.

Explanation of Unit Weight (pcf):

Unit weight was selected as SP-SM based on the fines content and soil classifications. The unit weight was selected using Figure 4 of the SPM and verified within the range of CODUTO (2001).

Notes:

= final selected soil design properties

REFERENCES:

California Department of Transportation (Caltrans). 2014. *Geotechnical Manual.*

Coduto, D.P. 2001. *Foundation Design Principles and Practices.* 2nd Edition. Prentice-Hall, Inc., New Jersey.

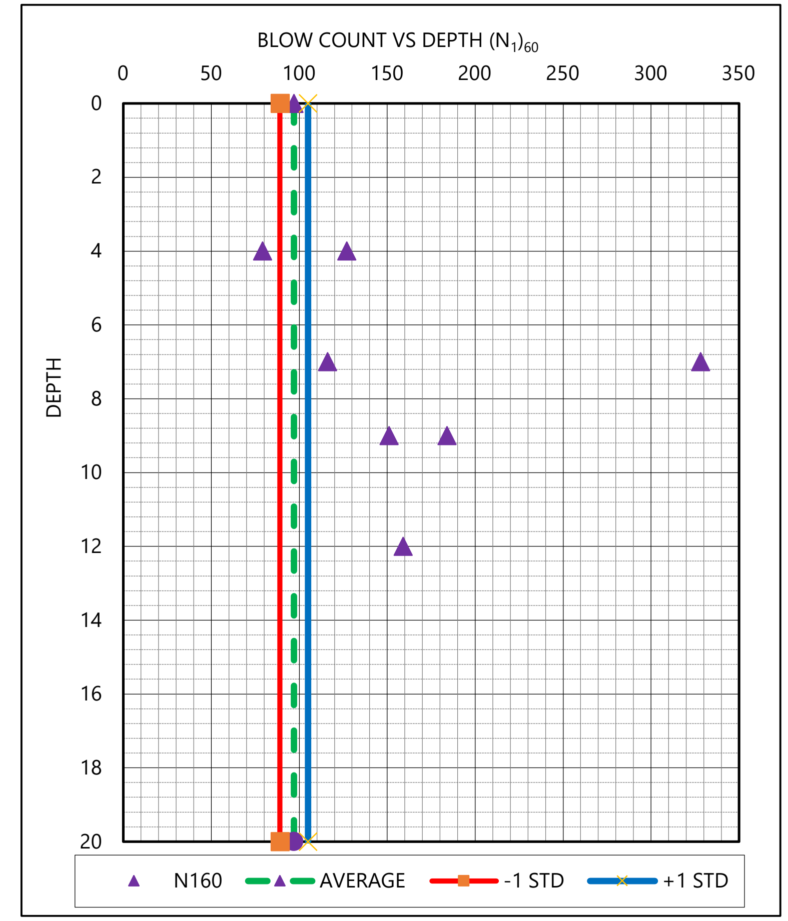
Duncan, J.M. 2000. "Factors of Safety and Reliability in Geotechnical Engineering." ASCE *Journal of Geotechnical and Geoenvironmental Engineering,* Vol. 126, No.4, pp. 307-316.

Sabatini, P.J., R.C. Bachus, P.W. Mayne, T.E. Schneider, and T. E. Zettler. 2002. *Geotechnical Engineering Circular No. 5: Evaluation of Soil and Rock Properties.* FHWA-IF-02-034.

ESU #4C Glacial Till (dense to very dense)

1	REVIEW $(N_1)_{60}$ PARAMETERS AND CHECK FOR OUTLIERS

Point ID	Depth	$(N_1)_{60}$ [1]	PI	USCS	Check $(N_1)_{60}$ data for outliers	
					deleted	why
R2B-65-17	4	100		SM		
R2B-65-17	7	100		SM		
R2B-65-17	9	100		SM		
R2B-65-17	12	100	2	SM		
R2B-66-17	4	79		SP-SM		
R2B-66-17	7	100		SW		
R2B-66-17	9	100		SW		
	AVERAGE	97.0				
	STD DEV	7.9				
	GEOMEAN	96.7				



Depth (ft)	A	B	C
0	97.0	104.9	89.1
20	97.0	104.9	89.1

A = Average $(N_1)_{60}$

B = Average $[(N_1)_{60}$ + (STD Dev $(N_1)_{60})]$

C = Average $[(N_1)_{60}$ - (STD Dev $(N_1)_{60})]$

Notes:

1. Truncated blow counts at 100

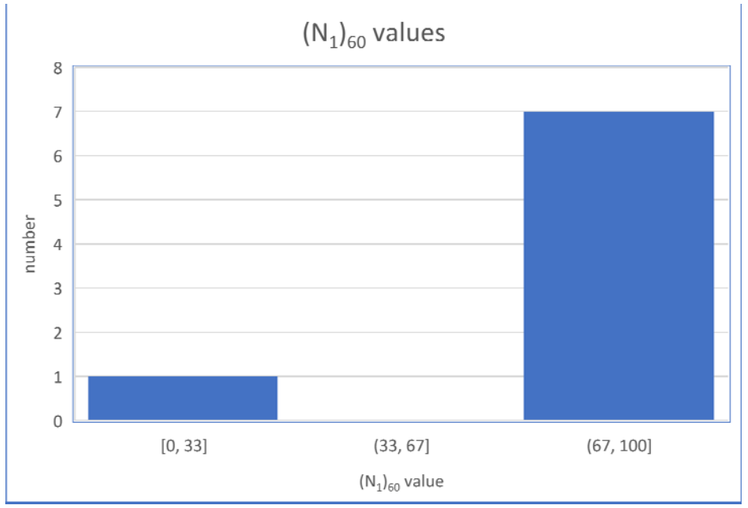
2	CHECK COV IS BETWEEN 15 AND 45%

(consider revising ESU limits if outside range)

Coefficient of Variation (V) = standard deviation/average	8%
(V_{low}) from Table 52 in GEC 5 Sabatini (2002)	15%
(V_{high}) from Table 52 in GEC 5 Sabatini (2002)	45%

Explanation of Covariance:
Covariance is within the range provided by Duncan (2000) per the SPM.

3 **PLOT HISTOGRAM AND COMPARE TO GEOMEAN VALUE**



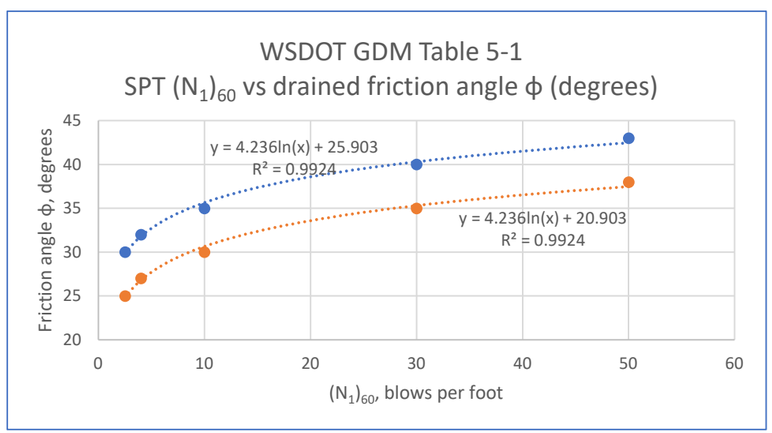
GEOMEAN	97

Explanation of Histogram:
Histogram represents a lognormal distribution curve.

4 **ESTIMATE PEAK FRICTION ANGLE (deg)**

Using WSDOT correlation

$(N_1)_{60}$ (blows per foot)	Friction angle ϕ (degrees)
2.5	25
2.5	30
4	27
4	32
10	30
10	35
30	35
30	40
50	38
50	43



	$(N_1)_{60}$	ϕ (high)	ϕ (low)	ϕ (avg)
Geomean	50.0	42	37	40
Average	97.0	45	40	43
Average minus one standard deviation	89.1	45	40	42

PEAK FRICTION ANGLE (deg) **43**

Explanation of Friction Angle:
The friction angle was selected based on the average of table 5-1 with the truncated blow count values of 50. The over-consolidated till material has high strength based on historic data, so the high fines content should not dictate a lower bound value. The blow counts were also capped at 100, which restricts the calculated friction angle for till material. Additionally, the selected friction angle is within a reasonable range by using*Engineering Geology in Washington, Vol.* 1, Till 35-45 and GDM section 5.13.3.

5	**USCS**	SM	USE PREDOMINANT USCS CLASSIFICATION
6	**Unit Weight (pcf)**	135	USE CALTRANS, verify with CODUTO (2001) or GDM for PEAT/ ORGANICS if no measurements.

Explanation of Unit Weight (pcf):
Unit weight was selected as SM based on the soil classification and avg. fines content of 30. The unit weight was selected using Figure 4 of the SPM and verified within the range of CODUTO (2001).

10	**Effective Cohesion (psf)**	500

Explanation of Cohesion (psf):
The selected effective cohesion is based on the average typical value of cohesion of 100 to 1,000 psf in GDM section 5.13.3. This value is less than the reasonable range in the Engineering Geology in Washington, Vol. 1, Till 1000-4000.

Notes:
= final selected soil design properties

REFERENCES:

California Department of Transportation (Caltrans). 2014. *Geotechnical Manual.*
Coduto, D.P. 2001. *Foundation Design Principles and Practices.* 2nd Edition. Prentice-Hall, Inc., New Jersey.
Duncan, J.M. 2000. "Factors of Safety and Reliability in Geotechnical Engineering." ASCE *Journal of Geotechnical and Geoenvironmental Engineering,* Vol. 126, No.4, pp. 307-316.
Sabatini, P.J., R.C. Bachus, P.W. Mayne, T.E. Schneider, and T. E. Zettler. 2002. *Geotechnical Engineering Circular No. 5: Evaluation of Soil and Rock Properties.* FHWA-IF-02-034.

In Association with

Appendix E
Test Pit Logs

Appendix E – Test Pit Logs

Test Pit Procedures

Test pits were excavated with a track-mounted excavator operated by the Flatiron-Lane Joint Venture. A geologist from Wood continuously observed the test pit excavations and logged the subsurface conditions. After logging each test pit, the perimeter around the pit was secured to allow the pit to remain open for a minimum of 24 hours. The following day, a geologist returned to the pits to document any changes, such as caving, spalling, seepage, etc.

The enclosed test pit logs indicate the vertical sequence of soils and materials encountered in each test pit, based primarily on field classifications and supported by laboratory examination and testing. Where a soil contact was observed to be gradational or undulating, our logs indicate the average contact depth. We estimated the relative density and consistency of the in-situ soils by means of the excavation characteristics and the stability of the test pit sidewalls. Our logs also indicate the approximate depths of any sidewall caving or groundwater seepage observed in the test pits, as well as all sample numbers and sampling locations.

Wood Environment & Infrastructure Solutions, Inc.
4020 Lake Washington Blvd. NE, Suite 200 Tel (425) 368-1000
Kirkland, WA 98033 Fax (425) 368-1001

Special Inspection Report

PROJECT NAME WSDOT I-405 Renton to Bellevue Design Build		PROJECT NO. PS19-203160-0	FIELD REPORT NO. 2021-03-17~CMM T. Soil Nail 09.05R
ADDRESS Soil Nail Wall: 09.05R		DATE March 17, 2021	PAGE 1 OF 3
CITY OR COUNTY Bellevue, WA	PERMIT NO.	ARRIVAL TIME 10:00AM	DEPARTURE TIME 10:30AM
CLIENT WSDOT	WOOD ENGINEER OF RECORD/PHONE NO. Dong-Soo Lee / (425) 330-3082		
GENERAL CONTRACTOR FLJV	WOOD FIELD REPRESENTATIVE/ MOBILE NO. Carlos Mendoza / (206) 661-4744		
SUBCONTRACTOR Drill Tech Drilling and Shoring Inc./Bill Creger (510) 598-0609	WEATHER Sunny, High 50's		
TYPE OF WORK PERFORMED Fill Wall 09.05R-B: Soil Nail Wall			
EQUIPMENT USED			

COMMENTS

09.05R: Soil Nail Wall

Wood was onsite to observe any caving on both test pit, after left open 24-hours. Both test pits showed no signs of caving.

The northern test pit consisted of 3 soil layers:

- Layer 1: 0-1' (bgs): sandy SILT with organics (Fill)
- Layer 2: 1-5' (bgs): silty SAND with gravel (Fill)
- Layer 3: 5-11' (bgs): poorly graded sand with interbedded gravels (Qva)

The southern test pit consisted of 3 soil layers:

- Layer 1: 0-1' (bgs): sandy SILT with organics (Fill)
- Layer 2: 1-3' (bgs): silty SAND with gravel (Fill)
- Layer 3: 3-8' (bgs): poorly graded sand with interbedded gravels (Qva)

The southernmost test pit has about 6' of fill intruding into the native soils, as depicted in Image 2: Southern TP.

☒ The contents of this field report were discussed with the contractor's on-site representative.

☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

WOOD FIELD REPRESENTATIVE

Lee, Dong Soo

WOOD ENGINEER OF RECORD

Picture Facing Southeast

Image 1: Northern Test Pit

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-17~CMM T. Soil Nail 09.05R
DESCRIPTION	DATE	PAGE
Northern Test Pit on 09.05R-B	March 17, 2021	2 OF 3

Picture Facing East

Image 2: Southern Test Pit

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-17~CMM T. Soil Nail 09.05R
DESCRIPTION	DATE	PAGE
Southern Test Pit on 09.05R-B	March 17, 2021	3 OF 3

In Association with

Appendix F
Calculation Packages

Cross Section	Case	Method	Page Number	Project Wall Height Factor of Safety
1+40	Permanent Static, Long-Term	Morgenstern-Price	F-1	2.1
	Permanent Static, Long-Term	Spencer	F-23	2.2
	Temporary, Non-Critical	Morgenstern-Price	F-45	1.3
	Temporary, Non-Critical	Spencer	F-65	1.4
	Seismic	Morgenstern-Price	F-85	1.3
	Seismic	Bishop	F-102	1.2
3+80	Permanent Static, Long-Term	Morgenstern-Price	F-124	1.9
	Permanent Static, Long-Term	Spencer	F-155	2.0
	Temporary, Non-Critical	Morgenstern-Price	F-186	1.6
	Temporary, Non-Critical	Spencer	F-215	1.7
	Seismic	Morgenstern-Price	F-244	1.6
	Seismic	Bishop	F-262	1.7
5+20	Permanent Static, Long-Term	Morgenstern-Price	F-284	1.8
	Permanent Static, Long-Term	Spencer	F-308	1.8
	Temporary, Non-Critical	Morgenstern-Price	F-332	1.5
	Temporary, Non-Critical	Spencer	F-354	1.5
	Seismic	Morgenstern-Price	F-376	1.4
	Seismic	Bishop	F-392	1.4

SnailPlus 2021: Report Output

Copyright@2009 - 2020 Deep Excavation LLC: www.deepexcavation.com A program for the evaluation of soil nail walls. Deep Excavation LLC, Astoria, New York, www.deepexcavation.com

Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 1+40 (Perm Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 3:34:51 PM

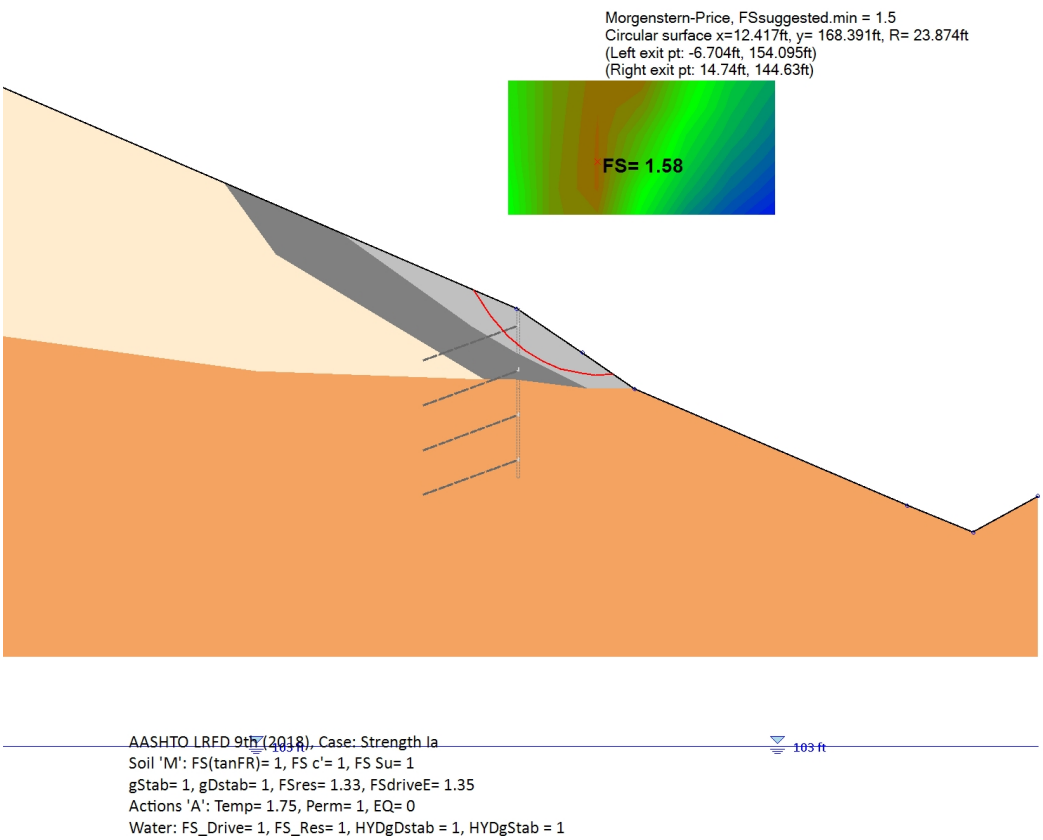
THIS PROGRAM IS PROTECTED BY U.S. COPYRIGHT LAWS AS DESCRIBED IN THE EULA. UNAUTHORIZED COPYING IS PROHIBITED. LICENSED TO: Deep Excavation LLC BY DEEP EXCAVATION LLC UNDER SPECIFIC LICENCE. This report has printed because the user has accepted responsibility as described in the disclaimer and EULA
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP

3/22

Quick analysis summary for design section: M-P

M-P

Soil	γ	c	φ	Su	R
M	140	0	0	1.1	1.3
ESU 4A	135	0	-	42	22



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	1.58	0	0	0	0	0	0	No	Yes
Exc. 147 ft	Calculated	2.141	6.01	4.6	6.01	0.164	0.178	0.067	No	Yes
Project Wall	Calculated	2.147	12.91	9.89	12.91	0.351	0.381	0.144	No	Yes
Project Heigh	Calculated	2.676	12.91	9.89	12.91	0.351	0.381	0.144	No	Yes
Exc. 137 ft	Calculated	1.699	19.23	14.72	19.23	0.471	0.568	0.215	No	Yes
Forward Com	Calculated	1.685	23.73	18.17	23.73	0.581	0.701	0.265	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

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Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.58	1.5	Circle	12.417	168.391	23.874	N/A	N/A
Exc. 147 ft	Yes	2.141	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	2.147	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Heig	Yes	2.676	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 137 ft	Yes	1.699	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.685	1.5	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-45 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	30.14	0.164	N/A	N/A	N/A
xL (-5 to -45)	xR (0.5 to 25)	N/A	AASHTO LRF	Strength Ia	11.02	0.351	N/A	N/A	N/A
xL (-80 to -35	xR (15 to 80)	N/A	AASHTO LRF	Strength Ia	0	0.351	N/A	N/A	N/A
xL (-45 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	38.3	0.471	N/A	N/A	N/A
xL (-25 to 0)	xR (1 to 25)	N/A	AASHTO LRF	Strength Ia	38.64	0.581	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

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Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N1	0: N1	15	0	150	15	0	6	2.7255	16.35
N2	0: N1	15	0	145	15	0	6	3.0284	18.17
N3	0: N1	15	0	140	15	0	6	2.9381	17.63
N4	0: N1	15	0	135	15	0	6	1.5111	9.07

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	177
2	0	152
3	0	133
4	45	134
5	50	134
6	60	134.3
7	70	135
8	80	135

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 1B	120	120	35	0	N/A	18	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table

c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
150	ESU 1A	1	0.47
146.96	ESU 1B	1	0.43
143.99	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 148ft
Radii search ends at point x= 0ft, z= 135ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 147 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -5ft, xLmax= -45ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Height-Global

Table: Basic analysis assumptions last stage

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Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -35ft
Right search limits: xRmin= 15ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 137 ft

Table: Basic analysis assumptions last stage

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Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-25ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 6 points.
Left search limits: xLmin= -25ft, xLmax= 0ft
Right search limits: xRmin= 1ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P

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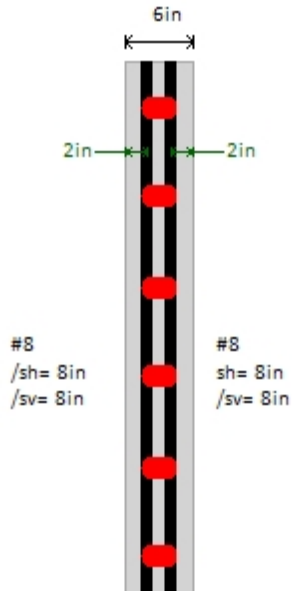

Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	152	143	N/A	6
Exc. 147 ft	Yes	152	147	N/A	6
Project Wall Height	Yes	152	142	N/A	6
Project Height-Global	Yes	152	142	N/A	6
Exc. 137 ft	Yes	152	137	N/A	6
Forward Compatible	Yes	152	132	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N1	0: N1	15	0	150	15	0	6	0.79	6	75
N2	0: N1	15	0	145	15	0	6	0.79	6	75
N3	0: N1	15	0	140	15	0	6	0.79	6	75
N4	0: N1	15	0	135	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N1	150	6	1	36	1	N/A	N/A	N/A
N2	145	6	1	36	1	N/A	N/A	N/A
N3	140	6	1	36	1	N/A	N/A	N/A
N4	135	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 12.417 z= 168.391 FS= 1.58

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -11.162 z= 165.488 FS= 2.141

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	11.65	30.14	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 3.6 z= 162 FS= 2.147

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	0	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N2	9.61	11.02	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -3.746 z= 163.171 FS= 2.676

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	0	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N2	0	0	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -5.628 z= 163.759 FS= 1.699

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	26.89	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	12.45	37.28	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	28.84	38.3	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= 6.544 z= 145.698 FS= 1.685

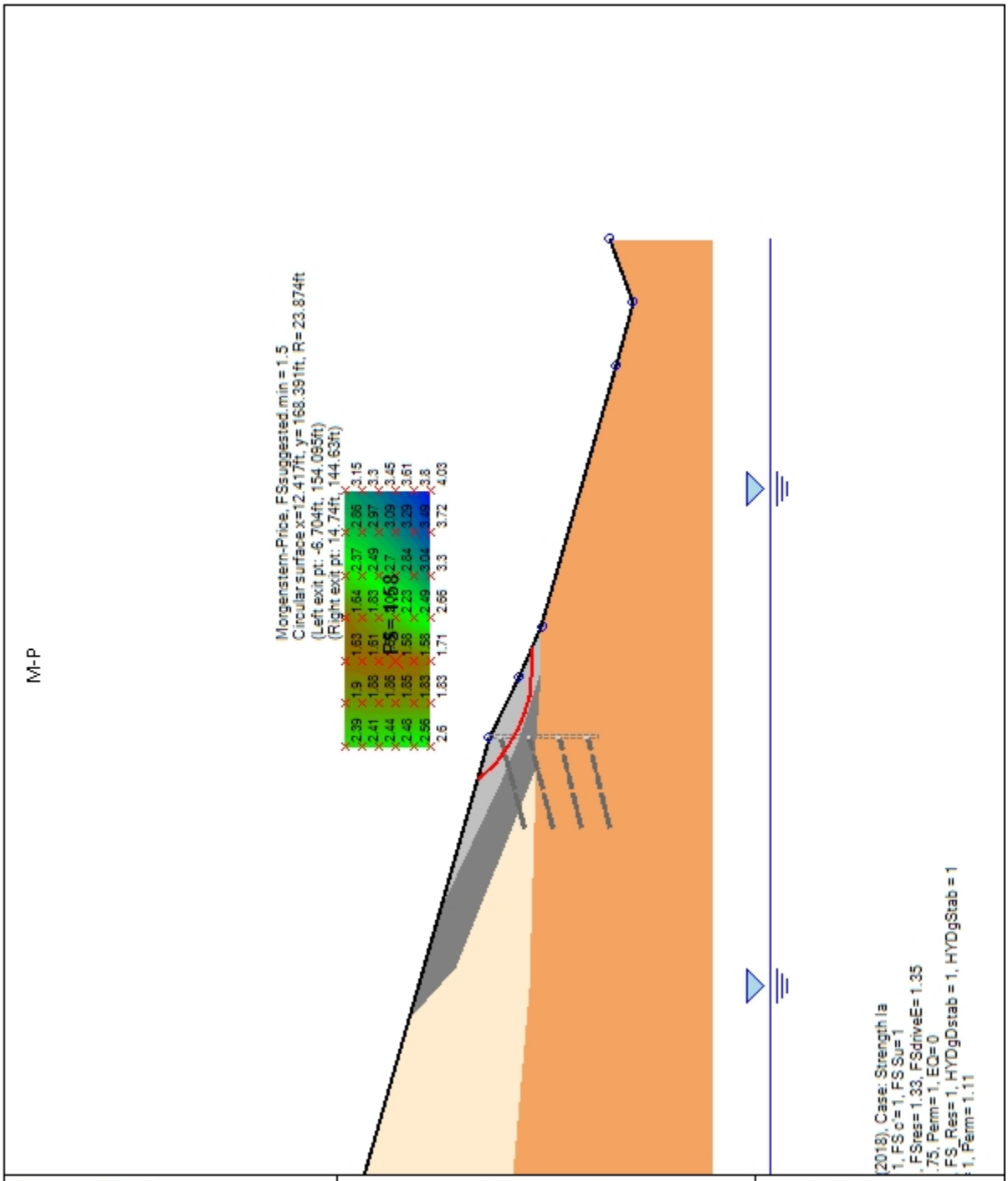
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	26.74	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	9.25	37.08	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	23.19	38.56	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	35.98	38.64	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP		12/1/2021

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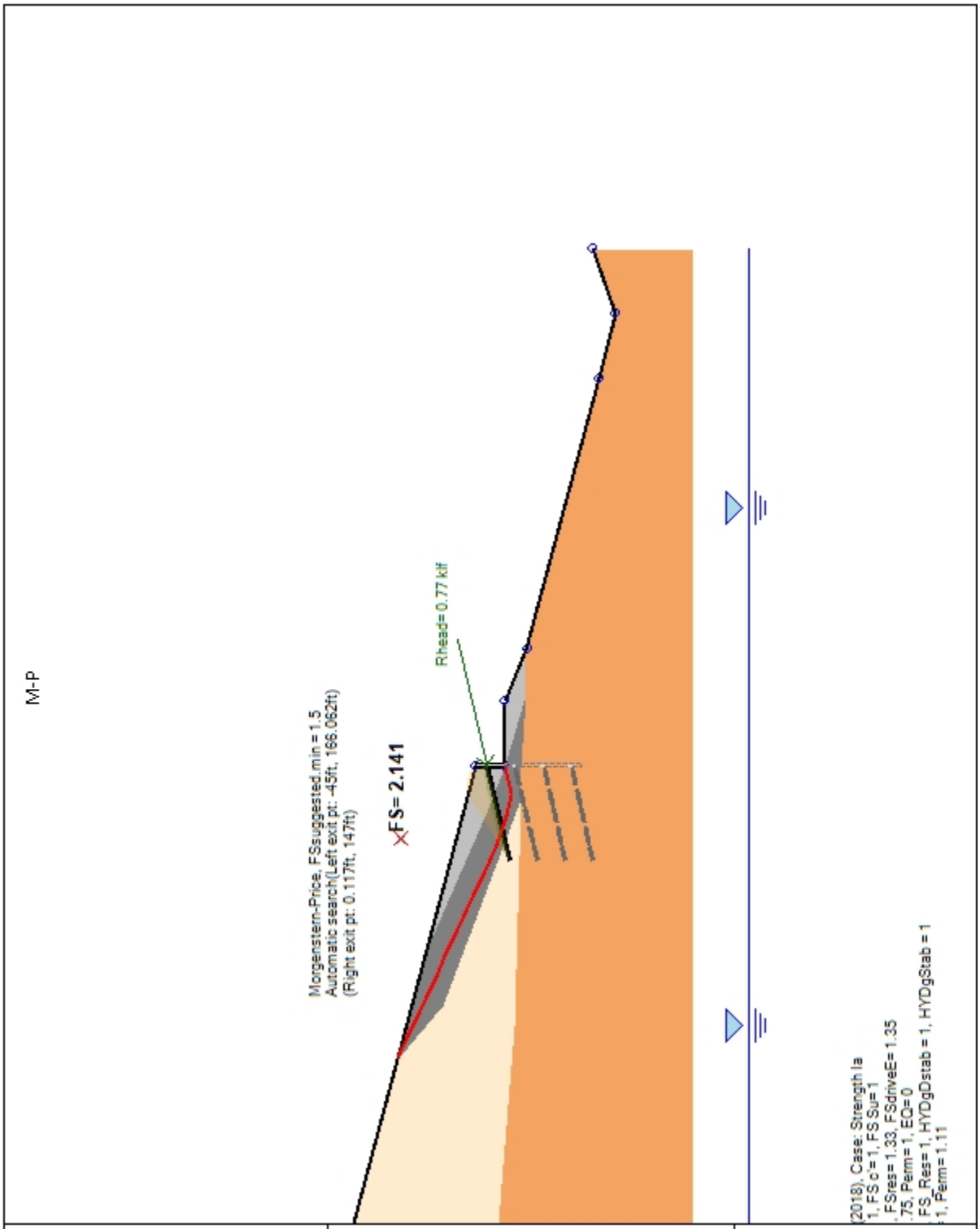
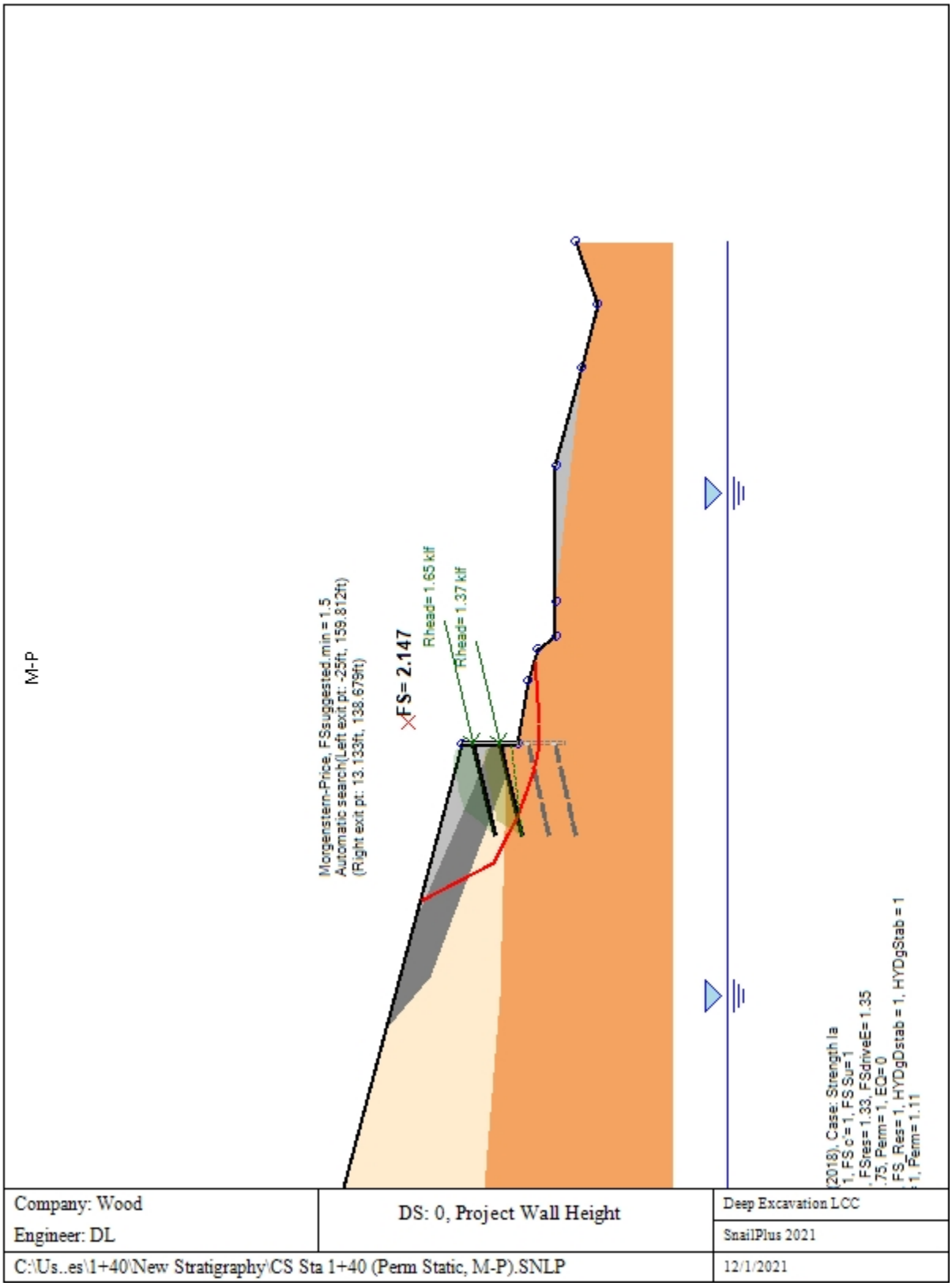


Company: Wood Engineer: DL	DS: 0, Exc. 147 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP		12/1/2021



Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP		12/1/2021

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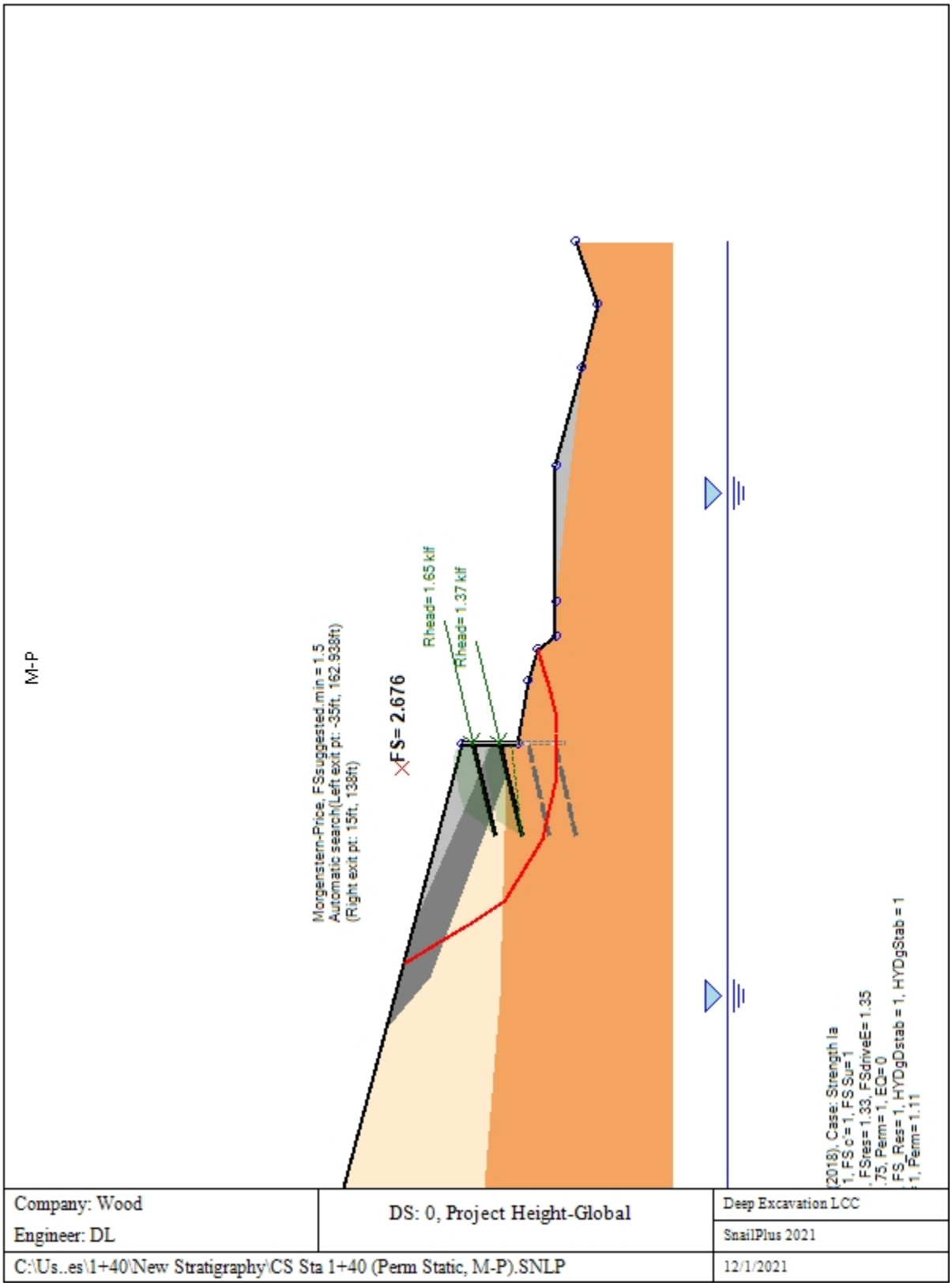
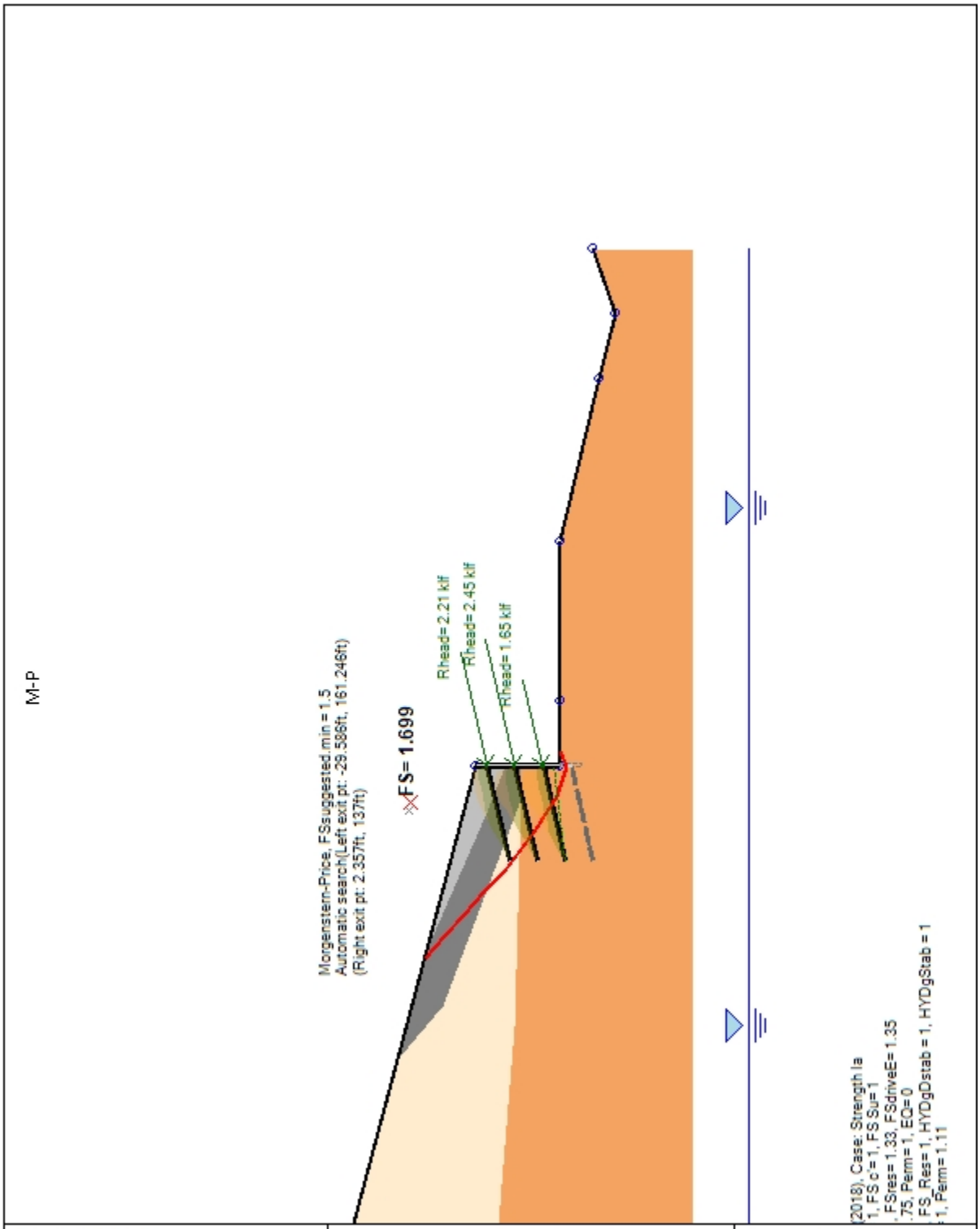
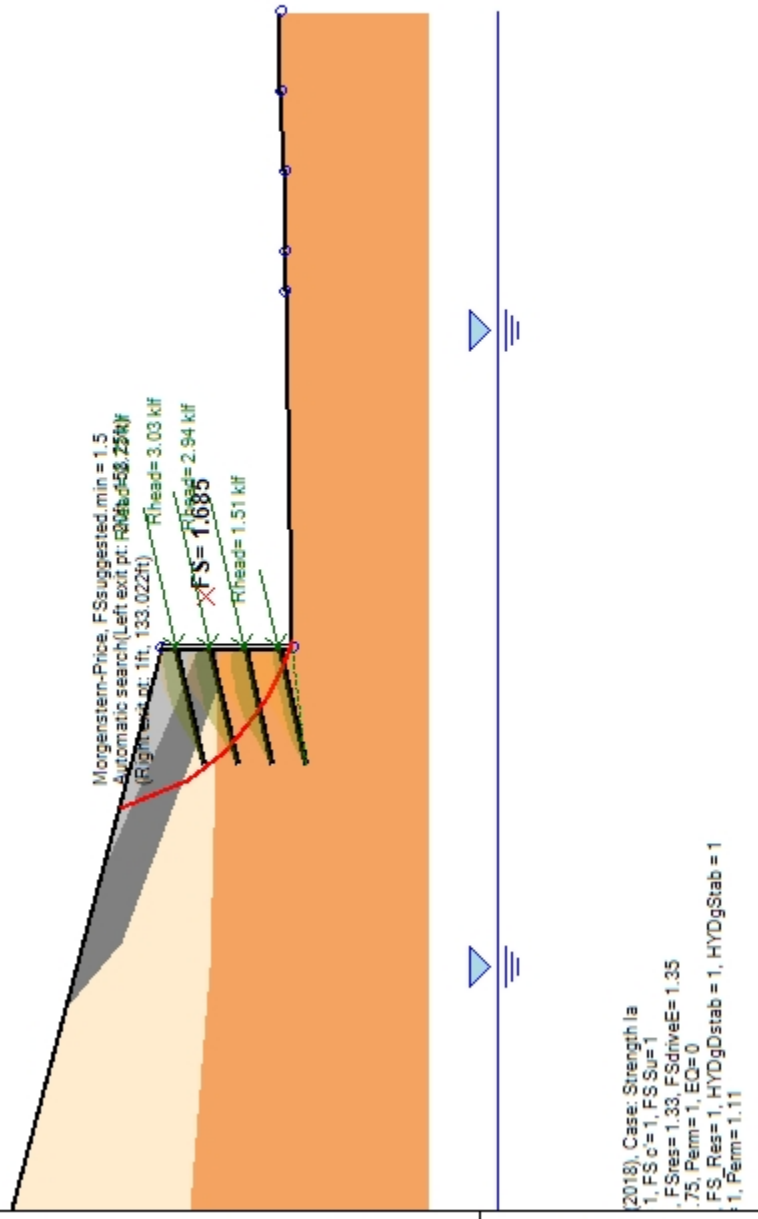

M-P
Morgenstern-Price, FSsuggested.min = 1.5
Automatic search(Left exit pt: -35ft, 162.938ft)
(Right exit pt: 15ft, 138ft)
FS= 2.676
Rhead= 1.65 klf
Rhead= 1.37 klf
(2018), Case: Strength Ia
1, FS c = 1, FS Su=1
FSres= 1.33, FSdriveE= 1.35
.75, Perm= 1, EQ=0
FS_Res= 1, HYDgDstab = 1, HYDgStab = 1
1, Perm= 1.11
Company: Wood
Engineer: DL
DS: 0, Project Height-Global
Deep Excavation LCC
SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP
12/1/2021



Company: Wood Engineer: DL	DS: 0, Exc. 137 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP		12/1/2021

M-P



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, M-P).SNLP		12/1/2021

SnailPlus 2021: Report Output

Copyright@2009 - 2020 Deep Excavation LLC: www.deepexcavation.com A program for the evaluation of soil nail walls. Deep Excavation LLC, Astoria, New York, www.deepexcavation.com

Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 1+40 (Perm Static, Spencer)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 3:38:16 PM

THIS PROGRAM IS PROTECTED BY U.S. COPYRIGHT LAWS AS DESCRIBED IN THE EULA. UNAUTHORIZED COPYING IS PROHIBITED. LICENSED TO: Deep Excavation LLC BY DEEP EXCAVATION LLC UNDER SPECIFIC LICENCE. This report has printed because the user has accepted responsibility as described in the disclaimer and EULA
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\1+40\New Stratigraphy\CS Sta 1+40 (Perm Static, Spencer) - Copy.SNLP

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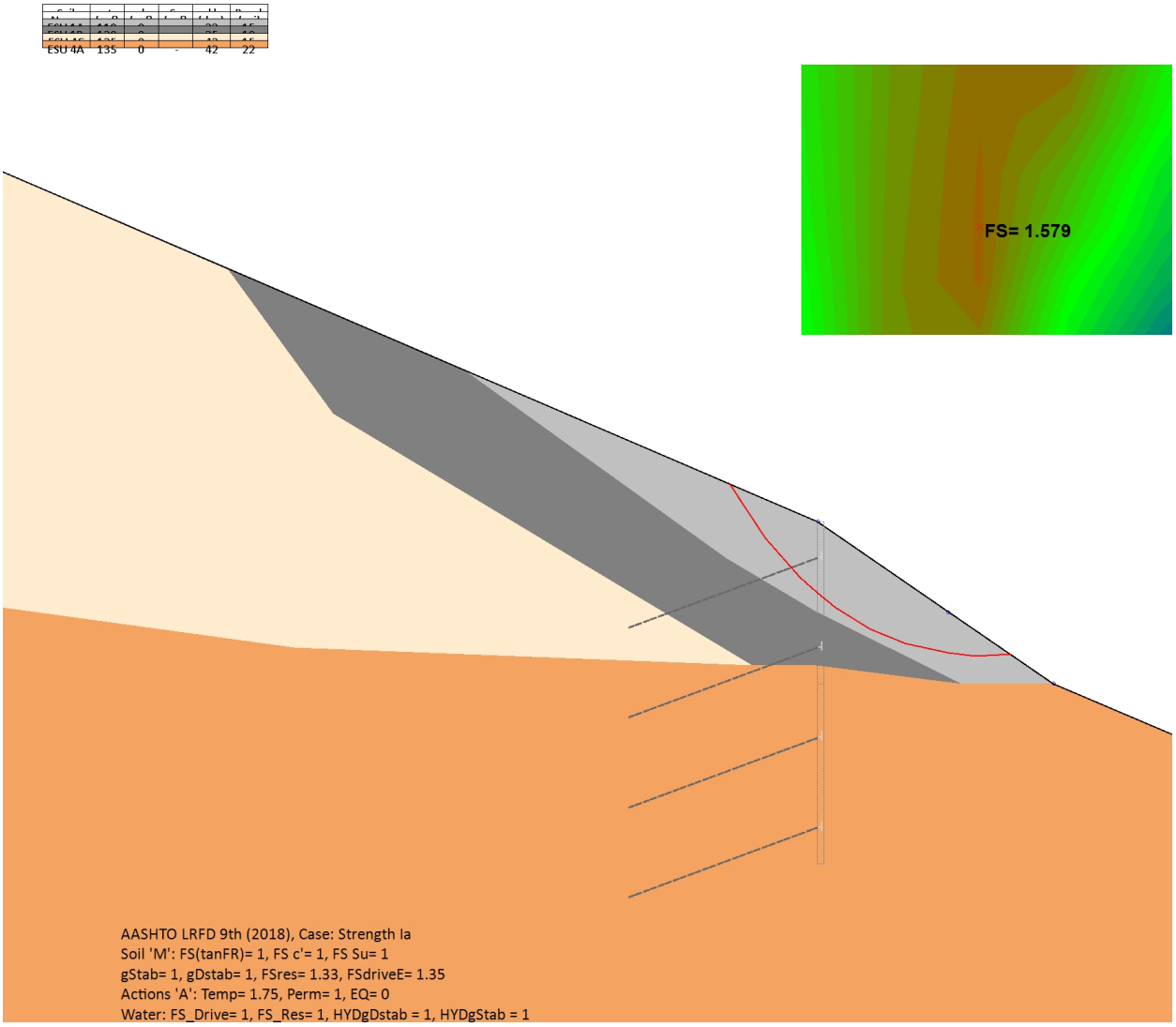
Quick analysis summary for design section: Spencer

Spencer



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	1.579	0	0	0	0	0	0	No	Yes
Exc. 147 ft	Calculated	2.169	6.01	4.6	6.01	0.164	0.178	0.067	No	Yes
Project Wall	Calculated	2.17	12.91	9.89	12.91	0.351	0.381	0.144	No	Yes
Project Heigh	Calculated	2.391	12.91	9.89	12.91	0.351	0.381	0.144	No	Yes
Exc. 137 ft	Calculated	1.846	19.23	14.72	19.23	0.471	0.568	0.215	No	Yes
Forward Com	Calculated	1.719	23.73	18.17	23.73	0.581	0.701	0.265	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.579	1.5	Circle	12.417	168.391	23.874	N/A	N/A
Exc. 147 ft	Yes	2.169	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	2.17	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Heig	Yes	2.391	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 137 ft	Yes	1.846	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.719	1.5	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-45 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	30.14	0.164	N/A	N/A	N/A
xL (-5 to -45)	xR (0.5 to 25)	N/A	AASHTO LRF	Strength Ia	8.61	0.351	N/A	N/A	N/A
xL (-80 to -35	xR (15 to 80)	N/A	AASHTO LRF	Strength Ia	0	0.351	N/A	N/A	N/A
xL (-45 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	38.3	0.471	N/A	N/A	N/A
xL (-30 to 0)	xR (1 to 25)	N/A	AASHTO LRF	Strength Ia	38.56	0.581	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

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Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N1	0: N1	15	0	150	15	0	6	2.7255	16.35
N2	0: N1	15	0	145	15	0	6	3.0284	18.17
N3	0: N1	15	0	140	15	0	6	2.9381	17.63
N4	0: N1	15	0	135	15	0	6	1.5111	9.07

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	177
2	0	152
3	0	133
4	45	134
5	50	134
6	60	134.3
7	70	135
8	80	135

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 1B	120	120	35	0	N/A	18	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table

c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
150	ESU 1A	1	0.47
146.96	ESU 1B	1	0.43
143.99	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 148ft
Radii search ends at point x= 0ft, z= 135ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 147 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -5ft, xLmax= -45ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Height-Global

Table: Basic analysis assumptions last stage

10/22

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -35ft
Right search limits: xRmin= 15ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 137 ft

Table: Basic analysis assumptions last stage

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Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-30ft to 0ft
Right limits	1ft to 25ft
Number of points	6
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 6 points.
Left search limits: xLmin= -30ft, xLmax= 0ft
Right search limits: xRmin= 1ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Spencer

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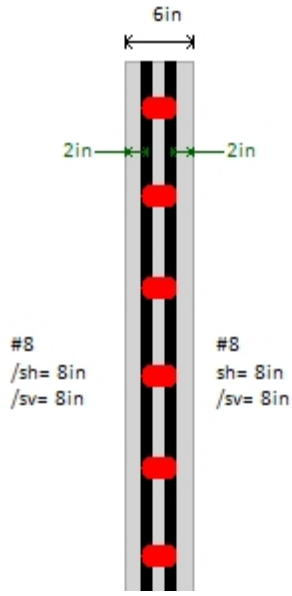

Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	152	143	N/A	6
Exc. 147 ft	Yes	152	147	N/A	6
Project Wall Height	Yes	152	142	N/A	6
Project Height-Global	Yes	152	142	N/A	6
Exc. 137 ft	Yes	152	137	N/A	6
Forward Compatible	Yes	152	132	N/A	6

Soil nail input data for design section Spencer

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N1	0: N1	15	0	150	15	0	6	0.79	6	75
N2	0: N1	15	0	145	15	0	6	0.79	6	75
N3	0: N1	15	0	140	15	0	6	0.79	6	75
N4	0: N1	15	0	135	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N1	150	6	1	36	1	N/A	N/A	N/A
N2	145	6	1	36	1	N/A	N/A	N/A
N3	140	6	1	36	1	N/A	N/A	N/A
N4	135	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Spencer

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 12.417 z= 168.391 FS= 1.579

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -11.129 z= 165.478 FS= 2.169

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	9.22	30.14	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 3.511 z= 162 FS= 2.17

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	0	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N2	7.5	8.61	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= 2.463 z= 162 FS= 2.391

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	0	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N2	0	0	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -9.637 z= 165.012 FS= 1.846

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	2.52	26.89	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	17.9	37.28	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	36.03	38.3	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= 6.544 z= 145.385 FS= 1.719

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	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	2.01	24.64	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	12.75	35.14	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	25.7	38.51	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	34.95	38.56	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)

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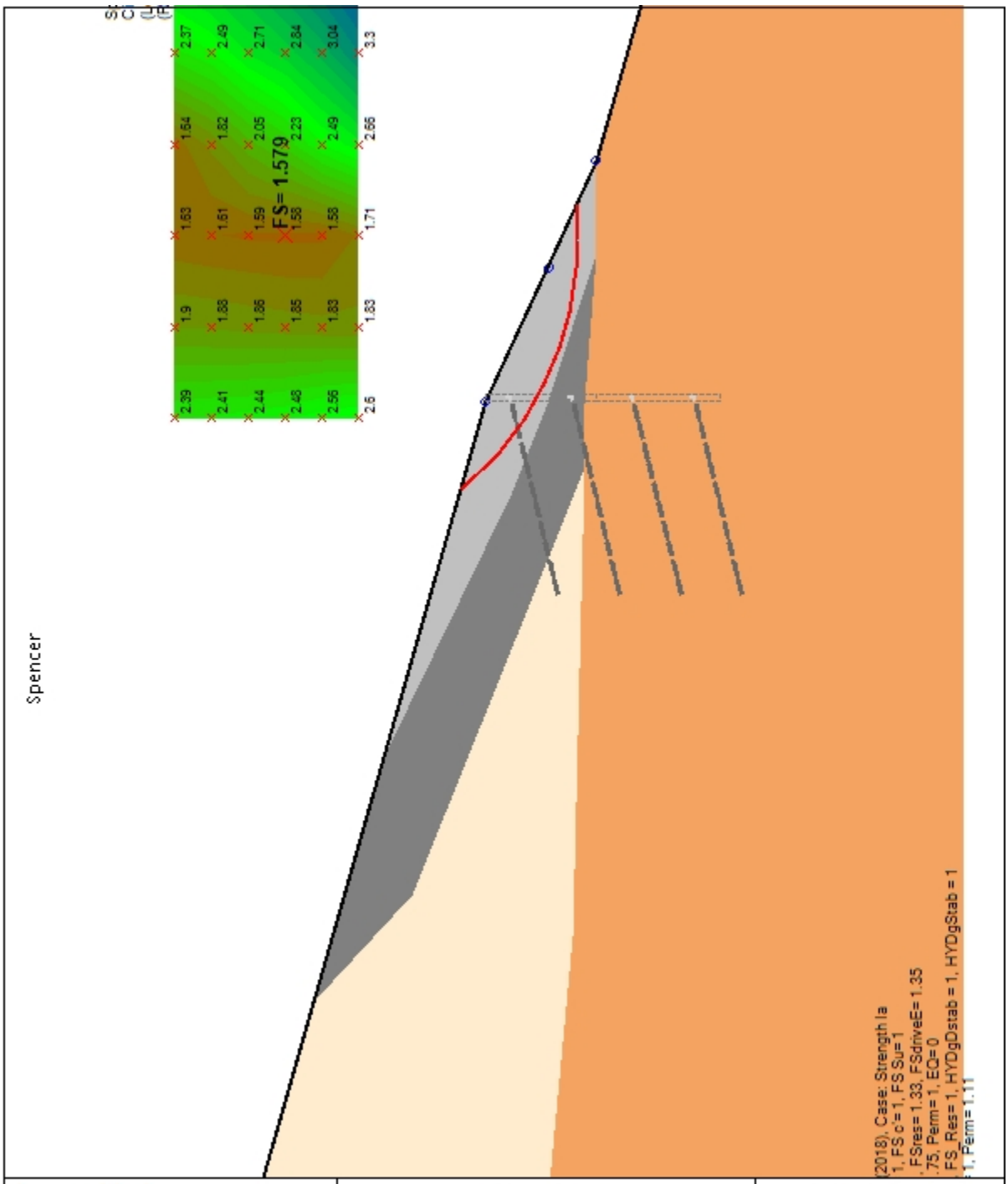

Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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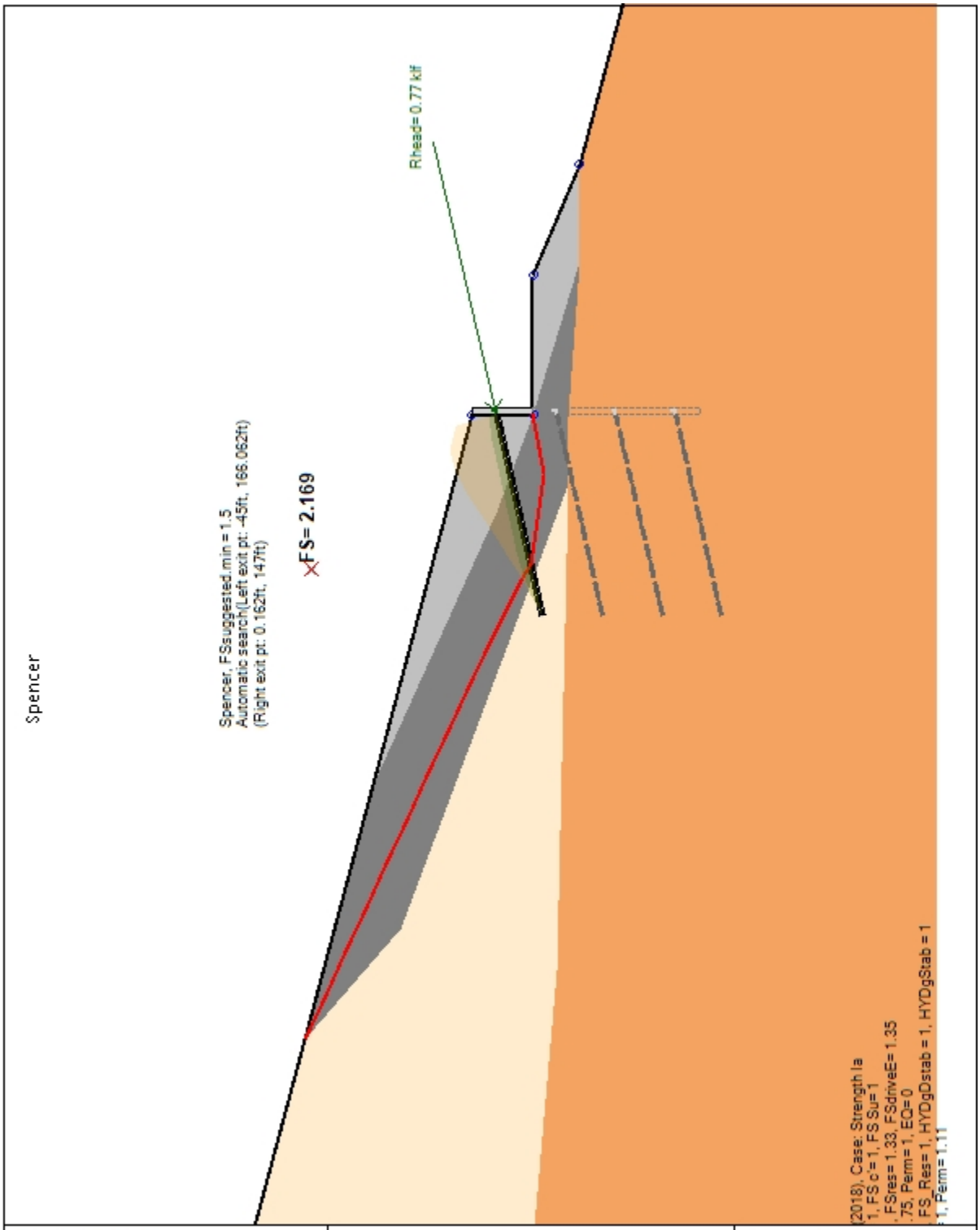

Company: Wood Engineer: DL	DS: 0, Exc. 147 ft	Deep Excavation LCC SnailPlus 2021
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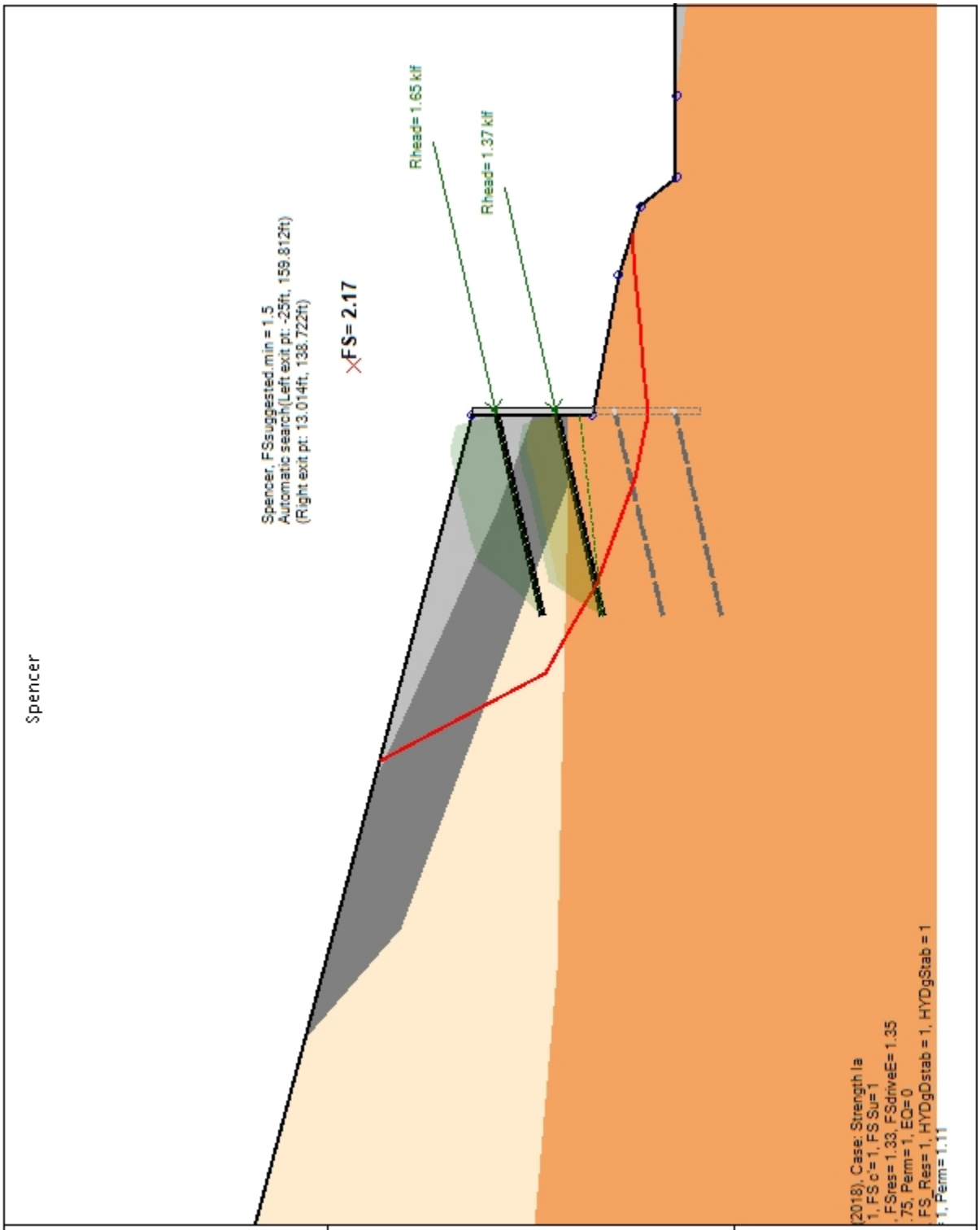

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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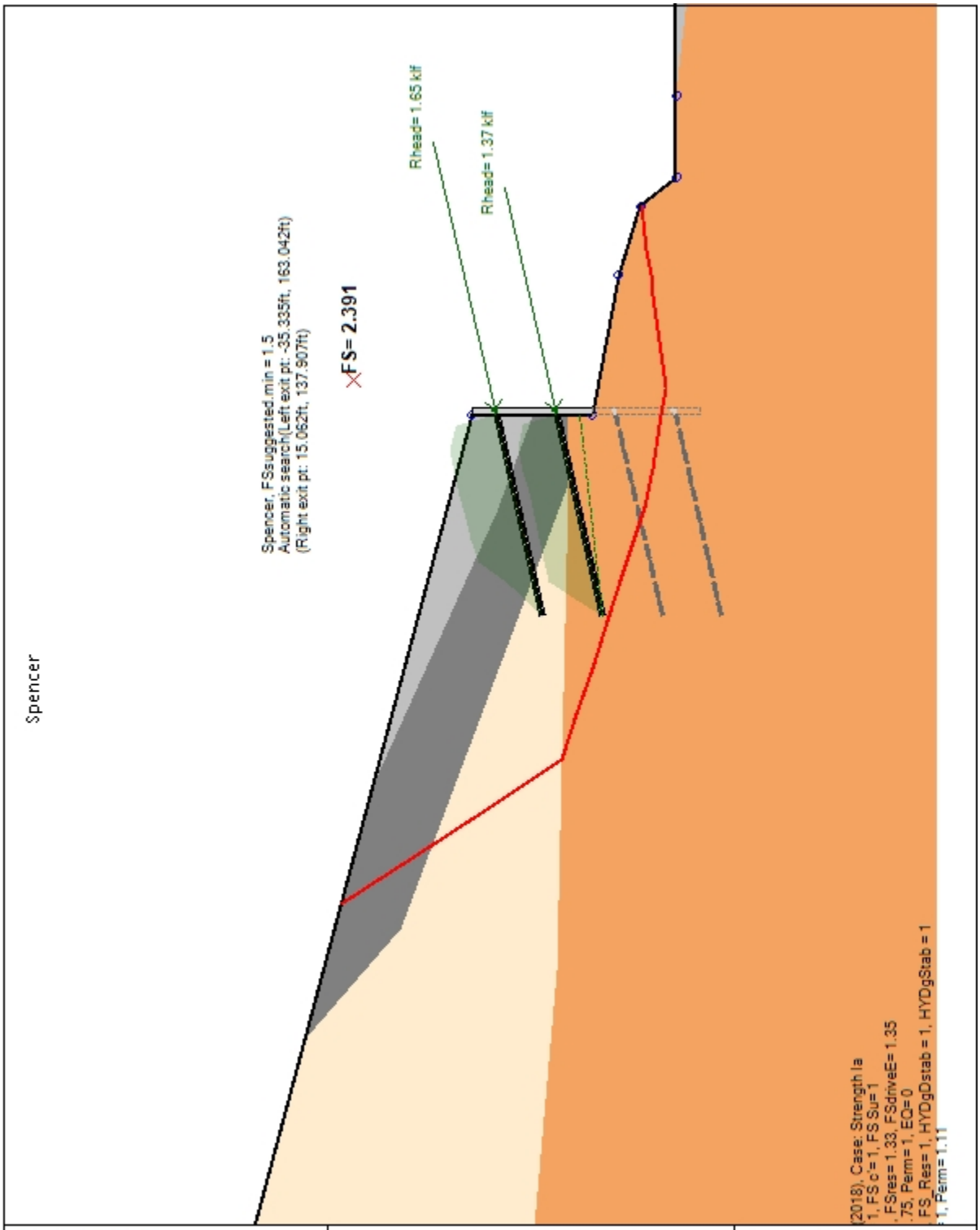
20/22



Company: Wood Engineer: DL	DS: 0, Project Height-Global	Deep Excavation LCC SnailPlus 2021
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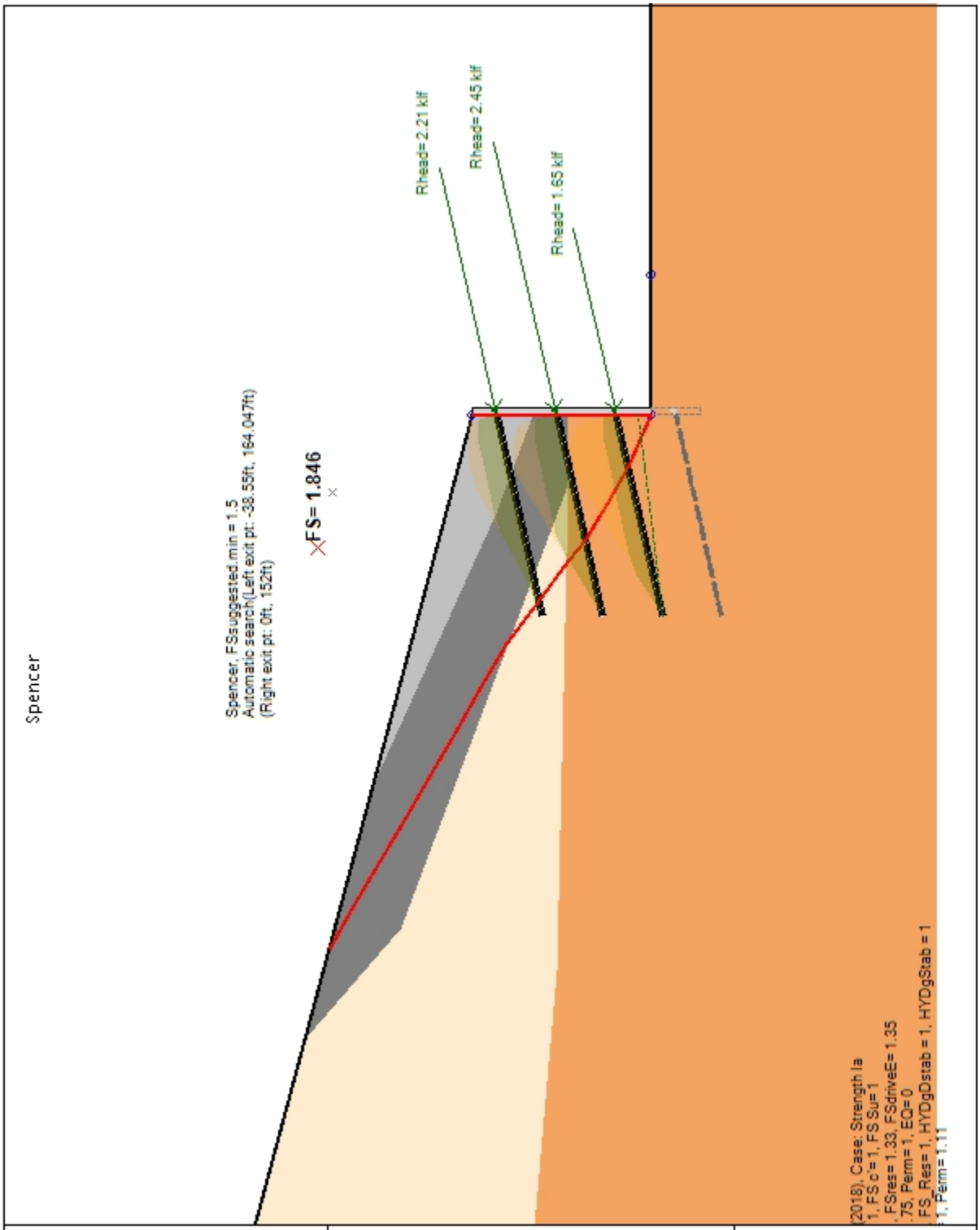

Company: Wood Engineer: DL	DS: 0, Exc. 137 ft	Deep Excavation LCC SnailPlus 2021
C:\Us.. Stratigraphy\CS Sta 1+40 (Perm Static, Spencer) - Copy.SNLP		12/1/2021

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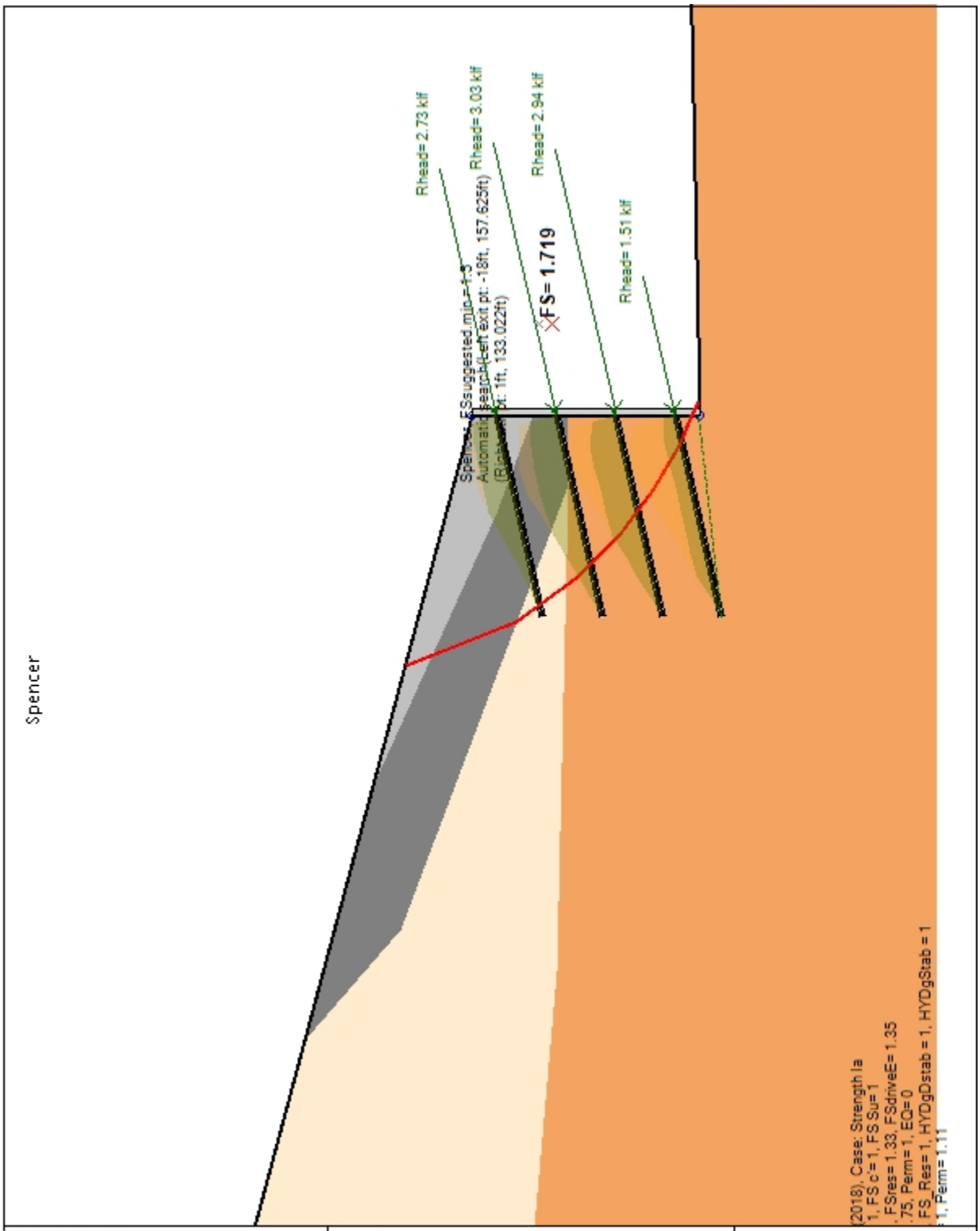

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us.. Stratigraphy\CS Sta 1+40 (Perm Static, Spencer) - Copy.SNLP		12/1/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 1+40 (Temp Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 4:16:12 PM

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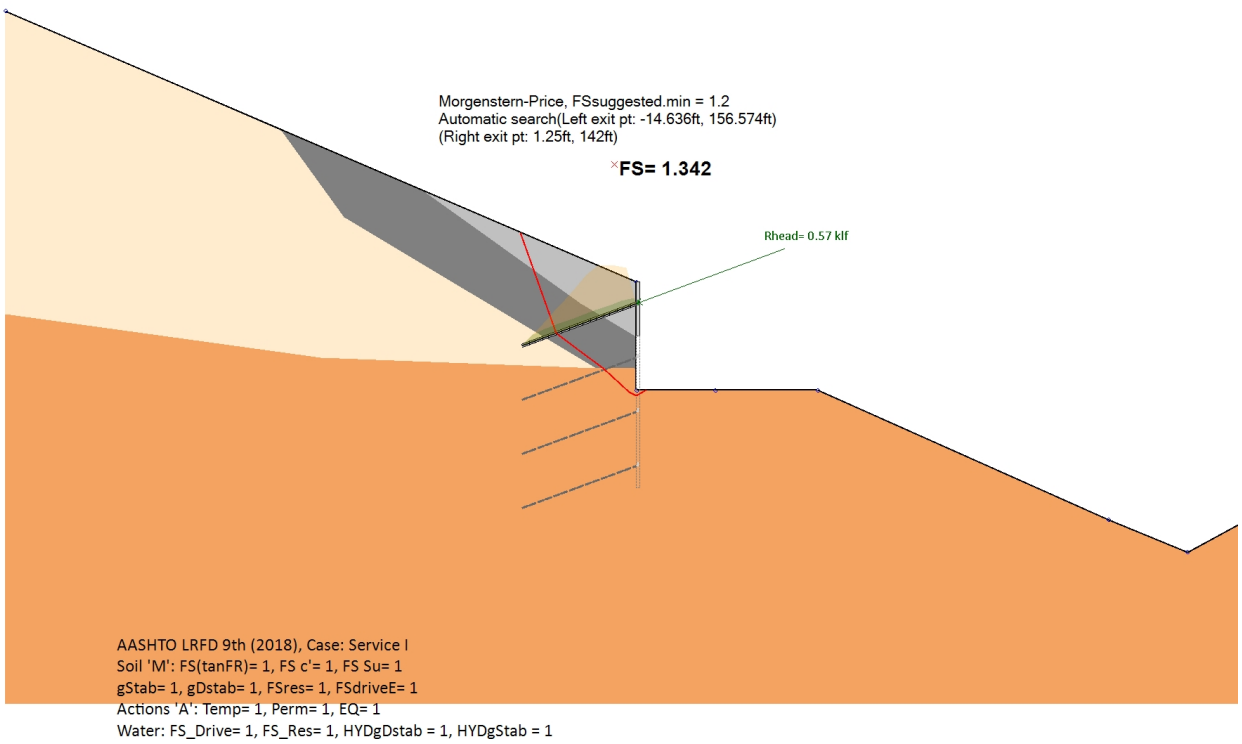
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\1+40\New Stratigraphy\CS Sta 1+40 (Temp Static, M-P).SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Existing	Calculated	1.58	0	0	0	0	0	0	No	Yes
Exc. 147 ft	Calculated	1.504	0	0	0	0	0	0	No	Yes
Project Wall	Calculated	1.342	4.45	3.41	4.45	0.121	0.132	0.05	No	Yes
Exc. 137 ft	Calculated	1.387	9.56	7.32	9.56	0.26	0.283	0.107	No	Yes
Forward Com	Calculated	1.37	14.24	10.91	14.24	0.349	0.421	0.159	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).

Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.58	1.2	Circle	12.417	168.391	23.874	N/A	N/A
Exc. 147 ft	Yes	1.504	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.342	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 137 ft	Yes	1.387	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.37	1.2	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Service I	-	-	N/A	N/A	N/A
xL (-45 to -5)	xR (0.5 to 25)	N/A	AASHTO LRF	Service I	-	-	N/A	N/A	N/A
xL (-45 to -5)	xR (0.5 to 25)	N/A	AASHTO LRF	Service I	28.06	0.121	N/A	N/A	N/A
xL (-45 to -5)	xR (0.5 to 25)	N/A	AASHTO LRF	Service I	36.94	0.26	N/A	N/A	N/A
xL (-23 to 0)	xR (1 to 20)	N/A	AASHTO LRF	Service I	38.44	0.349	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to 0ft
Right limits	1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

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Code	AASHTO LRFD 9th (2018)
Case	Service I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	1
Permanent loads	1
Temporary anchors	1
Permanent anchors	1
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N1	0: N1	15	0	150	15	0	6	1.636	9.82
N2	0: N1	15	0	145	15	0	6	1.8178	10.91
N3	0: N1	15	0	140	15	0	6	1.2229	7.34
N4	0: N1	15	0	135	15	0	6	0	0

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	177
2	0	152
3	0	133
4	45	134
5	50	134
6	60	134.3
7	70	135
8	80	135

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 1B	120	120	35	0	N/A	18	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table

c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
150	ESU 1A	1	0.47
146.96	ESU 1B	1	0.43
143.99	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to 0ft
Right limits	1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 148ft
Radii search ends at point x= 0ft, z= 135ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 147 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to 0ft
Right limits	1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

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Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to 0ft
Right limits	1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 137 ft

Table: Basic analysis assumptions last stage

10/20

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to 0ft
Right limits	1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

11/20

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to 0ft
Right limits	1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -23ft, xLmax= 0ft
Right search limits: xRmin= 1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P

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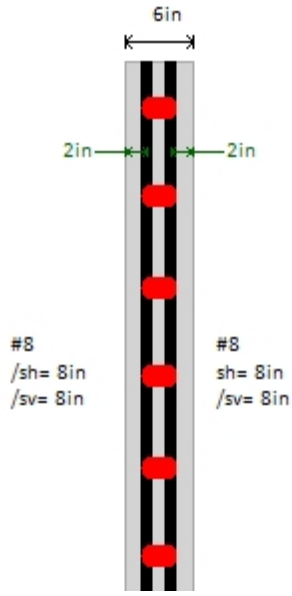

Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	152	143	N/A	6
Exc. 147 ft	No	152	147	N/A	6
Project Wall Height	Yes	152	147	N/A	6
Exc. 137 ft	Yes	152	142	N/A	6
Forward Compatible	Yes	152	137	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N1	0: N1	15	0	150	15	0	6	0.79	6	75
N2	0: N1	15	0	145	15	0	6	0.79	6	75
N3	0: N1	15	0	140	15	0	6	0.79	6	75
N4	0: N1	15	0	135	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N1	150	6	1	36	1	N/A	N/A	N/A
N2	145	6	1	36	1	N/A	N/A	N/A
N3	140	6	1	36	1	N/A	N/A	N/A
N4	135	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 12.417 z= 168.391 FS= 1.58

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -2.535 z= 162.792 FS= 1.504

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -2.722 z= 162.851 FS= 1.342

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	10.79	28.06	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -4.988 z= 163.559 FS= 1.387

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	27.23	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	12.16	36.94	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -4.326 z= 163.352 FS= 1.37

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	1.91	26.83	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	12.67	37.13	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	25.56	38.44	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

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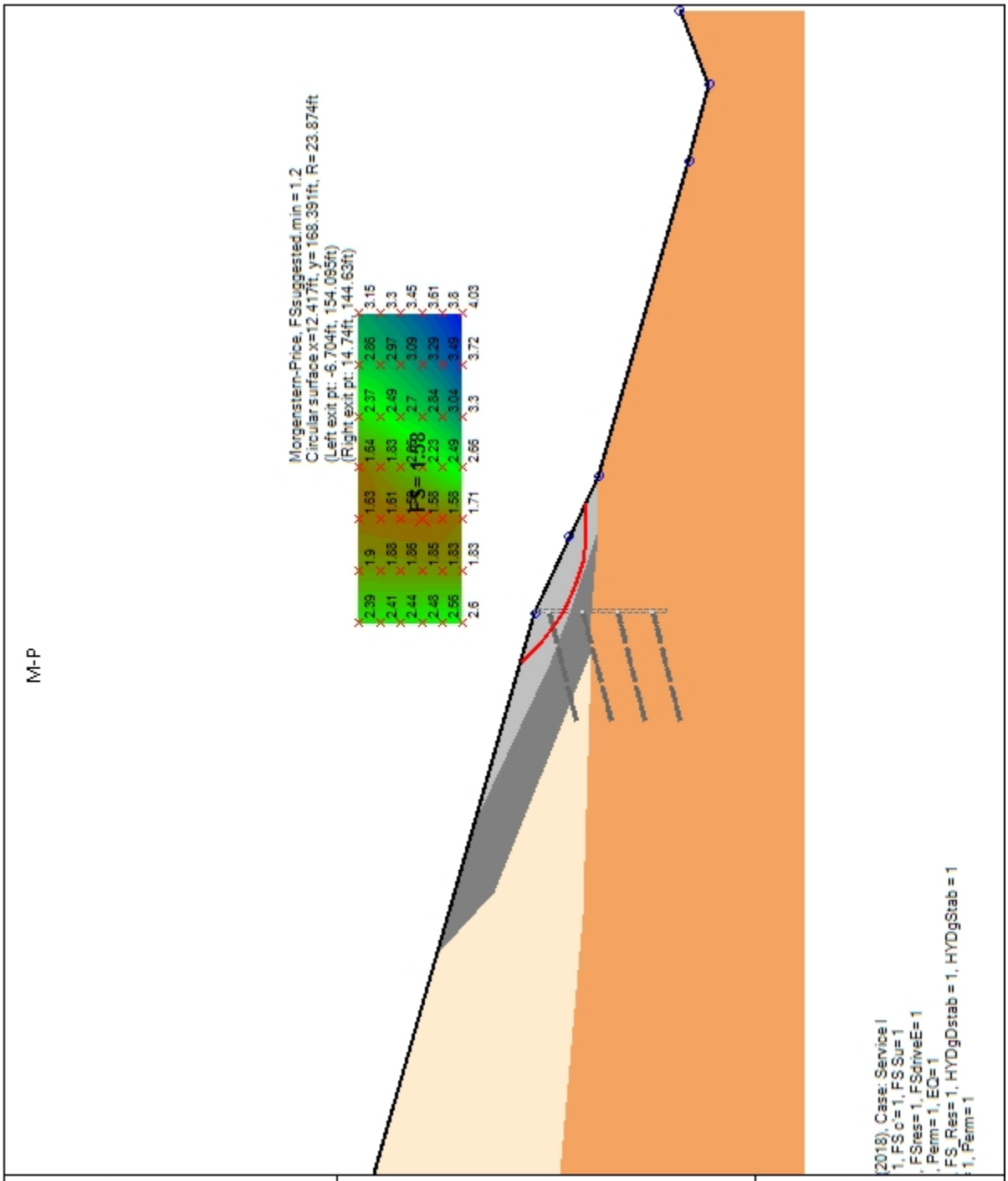
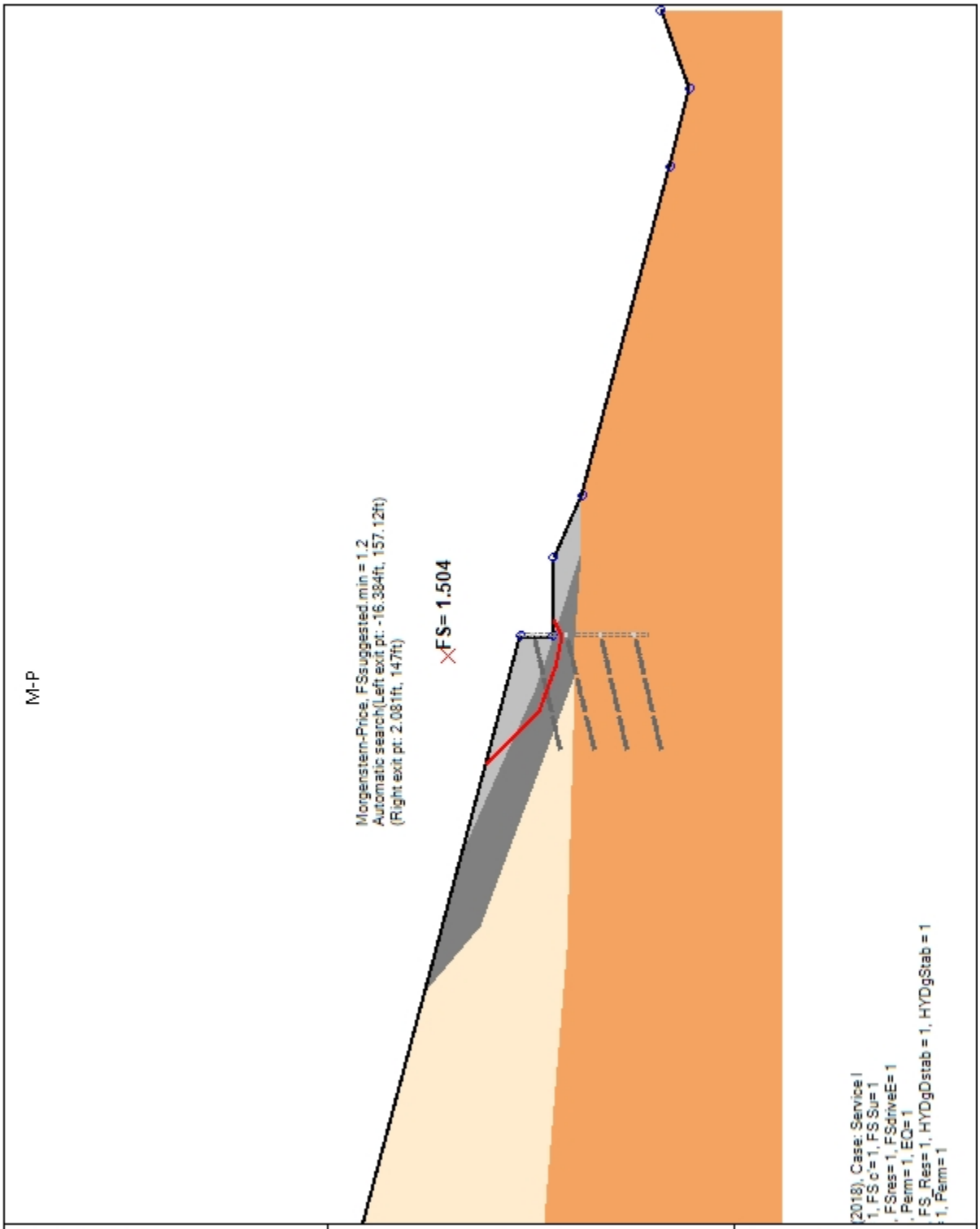
F	= Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax	= Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR	= Tensile structural design capacity for soil nail
CAP GEO	= Tensile geotechnical pull out resistance for soil nail
TcapGEO	= Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1	= Structural soil nail shear resistance
TC2	= Shear resistance according to Clouterre TC2 criterion
TC3	= Shear resistance according to Clouterre TC3 criterion
TC4	= Shear resistance according to Clouterre TC4 criterion
TC4 C4	= Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS	= Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po	= Soil lateral pressure at failure surface-soil nail intersection point
Pu	= Ultimate lateral pressure at failure surface-soil nail intersection point
Lo	= Flexure length for shear calculations
IxxCalc	= Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc	= Nail section modulus (adjusted for corrosion loss if assumed)
t.loss	= Structural thickness loss (if assumed by the user)
%STR	= Structural capacity loss as a percentage (if assumed by the user)

16/20



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Temp Static, M-P).SNLP		12/1/2021

17/20



Company: Wood Engineer: DL	DS: 0, Exc. 147 ft	Deep Excavation LCC SnailPlus 2021
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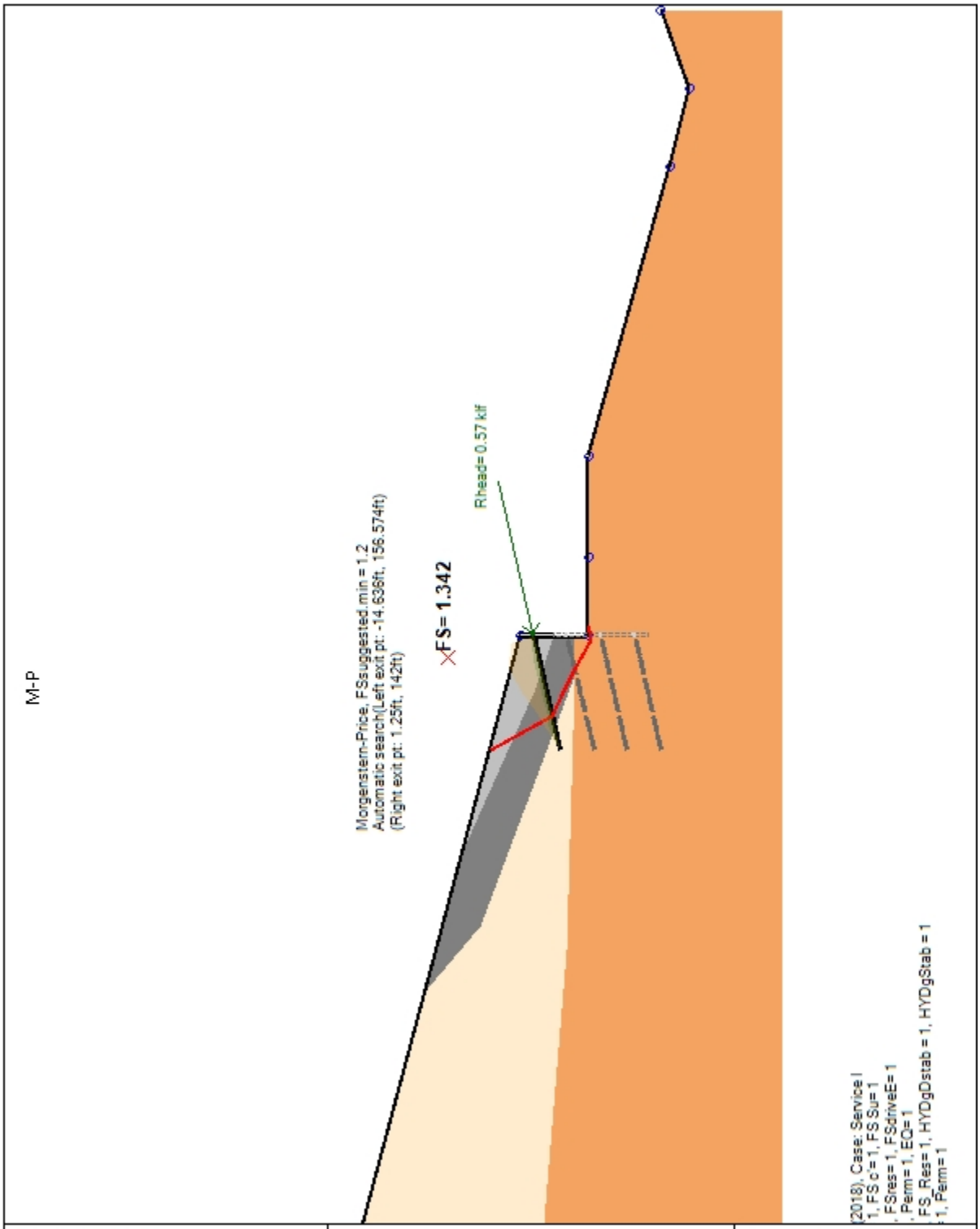
18/20



Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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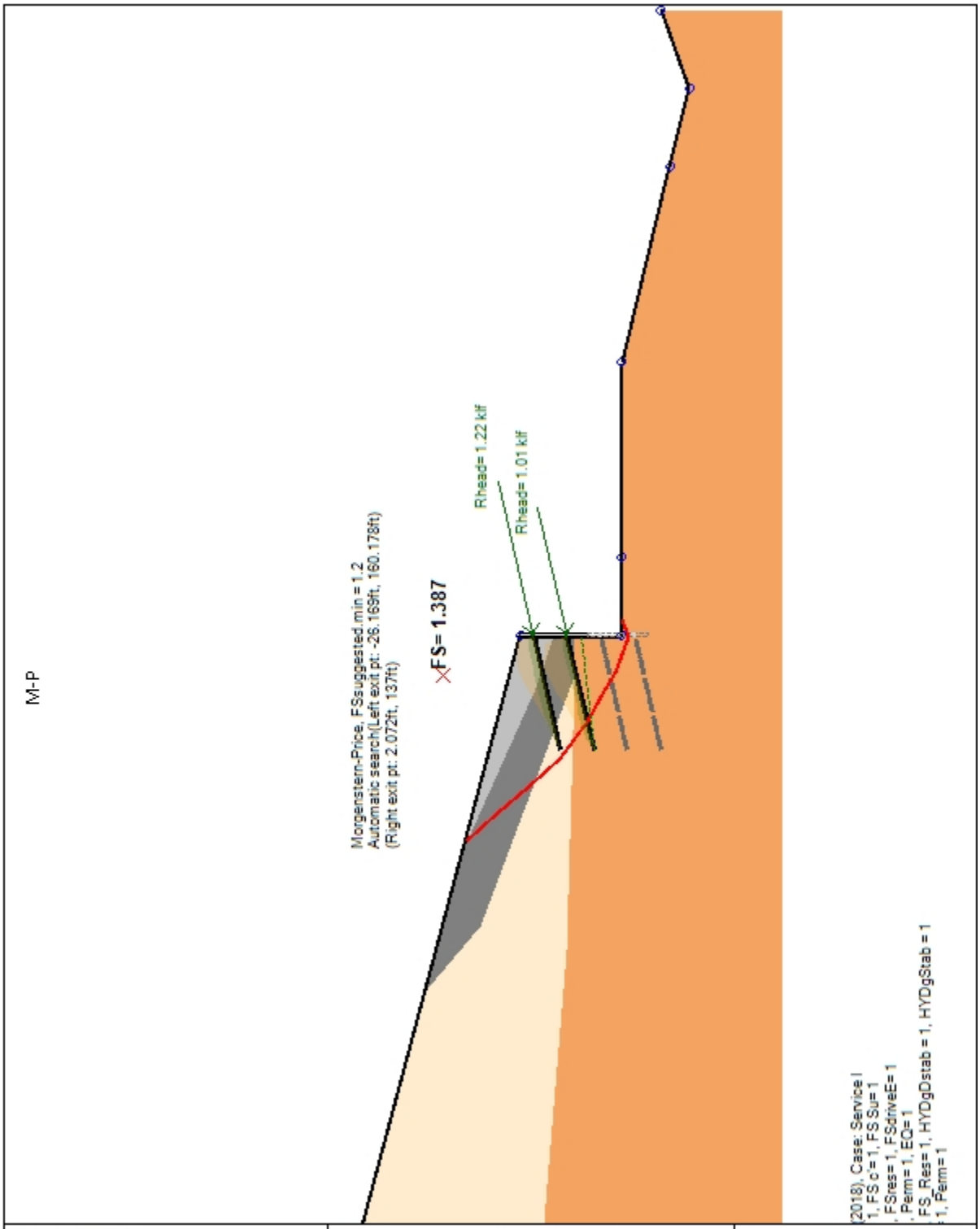
19/20



Company: Wood Engineer: DL	DS: 0, Exc. 137 ft	Deep Excavation LCC SnailPlus 2021
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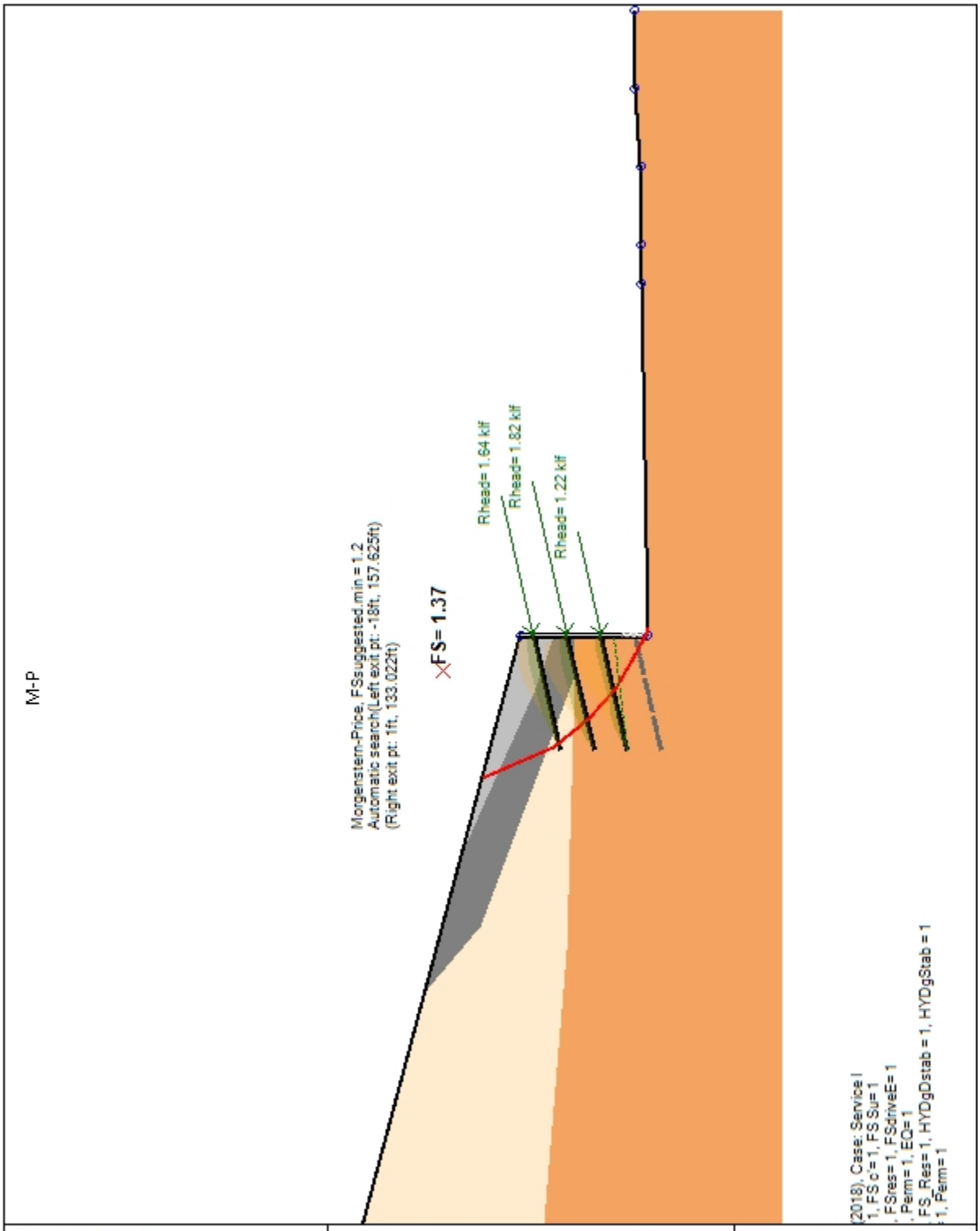
20/20



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..es\1+40\New Stratigraphy\CS Sta 1+40 (Temp Static, M-P).SNLP		12/1/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 1+40 (Temp Static, Spencer)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 4:18:28 PM

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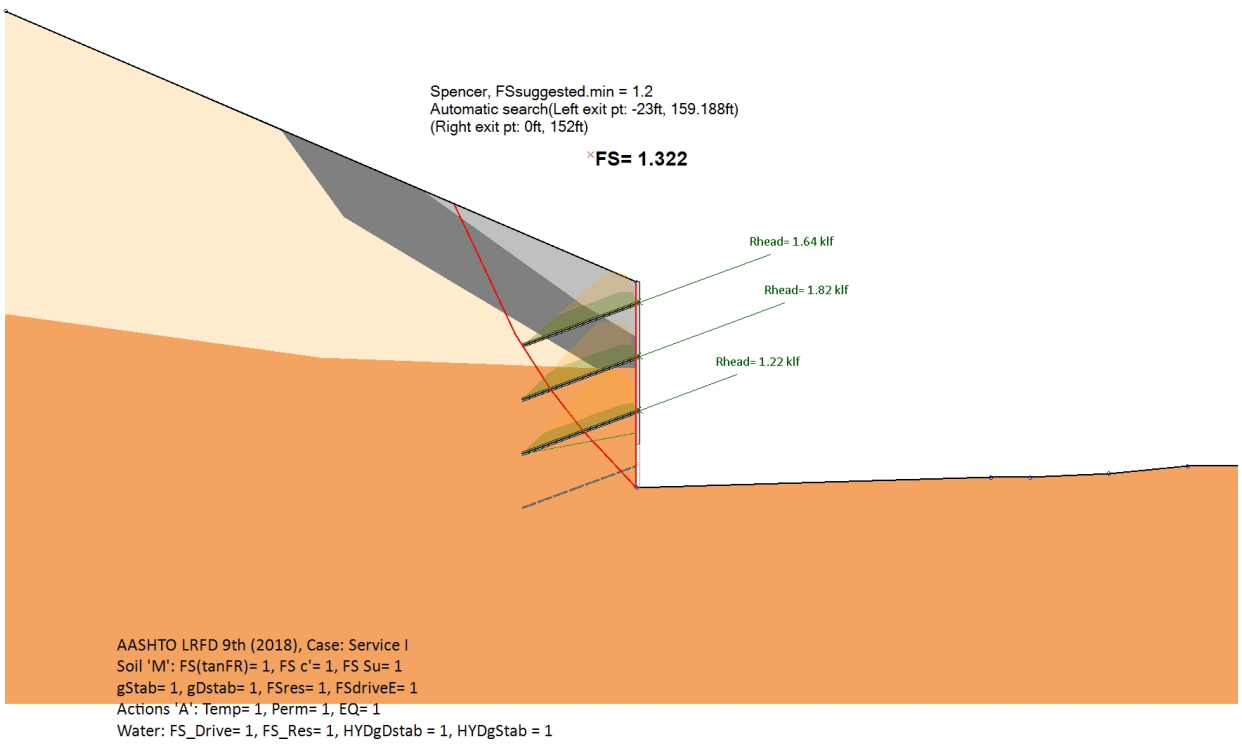
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\1+40\New Stratigraphy\CS Sta 1+40 (Temp Static, Spencer).SNLP

Quick analysis summary for design section: Spencer

Spencer

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Existing	Calculated	1.579	0	0	0	0	0	0	No	Yes
Exc. 147 ft	Calculated	1.603	0	0	0	0	0	0	No	Yes
Project Wall	Calculated	1.433	4.45	3.41	4.45	0.121	0.132	0.05	No	Yes
Exc. 137 ft	Calculated	1.422	9.56	7.32	9.56	0.26	0.283	0.107	No	Yes
Forward Com	Calculated	1.322	14.24	10.91	14.24	0.349	0.421	0.159	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).

Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.579	1.2	Circle	12.417	168.391	23.874	N/A	N/A
Exc. 147 ft	Yes	1.603	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.433	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 137 ft	Yes	1.422	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.322	1.2	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Service I	-	-	N/A	N/A	N/A
xL (-45 to -5)	xR (0.5 to 25)	N/A	AASHTO LRF	Service I	-	-	N/A	N/A	N/A
xL (-45 to -5)	xR (0.5 to 25)	N/A	AASHTO LRF	Service I	28.06	0.121	N/A	N/A	N/A
xL (-45 to -5)	xR (0.5 to 25)	N/A	AASHTO LRF	Service I	36.94	0.26	N/A	N/A	N/A
xL (-23 to -1)	xR (0 to 15)	N/A	AASHTO LRF	Service I	38.52	0.349	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to -1ft
Right limits	0ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

5/20

Code	AASHTO LRFD 9th (2018)
Case	Service I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	1
Permanent loads	1
Temporary anchors	1
Permanent anchors	1
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N1	0: N1	15	0	150	15	0	6	1.636	9.82
N2	0: N1	15	0	145	15	0	6	1.8178	10.91
N3	0: N1	15	0	140	15	0	6	1.2229	7.34
N4	0: N1	15	0	135	15	0	6	0	0

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	177
2	0	152
3	0	133
4	45	134
5	50	134
6	60	134.3
7	70	135
8	80	135

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 1B	120	120	35	0	N/A	18	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table

c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
150	ESU 1A	1	0.47
146.96	ESU 1B	1	0.43
143.99	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to -1ft
Right limits	0ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 148ft
Radii search ends at point x= 0ft, z= 135ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 147 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to -1ft
Right limits	0ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to -1ft
Right limits	0ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 137 ft

Table: Basic analysis assumptions last stage

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Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to -1ft
Right limits	0ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.5ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-23ft to -1ft
Right limits	0ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -23ft, xLmax= -1ft
Right search limits: xRmin= 0ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Spencer

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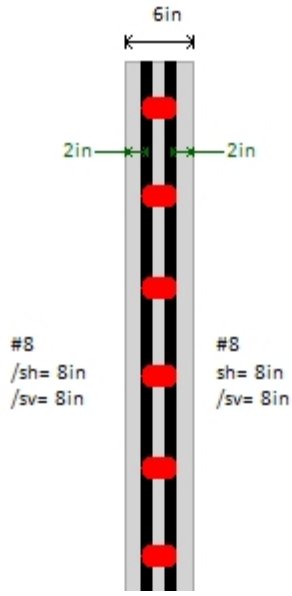

Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	152	143	N/A	6
Exc. 147 ft	No	152	147	N/A	6
Project Wall Height	Yes	152	147	N/A	6
Exc. 137 ft	Yes	152	142	N/A	6
Forward Compatible	Yes	152	137	N/A	6

Soil nail input data for design section Spencer

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N1	0: N1	15	0	150	15	0	6	0.79	6	75
N2	0: N1	15	0	145	15	0	6	0.79	6	75
N3	0: N1	15	0	140	15	0	6	0.79	6	75
N4	0: N1	15	0	135	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N1	150	6	1	36	1	N/A	N/A	N/A
N2	145	6	1	36	1	N/A	N/A	N/A
N3	140	6	1	36	1	N/A	N/A	N/A
N4	135	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Spencer

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 12.417 z= 168.391 FS= 1.579

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -0.449 z= 162.14 FS= 1.603

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -0.321 z= 162.1 FS= 1.433

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	10.12	28.06	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -3.888 z= 163.215 FS= 1.422

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	27.23	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	12.79	36.94	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -5.75 z= 163.797 FS= 1.322

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0.28	31.08	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	12.16	36.34	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	26.31	38.52	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

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F	= Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax	= Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR	= Tensile structural design capacity for soil nail
CAP GEO	= Tensile geotechnical pull out resistance for soil nail
TcapGEO	= Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1	= Structural soil nail shear resistance
TC2	= Shear resistance according to Clouterre TC2 criterion
TC3	= Shear resistance according to Clouterre TC3 criterion
TC4	= Shear resistance according to Clouterre TC4 criterion
TC4 C4	= Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS	= Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po	= Soil lateral pressure at failure surface-soil nail intersection point
Pu	= Ultimate lateral pressure at failure surface-soil nail intersection point
Lo	= Flexure length for shear calculations
IxxCalc	= Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc	= Nail section modulus (adjusted for corrosion loss if assumed)
t.loss	= Structural thickness loss (if assumed by the user)
%STR	= Structural capacity loss as a percentage (if assumed by the user)

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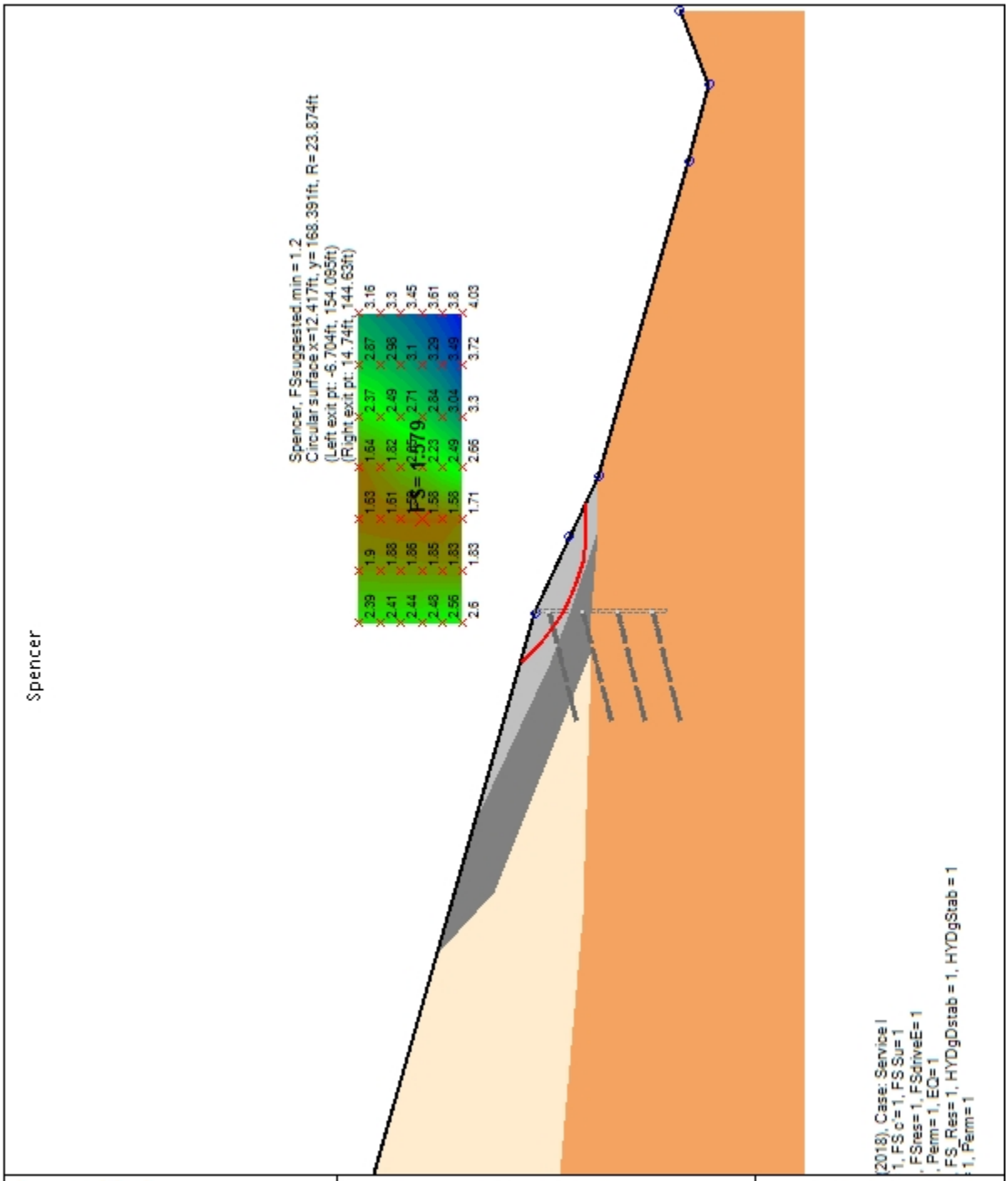

Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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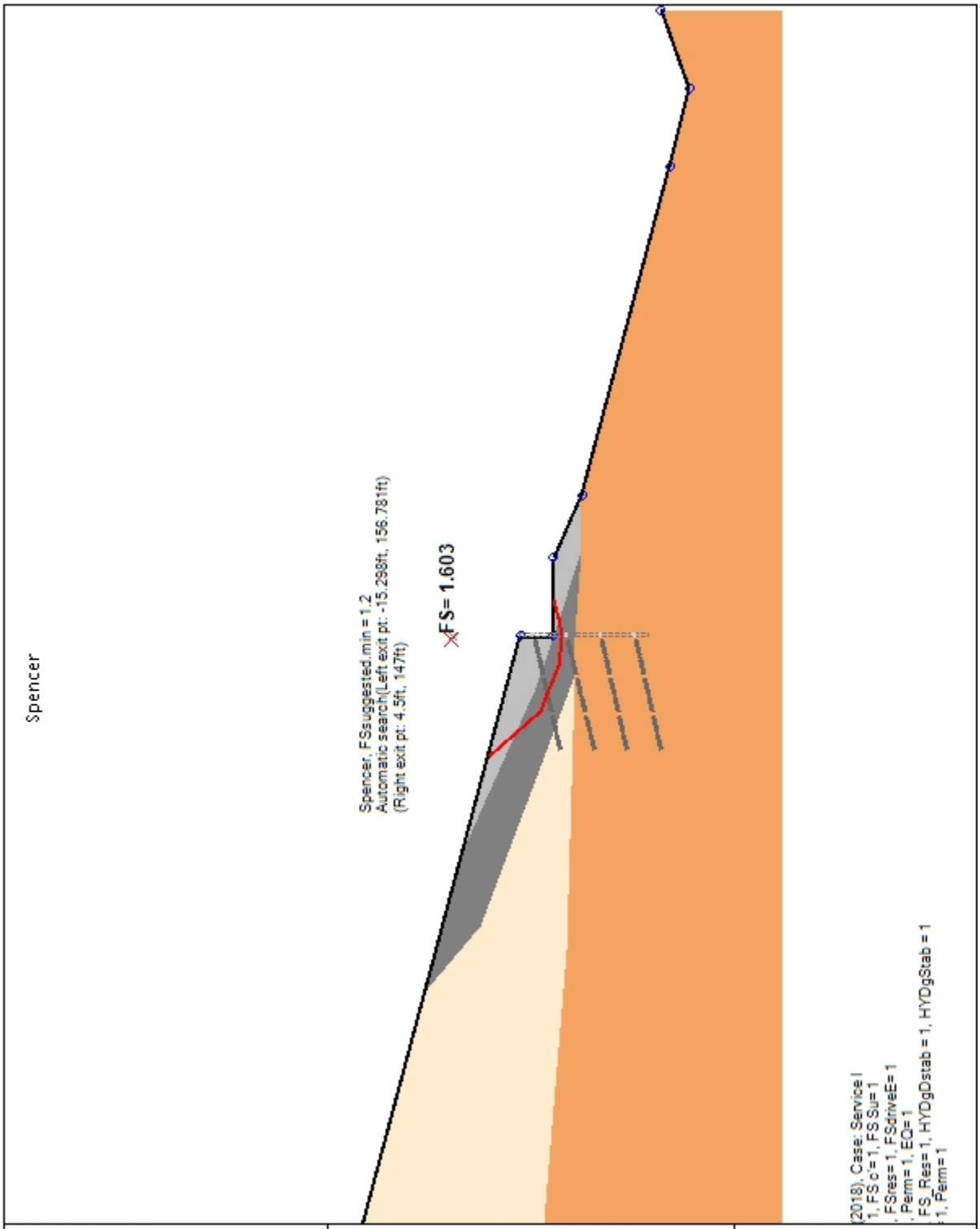
17/20



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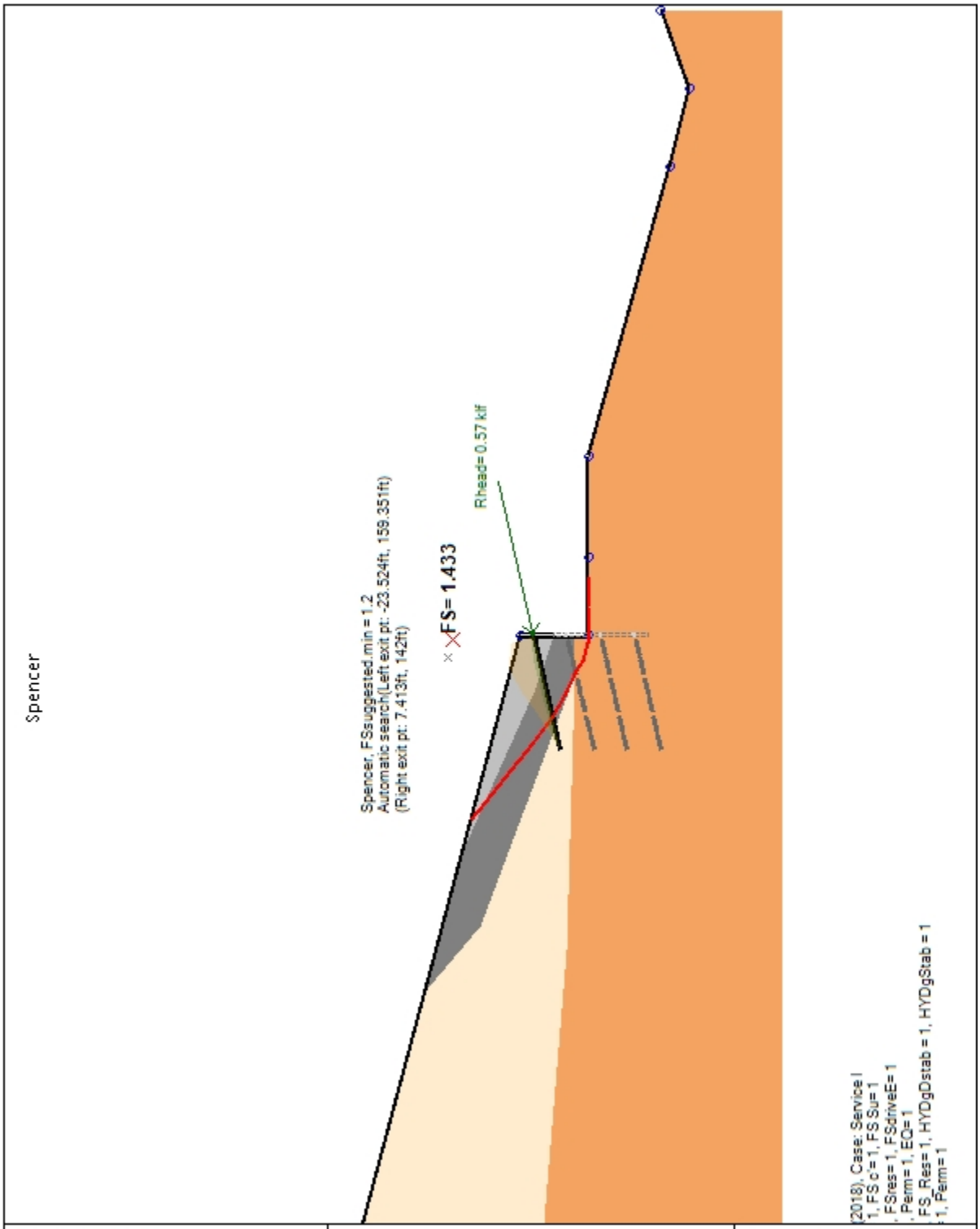
18/20



Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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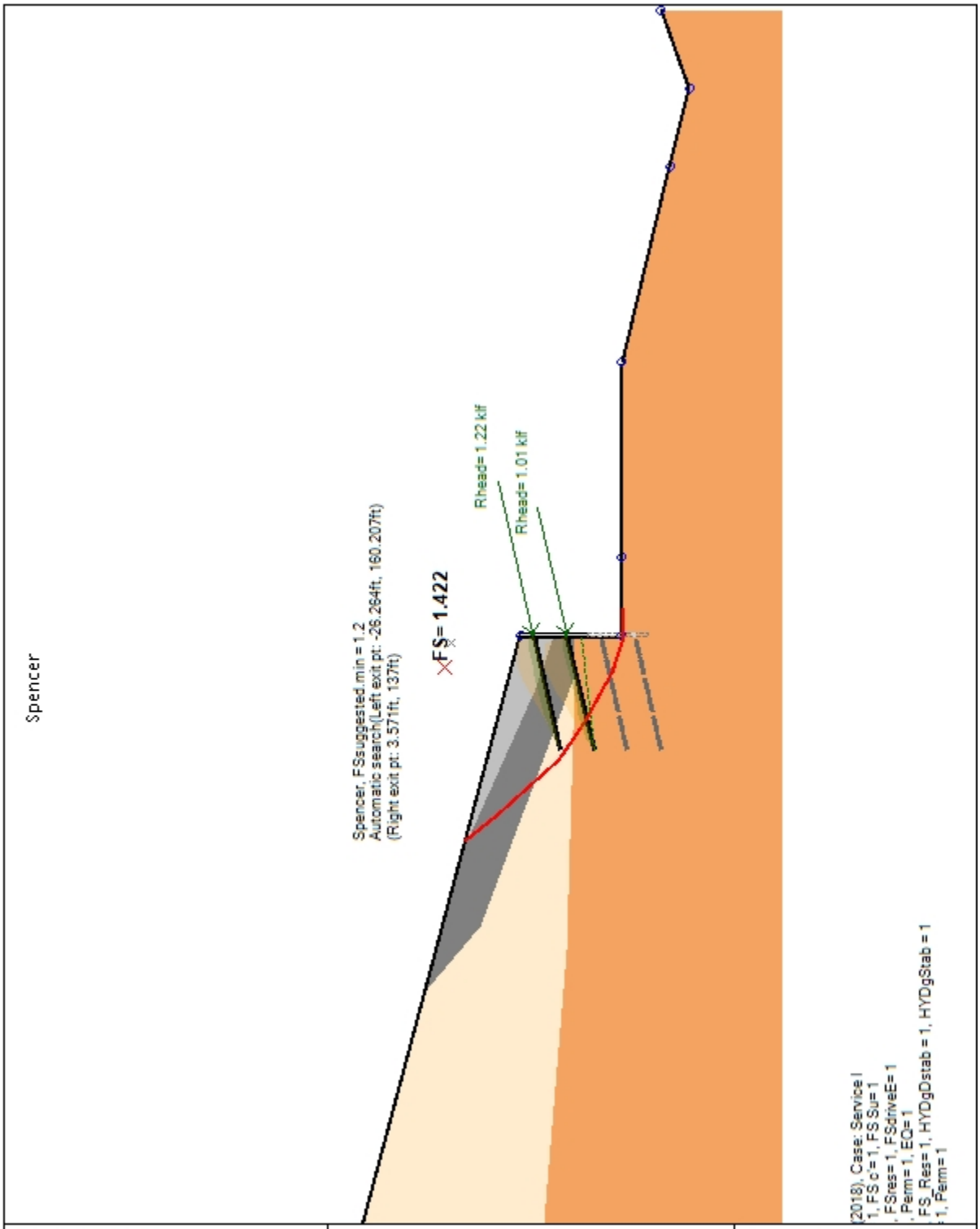

Company: Wood Engineer: DL	DS: 0, Exc. 137 ft	Deep Excavation LCC SnailPlus 2021
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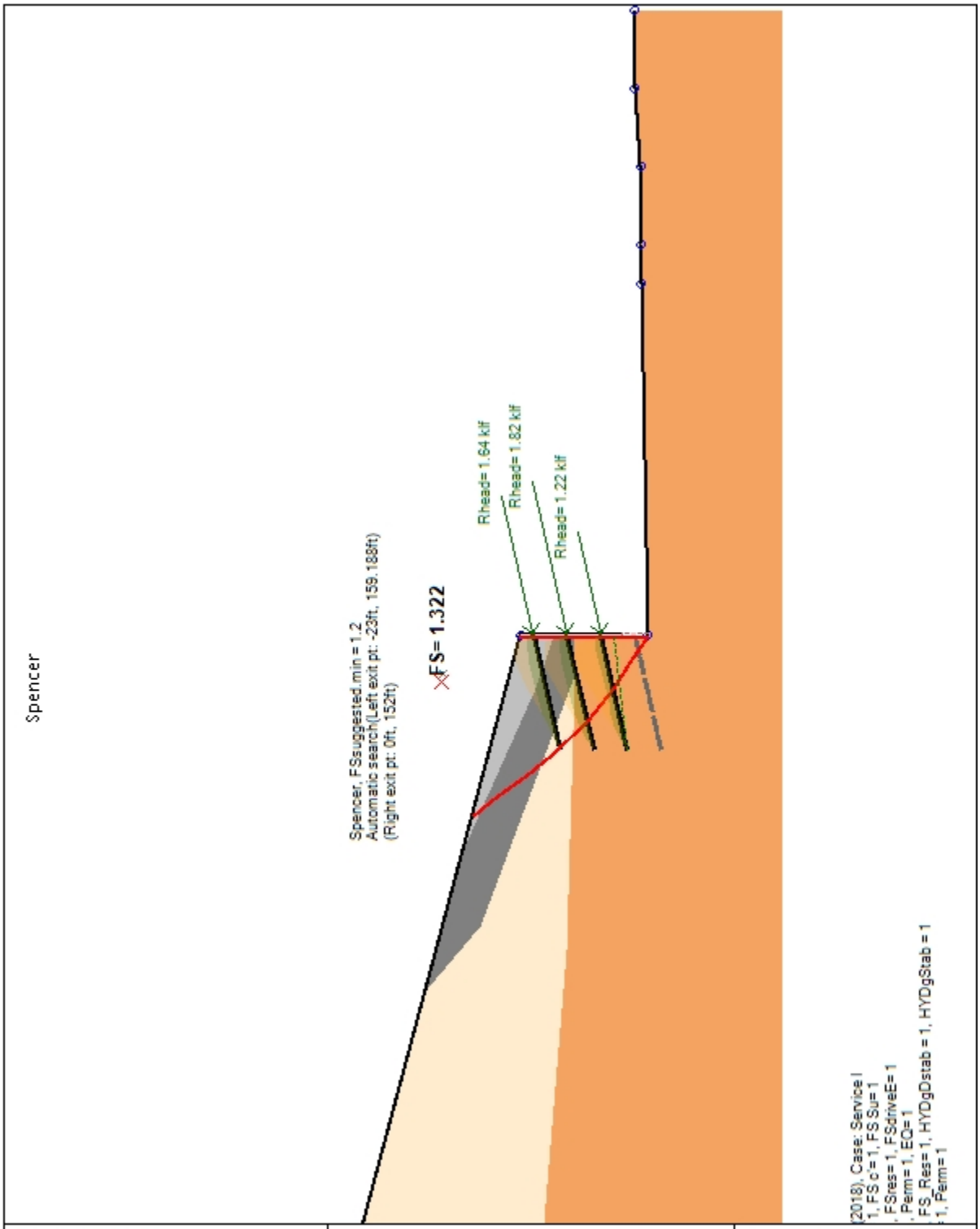

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..+40\New Stratigraphy\CS Sta 1+40 (Temp Static, Spencer).SNLP		12/1/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 1+40 (Seismic, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 7:50:48 AM

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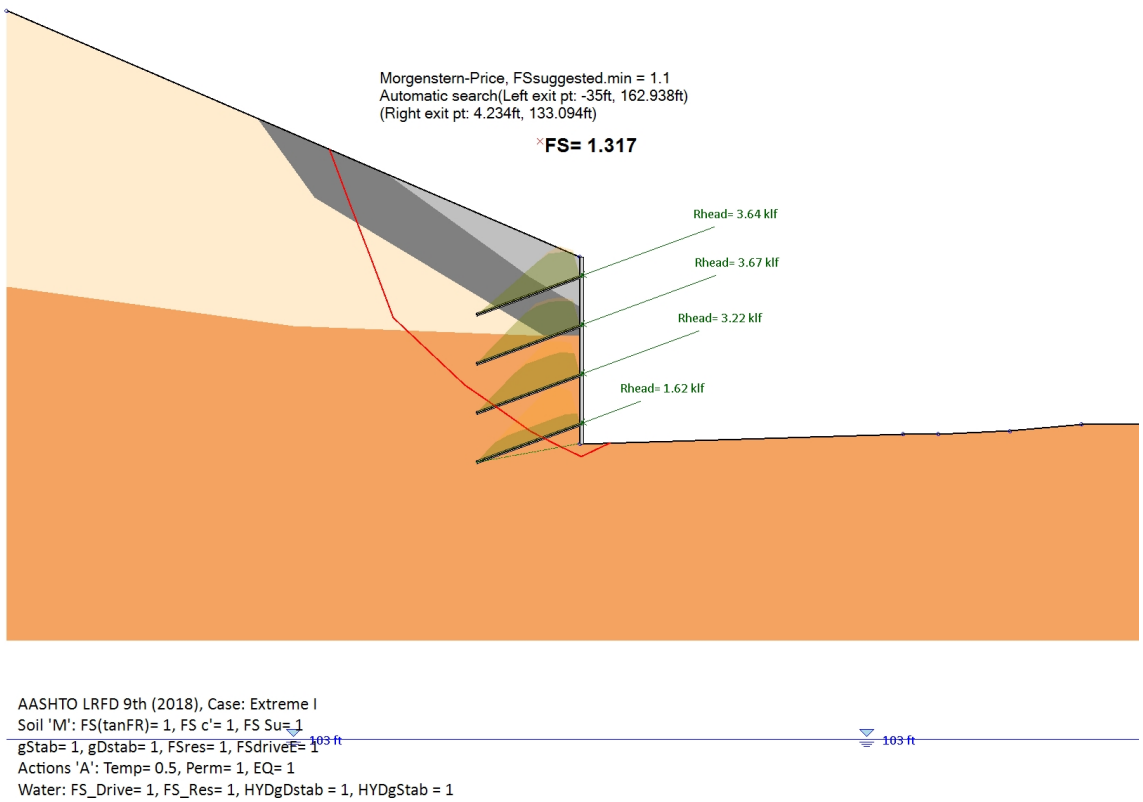
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\1+40\New Stratigraphy\CS Sta 1+40 (Seismic, M-P).SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Stage 0	Calculated	1.517	24.9	22.86	22.86	0.56	0.882	0.29	No	Yes
Project Wall	Calculated	1.325	24.9	22.86	22.86	0.592	0.882	0.29	No	Yes
Project Wall	Calculated	1.747	24.9	22.86	22.86	0.592	0.882	0.29	No	Yes
Forward Com	Calculated	1.317	28.79	22.86	28.79	0.776	0.882	0.321	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)

STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Stage 0	Yes	1.517	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.325	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.747	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.317	1.1	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
xL (-45 to -5)	xR (0.1 to 20)	N/A	AASHTO LRF	Service I	36.4	0.56	N/A	N/A	N/A
xL (-55 to -5)	xR (0.1 to 20)	N/A	AASHTO LRF	Extreme I	37.21	0.592	N/A	N/A	N/A
xL (-80 to -40	xR (13 to 80)	N/A	AASHTO LRF	Extreme I	0	0.592	N/A	N/A	N/A
xL (-35 to -1)	xR (0.5 to 23)	N/A	AASHTO LRF	Extreme I	38.51	0.776	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-35ft to -1ft
Right limits	0.5ft to 23ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Extreme I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	0.5
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N1	0: N1	15	0	150	15	0	6	3.6406	21.84
N2	0: N1	15	0	145	15	0	6	3.8097	22.86
N3	0: N1	15	0	140	15	0	6	3.2171	19.3
N4	0: N1	15	0	135	15	0	6	1.6156	9.69

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	177
2	0	152
3	0	133
4	45	134
5	50	134
6	60	134.3
7	70	135
8	80	135

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 1B	120	120	35	0	N/A	18	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table

c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
150	ESU 1A	1	0.47
146.96	ESU 1B	1	0.43
143.99	ESU 4A	1	0.33

Slope stability assumptions: Stage 0

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-35ft to -1ft
Right limits	0.5ft to 23ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-35ft to -1ft
Right limits	0.5ft to 23ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-35ft to -1ft
Right limits	0.5ft to 23ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -40ft
Right search limits: xRmin= 13ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

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Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-35ft to -1ft
Right limits	0.5ft to 23ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -35ft, xLmax= -1ft
Right search limits: xRmin= 0.5ft, xRmax= 23ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P

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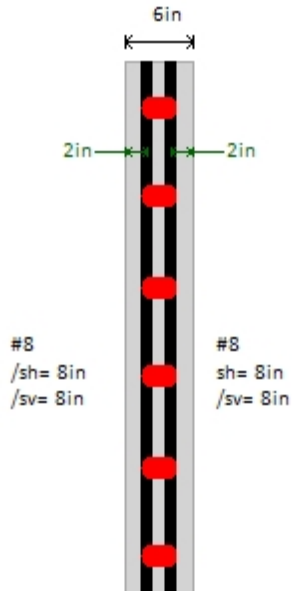

Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Stage 0	Yes	152	133	N/A	6
Project Wall Height	Yes	152	143	N/A	6
Project Wall Height-G	Yes	152	143	N/A	6
Forward Compatible	Yes	152	133	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N1	0: N1	15	0	150	15	0	6	0.79	6	75
N2	0: N1	15	0	145	15	0	6	0.79	6	75
N3	0: N1	15	0	140	15	0	6	0.79	6	75
N4	0: N1	15	0	135	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N1	150	6	1	36	1	N/A	N/A	N/A
N2	145	6	1	36	1	N/A	N/A	N/A
N3	140	6	1	36	1	N/A	N/A	N/A
N4	135	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -4.342 z= 163.357 FS= 1.325

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	28.06	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	15.27	37.21	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -0.555 z= 162.173 FS= 1.747

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	0	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N2	0	0	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -5.574 z= 163.742 FS= 1.317

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	31.06	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	0	31.14	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	8.83	37.7	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	31.39	38.51	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)

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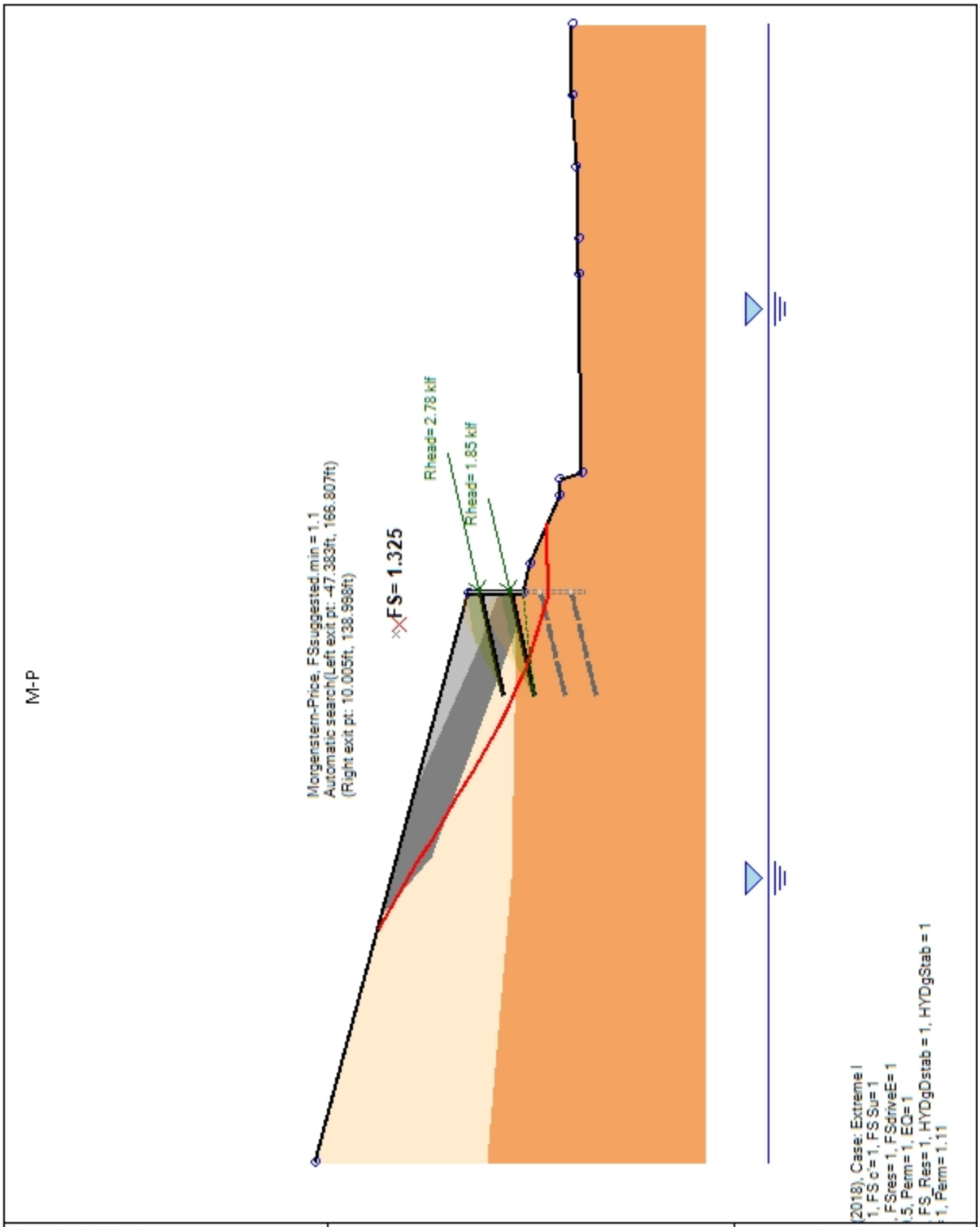

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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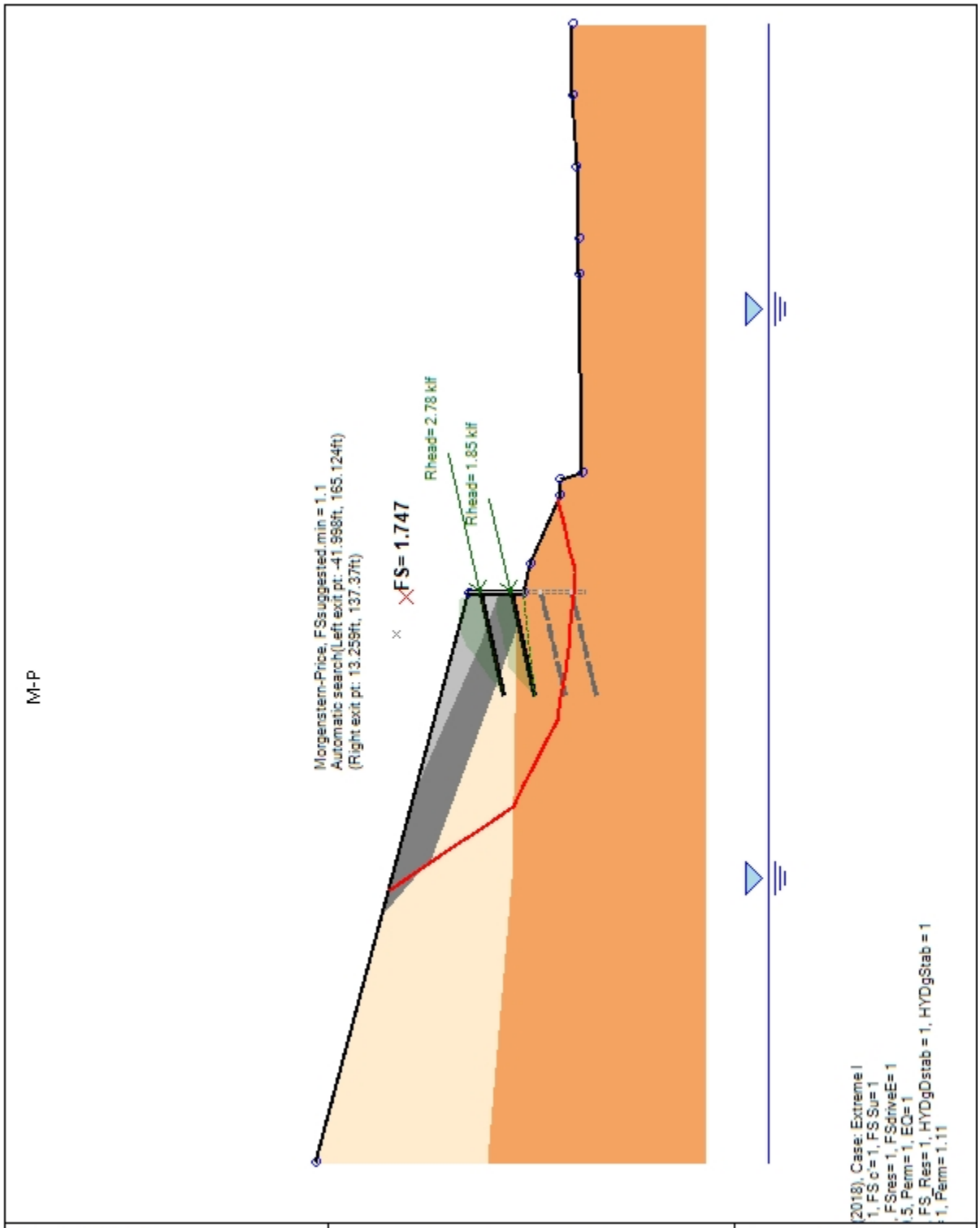

Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
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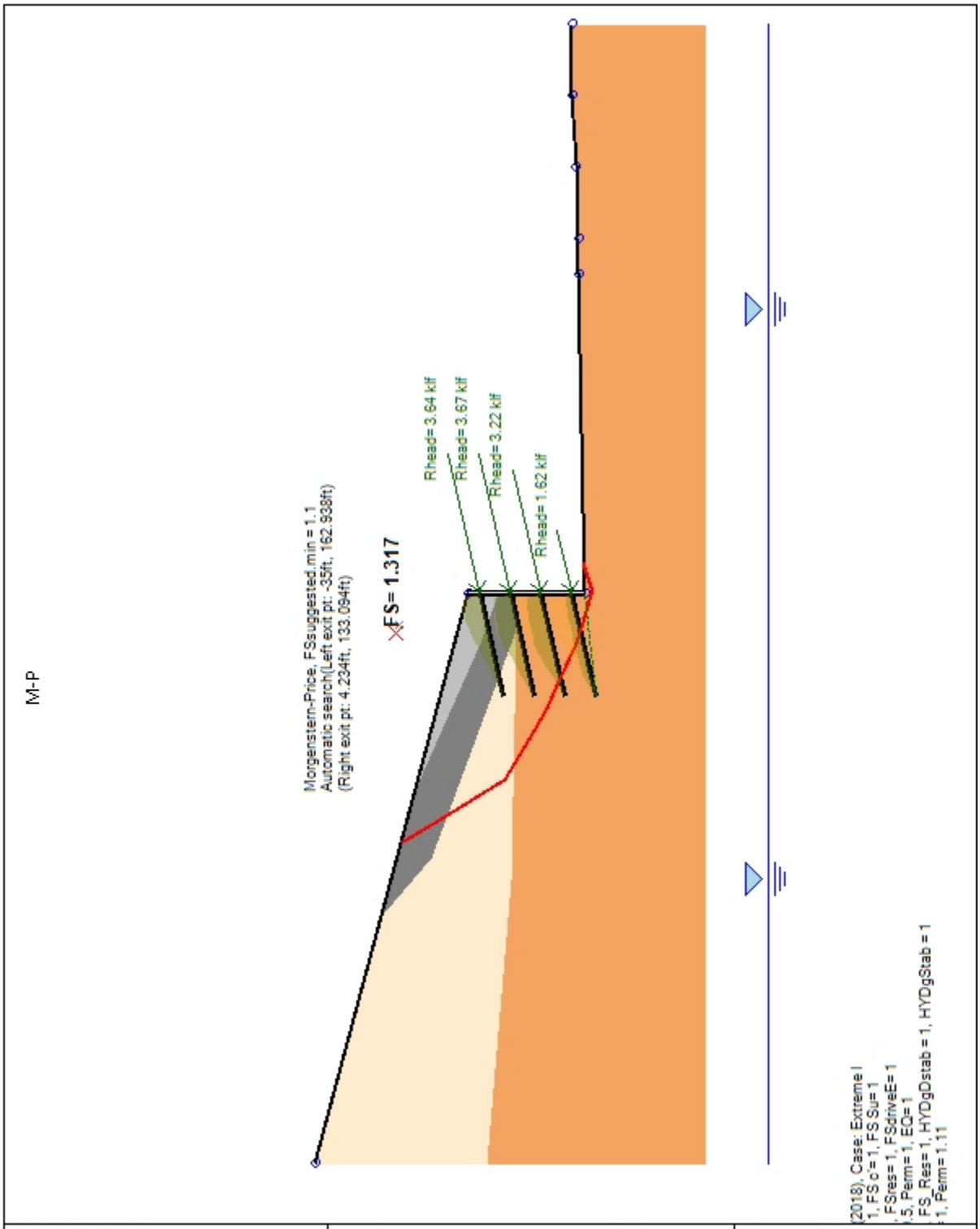

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us.. Files\1+40\New Stratigraphy\CS Sta 1+40 (Seismic, M-P).SNLP		12/2/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 1+40 (Seismic, Bishop)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 7:58:21 AM

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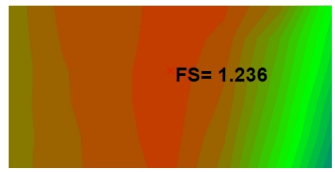
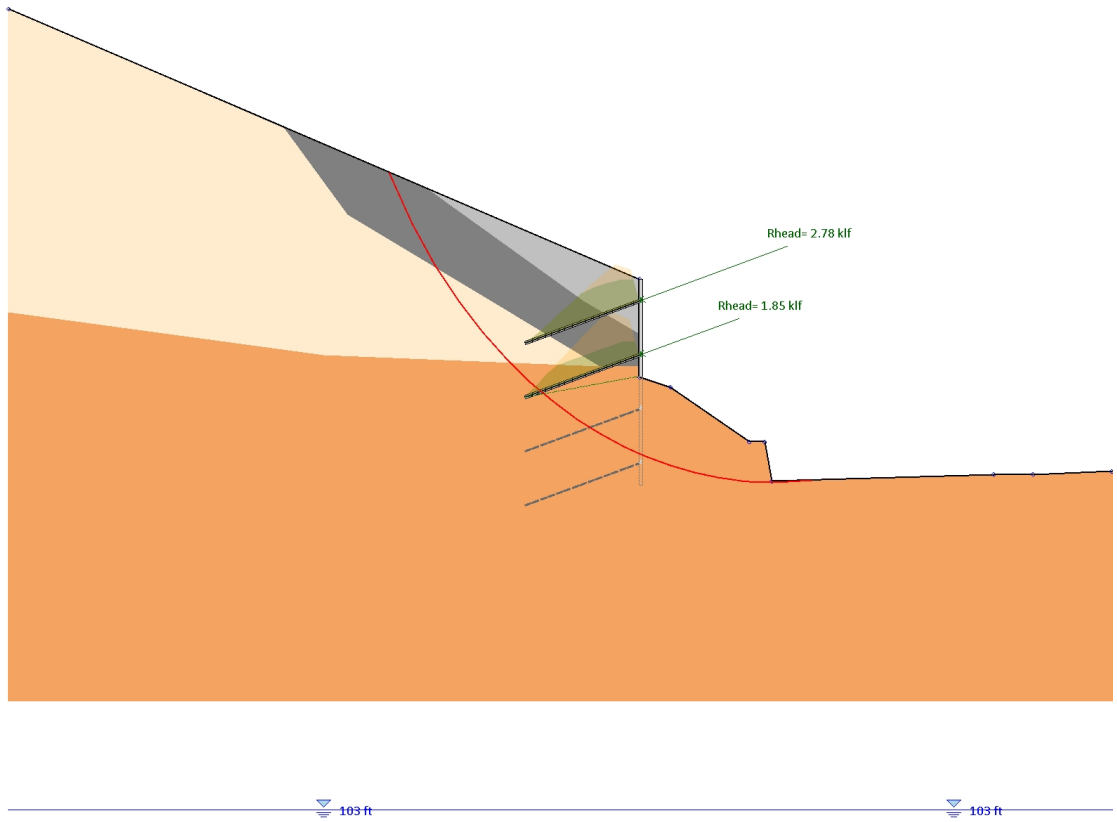
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\1+40\New Stratigraphy\CS Sta 1+40 (Seismic, Bishop).SNLP

Quick analysis summary for design section: Bishop

ESU 4A	135	0	-	42	22

Bishop





AASHTO LRFD 9th (2018), Case: Extreme I
Soil 'M': FS(tanFR)= 1, FS c'= 1, FS Su= 1
gStab= 1, gDstab= 1, FSres= 1, FSdriveE= 1
Actions 'A': Temp= 0.5, Perm= 1, EQ= 1
Water: FS_Drive= 1, FS_Res= 1, HYDgDstab = 1, HYDgStab = 1

Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Stage 0	Calculated	1.517	24.9	22.86	22.86	0.56	0.882	0.29	No	Yes
Project Wall	Calculated	5.005	24.9	22.86	22.86	0.592	0.882	0.29	No	Yes
Project Wall	Calculated	1.236	24.9	22.86	22.86	0.592	0.882	0.29	No	Yes
Project Wall	Calculated	1.299	24.9	22.86	22.86	0.592	0.882	0.29	No	Yes
Forward Com	Calculated	3.317	28.79	22.86	28.79	0.776	0.882	0.321	No	Yes
Project Wall	Calculated	1.388	28.79	22.86	28.79	0.776	0.882	0.321	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Stage 0	Yes	1.517	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	5.005	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.236	1.1	Circle	16.958	189	55.736	N/A	N/A
Project Wall	Yes	1.299	1.1	Circle	16.833	190	58.475	N/A	N/A
Forward Co	Yes	3.317	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.388	1.1	Circle	6.211	184	52.377	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
xL (-45 to -5)	xR (0.1 to 20)	N/A	AASHTO LRF	Service I	36.4	0.56	N/A	N/A	N/A
xL (-45 to -5)	xR (0.1 to 20)	N/A	AASHTO LRF	Extreme I	37.21	0.592	1494.909	0	-362.435
N/A	N/A	N/A	AASHTO LRF	Extreme I	37.37	0.592	86.082	0	542.487
N/A	N/A	N/A	AASHTO LRF	Extreme I	20.97	0.592	0	0	763.443
xL (-35 to -1)	xR (0.5 to 23)	N/A	AASHTO LRF	Extreme I	38.51	0.776	2054.626	0	-1187.19
N/A	N/A	N/A	AASHTO LRF	Extreme I	38.51	0.776	300.217	0	723.467

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Extreme I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	0.5
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N1	0: N1	15	0	150	15	0	6	3.6406	21.84
N2	0: N1	15	0	145	15	0	6	3.8097	22.86
N3	0: N1	15	0	140	15	0	6	3.2171	19.3
N4	0: N1	15	0	135	15	0	6	1.6156	9.69

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	177
2	0	152
3	0	133
4	45	134
5	50	134
6	60	134.3
7	70	135
8	80	135

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 1B	120	120	35	0	N/A	18	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table

c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
150	ESU 1A	1	0.47
146.96	ESU 1B	1	0.43
143.99	ESU 4A	1	0.33

Slope stability assumptions: Stage 0

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Auto

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -45ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Circ

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 148ft
Radii search ends at point x= 0ft, z= 128ft
10 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Circ-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 134ft
Radii search ends at point x= 0ft, z= 114ft
10 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall-Auto

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -35ft, xLmax= -1ft
Right search limits: xRmin= 0.5ft, xRmax= 23ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

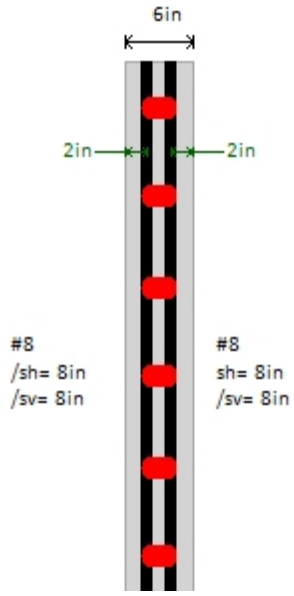
Slope stability assumptions: Project Wall Height-Circ

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.23g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = 2 ft, Right = 20 ft, Horizontal intervals = 6
Top = 152 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 141ft
Radii search ends at point x= 0ft, z= 126ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Bishop



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Stage 0	Yes	152	133	N/A	6
Project Wall Height-A	Yes	152	143	N/A	6
Project Wall Height-Ci	Yes	152	143	N/A	6
Project Wall Height-Ci	Yes	152	143	N/A	6
Forward Compatible	Yes	152	133	N/A	6
Project Wall Height-Ci	Yes	152	133	N/A	6

Soil nail input data for design section Bishop

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N1	0: N1	15	0	150	15	0	6	0.79	6	75
N2	0: N1	15	0	145	15	0	6	0.79	6	75
N3	0: N1	15	0	140	15	0	6	0.79	6	75
N4	0: N1	15	0	135	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N1	150	6	1	36	1	N/A	N/A	N/A
N2	145	6	1	36	1	N/A	N/A	N/A
N3	140	6	1	36	1	N/A	N/A	N/A
N4	135	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Bishop

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -3.542 z= 163.107 FS= 5.005

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	15.53	28.06	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	36.88	37.21	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 16.958 z= 189 FS= 1.236

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	32.81	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	6.91	37.37	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= 16.833 z= 190 FS= 1.299

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	7.57	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	0	20.97	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -7.456 z= 164.33 FS= 3.317

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	31.06	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	7.92	31.14	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	22.2	37.7	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	38.51	38.51	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	STR

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= 6.211 z= 184 FS= 1.388

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N1	0	21.88	53.32	36.76	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N2	0	37.39	53.32	46.07	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N3	0	38.51	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N4	26.36	38.46	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F	= Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax	= Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR	= Tensile structural design capacity for soil nail
CAP GEO	= Tensile geotechnical pull out resistance for soil nail
TcapGEO	= Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1	= Structural soil nail shear resistance
TC2	= Shear resistance according to Clouterre TC2 criterion
TC3	= Shear resistance according to Clouterre TC3 criterion
TC4	= Shear resistance according to Clouterre TC4 criterion
TC4 C4	= Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS	= Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po	= Soil lateral pressure at failure surface-soil nail intersection point
Pu	= Ultimate lateral pressure at failure surface-soil nail intersection point
Lo	= Flexure length for shear calculations
IxxCalc	= Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc	= Nail section modulus (adjusted for corrosion loss if assumed)
t.loss	= Structural thickness loss (if assumed by the user)
%STR	= Structural capacity loss as a percentage (if assumed by the user)

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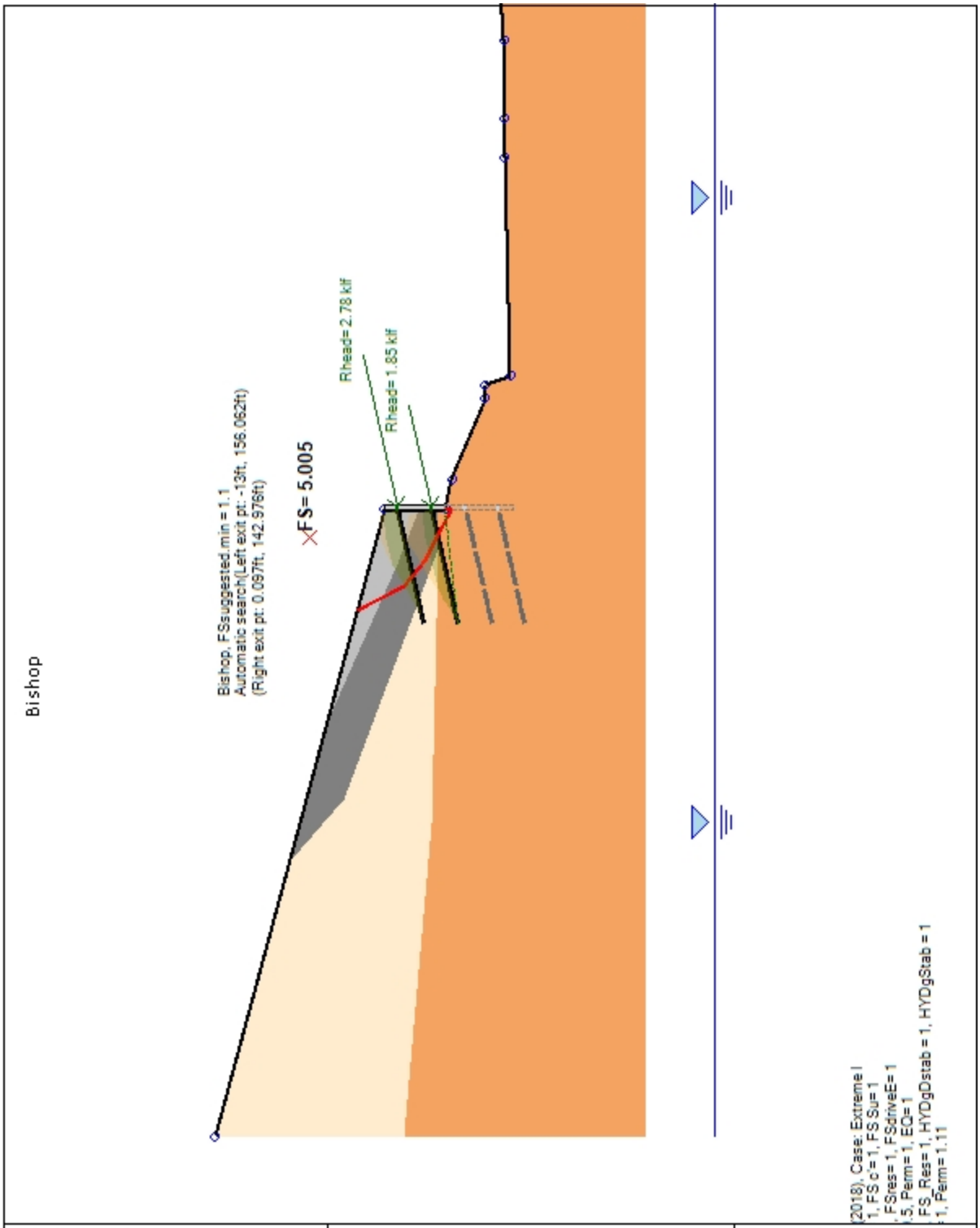

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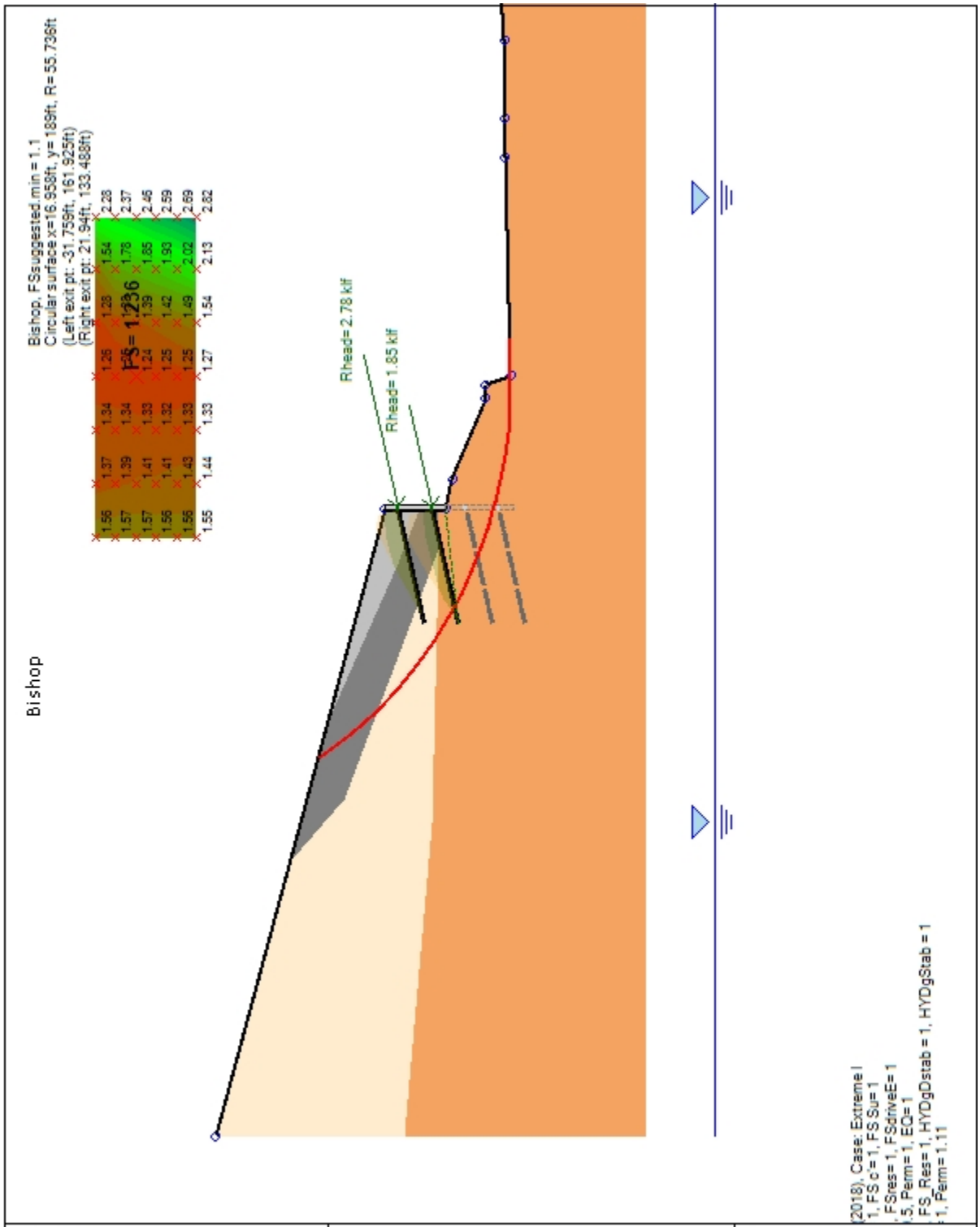

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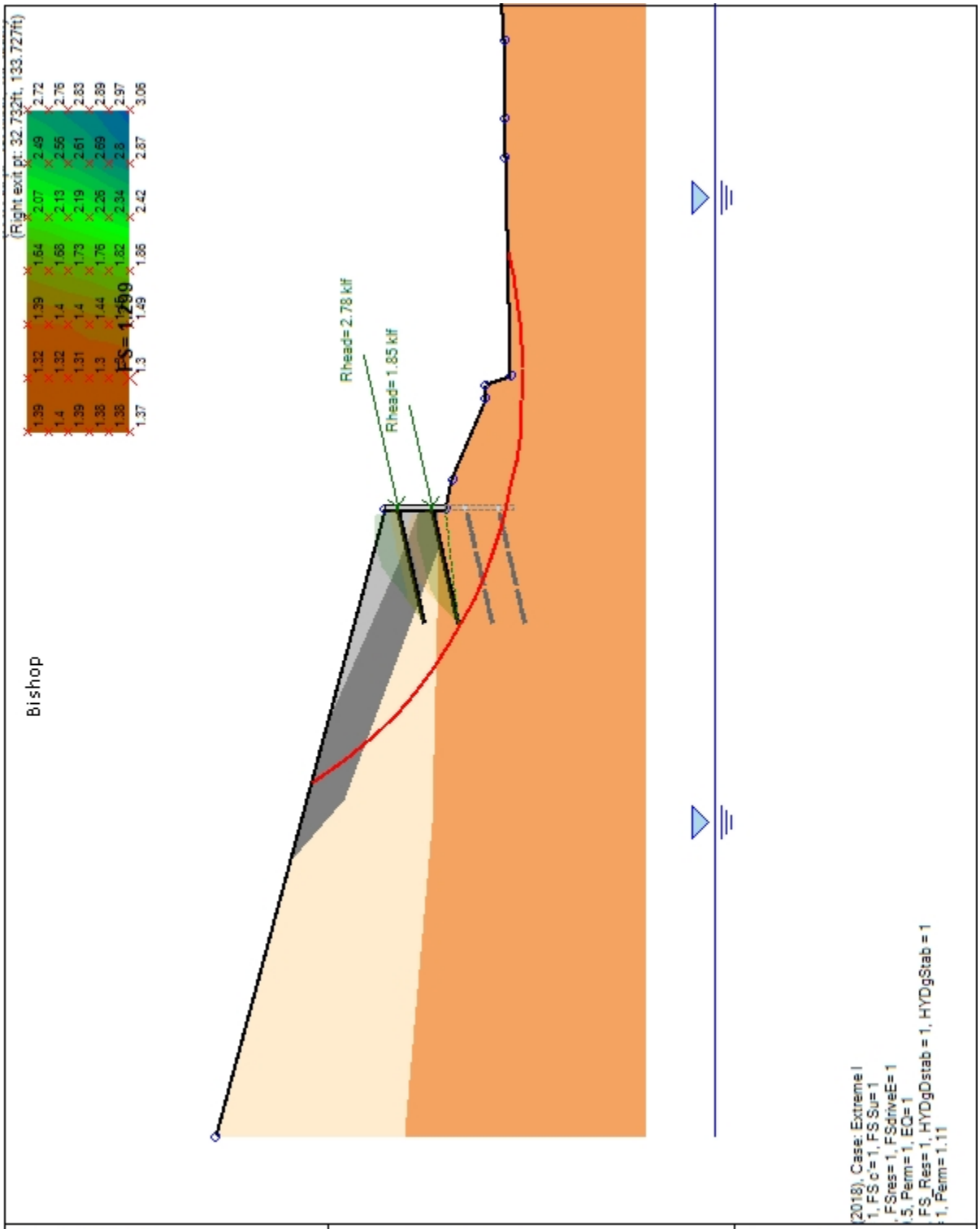

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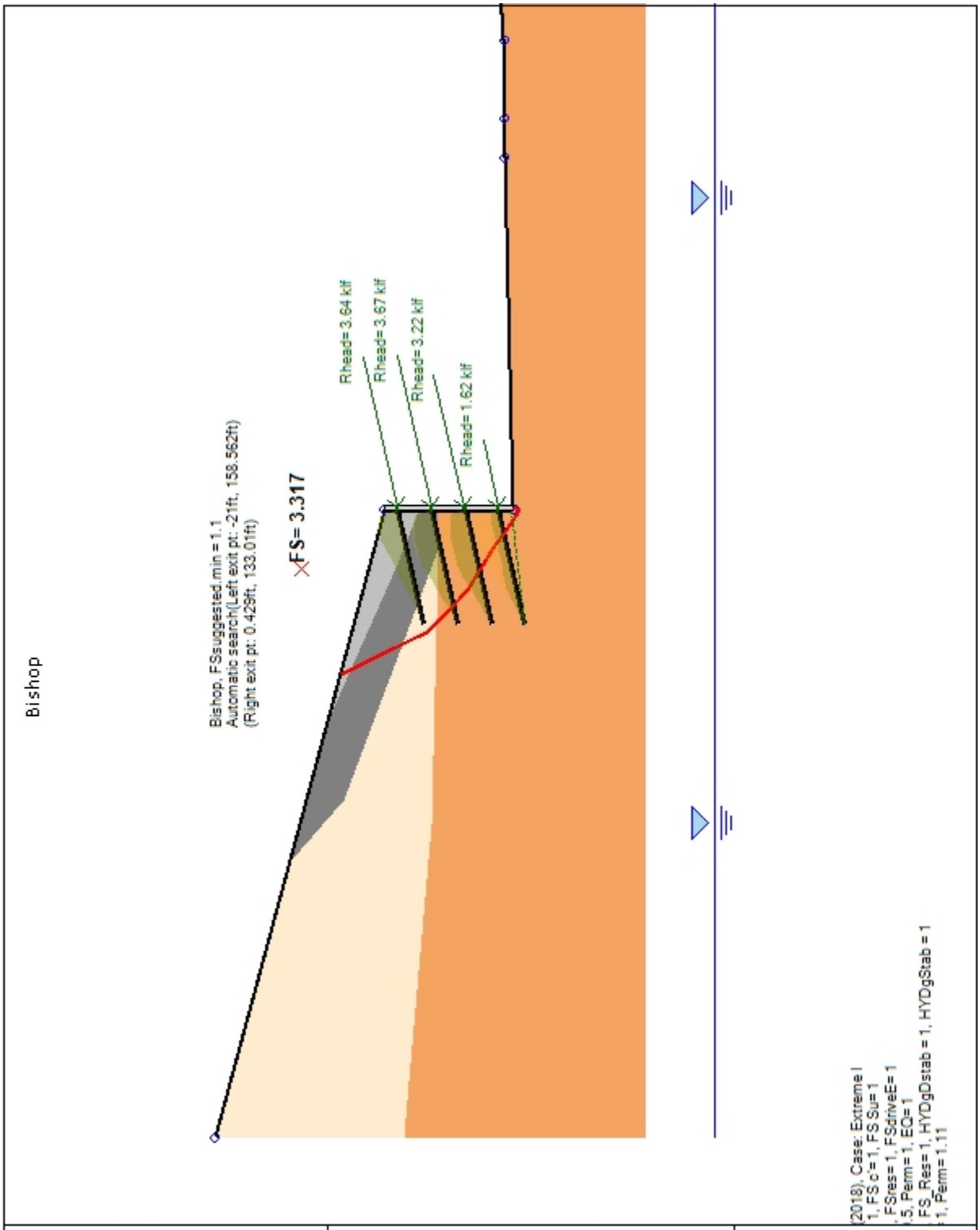

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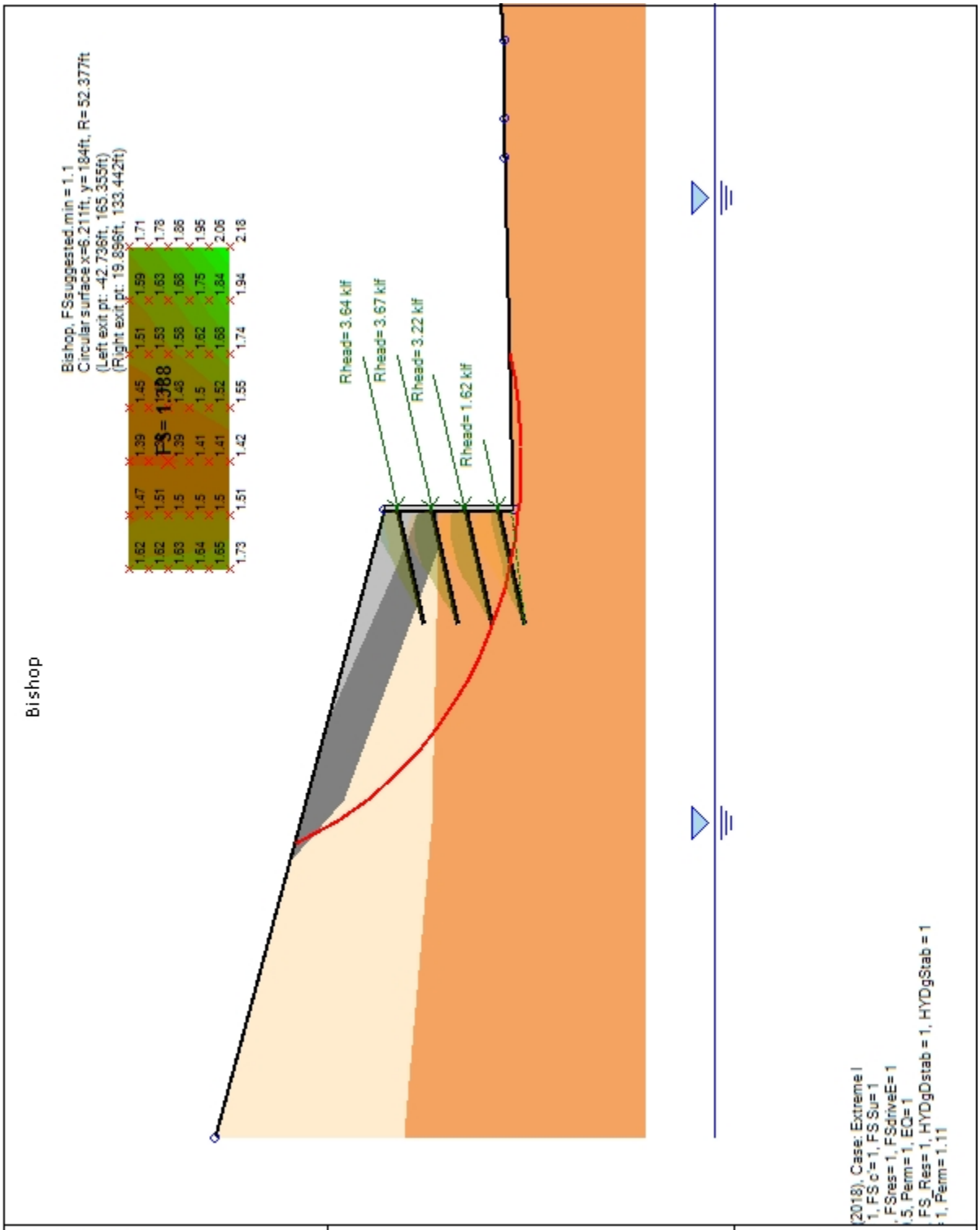

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C:\Us..les\1+40\New Stratigraphy\CS Sta 1+40 (Seismic, Bishop).SNLP		12/2/2021

SnailPlus 2021: Report Output

Copyright@2009 - 2020 Deep Excavation LLC: www.deepexcavation.com A program for the evaluation of soil nail walls. Deep Excavation LLC, Astoria, New York, www.deepexcavation.com

Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 3+80 (Perm Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 5:07:27 PM

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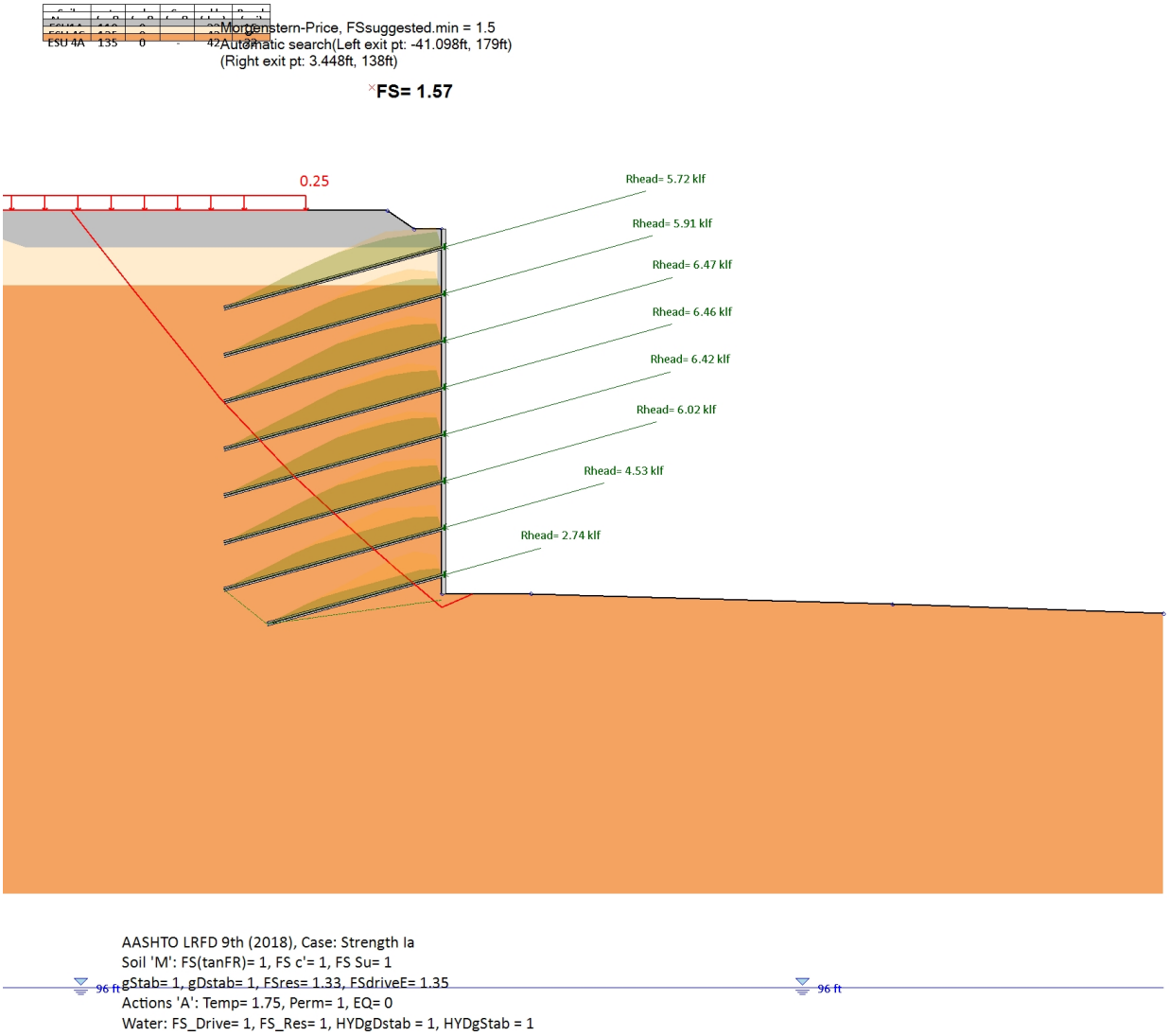
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, M-P).SNLP

Quick analysis summary for design section: M-P

M-P



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	2.096	0	0	0	0	0	0	No	Yes
Exc. 172 ft	Calculated	7.308	4.45	3.14	4.45	0.068	0.08	0.038	No	Yes
Exc. 167 ft	Calculated	4.572	11.02	7.76	11.02	0.169	0.199	0.095	No	Yes
Exc. 162 ft	Calculated	3.455	17.47	12.31	17.47	0.248	0.316	0.151	No	Yes
Exc. 157 ft	Calculated	3.024	24.89	17.65	25.04	0.351	0.452	0.216	No	Yes
Exc. 152 ft	Calculated	2.227	30.7	21.77	30.88	0.432	0.558	0.267	No	Yes

Project Wall	Calculated	1.902	36.15	25.63	36.37	0.509	0.657	0.314	No	Yes
Project Wall	Calculated	2.729	36.15	25.63	36.37	0.509	0.657	0.314	No	Yes
Exc. 142 ft	Calculated	1.807	41.53	29.45	41.78	0.585	0.755	0.361	No	Yes
Forward Com	Calculated	1.57	45.64	32.36	45.91	0.643	0.829	0.397	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	2.096	1.5	Circle	34.575	207.1	47.179	N/A	N/A
Exc. 172 ft	Yes	7.308	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 167 ft	Yes	4.572	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 162 ft	Yes	3.455	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	3.024	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	2.227	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.902	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	2.729	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 142 ft	Yes	1.807	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.57	1.5	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 20)	N/A	AASHTO LRF	Strength Ia	52.52	0.068	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	59.7	0.169	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	60.54	0.248	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	60.56	0.351	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.77	0.432	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.75	0.509	N/A	N/A	N/A
xL (-80 to -58	xR (30 to 80)	N/A	AASHTO LRF	Strength Ia	0	0.509	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.66	0.585	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 25)	N/A	AASHTO LRF	Strength Ia	60.54	0.643	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	175	25	0	5	5.7235	28.62
N1	0: N1	15	0	170	25	0	5	5.9051	29.53
N2	0: N1	15	0	165	25	0	5	6.4721	32.36
N3	0: N1	15	0	160	25	0	5	6.4648	32.32
N4	0: N1	15	0	155	25	0	5	6.4185	32.09
N5	0: N1	15	0	150	25	0	5	6.0249	30.12
N6	0: N1	15	0	145	25	0	5	4.5323	22.66
N7	0: N1	15	0	140	20	0	5	2.7355	13.68

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	193
2	-58	179
3	-6	179
4	-3	177
5	0	177
6	0	138
7	10	138
8	50	137
9	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU1A	110	110	32	0	N/A	15	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
177	ESU 4C	1	0.32
160	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 175ft
Radii search ends at point x= 0ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 172 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 167 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -58ft
Right search limits: xRmin= 30ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 142 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

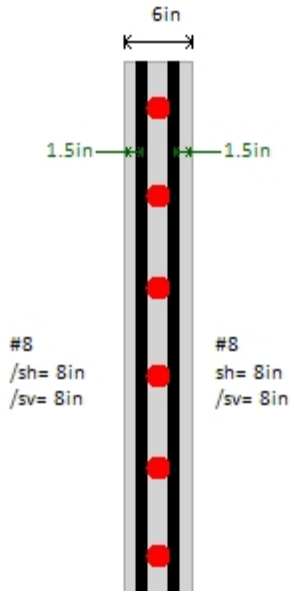
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	177	136	N/A	6
Exc. 172 ft	Yes	177	172	N/A	6
Exc. 167 ft	Yes	177	167	N/A	6
Exc. 162 ft	Yes	177	162	N/A	6
Exc. 157 ft	Yes	177	157	N/A	6
Exc. 152 ft	Yes	177	152	N/A	6
Project Wall Height	Yes	177	147	N/A	6
Project Wall Height-G	Yes	177	147	N/A	6
Exc. 142 ft	Yes	177	142	N/A	6
Forward Compatible	Yes	177	136	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	175	25	0	5	1.27	6	75
N1	0: N1	15	0	170	25	0	5	1.27	6	75
N2	0: N1	15	0	165	25	0	5	1.27	6	75
N3	0: N1	15	0	160	25	0	5	1.27	6	75
N4	0: N1	15	0	155	25	0	5	1.27	6	75
N5	0: N1	15	0	150	25	0	5	1.27	6	75
N6	0: N1	15	0	145	25	0	5	1.27	6	75
N7	0: N1	15	0	140	20	0	5	1.27	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	175	8	2.25	36	1	N/A	N/A	N/A
N1	170	8	2.25	36	1	N/A	N/A	N/A
N2	165	8	2.25	36	1	N/A	N/A	N/A
N3	160	8	2.25	36	1	N/A	N/A	N/A
N4	155	8	2.25	36	1	N/A	N/A	N/A
N5	150	8	2.25	36	1	N/A	N/A	N/A
N6	145	8	2.25	36	1	N/A	N/A	N/A
N7	140	8	2.25	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 34.575 z= 207.1 FS= 2.096

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -1.289 z= 190.1 FS= 7.308

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.52	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 0.917 z= 190.1 FS= 4.572

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	38.14	51.07	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	59.34	59.7	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -3.309 z= 190.306 FS= 3.455

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	30.31	52.1	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	47.06	60.54	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	54.8	59.92	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -4.011 z= 190.774 FS= 3.024

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	12.28	52.57	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	31.42	59.73	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	50.64	55.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	53.58	60.56	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -5.285 z= 191.623 FS= 2.227

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.92	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	9.63	56.86	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	26.11	54.46	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	42.81	59.63	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	60.38	60.77	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 6

Soil nail results available for this stage.

Critical point at x= -6.499 z= 192.1 FS= 1.902

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.86	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	3.42	57.35	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	18.19	55.72	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	32.96	53.01	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	50.22	60.5	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	54.11	60.75	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 7

Soil nail results available for this stage.

Critical point at x= 2.887 z= 190.1 FS= 2.729

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N1	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N2	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A

3: N3	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
4: N4	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
5: N5	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 8

Soil nail results available for this stage.

Critical point at x= -5.038 z= 191.459 FS= 1.807

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.71	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	57.67	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	9.87	56.18	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	22.78	53.98	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	36.33	57.34	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	52.63	60.64	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	52.46	60.66	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 9

Soil nail results available for this stage.

Critical point at x= -7.689 z= 192.1 FS= 1.57

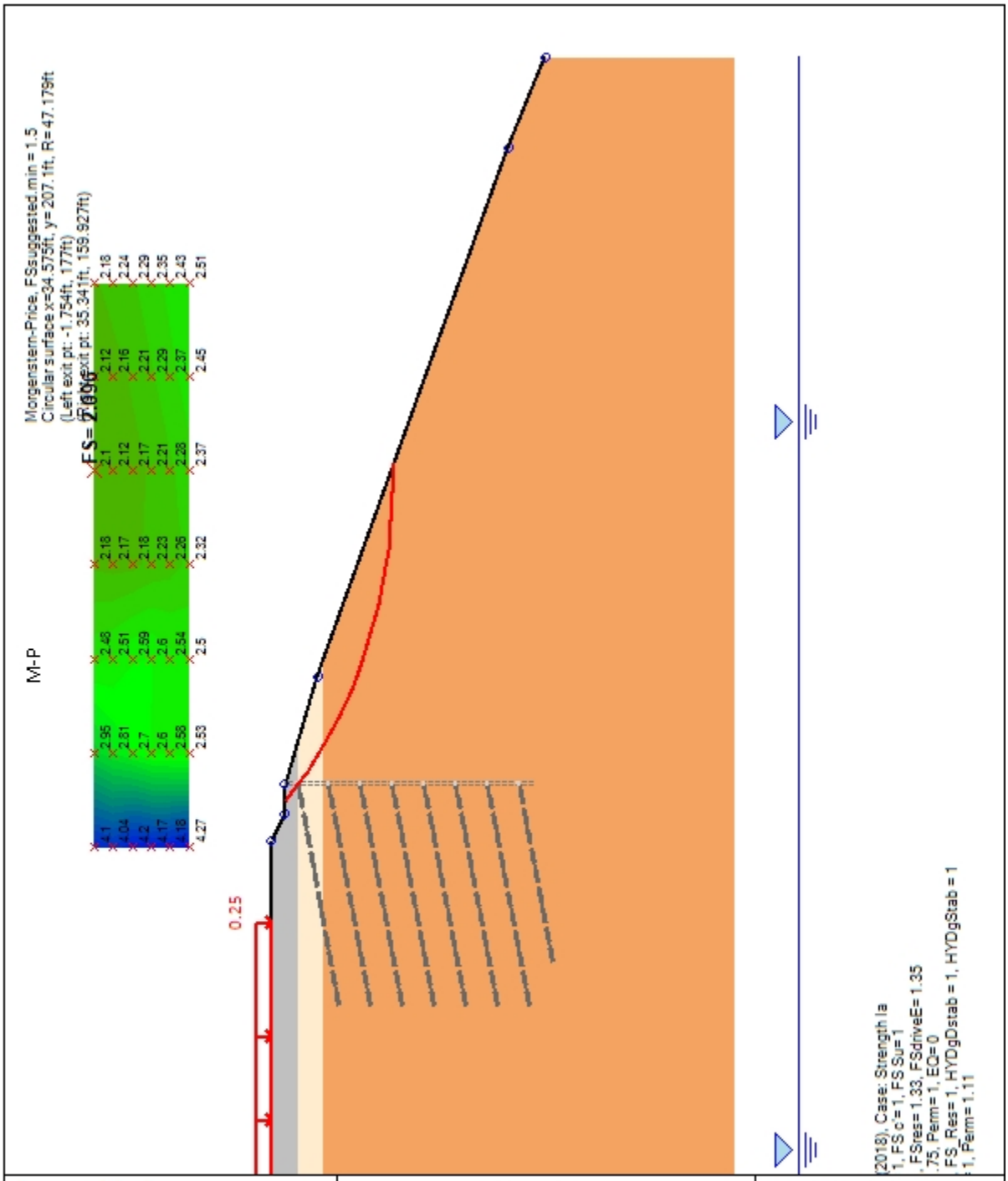
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.56	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	58.48	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0.04	57.37	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	13.11	56.27	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	26.18	54.76	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	40.67	59.94	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	55.17	60.54	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: N7	51.12	52.63	85.72	64.69	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE

GENERAL SOIL NAIL DATA

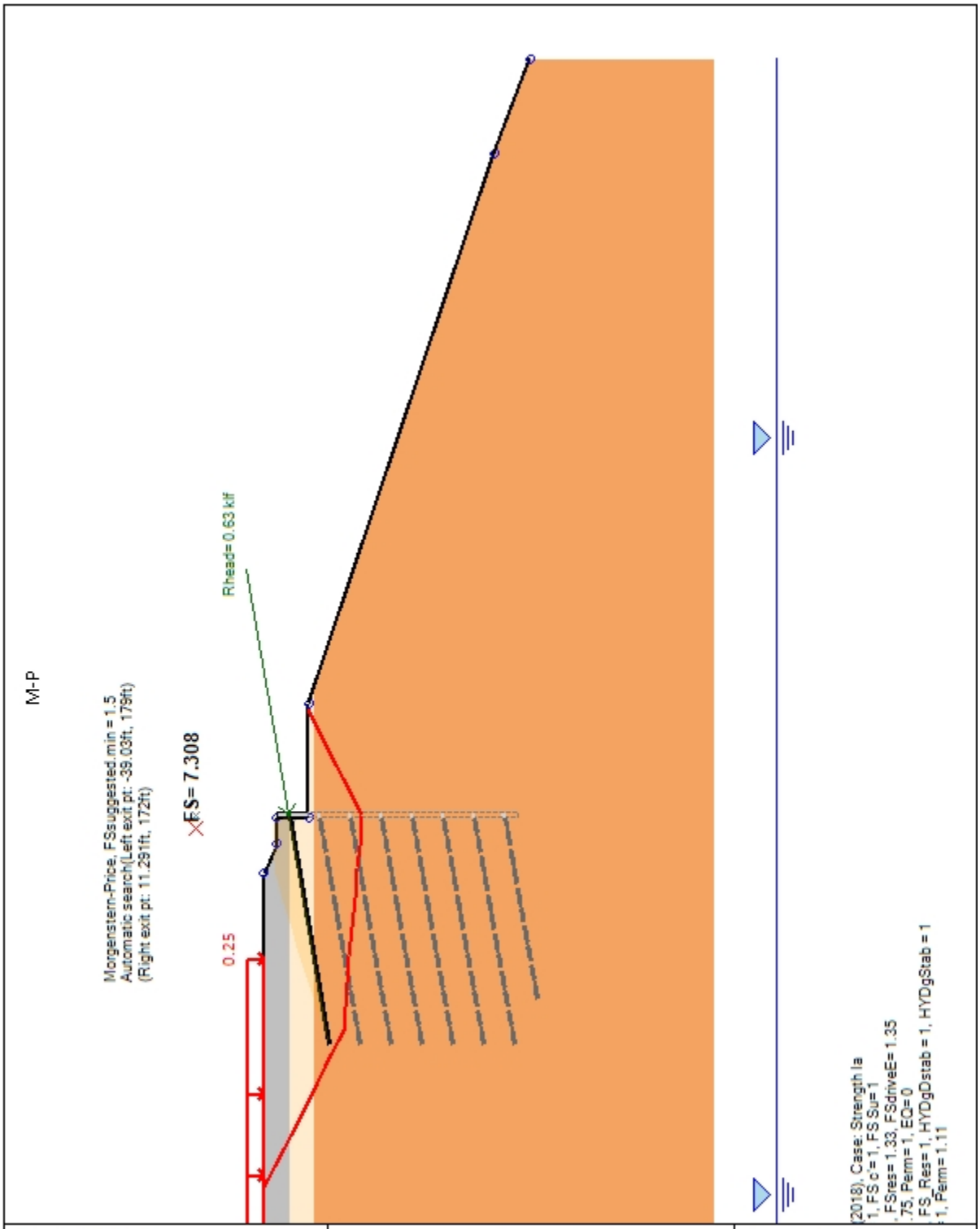
Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
C:\Us..es\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, M-P).SNLP		12/1/2021



Company: Wood Engineer: DL	DS: 0, Exc. 172 ft	Deep Excavation LCC SnailPlus 2021
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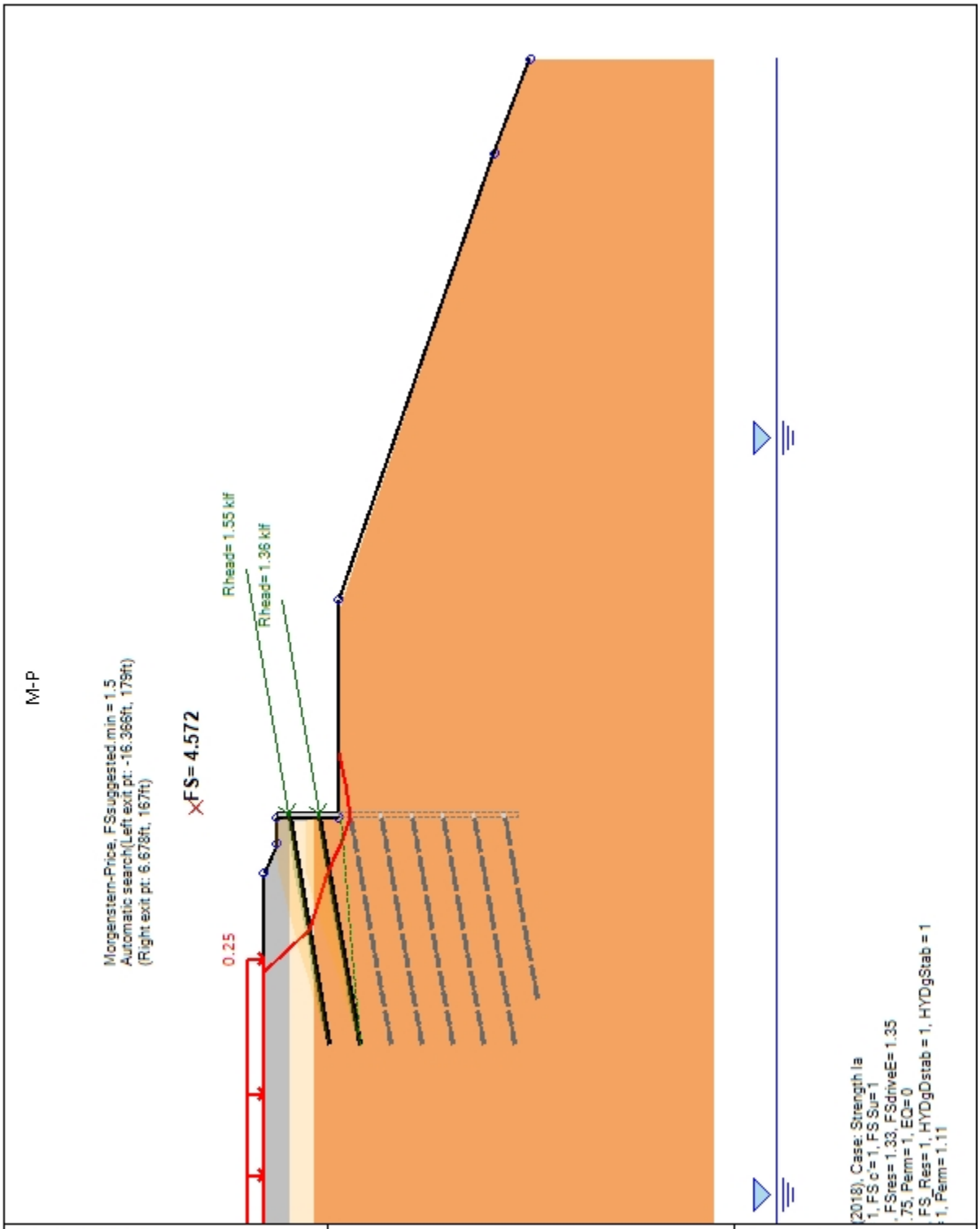

Company: Wood Engineer: DL	DS: 0, Exc. 167 ft	Deep Excavation LCC SnailPlus 2021
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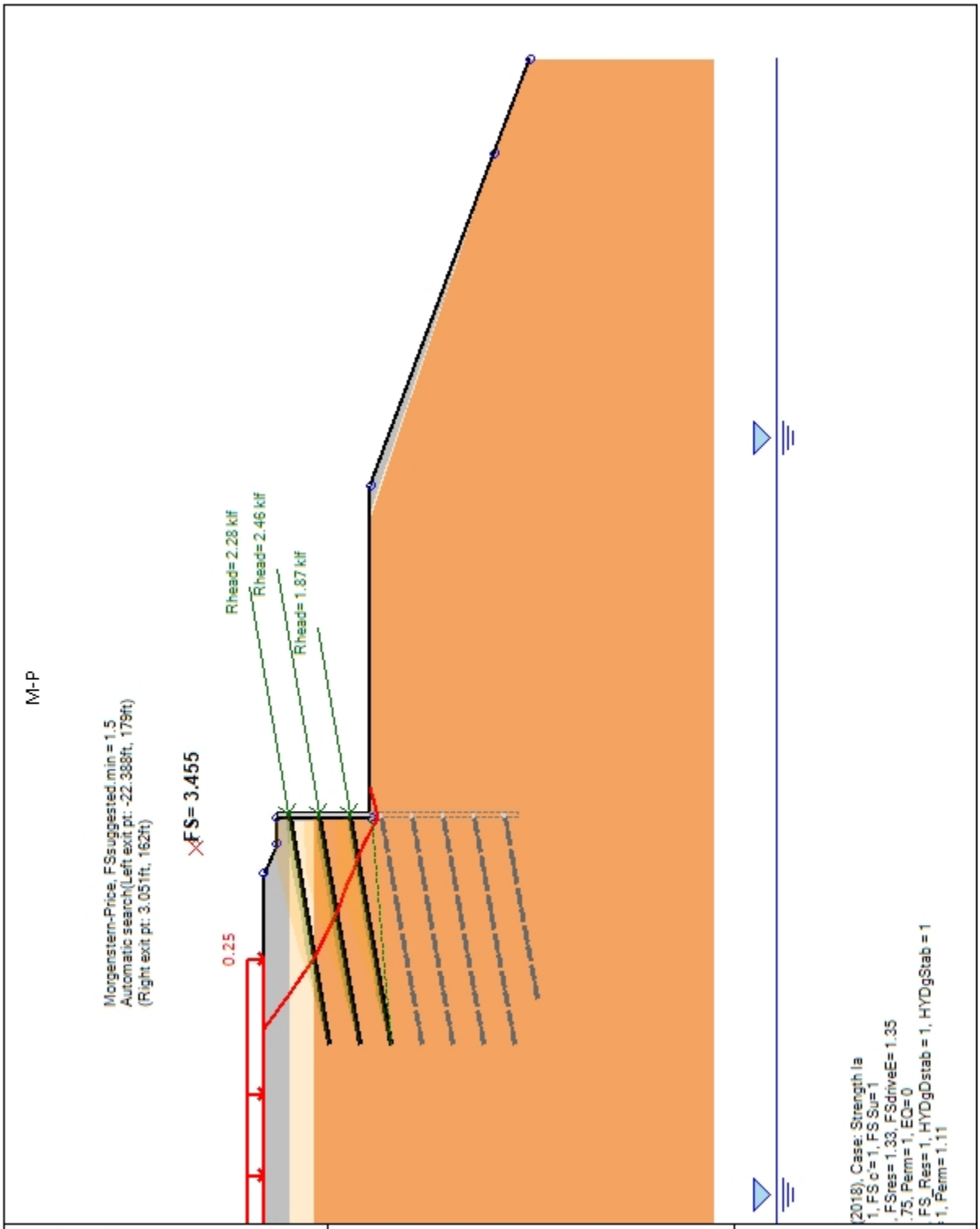
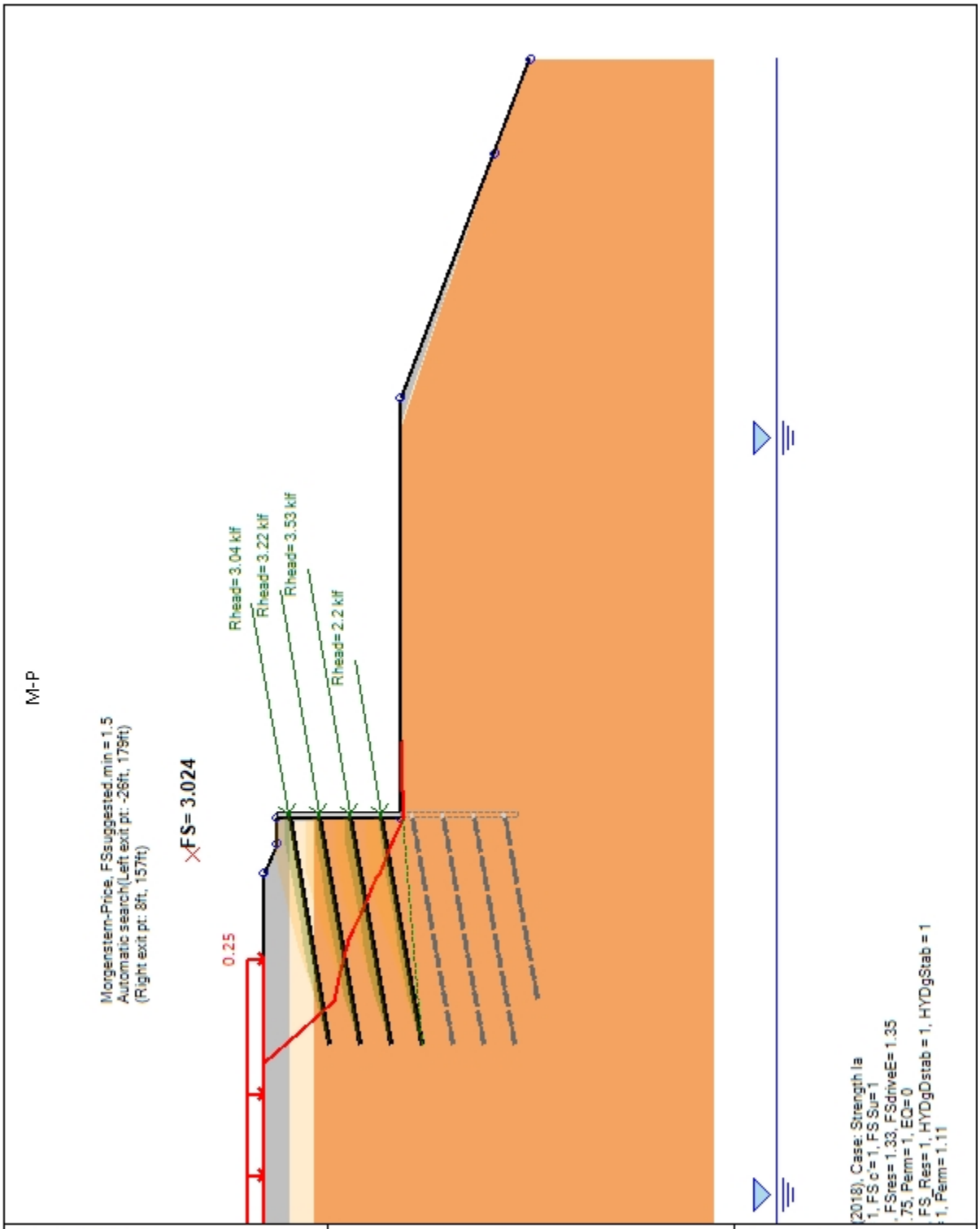


Company: Wood Engineer: DL	DS: 0, Exc. 162 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, M-P).SNLP		12/1/2021



Company: Wood Engineer: DL	DS: 0, Exc. 157 ft	Deep Excavation LCC SnailPlus 2021
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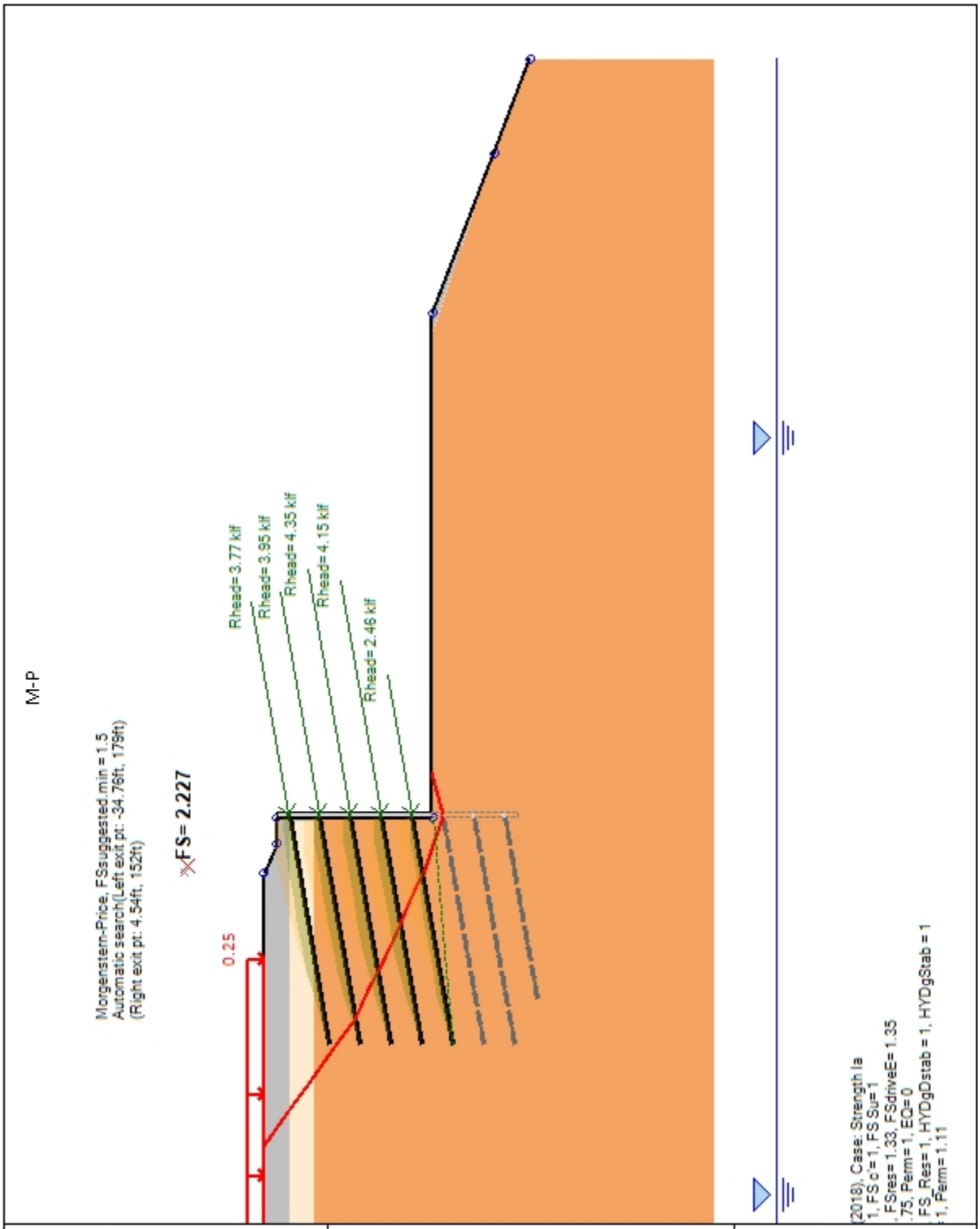

Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
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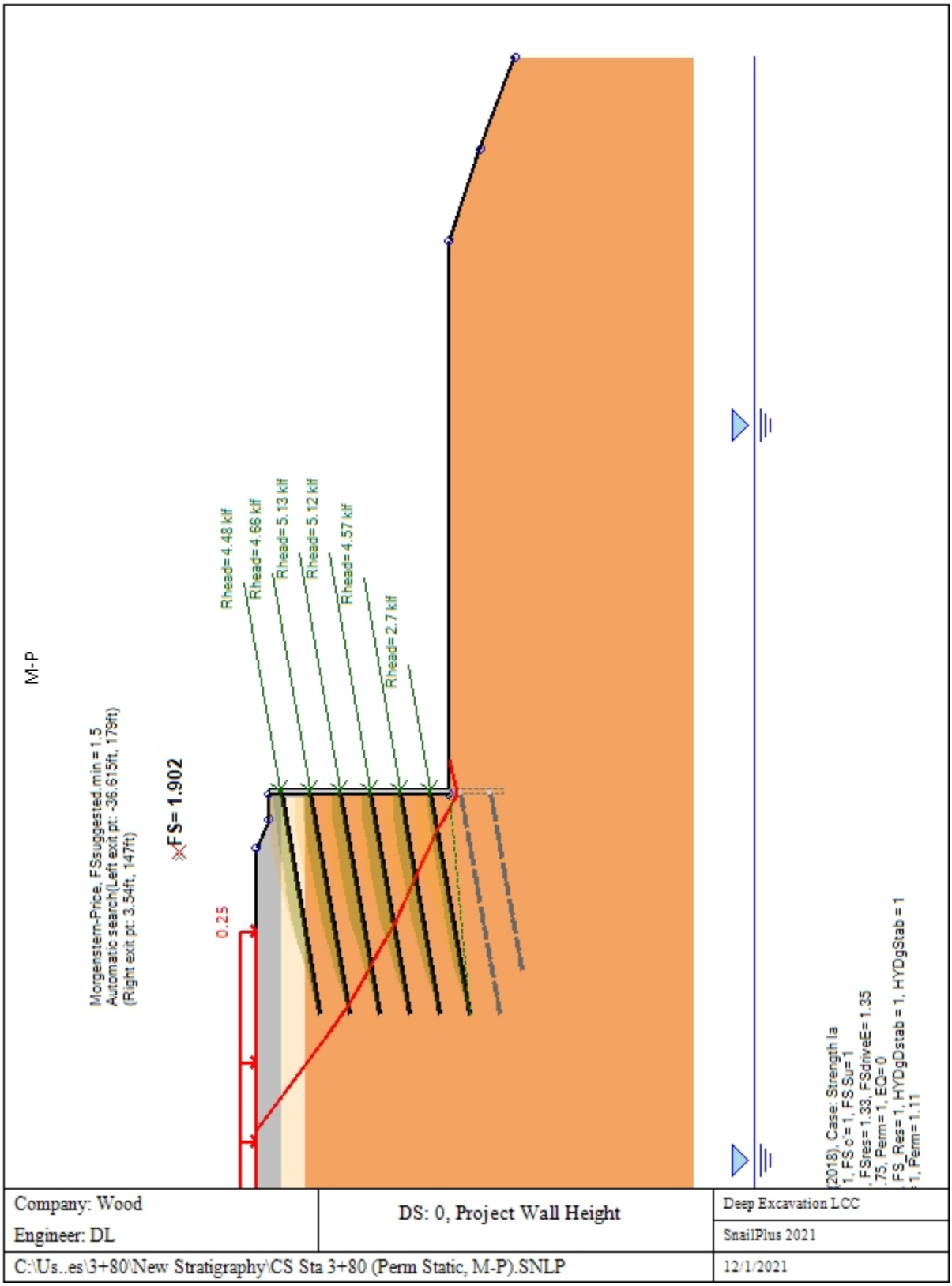

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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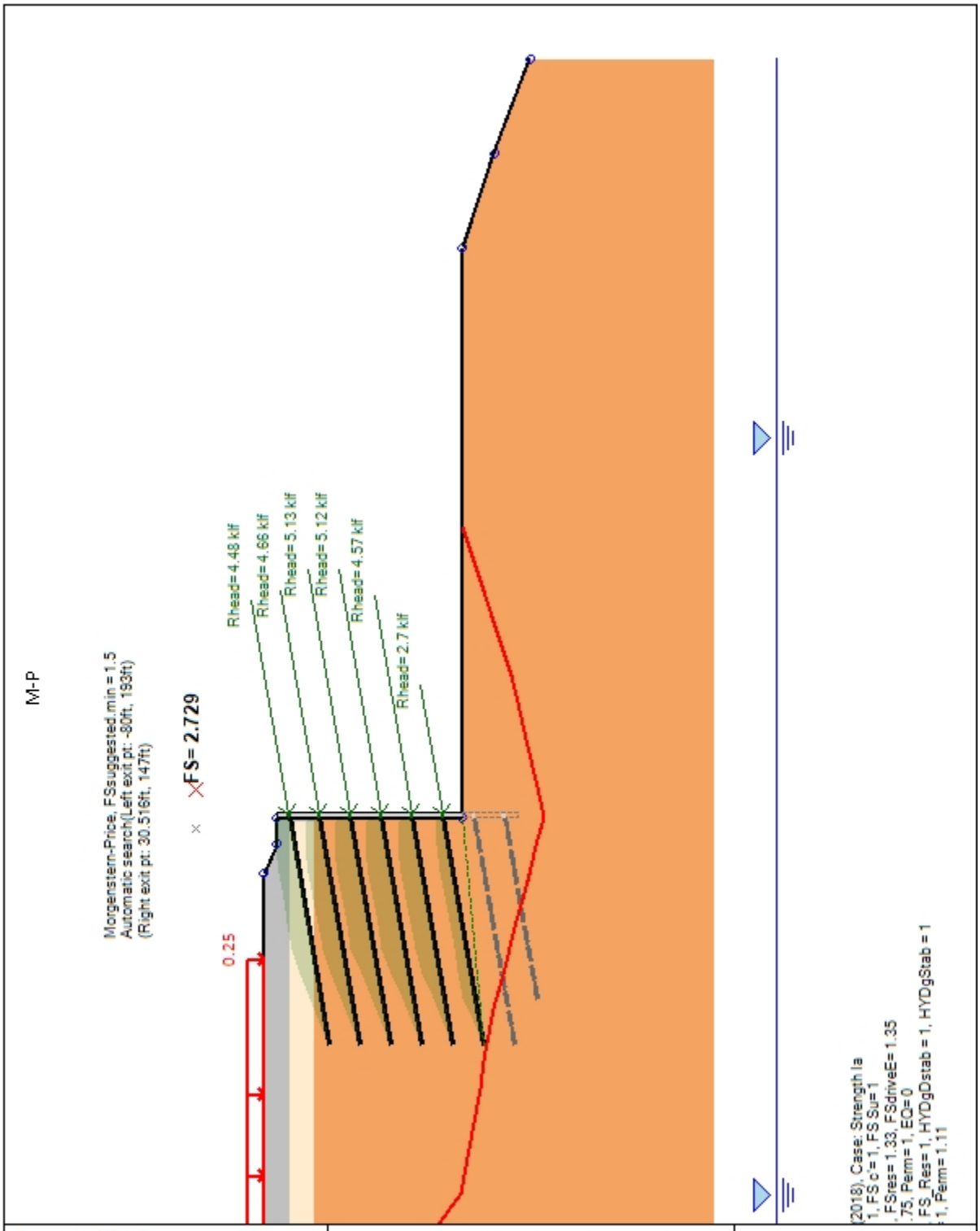
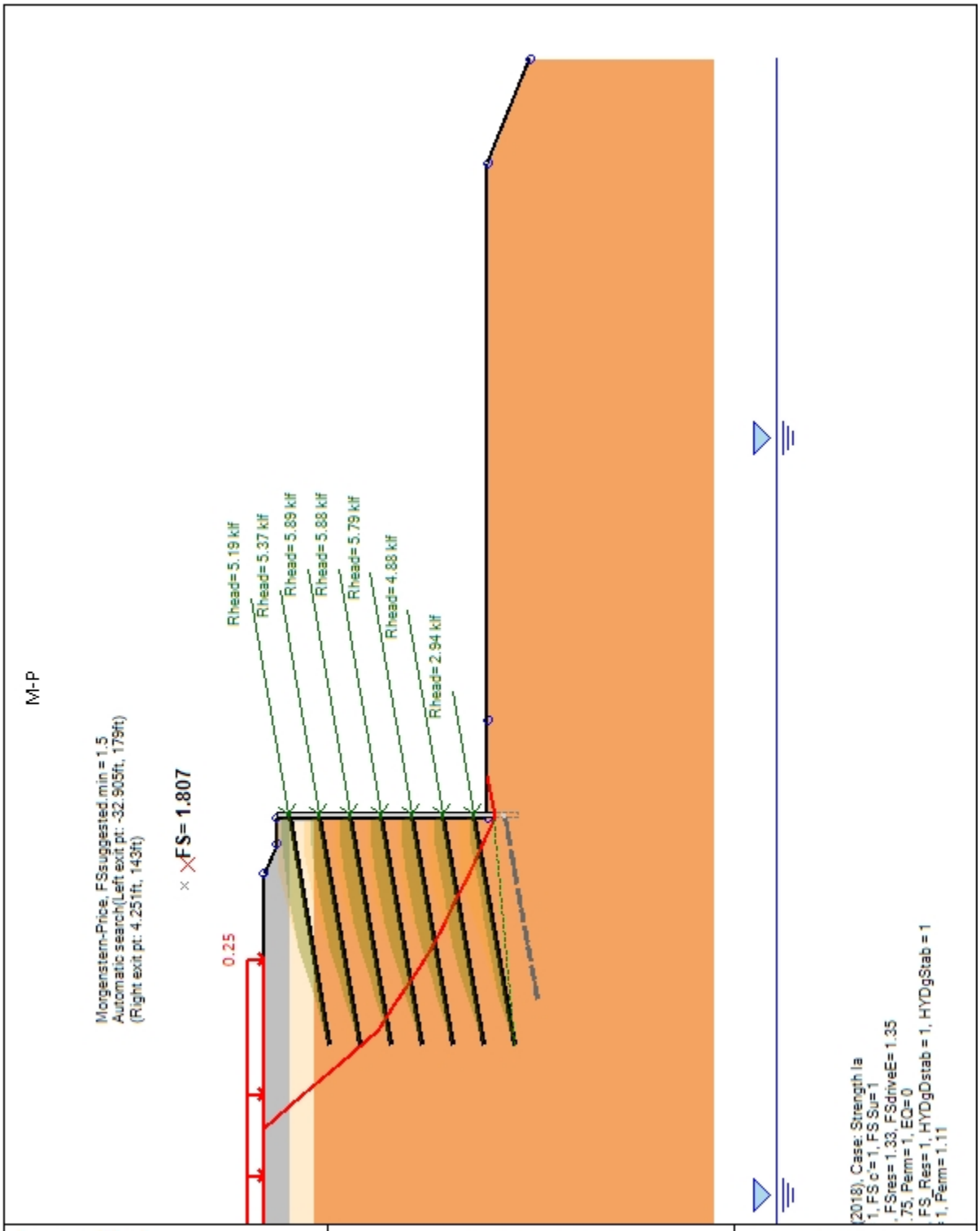
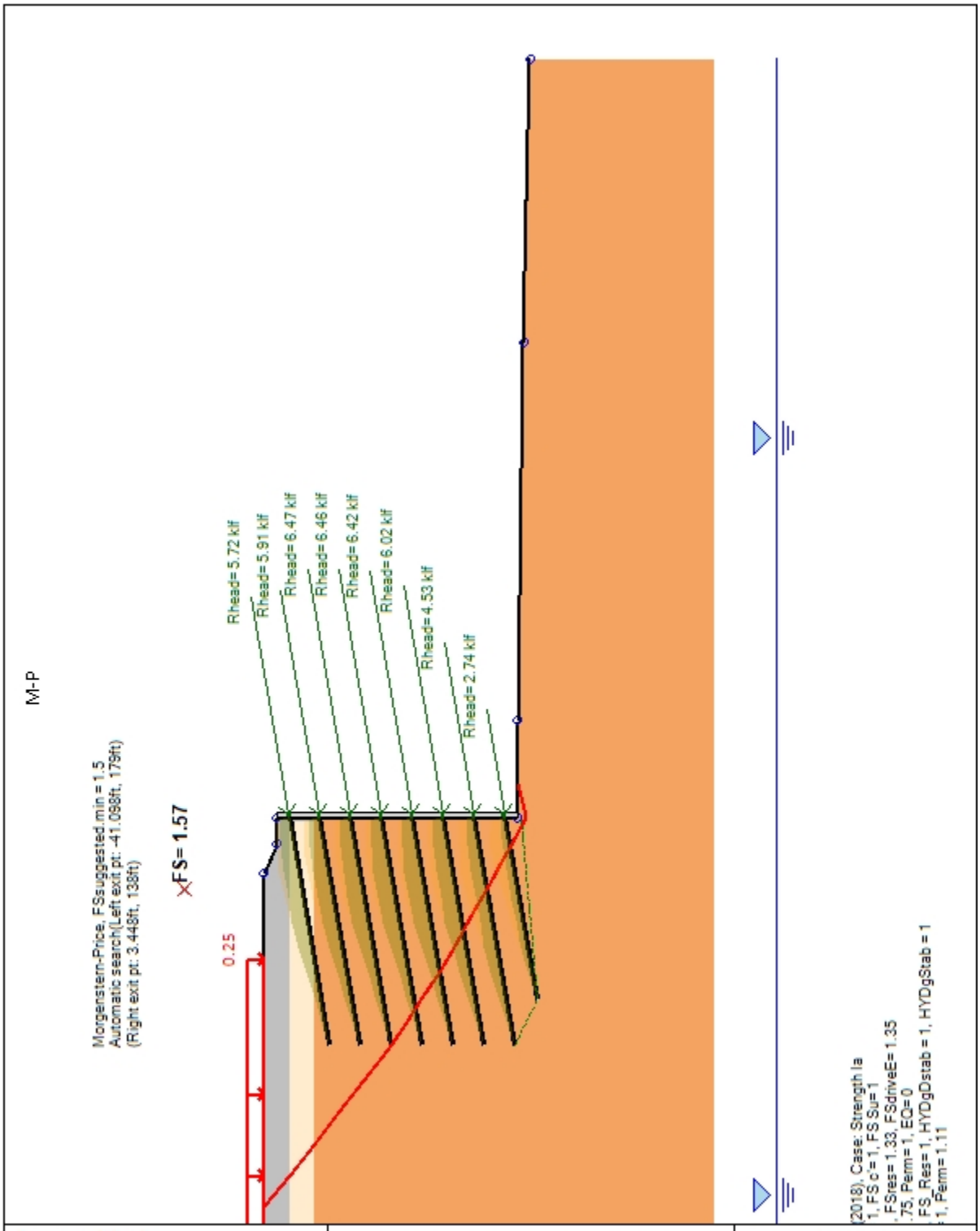


Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
C:\Us..es\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, M-P).SNLP		12/1/2021



Company: Wood Engineer: DL	DS: 0, Exc. 142 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, M-P).SNLP		12/1/2021



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..es\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, M-P).SNLP		12/1/2021

SnailPlus 2021: Report Output

Copyright@2009 - 2020 Deep Excavation LLC: www.deepexcavation.com A program for the evaluation of soil nail walls. Deep Excavation LLC, Astoria, New York, www.deepexcavation.com

Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 3+80 (Perm Static, Spencer)

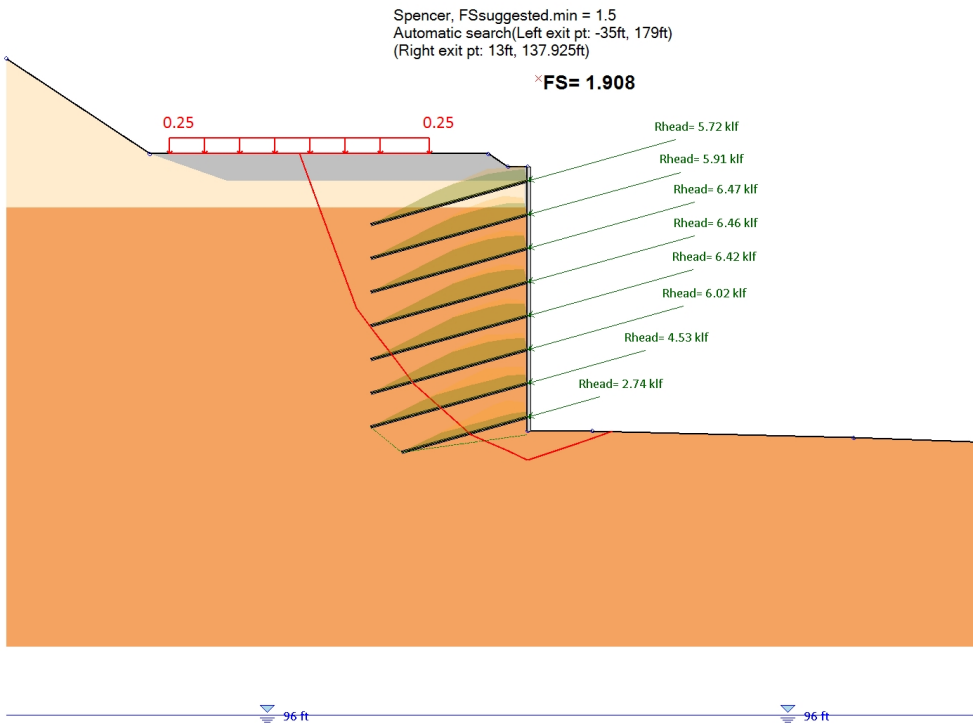
Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 5:15:26 PM

THIS PROGRAM IS PROTECTED BY U.S. COPYRIGHT LAWS AS DESCRIBED IN THE EULA. UNAUTHORIZED COPYING IS PROHIBITED. LICENSED TO: Deep Excavation LLC BY DEEP EXCAVATION LLC UNDER SPECIFIC LICENCE. This report has printed because the user has accepted responsibility as described in the disclaimer and EULA
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\3+80\New Stratigraphy\CS Sta 3+80 (Perm Static, Spencer) - Copy.SNLP

Quick analysis summary for design section: Spencer

Spencer

ESU 4A	135	0	-	42	22



AASHTO LRFD 9th (2018), Case: Strength Ia
Soil 'M': FS(tanFR)= 1, FS c'= 1, FS Su= 1
gStab= 1, gDstab= 1, FSres= 1.33, FSdriveE= 1.35
Actions 'A': Temp= 1.75, Perm= 1, EQ= 0
Water: FS_Drive= 1, FS_Res= 1, HYDgDstab = 1, HYDgStab = 1

Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	2.097	0	0	0	0	0	0	No	Yes
Exc. 172 ft	Calculated	16.087	4.45	3.14	4.45	0.068	0.08	0.038	No	Yes
Exc. 167 ft	Calculated	4.516	11.02	7.76	11.02	0.169	0.199	0.095	No	Yes
Exc. 162 ft	Calculated	3.534	17.47	12.31	17.47	0.248	0.316	0.151	No	Yes
Exc. 157 ft	Calculated	3.029	24.89	17.65	25.04	0.351	0.452	0.216	No	Yes
Exc. 152 ft	Calculated	2.291	30.7	21.77	30.88	0.432	0.558	0.267	No	Yes

Project Wall	Calculated	1.996	36.15	25.63	36.37	0.509	0.657	0.314	No	Yes
Project Wall	Calculated	2.724	36.15	25.63	36.37	0.509	0.657	0.314	No	Yes
Exc. 142 ft	Calculated	1.914	41.53	29.45	41.78	0.585	0.755	0.361	No	Yes
Forward Com	Calculated	1.908	45.64	32.36	45.91	0.643	0.829	0.397	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	2.097	1.5	Circle	34.575	207.1	47.179	N/A	N/A
Exc. 172 ft	Yes	16.087	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 167 ft	Yes	4.516	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 162 ft	Yes	3.534	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	3.029	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	2.291	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.996	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	2.724	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 142 ft	Yes	1.914	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.908	1.5	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 20)	N/A	AASHTO LRF	Strength Ia	52.52	0.068	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	59.53	0.169	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	60.54	0.248	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	60.56	0.351	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.66	0.432	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.5	0.509	N/A	N/A	N/A
xL (-80 to -58	xR (30 to 80)	N/A	AASHTO LRF	Strength Ia	0.48	0.509	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.66	0.585	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 25)	N/A	AASHTO LRF	Strength Ia	60.54	0.643	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	175	25	0	5	5.7235	28.62
N1	0: N1	15	0	170	25	0	5	5.9051	29.53
N2	0: N1	15	0	165	25	0	5	6.4721	32.36
N3	0: N1	15	0	160	25	0	5	6.4648	32.32
N4	0: N1	15	0	155	25	0	5	6.4185	32.09
N5	0: N1	15	0	150	25	0	5	6.0249	30.12
N6	0: N1	15	0	145	25	0	5	4.5323	22.66
N7	0: N1	15	0	140	20	0	5	2.7355	13.68

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	193
2	-58	179
3	-6	179
4	-3	177
5	0	177
6	0	138
7	10	138
8	50	137
9	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU1A	110	110	32	0	N/A	15	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
177	ESU 4C	1	0.32
160	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 175ft
Radii search ends at point x= 0ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 172 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 167 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -58ft
Right search limits: xRmin= 30ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 142 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

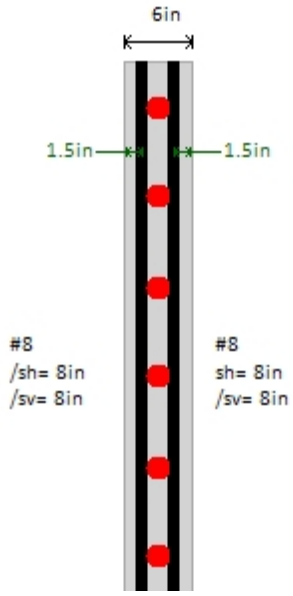
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.1ft to 25ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Spencer



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	177	136	N/A	6
Exc. 172 ft	Yes	177	172	N/A	6
Exc. 167 ft	Yes	177	167	N/A	6
Exc. 162 ft	Yes	177	162	N/A	6
Exc. 157 ft	Yes	177	157	N/A	6
Exc. 152 ft	Yes	177	152	N/A	6
Project Wall Height	Yes	177	147	N/A	6
Project Wall Height-G	Yes	177	147	N/A	6
Exc. 142 ft	Yes	177	142	N/A	6
Forward Compatible	Yes	177	136	N/A	6

Soil nail input data for design section Spencer

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	175	25	0	5	1.27	6	75
N1	0: N1	15	0	170	25	0	5	1.27	6	75
N2	0: N1	15	0	165	25	0	5	1.27	6	75
N3	0: N1	15	0	160	25	0	5	1.27	6	75
N4	0: N1	15	0	155	25	0	5	1.27	6	75
N5	0: N1	15	0	150	25	0	5	1.27	6	75
N6	0: N1	15	0	145	25	0	5	1.27	6	75
N7	0: N1	15	0	140	20	0	5	1.27	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	175	8	2.25	36	1	N/A	N/A	N/A
N1	170	8	2.25	36	1	N/A	N/A	N/A
N2	165	8	2.25	36	1	N/A	N/A	N/A
N3	160	8	2.25	36	1	N/A	N/A	N/A
N4	155	8	2.25	36	1	N/A	N/A	N/A
N5	150	8	2.25	36	1	N/A	N/A	N/A
N6	145	8	2.25	36	1	N/A	N/A	N/A
N7	140	8	2.25	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Spencer

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 34.575 z= 207.1 FS= 2.097

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -0.18 z= 190.1 FS= 16.087

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.52	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 1.944 z= 190.1 FS= 4.516

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	39.2	51.07	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	58.63	59.53	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= 2.59 z= 190.1 FS= 3.534

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	29.64	52.1	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	45.25	60.54	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	56.38	59.92	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -4.011 z= 190.774 FS= 3.029

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	12.28	52.57	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	31.42	59.73	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	50.64	55.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	53.58	60.56	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -4.18 z= 190.887 FS= 2.291

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.92	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	4.46	56.86	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	21.89	54.46	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	39.32	59.63	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	59.31	60.66	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 6

Soil nail results available for this stage.

Critical point at x= -3.22 z= 190.247 FS= 1.996

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.86	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	57.35	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	7.64	55.72	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	24.09	53.01	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	40.54	60.5	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	59.02	60.01	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 7

Soil nail results available for this stage.

Critical point at x= 3.017 z= 190.1 FS= 2.724

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N1	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N2	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A

3: N3	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
4: N4	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
5: N5	0	0.48	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 8

Soil nail results available for this stage.

Critical point at x= -6.957 z= 192.1 FS= 1.914

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.71	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	57.67	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	1.1	56.18	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	16.34	53.98	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	32.18	57.34	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	50.95	60.64	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	51.56	60.66	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	FACE
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 9

Soil nail results available for this stage.

Critical point at x= 1.694 z= 190.1 FS= 1.908

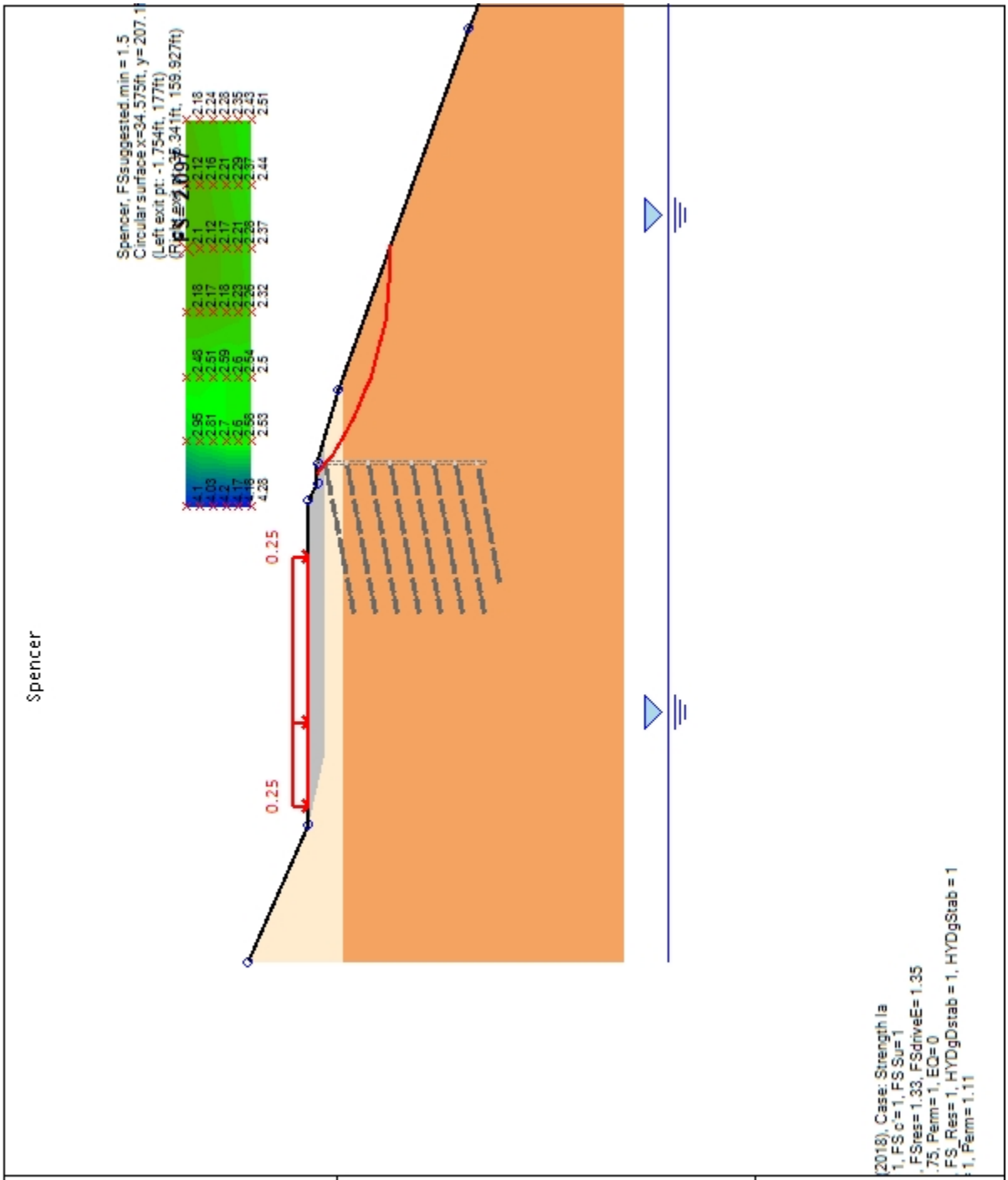
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.56	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	58.48	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	57.37	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	0	56.27	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	10.72	54.76	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	21.59	59.94	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	36.23	60.54	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: N7	35	52.58	85.72	64.69	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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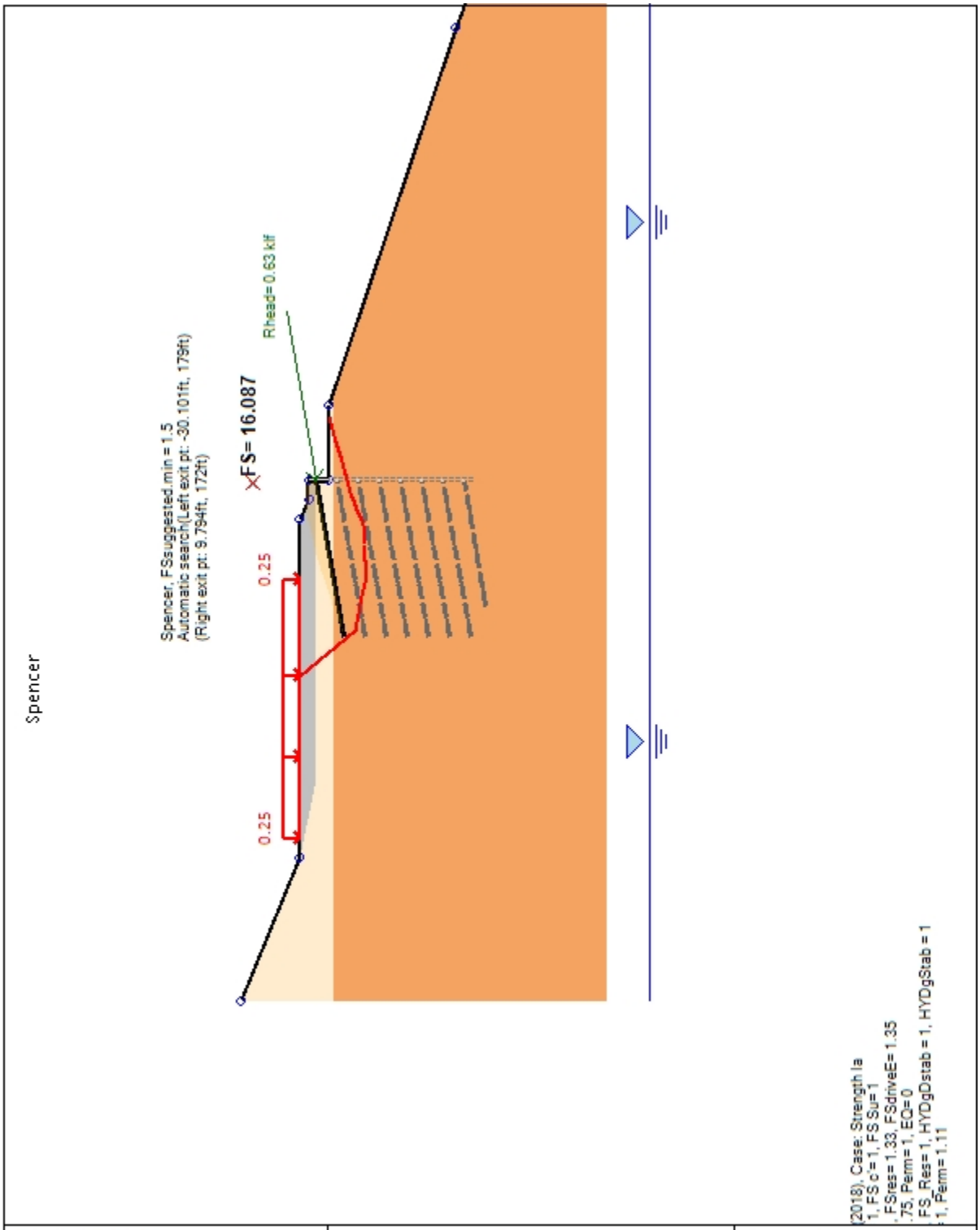

Company: Wood Engineer: DL	DS: 0, Exc. 172 ft	Deep Excavation LCC SnailPlus 2021
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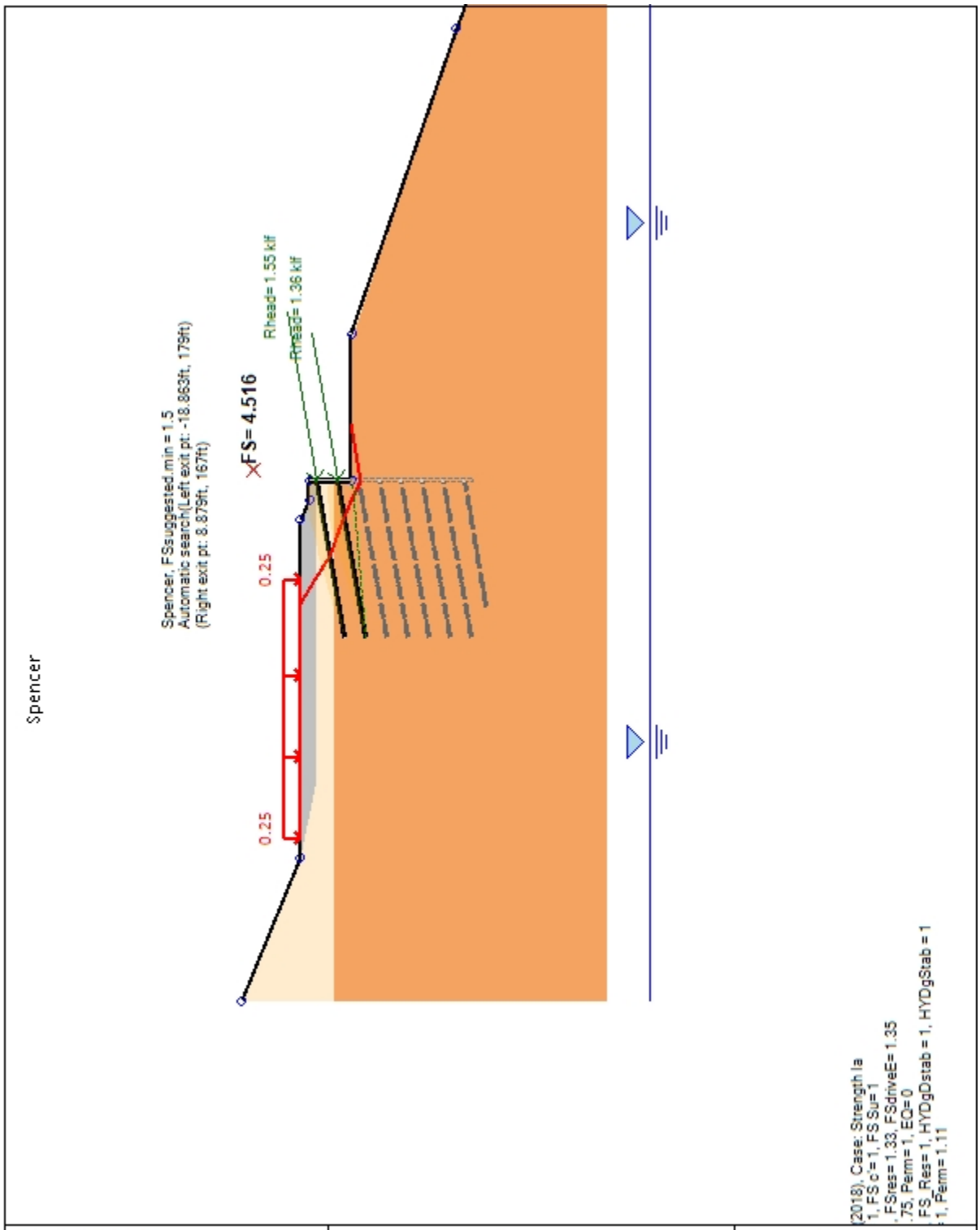

Company: Wood Engineer: DL	DS: 0, Exc. 167 ft	Deep Excavation LCC SnailPlus 2021
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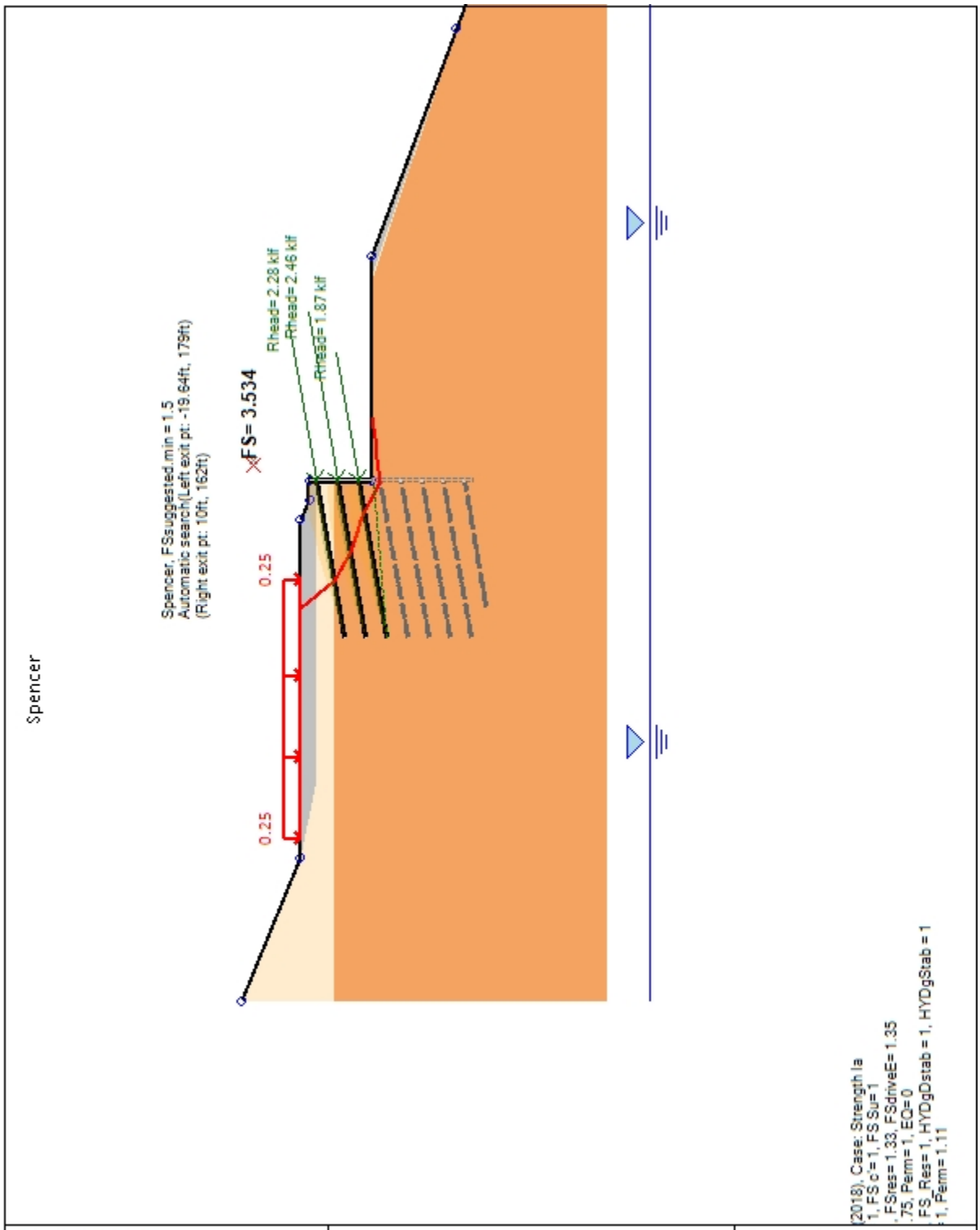

Company: Wood Engineer: DL	DS: 0, Exc. 162 ft	Deep Excavation LCC SnailPlus 2021
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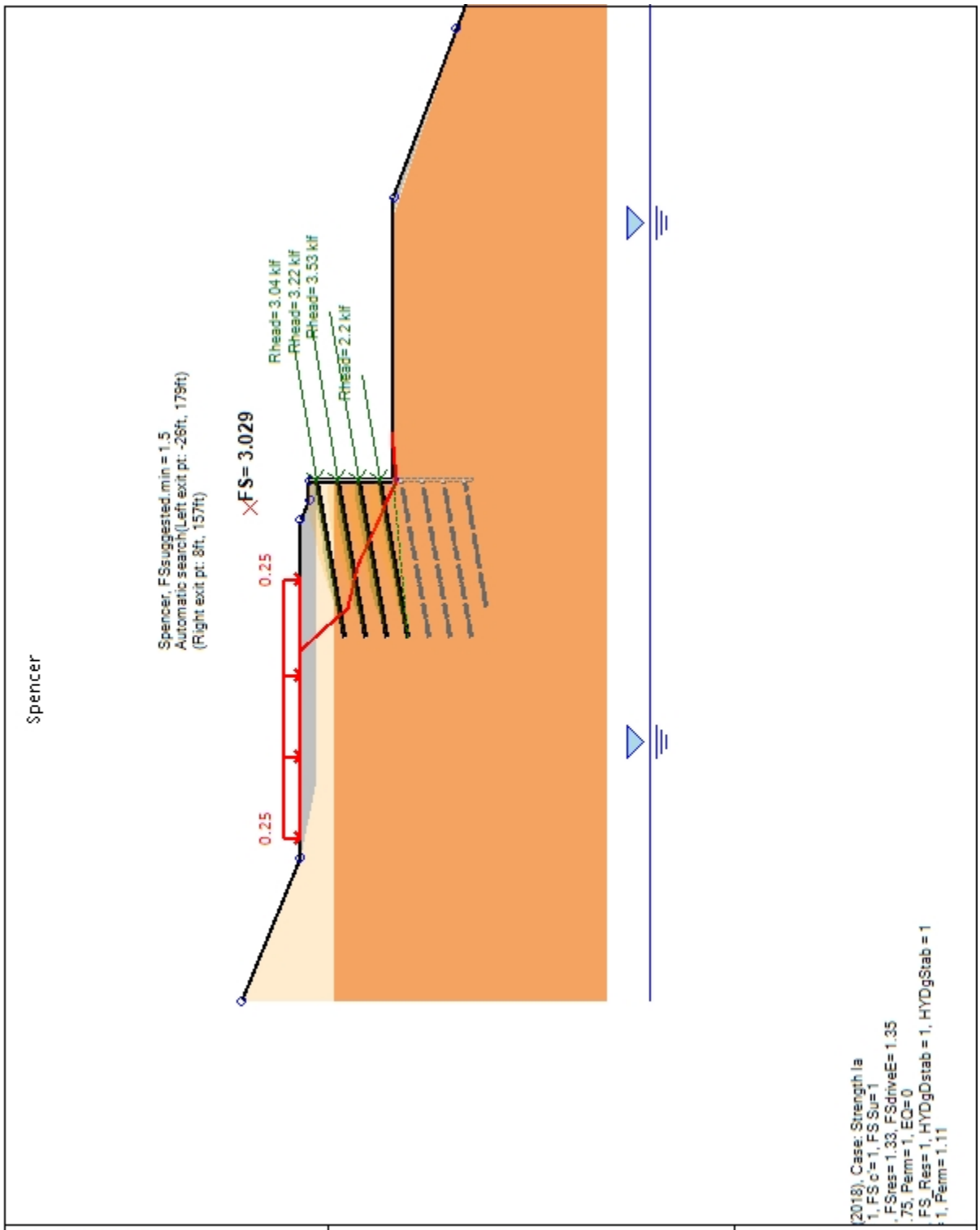

Company: Wood Engineer: DL	DS: 0, Exc. 157 ft	Deep Excavation LCC SnailPlus 2021
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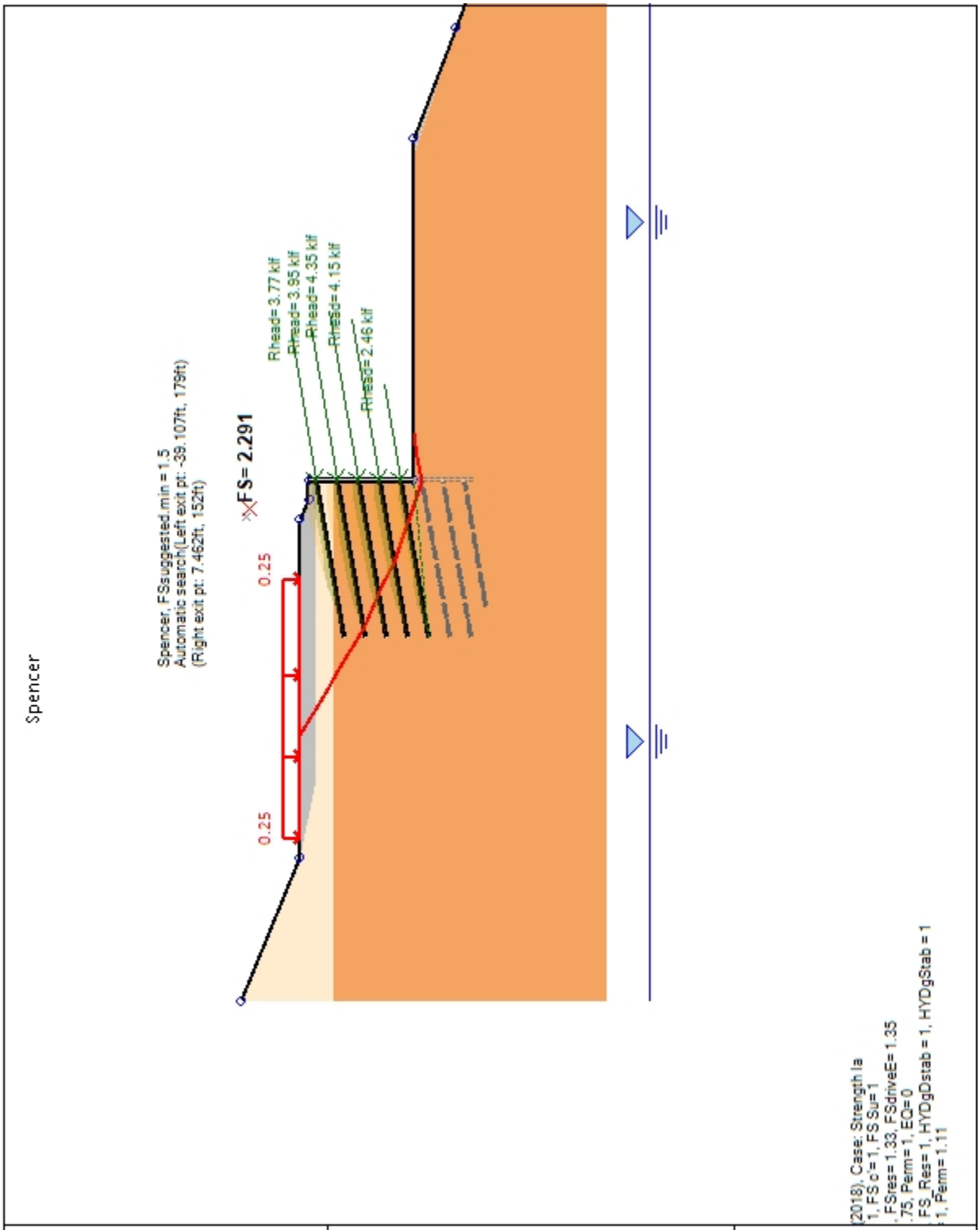

Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
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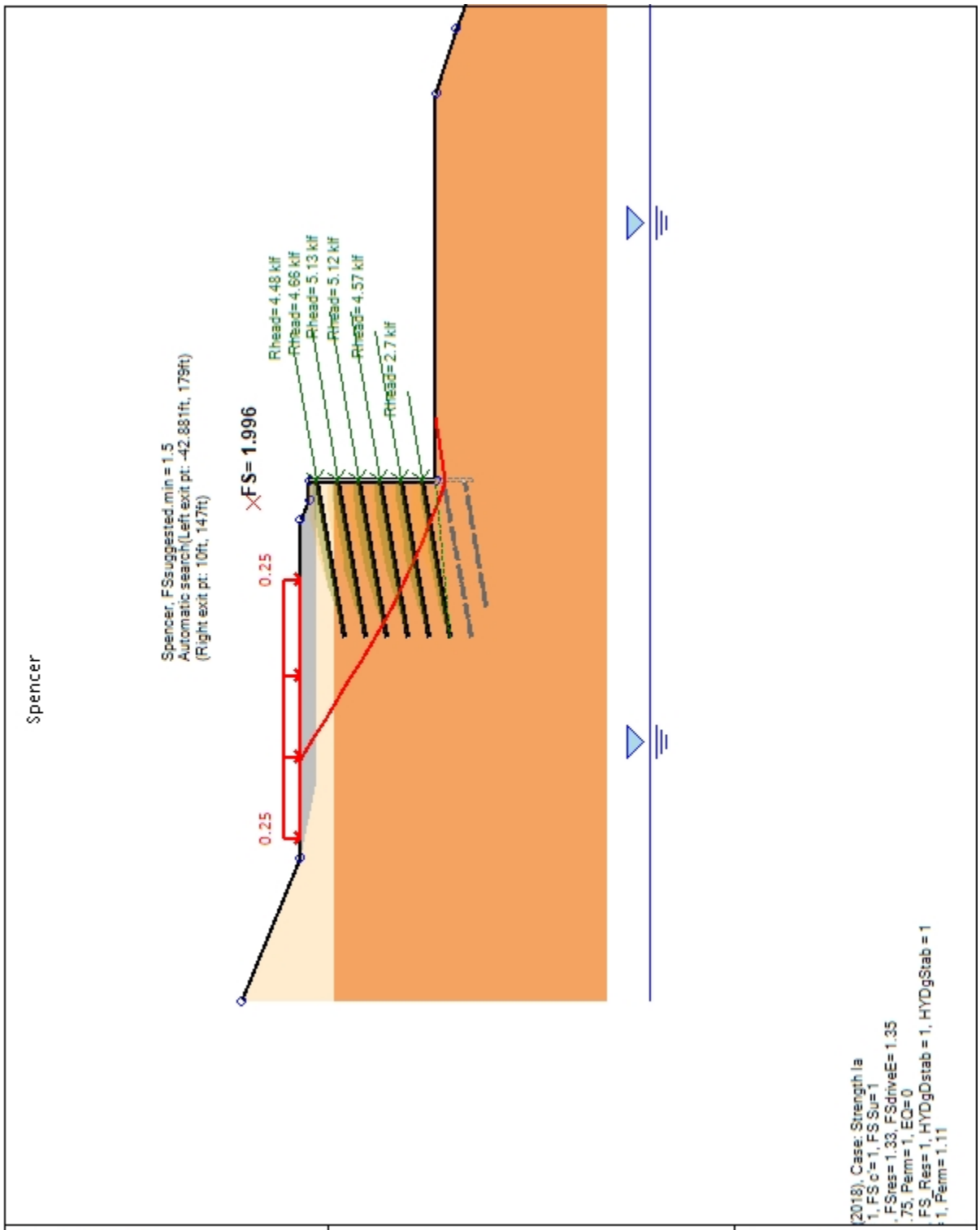

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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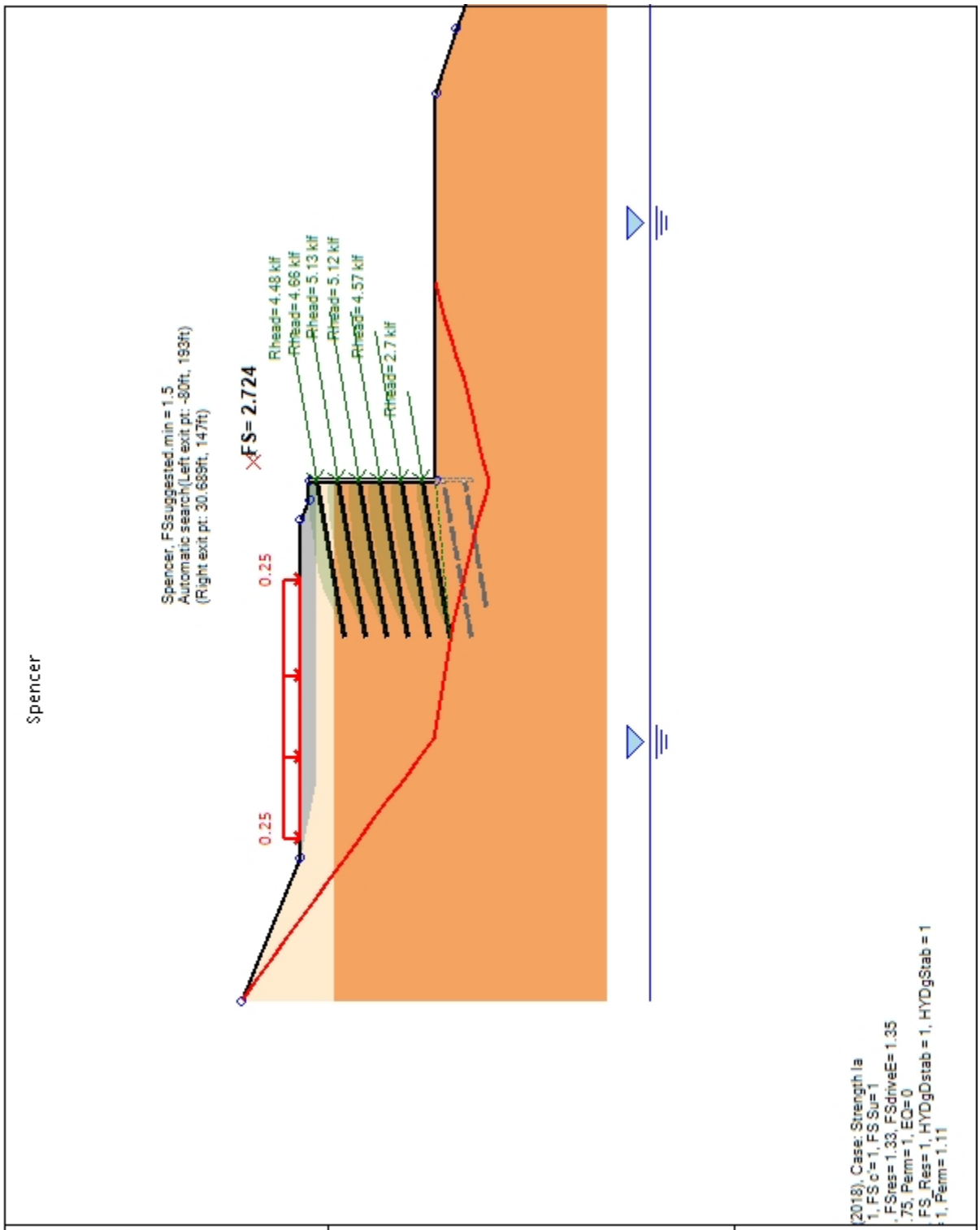

Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
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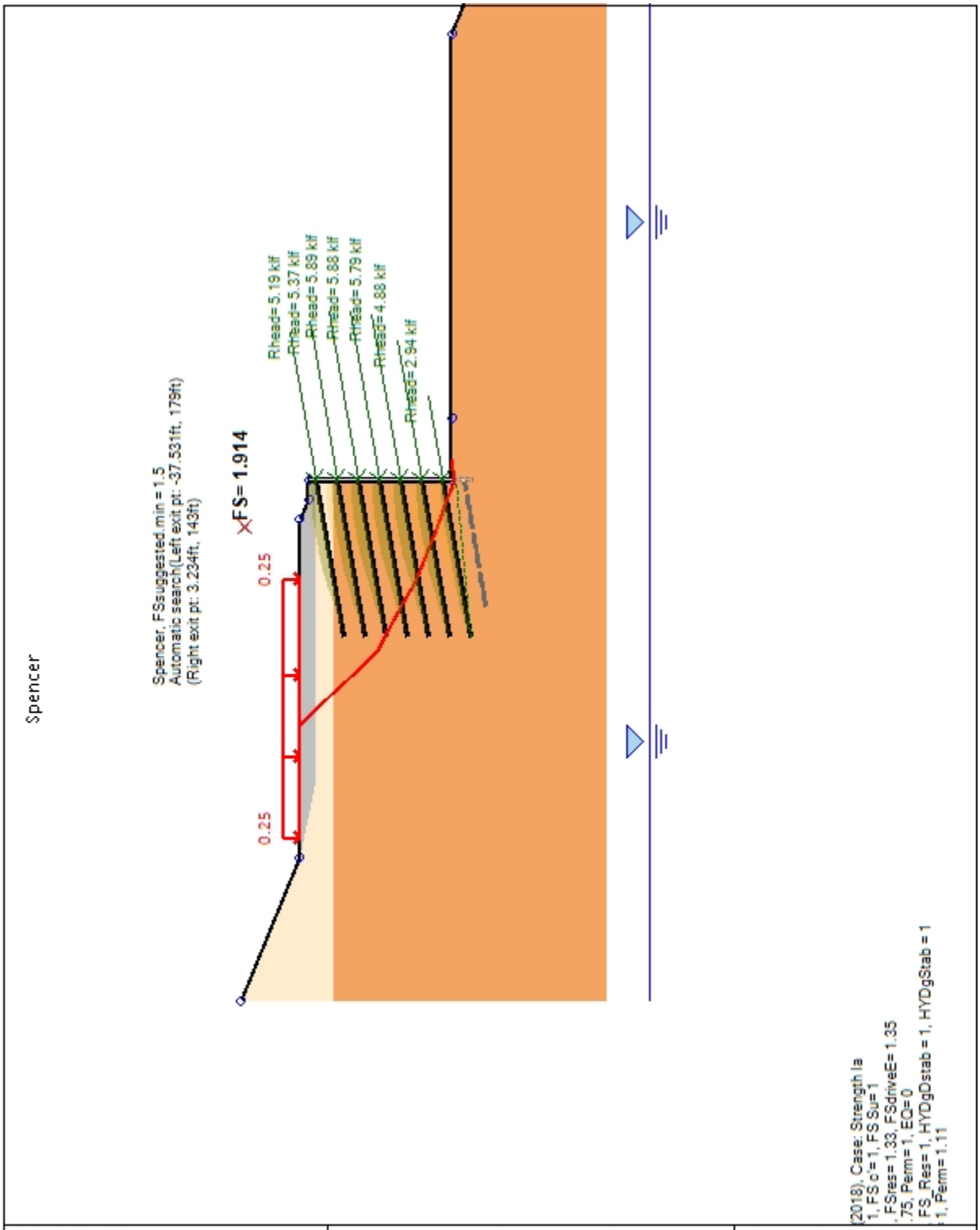
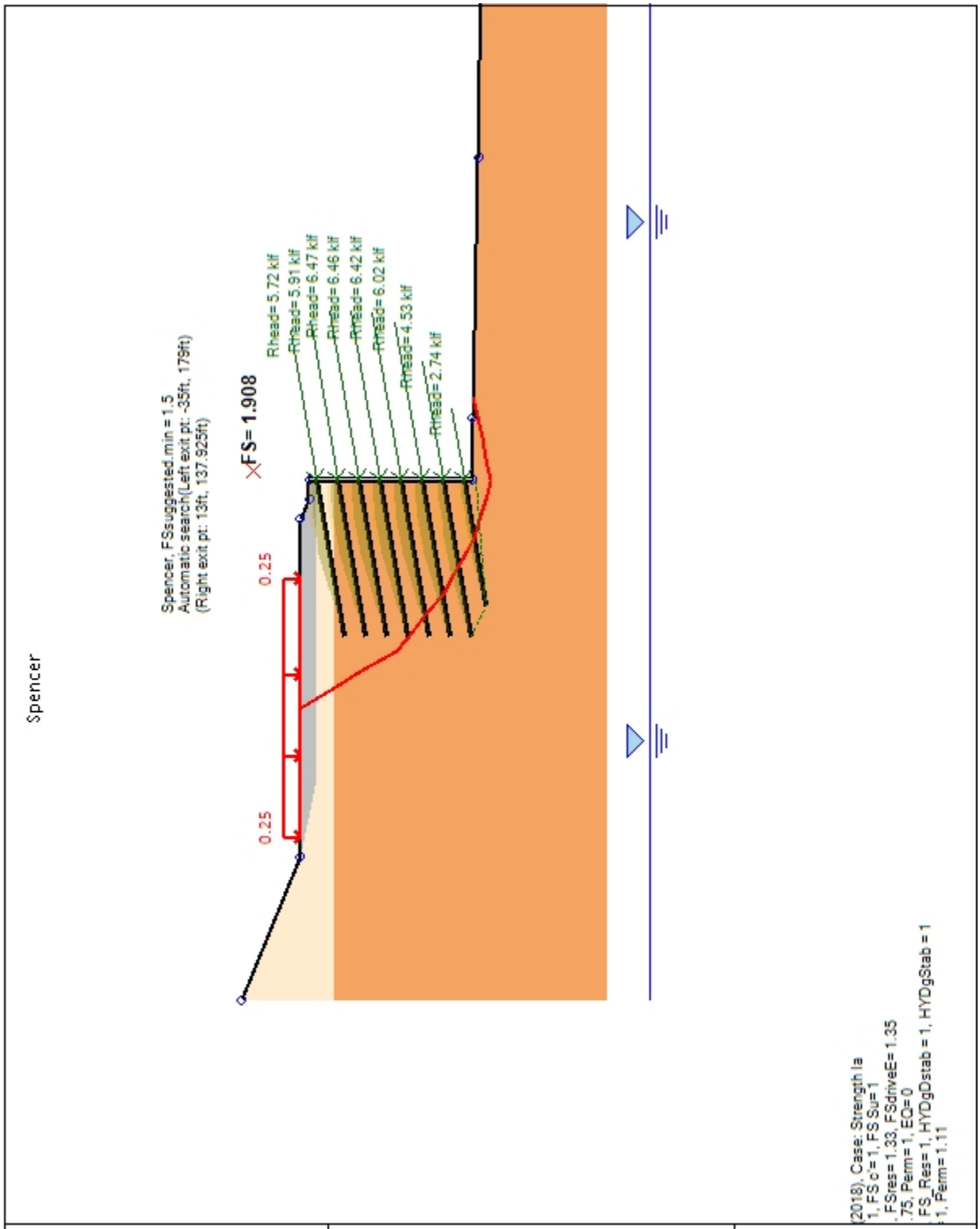


Company: Wood Engineer: DL	DS: 0, Exc. 142 ft	Deep Excavation LCC SnailPlus 2021
C:\Us.. Stratigraphy\CS Sta 3+80 (Perm Static, Spencer) - Copy.SNLP		12/1/2021



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us.. Stratigraphy\CS Sta 3+80 (Perm Static, Spencer) - Copy.SNLP		12/1/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 3+80 (Temp Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 11:52:53 AM

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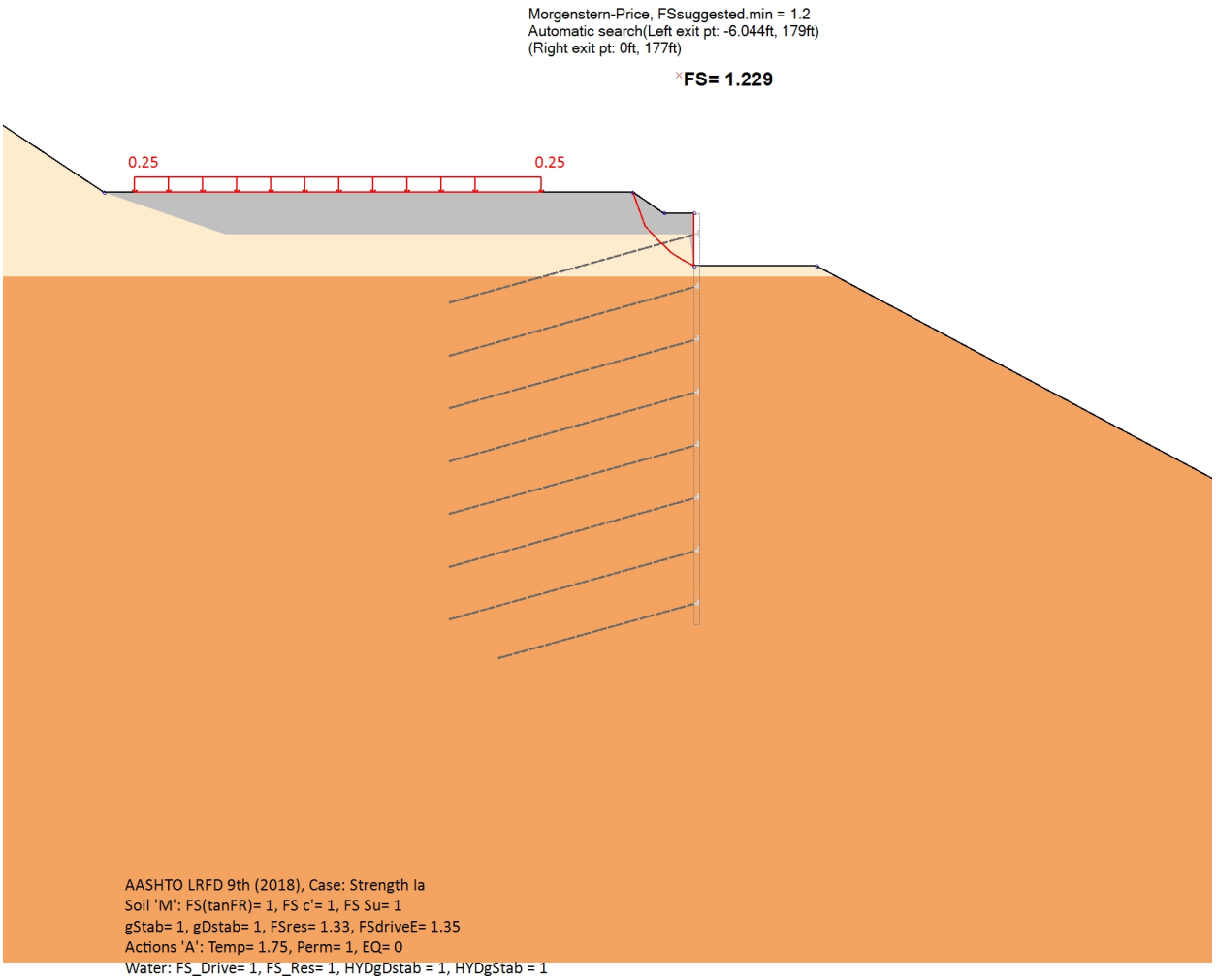
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\3+80\New Stratigraphy\CS Sta 3+80 (Temp Static, M-P).SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	2.096	0	0	0	0	0	0	No	Yes
Exc. 172 ft	Calculated	1.229	0	0	0	0	0	0	No	Yes
Exc. 167 ft	Calculated	2.452	4.45	3.14	4.45	0.068	0.08	0.038	No	Yes
Exc. 162 ft	Calculated	2.896	11.02	7.76	11.02	0.169	0.199	0.095	No	Yes
Exc. 157 ft	Calculated	2.437	17.47	12.31	17.47	0.248	0.316	0.151	No	Yes
Exc. 152 ft	Calculated	1.831	24.89	17.65	25.04	0.351	0.452	0.216	No	Yes

Project Wall	Calculated	1.629	30.7	21.77	30.88	0.432	0.558	0.267	No	Yes
Exc. 142 ft	Calculated	1.55	36.15	25.63	36.37	0.509	0.657	0.314	No	Yes
Forward Com	Calculated	1.57	40.29	28.57	40.54	0.567	0.732	0.35	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	2.096	1.2	Circle	34.575	207.1	47.179	N/A	N/A
Exc. 172 ft	Yes	1.229	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 167 ft	Yes	2.452	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 162 ft	Yes	2.896	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	2.437	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	1.831	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.629	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 142 ft	Yes	1.55	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.57	1.2	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 20)	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	51.07	0.068	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	60.54	0.169	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	59.73	0.248	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	59.63	0.351	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.5	0.432	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.64	0.509	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 20)	N/A	AASHTO LRF	Strength Ia	60.58	0.567	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	175	25	0	5	5.024	25.12
N1	0: N1	15	0	170	25	0	5	5.2056	26.03
N2	0: N1	15	0	165	25	0	5	5.7143	28.57
N3	0: N1	15	0	160	25	0	5	5.7071	28.54
N4	0: N1	15	0	155	25	0	5	5.56	27.8
N5	0: N1	15	0	150	25	0	5	4.5604	22.8
N6	0: N1	15	0	145	25	0	5	2.4593	12.3
N7	0: N1	15	0	140	20	0	5	0	0

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	193
2	-58	179
3	-6	179
4	-3	177
5	0	177
6	0	138
7	10	138
8	50	137
9	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
177	ESU 4C	1	0.32
160	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 175ft
Radii search ends at point x= 0ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 172 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 167 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 142 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

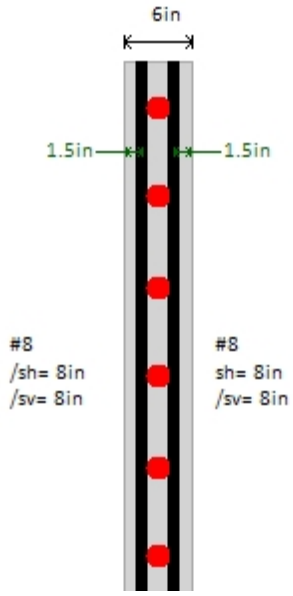
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	177	136	N/A	6
Exc. 172 ft	No	177	172	N/A	6
Exc. 167 ft	Yes	177	172	N/A	6
Exc. 162 ft	Yes	177	167	N/A	6
Exc. 157 ft	Yes	177	162	N/A	6
Exc. 152 ft	Yes	177	157	N/A	6
Project Wall Height	Yes	177	152	N/A	6
Exc. 142 ft	Yes	177	147	N/A	6
Forward Compatible	Yes	177	143	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	175	25	0	5	1.27	6	75
N1	0: N1	15	0	170	25	0	5	1.27	6	75
N2	0: N1	15	0	165	25	0	5	1.27	6	75
N3	0: N1	15	0	160	25	0	5	1.27	6	75
N4	0: N1	15	0	155	25	0	5	1.27	6	75
N5	0: N1	15	0	150	25	0	5	1.27	6	75
N6	0: N1	15	0	145	25	0	5	1.27	6	75
N7	0: N1	15	0	140	20	0	5	1.27	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	175	8	2.25	36	1	N/A	N/A	N/A
N1	170	8	2.25	36	1	N/A	N/A	N/A
N2	165	8	2.25	36	1	N/A	N/A	N/A
N3	160	8	2.25	36	1	N/A	N/A	N/A
N4	155	8	2.25	36	1	N/A	N/A	N/A
N5	150	8	2.25	36	1	N/A	N/A	N/A
N6	145	8	2.25	36	1	N/A	N/A	N/A
N7	140	8	2.25	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 34.575 z= 207.1 FS= 2.096

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -1.511 z= 190.1 FS= 1.229

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 0.249 z= 190.1 FS= 2.452

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	38.1	51.07	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -4 z= 190.767 FS= 2.896

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	35.67	52.1	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	48.24	60.54	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -4.042 z= 190.794 FS= 2.437

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	12.28	52.57	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	31.42	59.73	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	50.64	55.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -5.265 z= 191.61 FS= 1.831

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.92	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	11.94	56.86	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	28.32	54.46	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	44.99	59.63	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 6

Soil nail results available for this stage.

Critical point at x= -6.122 z= 192.1 FS= 1.629

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.86	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0.67	57.35	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	15.32	55.72	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	29.97	53.01	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	47.04	60.5	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 7

Soil nail results available for this stage.

Critical point at x= -6.949 z= 192.1 FS= 1.55

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.71	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	57.67	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	12.24	56.18	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

3: N3	25.75	53.98	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	39.54	57.34	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	53.74	60.64	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 8

Soil nail results available for this stage.

Critical point at x= -6.522 z= 192.1 FS= 1.57

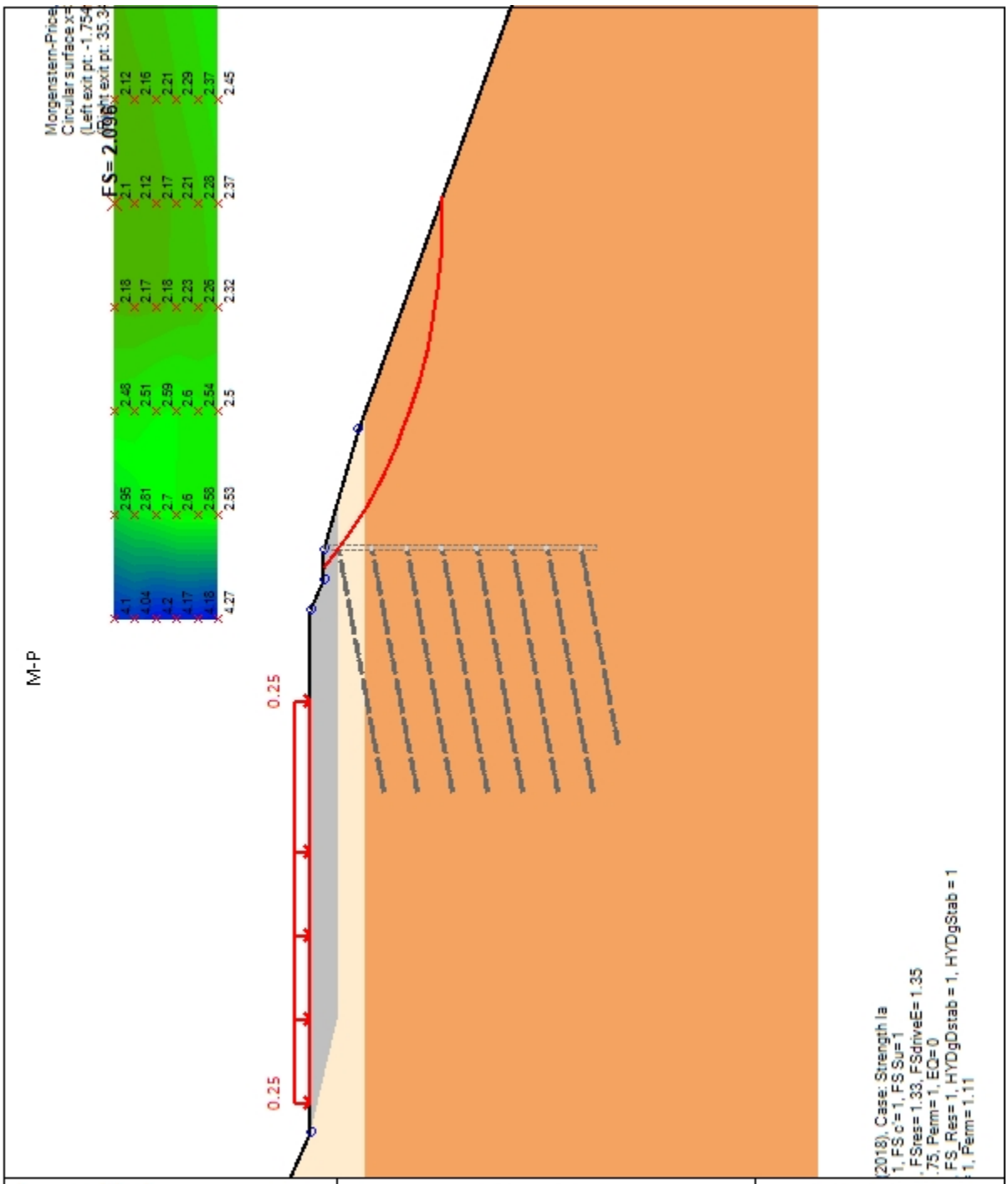
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	4.17	52.52	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	9.03	57.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	16.16	60.55	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	24.76	59.8	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	34.84	58.59	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	46.16	60.58	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	59.63	59.63	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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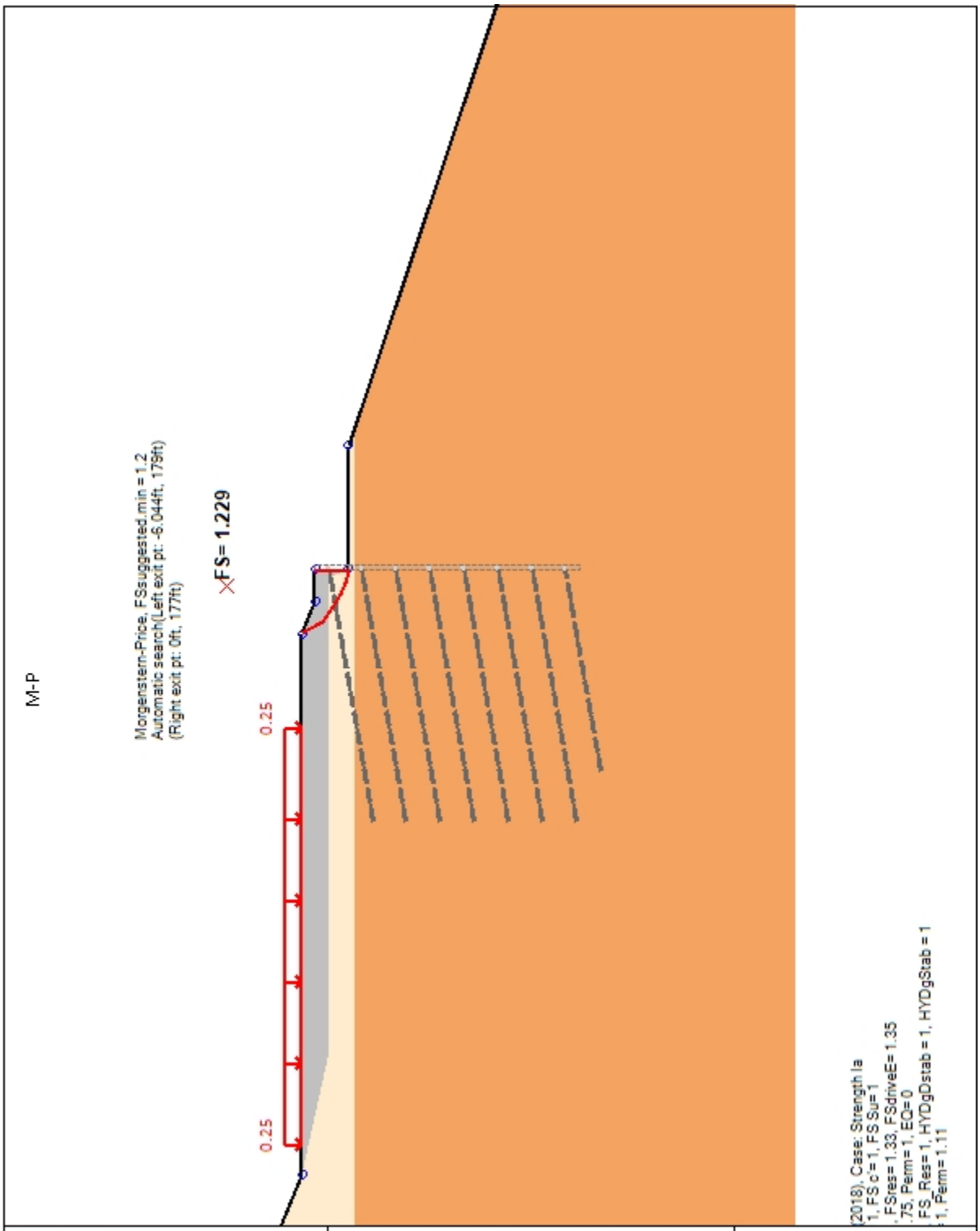

Company: Wood Engineer: DL	DS: 0, Exc. 172 ft	Deep Excavation LCC SnailPlus 2021
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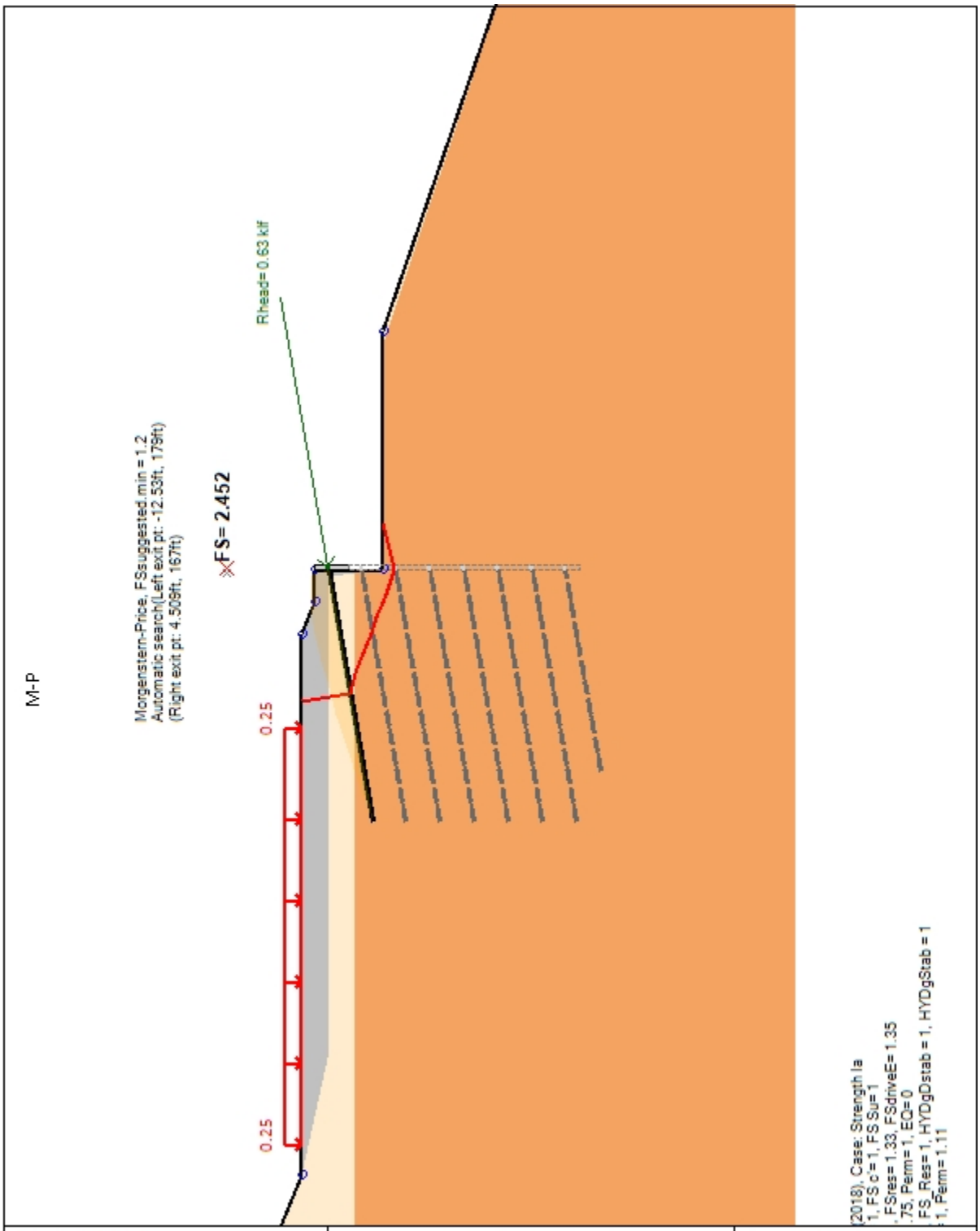

Company: Wood Engineer: DL	DS: 0, Exc. 167 ft	Deep Excavation LCC SnailPlus 2021
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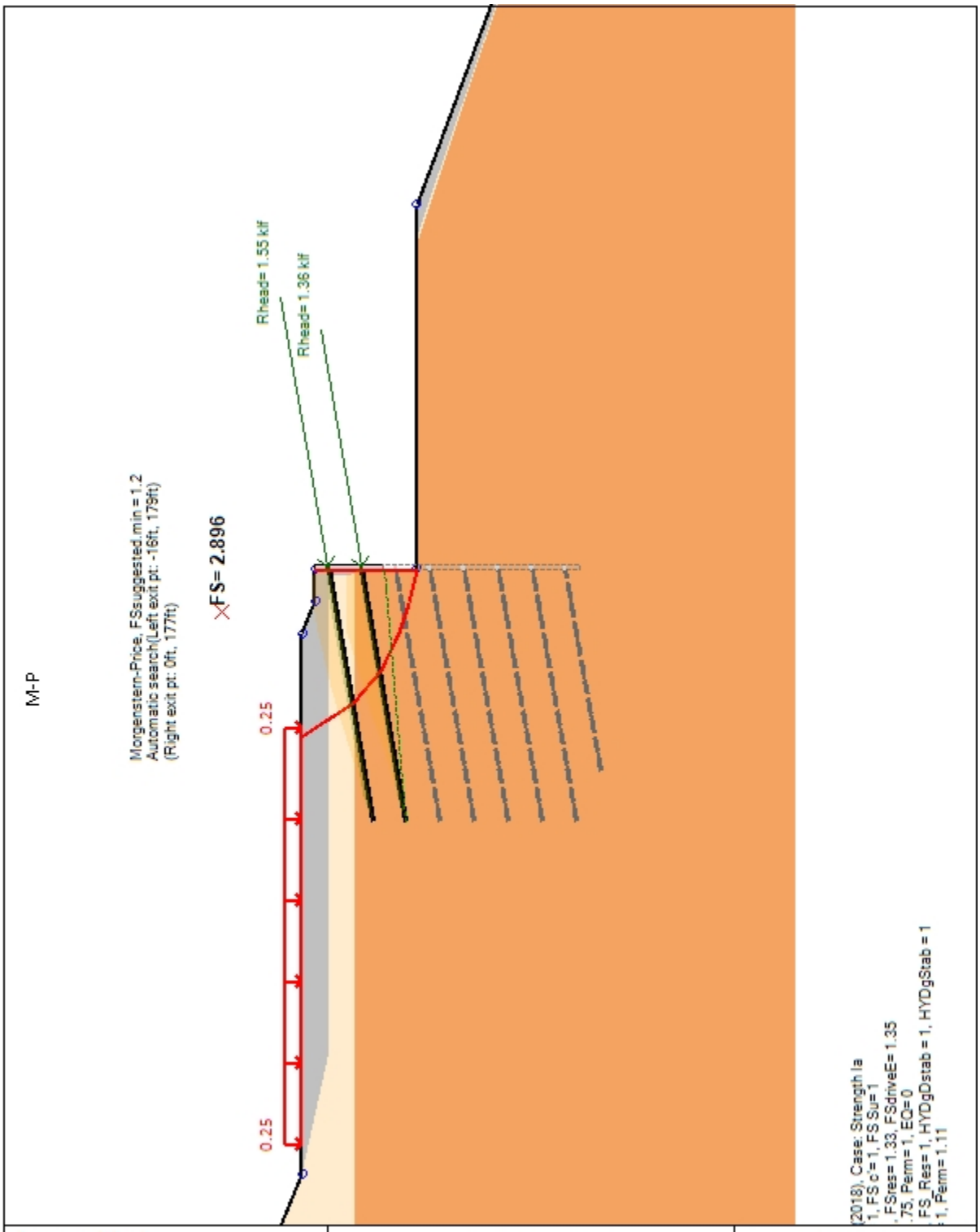

Company: Wood Engineer: DL	DS: 0, Exc. 162 ft	Deep Excavation LCC SnailPlus 2021
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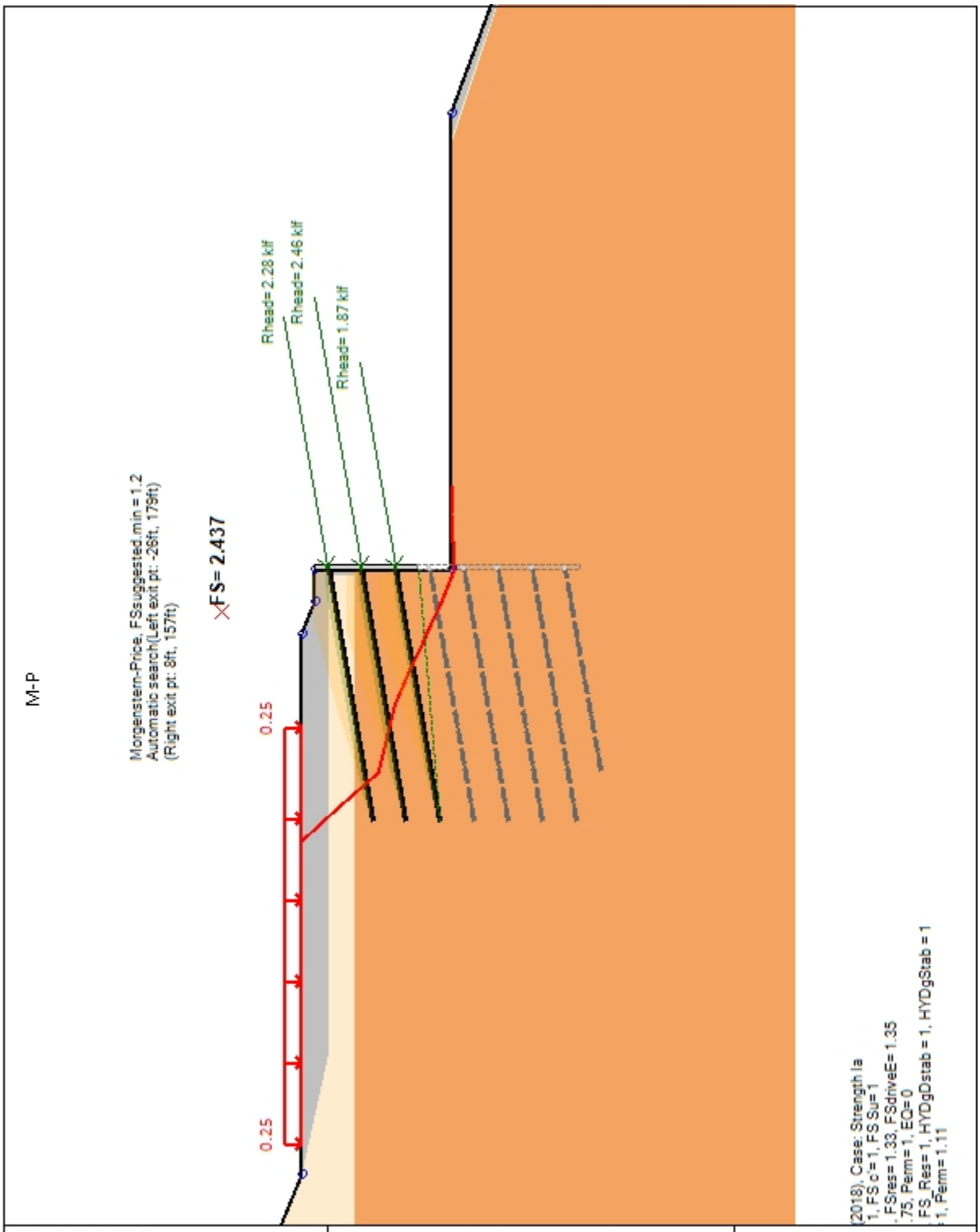

Company: Wood Engineer: DL	DS: 0, Exc. 157 ft	Deep Excavation LCC SnailPlus 2021
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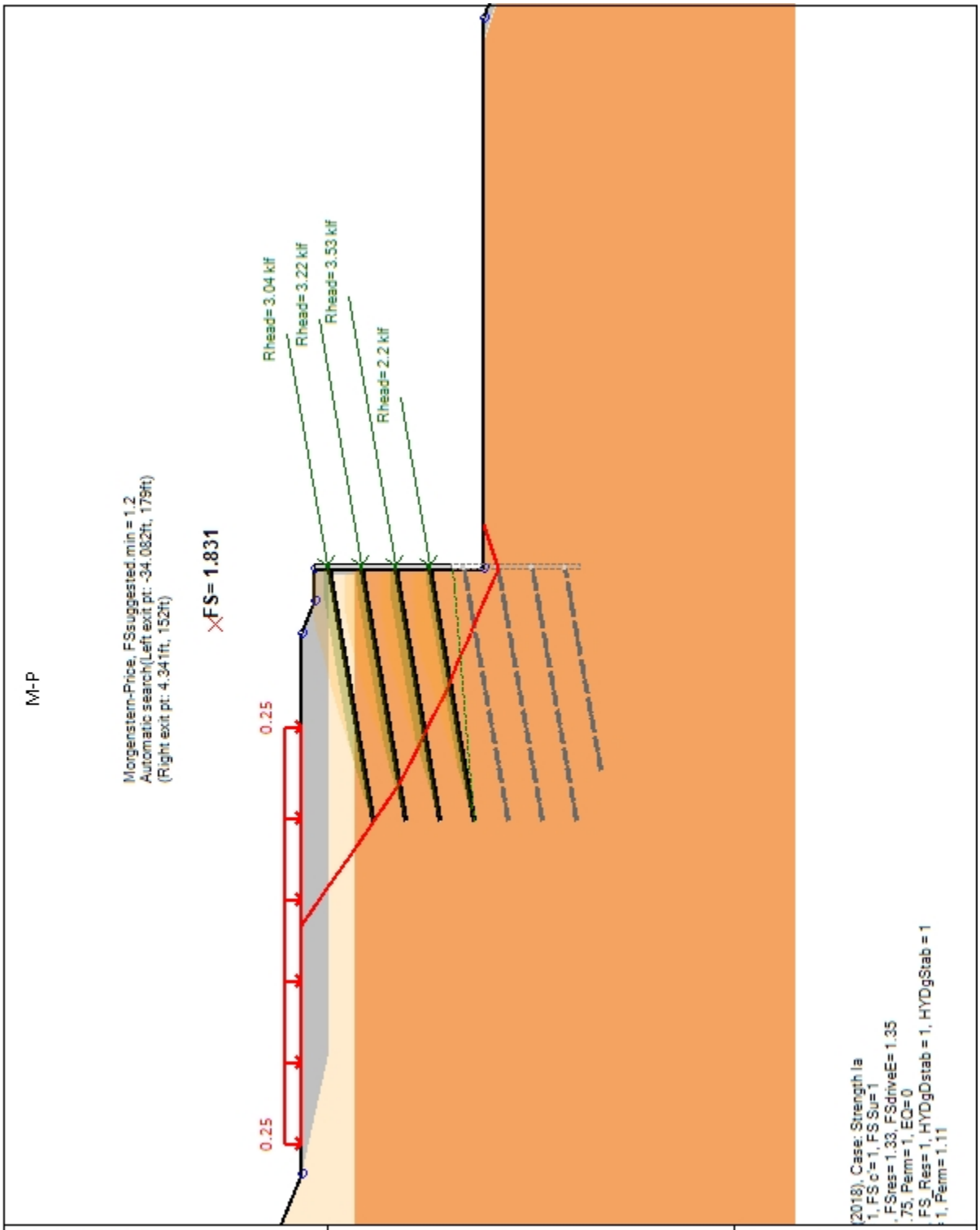

Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
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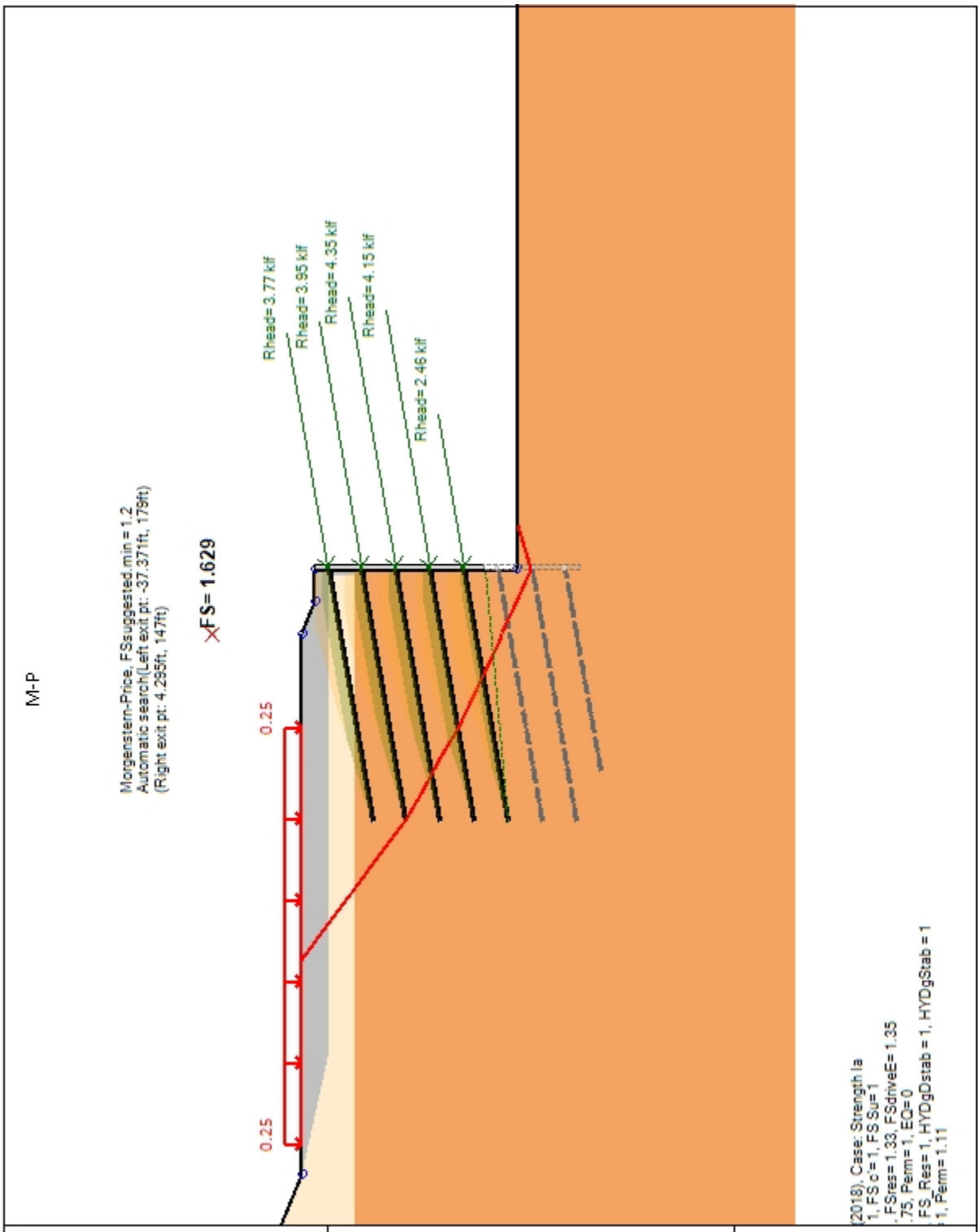

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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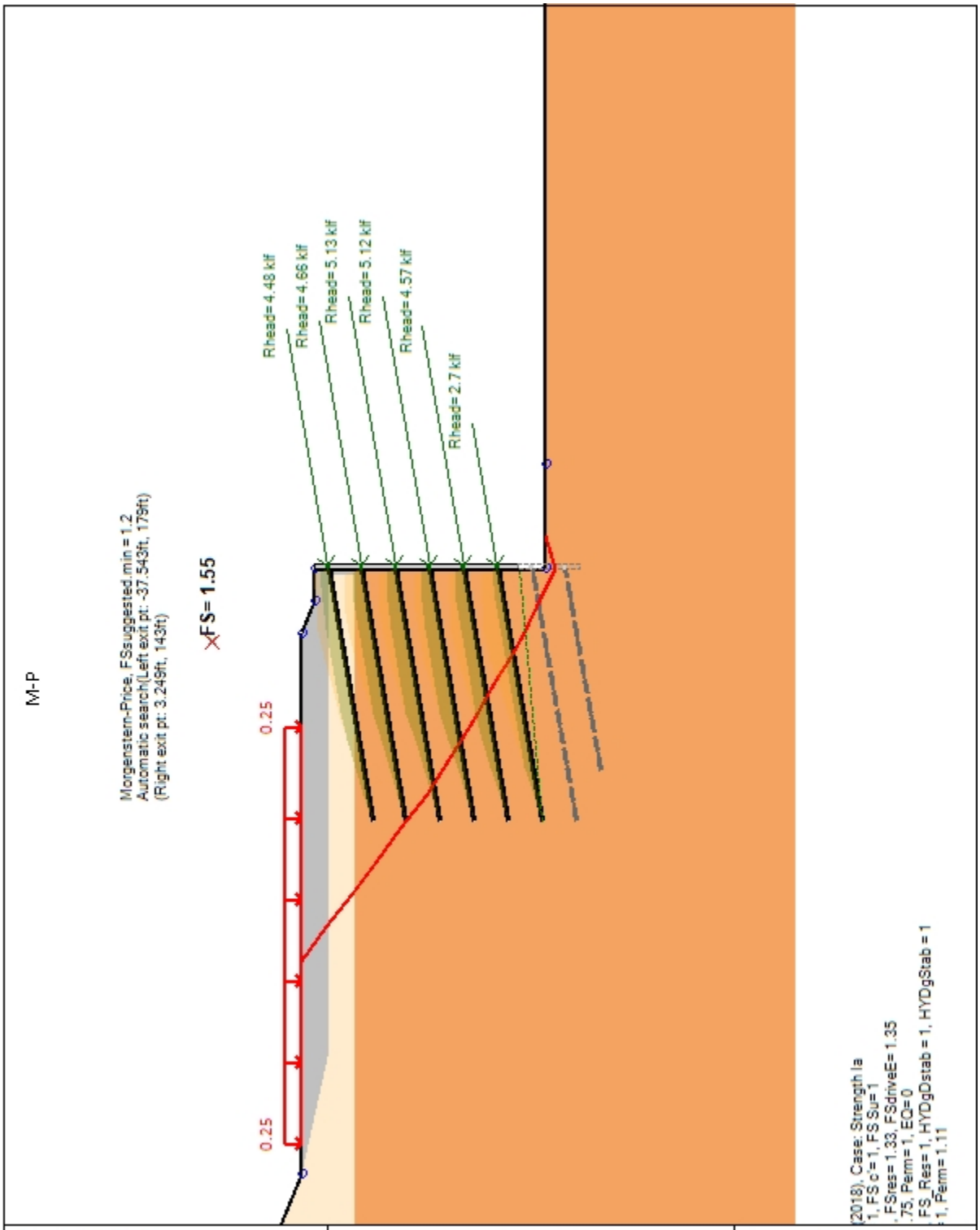

Company: Wood Engineer: DL	DS: 0, Exc. 142 ft	Deep Excavation LCC SnailPlus 2021
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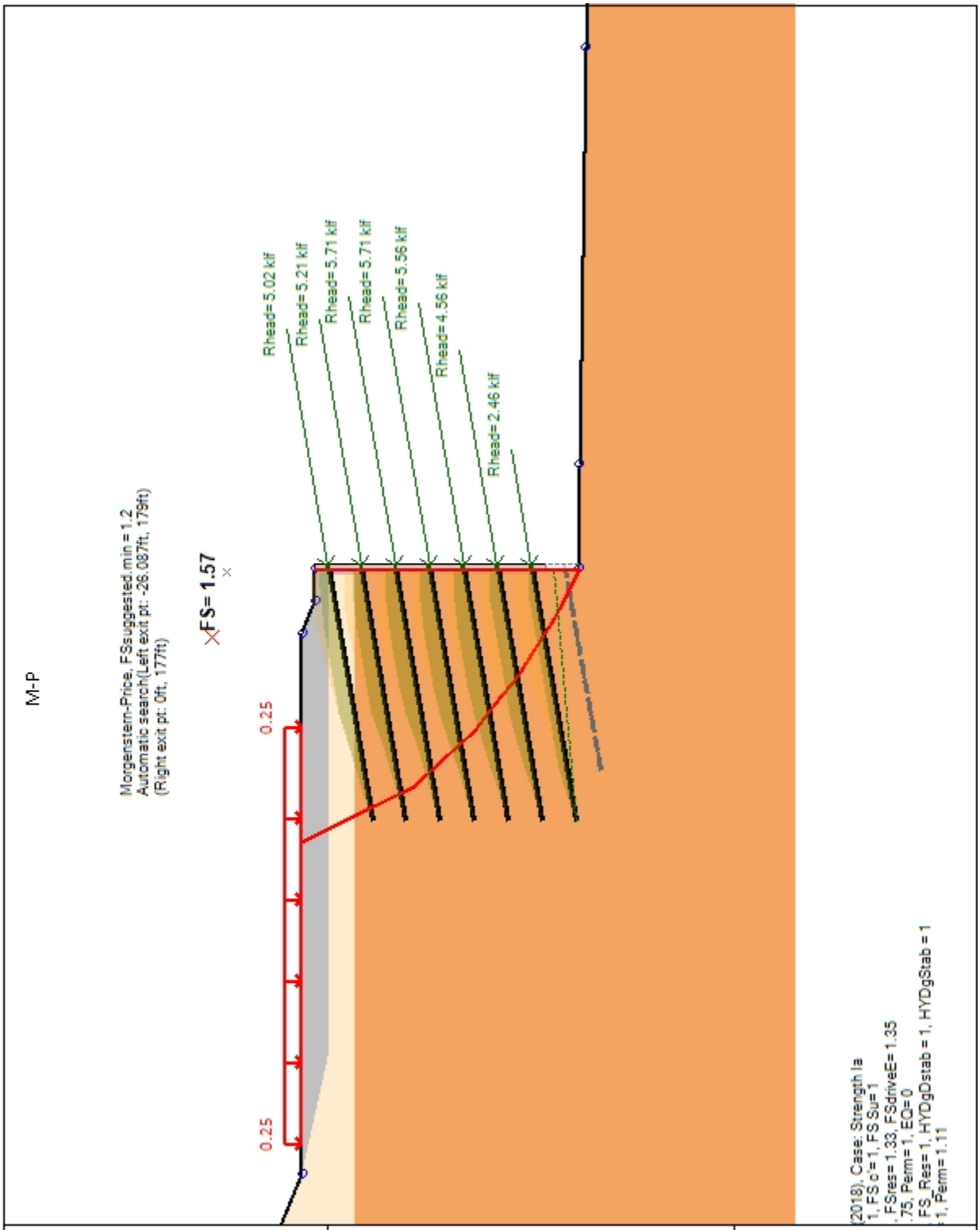


Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..es\3+80\New Stratigraphy\CS Sta 3+80 (Temp Static, M-P).SNLP		12/2/2021

SnailPlus 2021: Report Output

Copyright@2009 - 2020 Deep Excavation LLC: www.deepexcavation.com A program for the evaluation of soil nail walls. Deep Excavation LLC, Astoria, New York, www.deepexcavation.com

Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 3+80 (Temp Static, Spencer)

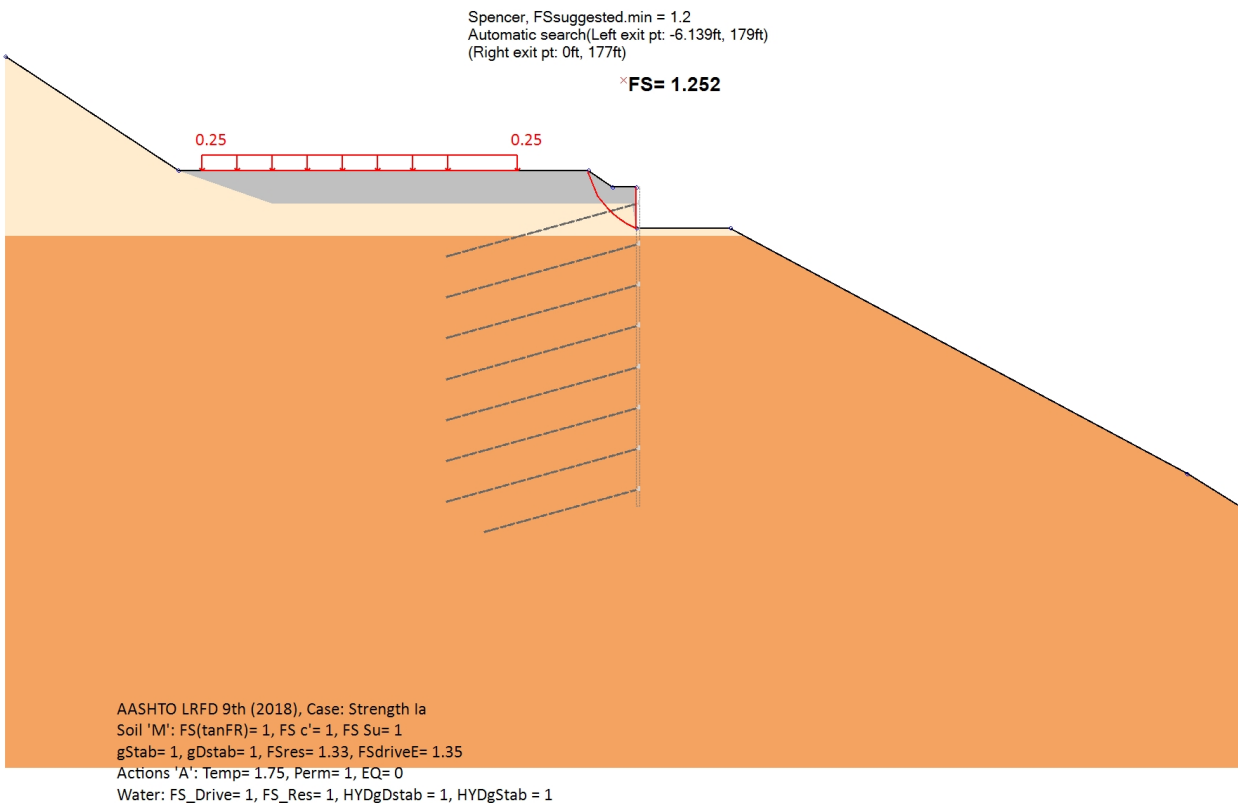
Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 5:33:02 PM

THIS PROGRAM IS PROTECTED BY U.S. COPYRIGHT LAWS AS DESCRIBED IN THE EULA. UNAUTHORIZED COPYING IS PROHIBITED. LICENSED TO: Deep Excavation LLC BY DEEP EXCAVATION LLC UNDER SPECIFIC LICENCE. This report has printed because the user has accepted responsibility as described in the disclaimer and EULA
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\3+80\New Stratigraphy\CS Sta 3+80 (Temp Static, Spencer) - Copy.SNLP

Quick analysis summary for design section: Spencer

Spencer

ESU 4A	135	0	-	42	22



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	2.097	0	0	0	0	0	0	No	Yes
Exc. 172 ft	Calculated	1.252	0	0	0	0	0	0	No	Yes
Exc. 167 ft	Calculated	2.468	4.45	3.14	4.45	0.068	0.08	0.038	No	Yes
Exc. 162 ft	Calculated	2.57	11.02	7.76	11.02	0.169	0.199	0.095	No	Yes
Exc. 157 ft	Calculated	2.437	17.47	12.31	17.47	0.248	0.316	0.151	No	Yes
Exc. 152 ft	Calculated	1.908	24.89	17.65	25.04	0.351	0.452	0.216	No	Yes

Project Wall	Calculated	1.704	30.7	21.77	30.88	0.432	0.558	0.267	No	Yes
Exc. 142 ft	Calculated	1.982	36.15	25.63	36.37	0.509	0.657	0.314	No	Yes
Forward Com	Calculated	1.587	40.29	28.57	40.54	0.567	0.732	0.35	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	2.097	1.2	Circle	34.575	207.1	47.179	N/A	N/A
Exc. 172 ft	Yes	1.252	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 167 ft	Yes	2.468	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 162 ft	Yes	2.57	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	2.437	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	1.908	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.704	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 142 ft	Yes	1.982	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.587	1.2	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 20)	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	51.07	0.068	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	60.54	0.169	N/A	N/A	N/A
xL (-55 to -6)	xR (0 to 10)	N/A	AASHTO LRF	Strength Ia	59.73	0.248	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	59.63	0.351	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.5	0.432	N/A	N/A	N/A
xL (-55 to -6)	xR (0.1 to 10)	N/A	AASHTO LRF	Strength Ia	60.64	0.509	N/A	N/A	N/A
xL (-55 to -6)	xR (0.2 to 15)	N/A	AASHTO LRF	Strength Ia	60.14	0.567	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	175	25	0	5	5.024	25.12
N1	0: N1	15	0	170	25	0	5	5.2056	26.03
N2	0: N1	15	0	165	25	0	5	5.7143	28.57
N3	0: N1	15	0	160	25	0	5	5.7071	28.54
N4	0: N1	15	0	155	25	0	5	5.56	27.8
N5	0: N1	15	0	150	25	0	5	4.5604	22.8
N6	0: N1	15	0	145	25	0	5	2.4593	12.3
N7	0: N1	15	0	140	20	0	5	0	0

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	193
2	-58	179
3	-6	179
4	-3	177
5	0	177
6	0	138
7	10	138
8	50	137
9	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
177	ESU 4C	1	0.32
160	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 175ft
Radii search ends at point x= 0ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 172 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 167 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 142 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 10ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

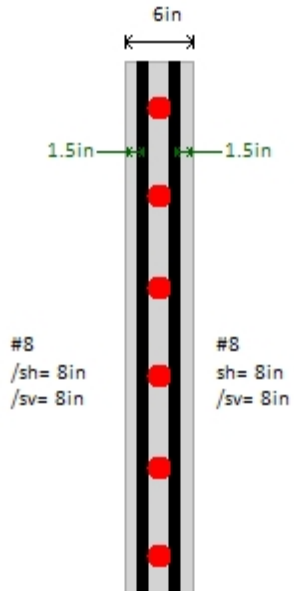
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-55ft to -6ft
Right limits	0.2ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.2ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Spencer



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	177	136	N/A	6
Exc. 172 ft	No	177	172	N/A	6
Exc. 167 ft	Yes	177	172	N/A	6
Exc. 162 ft	Yes	177	167	N/A	6
Exc. 157 ft	Yes	177	162	N/A	6
Exc. 152 ft	Yes	177	157	N/A	6
Project Wall Height	Yes	177	152	N/A	6
Exc. 142 ft	Yes	177	147	N/A	6
Forward Compatible	Yes	177	143	N/A	6

Soil nail input data for design section Spencer

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	175	25	0	5	1.27	6	75
N1	0: N1	15	0	170	25	0	5	1.27	6	75
N2	0: N1	15	0	165	25	0	5	1.27	6	75
N3	0: N1	15	0	160	25	0	5	1.27	6	75
N4	0: N1	15	0	155	25	0	5	1.27	6	75
N5	0: N1	15	0	150	25	0	5	1.27	6	75
N6	0: N1	15	0	145	25	0	5	1.27	6	75
N7	0: N1	15	0	140	20	0	5	1.27	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	175	8	2.25	36	1	N/A	N/A	N/A
N1	170	8	2.25	36	1	N/A	N/A	N/A
N2	165	8	2.25	36	1	N/A	N/A	N/A
N3	160	8	2.25	36	1	N/A	N/A	N/A
N4	155	8	2.25	36	1	N/A	N/A	N/A
N5	150	8	2.25	36	1	N/A	N/A	N/A
N6	145	8	2.25	36	1	N/A	N/A	N/A
N7	140	8	2.25	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Spencer

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 34.575 z= 207.1 FS= 2.097

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -1.535 z= 190.1 FS= 1.252

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 2.449 z= 190.1 FS= 2.468

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	38.57	51.07	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= 4.062 z= 190.1 FS= 2.57

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	35.91	52.1	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	46.35	60.54	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -4.042 z= 190.794 FS= 2.437

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	12.28	52.57	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	31.42	59.73	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	50.64	55.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -3.893 z= 190.695 FS= 1.908

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.92	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	10.75	56.86	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	27.39	54.46	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	44.03	59.63	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 6

Soil nail results available for this stage.

Critical point at x= -4.724 z= 191.249 FS= 1.704

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.86	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	57.35	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	14.72	55.72	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	29.76	53.01	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	47.54	60.5	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 7

Soil nail results available for this stage.

Critical point at x= -3.785 z= 190.624 FS= 1.982

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.71	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0.32	57.67	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	7.53	56.18	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

3: N3	19.33	53.98	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	31.23	57.34	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	47.01	60.64	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 8

Soil nail results available for this stage.

Critical point at x= -2.5 z= 190.1 FS= 1.587

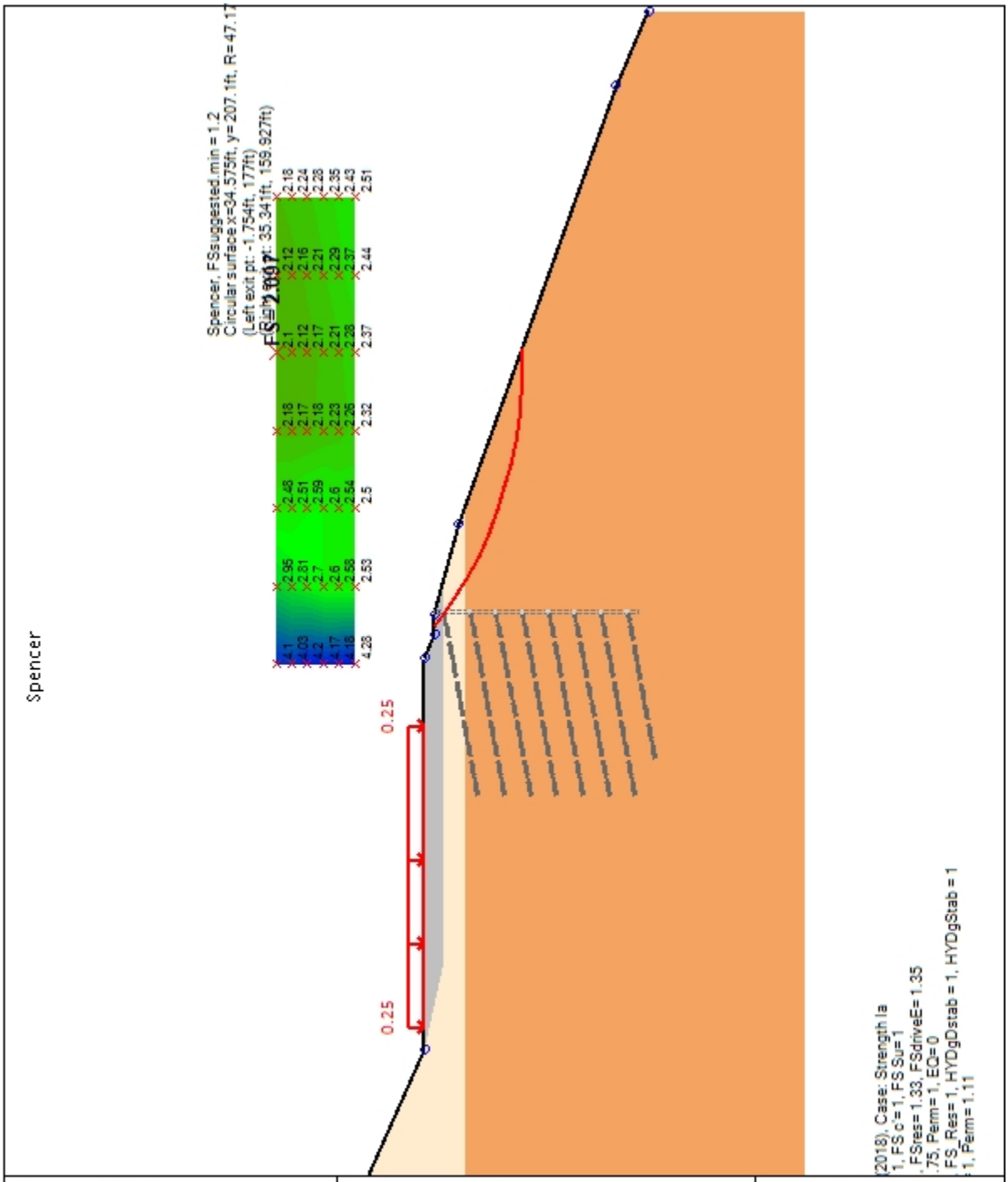
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.58	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	58.12	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	56.84	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	0	55.52	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	13.88	53.33	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	27.75	60.14	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	44.35	60.1	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: N7	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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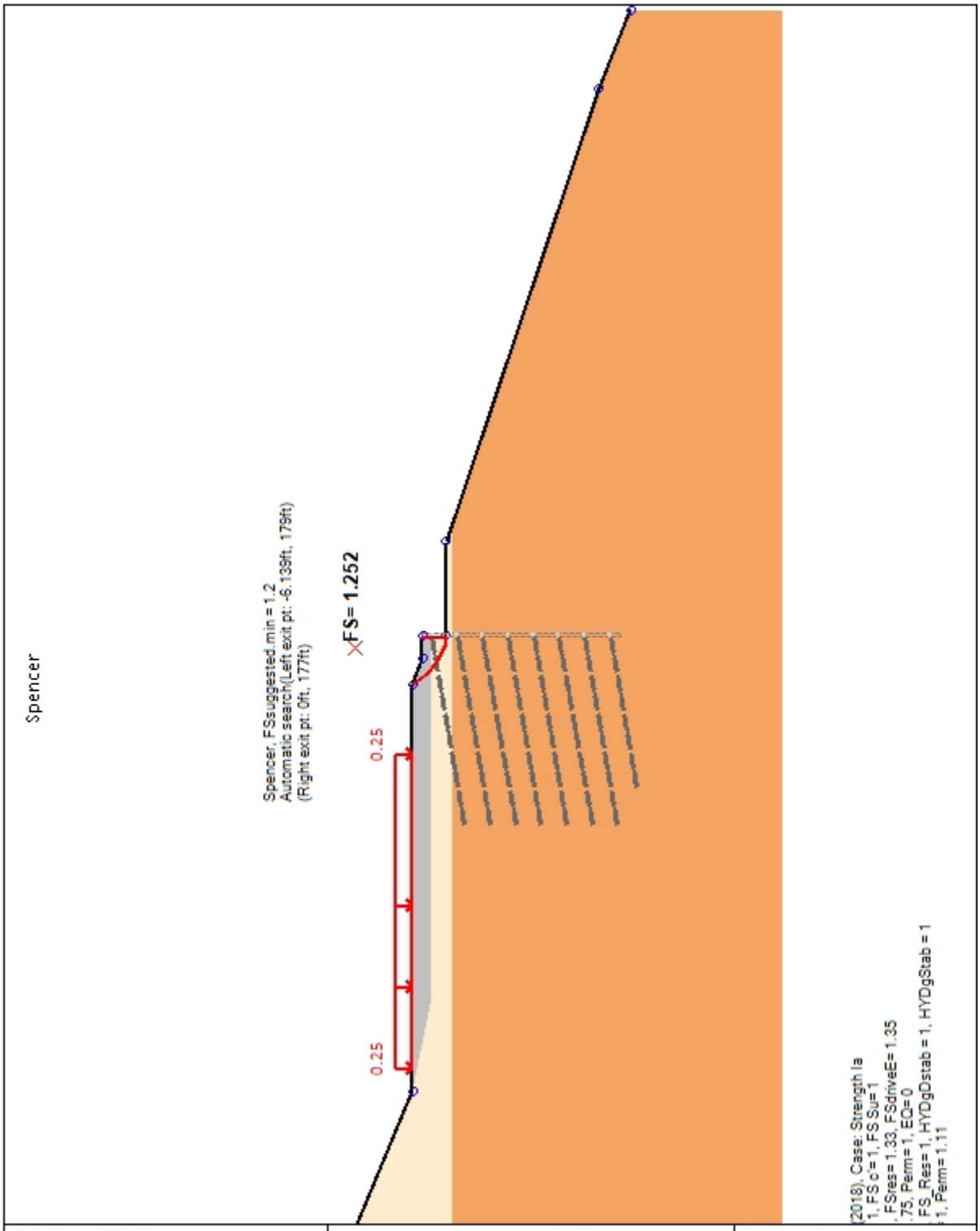

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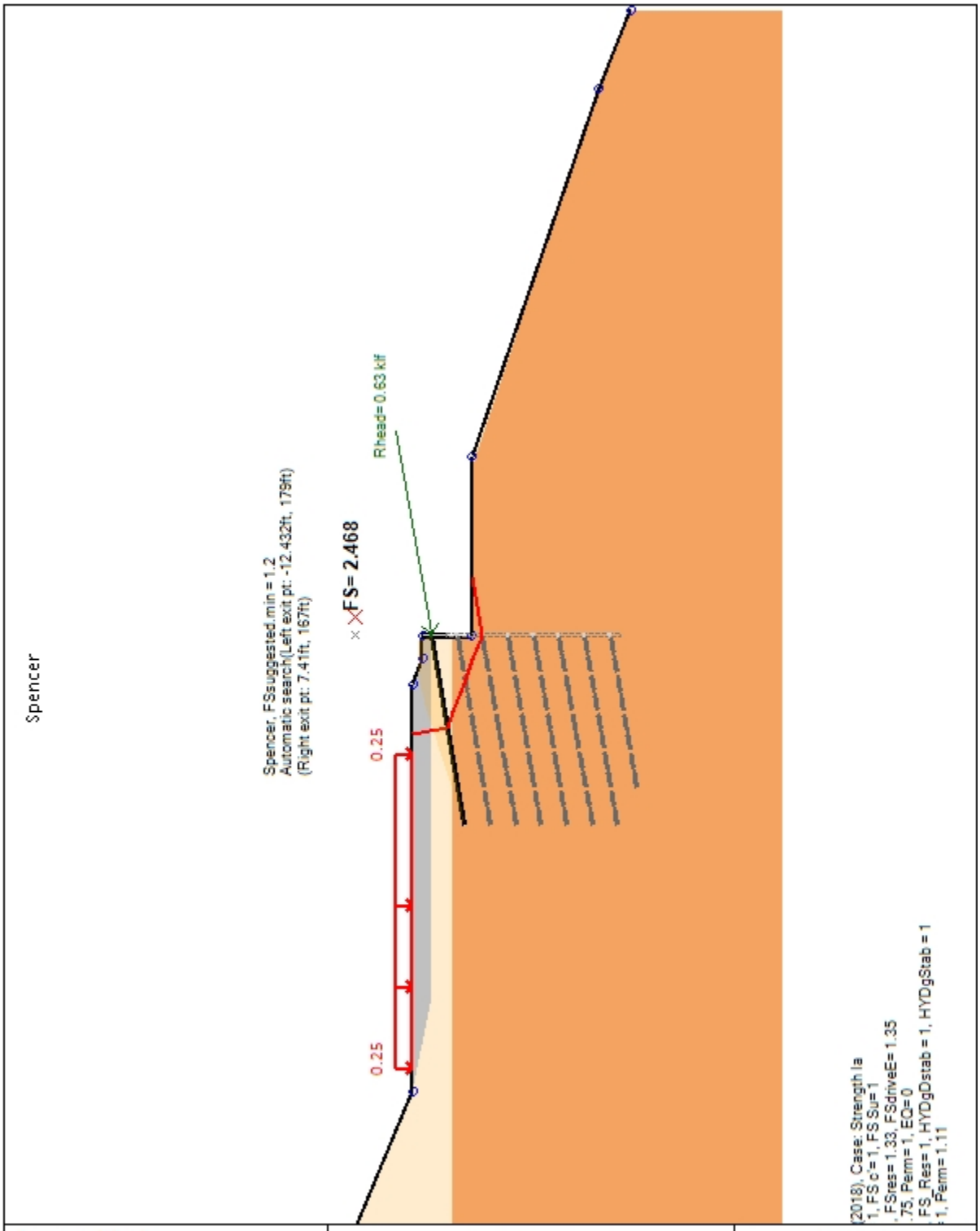

Company: Wood Engineer: DL	DS: 0, Exc. 167 ft	Deep Excavation LCC SnailPlus 2021
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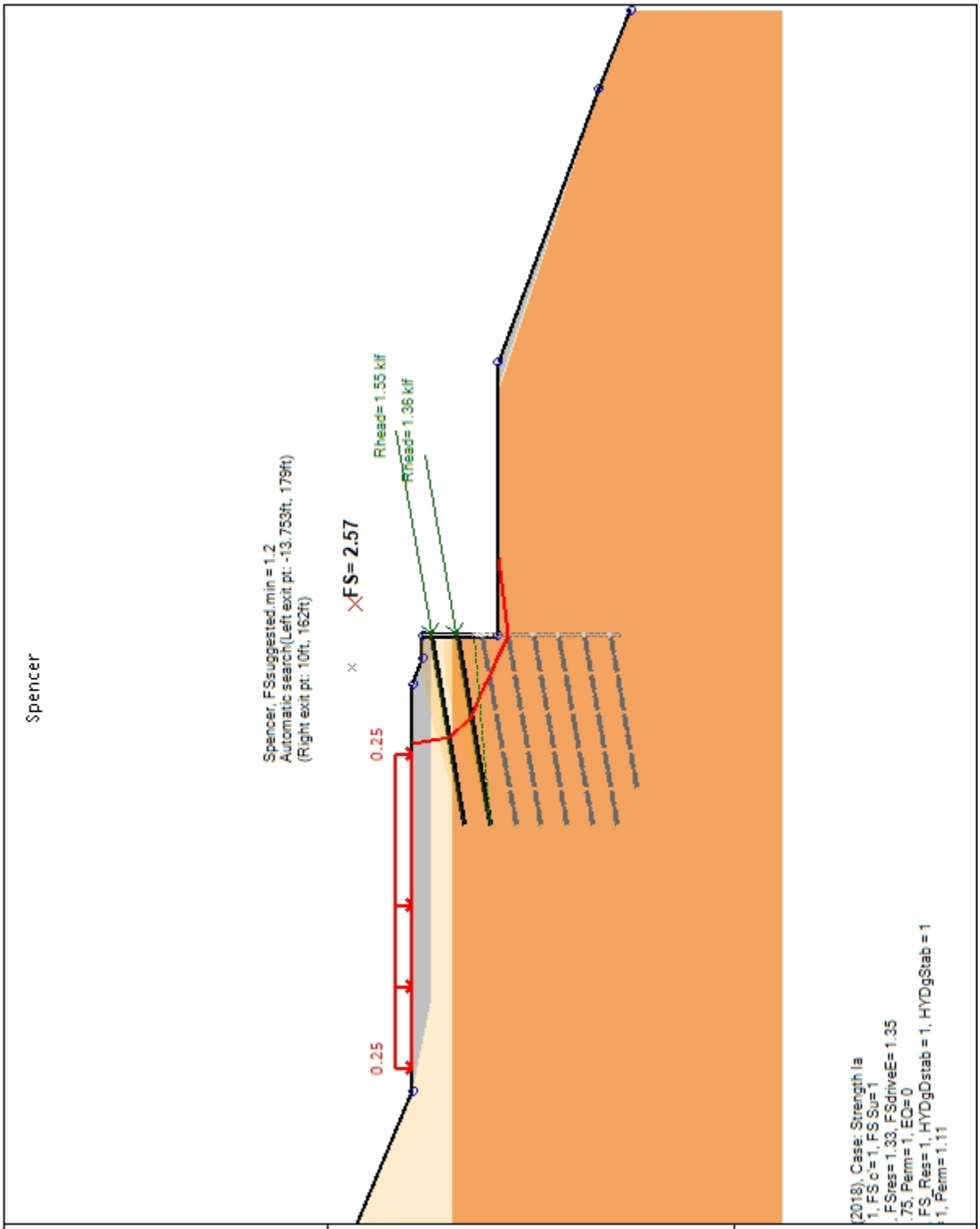

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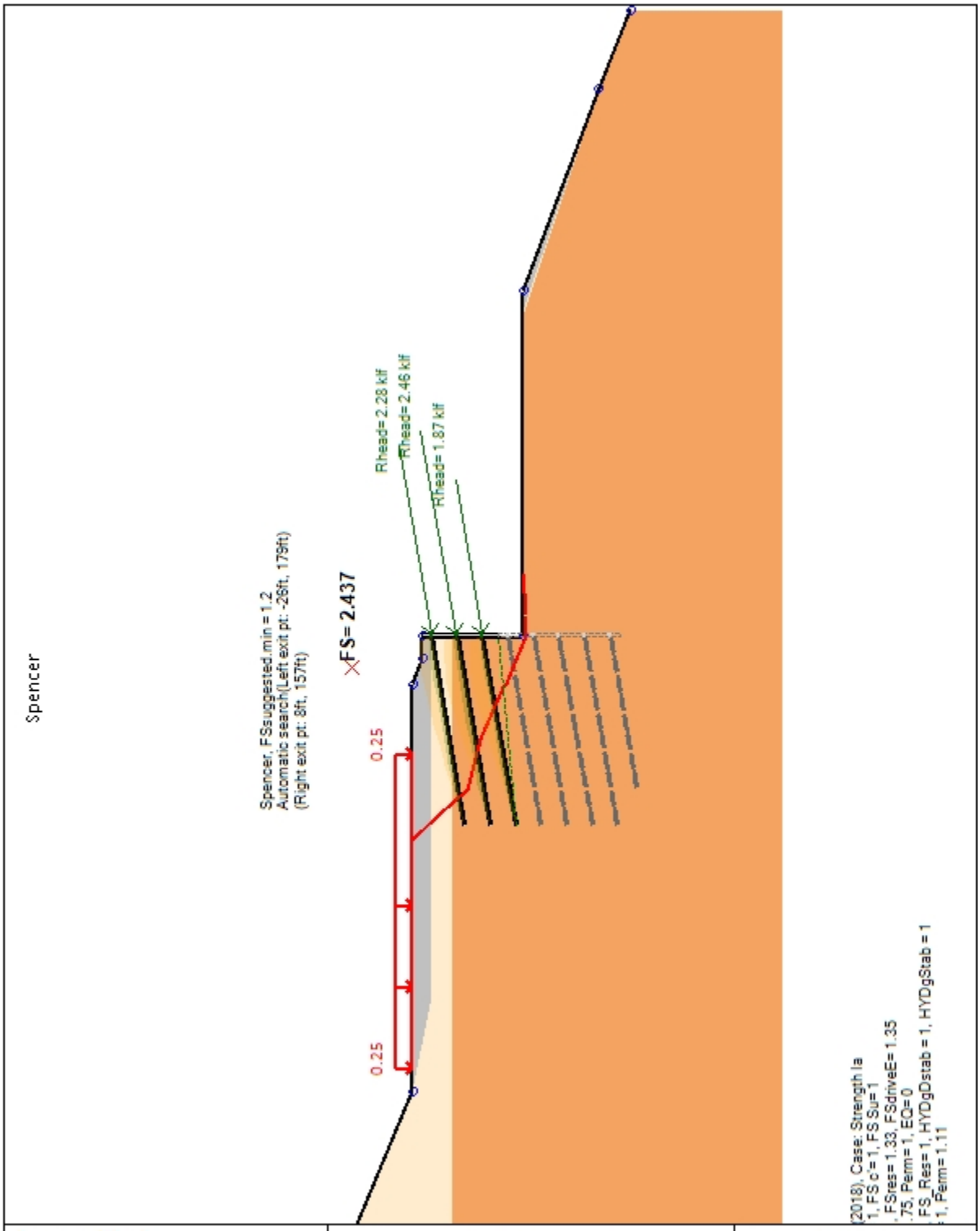

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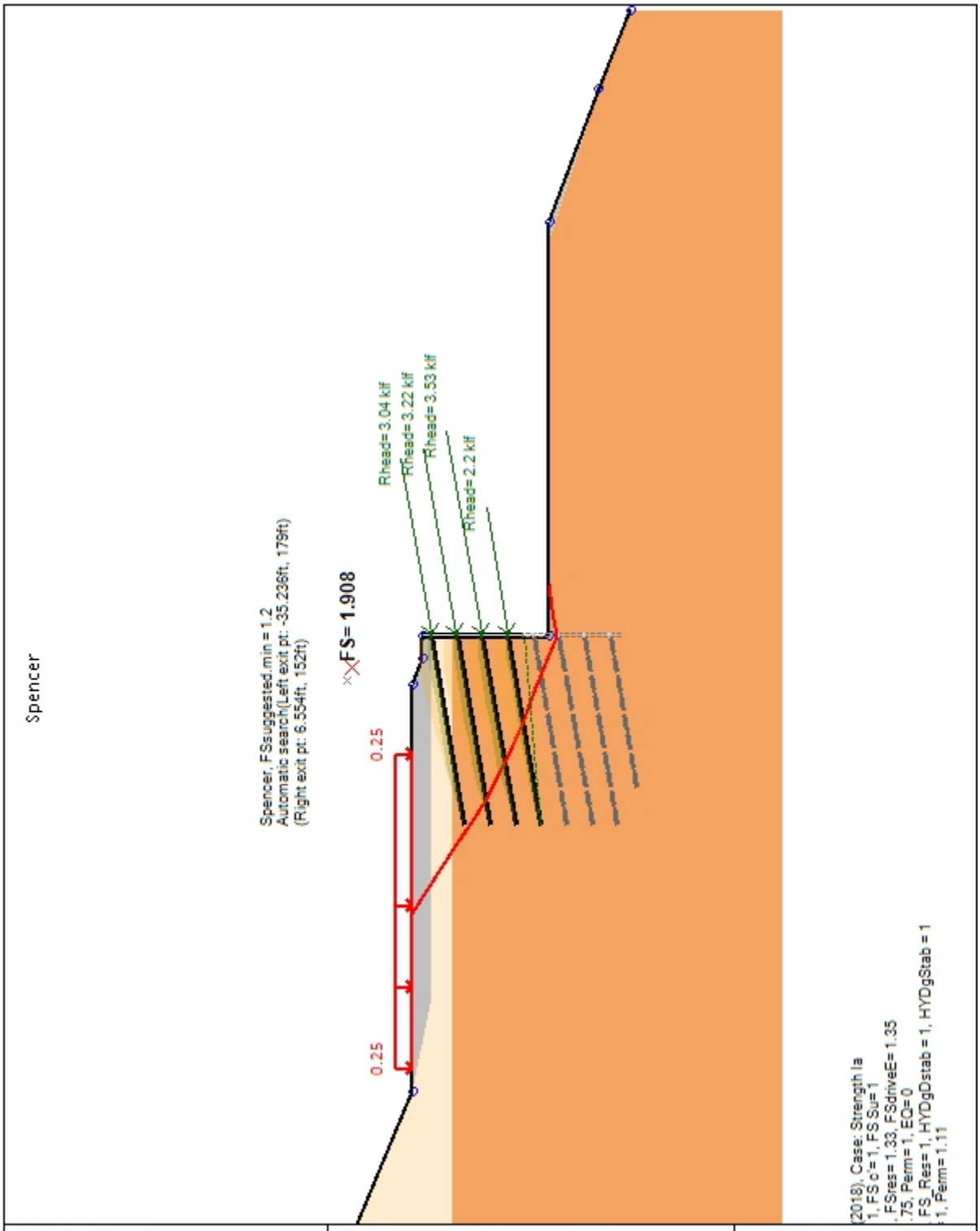

Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
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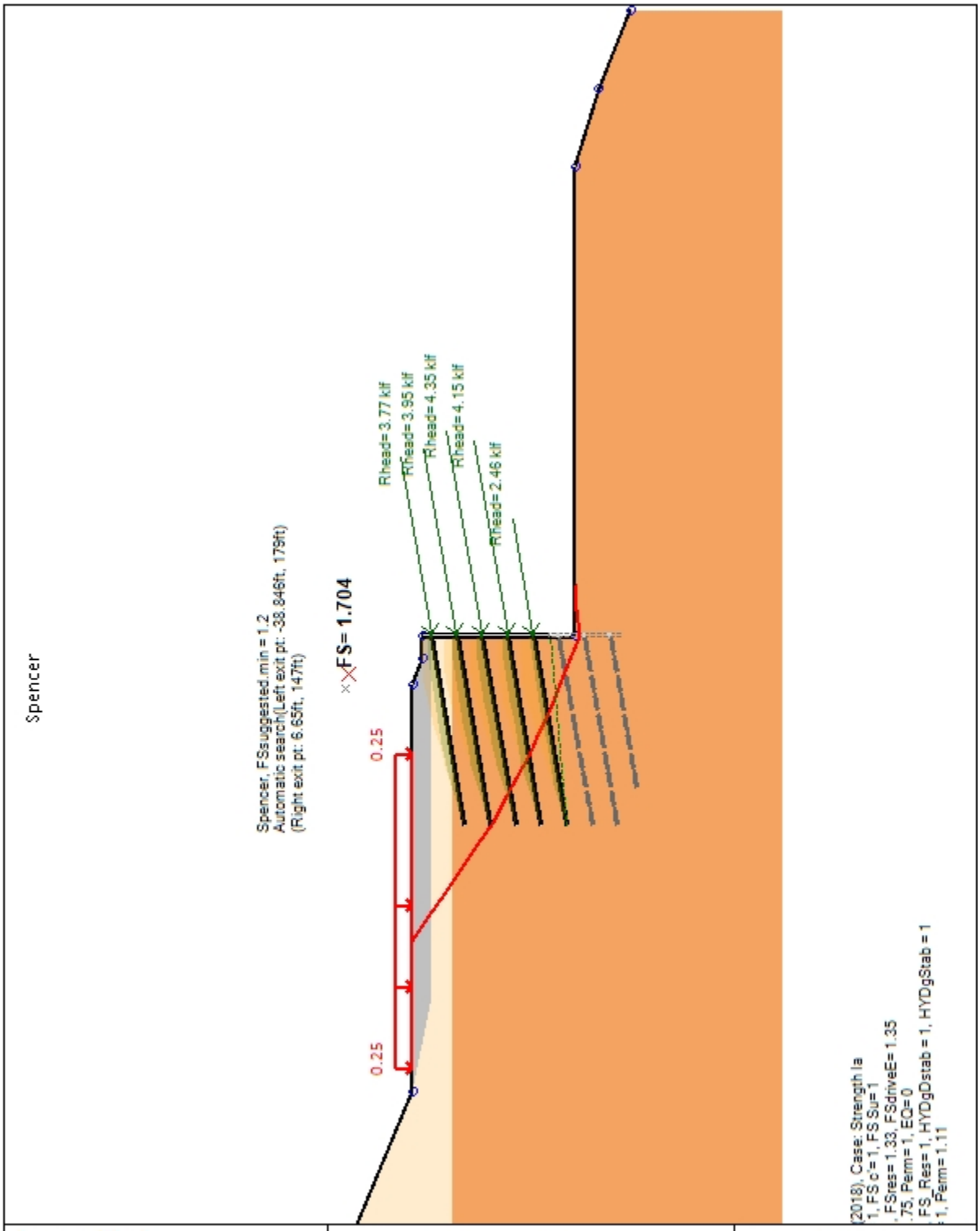

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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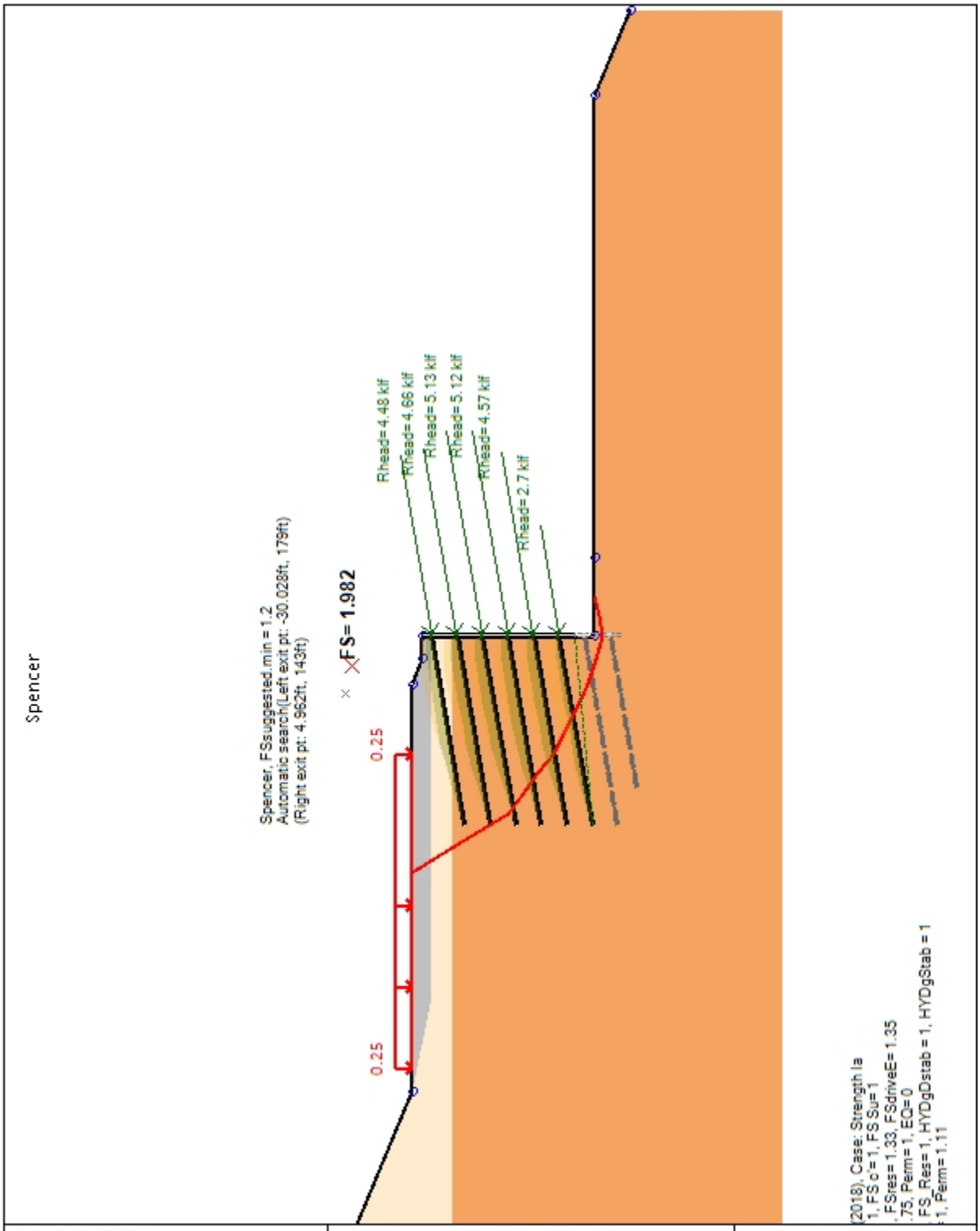

Company: Wood Engineer: DL	DS: 0, Exc. 142 ft	Deep Excavation LCC SnailPlus 2021
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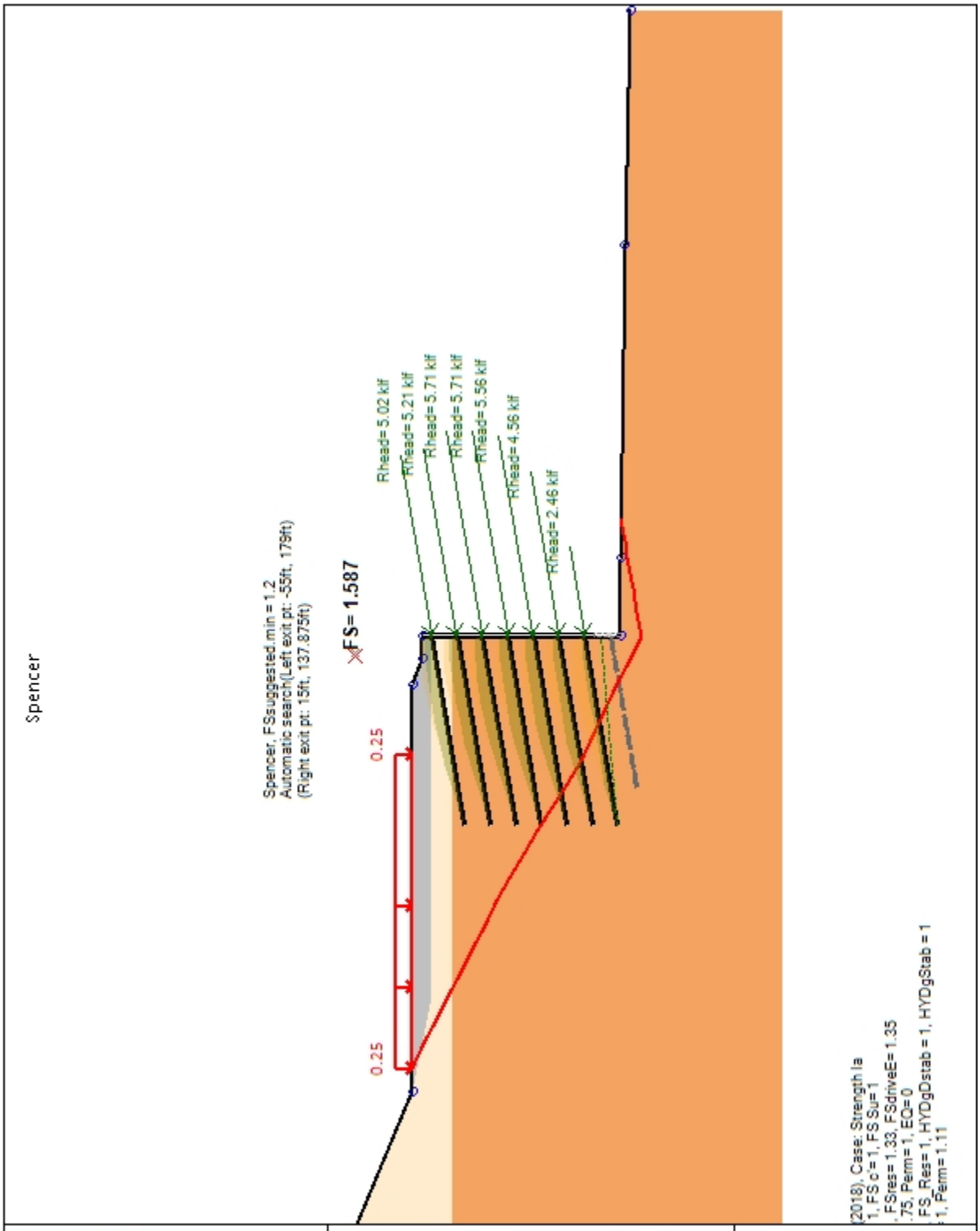

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us.. Stratigraphy\CS Sta 3+80 (Temp Static, Spencer) - Copy.SNLP		12/1/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 3+80 (Seismic, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 5:39:04 PM

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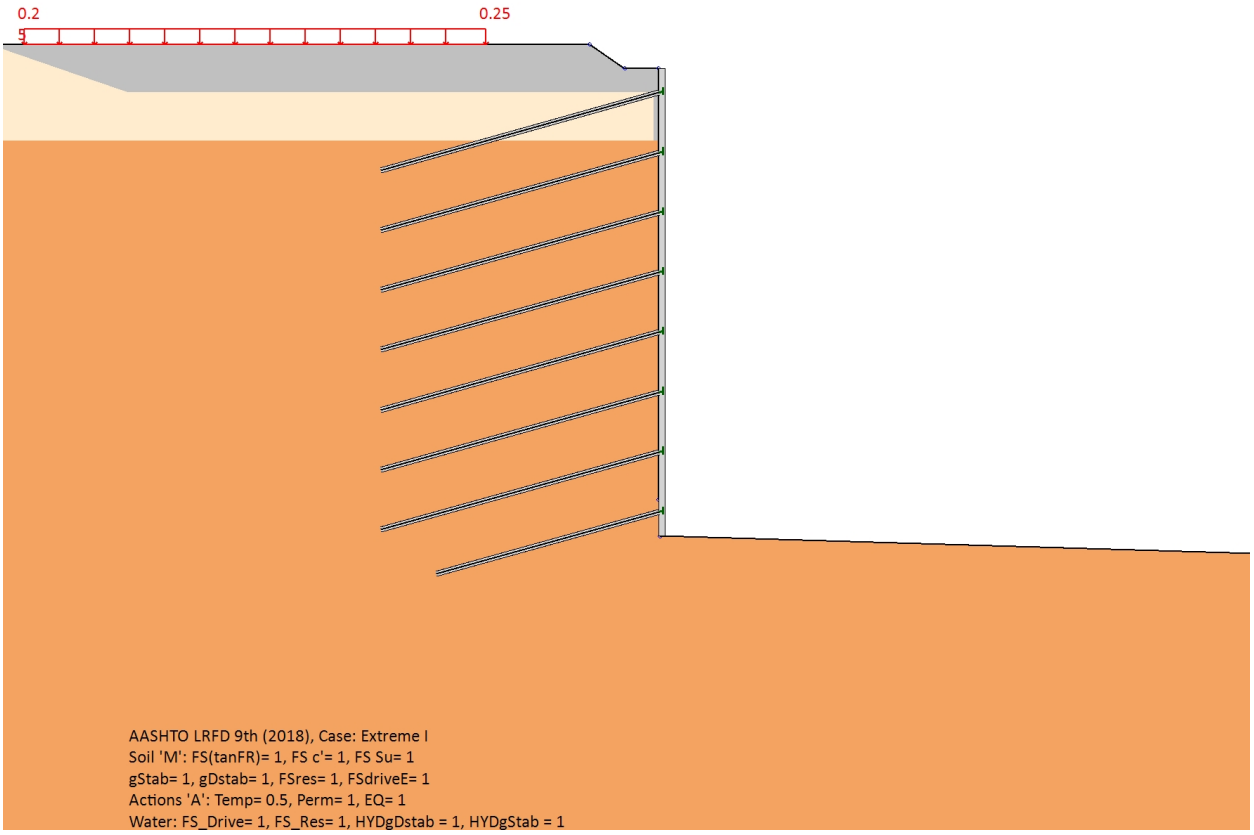
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\3+80\New Stratigraphy\CS Sta 3+80 (Seismic, M-P) .SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Stage 0	Not converg	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Project Wall	Calculated	1.609	40.58	28.77	40.82	0.659	0.664	0.353	No	Yes
Project Wall	Calculated	1.92	40.58	28.77	40.82	0.659	0.664	0.353	No	Yes
Forward Com	Calculated	1.447	44.54	31.58	44.81	0.724	0.729	0.387	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)

STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Stage 0	No	-	-	-	-	-	-	-	-
Project Wall	Yes	1.609	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.92	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.447	1.1	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
-	-	-	-	-	-	-	-	-	-
xL (-58 to -6)	xR (0.1 to 20)	N/A	AASHTO LRF	Extreme I	60.8	0.659	N/A	N/A	N/A
xL (-80 to -58	xR (30 to 80)	N/A	AASHTO LRF	Extreme I	0	0.659	N/A	N/A	N/A
xL (-58 to -6)	xR (0.1 to 20)	N/A	AASHTO LRF	Extreme I	59.94	0.724	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-58ft to -6ft
Right limits	0.1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Extreme I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	0.5
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	175	25	0	5	6.1482	30.74
N1	0: N1	15	0	170	25	0	5	6.0091	30.05
N2	0: N1	15	0	165	25	0	5	6.3158	31.58
N3	0: N1	15	0	160	25	0	5	6.0896	30.45
N4	0: N1	15	0	155	25	0	5	5.8522	29.26
N5	0: N1	15	0	150	25	0	5	5.3632	26.82
N6	0: N1	15	0	145	25	0	5	4.0133	20.07
Nail 1	0: N1	15	0	140	20	0	5	2.4071	12.04

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	193
2	-58	179
3	-6	179
4	-3	177
5	0	177
6	0	141
7	0.1	138
8	70	136
9	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
177	ESU 4C	1	0.32
160	ESU 4A	1	0.33

Slope stability assumptions: Stage 0

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-58ft to -6ft
Right limits	0.1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.5ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-58ft to -6ft
Right limits	0.1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -58ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-58ft to -6ft
Right limits	0.1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -58ft
Right search limits: xRmin= 30ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

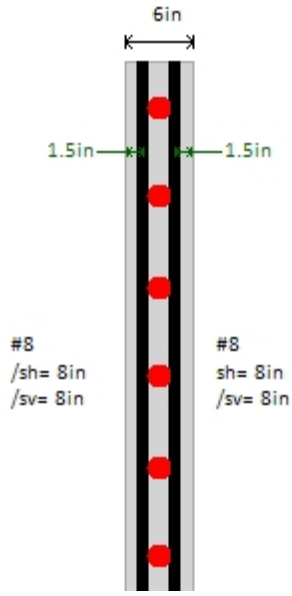
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-58ft to -6ft
Right limits	0.1ft to 20ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -58ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Stage 0	Yes	177	136	N/A	6
Project Wall Height	Yes	177	143	N/A	6
Project Wall Height-G	Yes	177	143	N/A	6
Forward Compatible	Yes	177	136	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	175	25	0	5	1.27	6	75
N1	0: N1	15	0	170	25	0	5	1.27	6	75
N2	0: N1	15	0	165	25	0	5	1.27	6	75
N3	0: N1	15	0	160	25	0	5	1.27	6	75
N4	0: N1	15	0	155	25	0	5	1.27	6	75
N5	0: N1	15	0	150	25	0	5	1.27	6	75
N6	0: N1	15	0	145	25	0	5	1.27	6	75
Nail 1	0: N1	15	0	140	20	0	5	1.27	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	175	8	2.25	36	1	N/A	N/A	N/A
N1	170	8	2.25	36	1	N/A	N/A	N/A
N2	165	8	2.25	36	1	N/A	N/A	N/A
N3	160	8	2.25	36	1	N/A	N/A	N/A
N4	155	8	2.25	36	1	N/A	N/A	N/A
N5	150	8	2.25	36	1	N/A	N/A	N/A
N6	145	8	2.25	36	1	N/A	N/A	N/A
Nail 1	140	8	2.25	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -5.453 z= 191.735 FS= 1.609

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.71	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	58.08	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	56.79	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	3.32	55.35	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	19.14	57.34	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	38.9	60.64	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	60.42	60.8	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -5.453 z= 191.735 FS= 1.92

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N1	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N2	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
3: N3	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
4: N4	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
5: N5	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
6: N6	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
7: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -6.759 z= 192.1 FS= 1.447

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.56	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	58.32	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	57.14	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	0	55.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	11.25	54.11	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	25.23	59.94	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	42.45	59.9	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	47.34	52.27	85.72	64.69	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)

Fmax = Maximum soil nail tension from all analyzed critical failure surfaces

CAP STR = Tensile structural design capacity for soil nail

CAP GEO = Tensile geotechnical pull out resistance for soil nail

TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)

TC1 = Structural soil nail shear resistance

TC2 = Shear resistance according to Clouterre TC2 criterion

TC3	= Shear resistance according to Clouterre TC3 criterion
TC4	= Shear resistance according to Clouterre TC4 criterion
TC4 C4	= Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS	= Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po	= Soil lateral pressure at failure surface-soil nail intersection point
Pu	= Ultimate lateral pressure at failure surface-soil nail intersection point
Lo	= Flexure length for shear calculations
IxxCalc	= Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc	= Nail section modulus (adjusted for corrosion loss if assumed)
t.loss	= Structural thickness loss (if assumed by the user)
%STR	= Structural capacity loss as a percentage (if assumed by the user)

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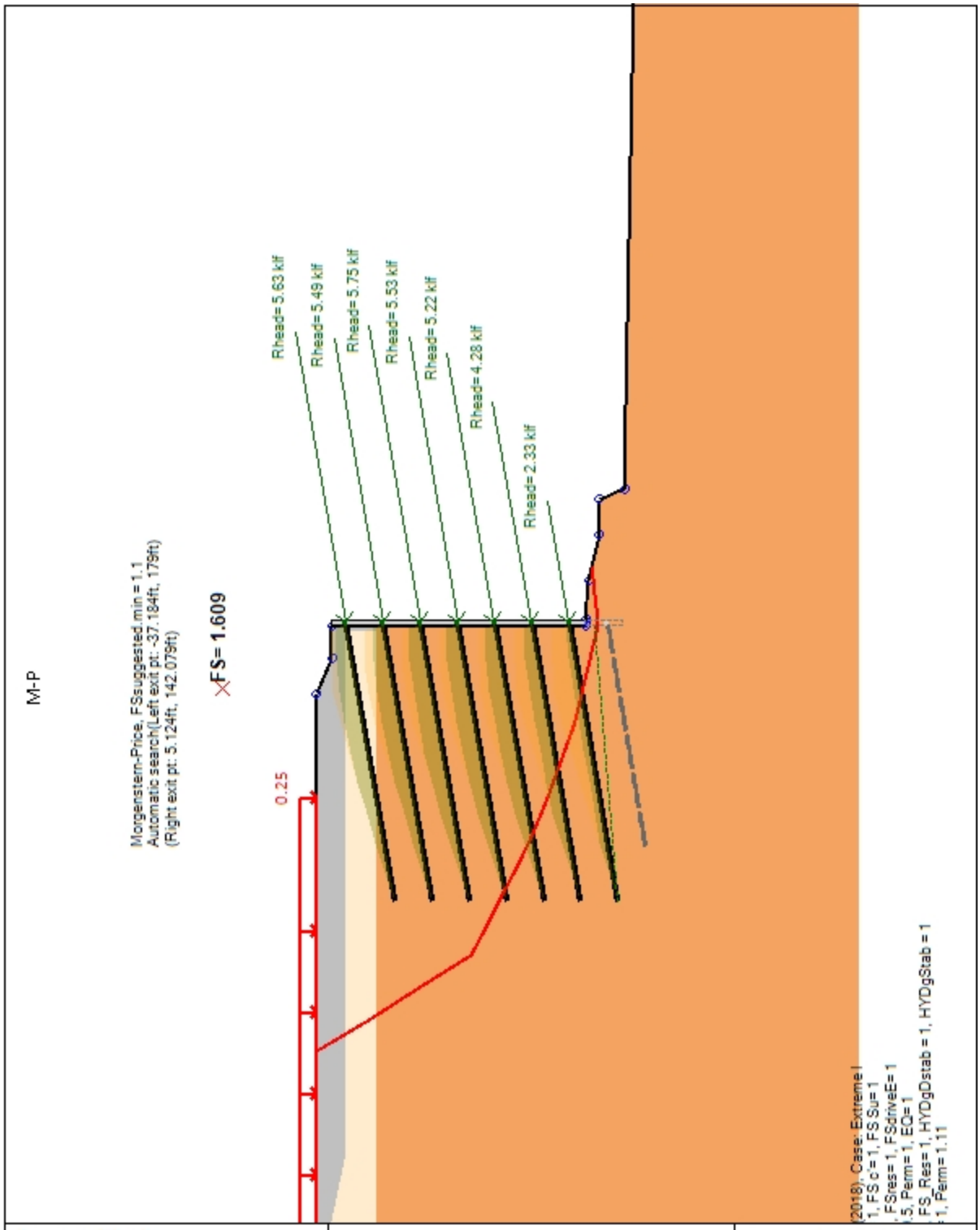

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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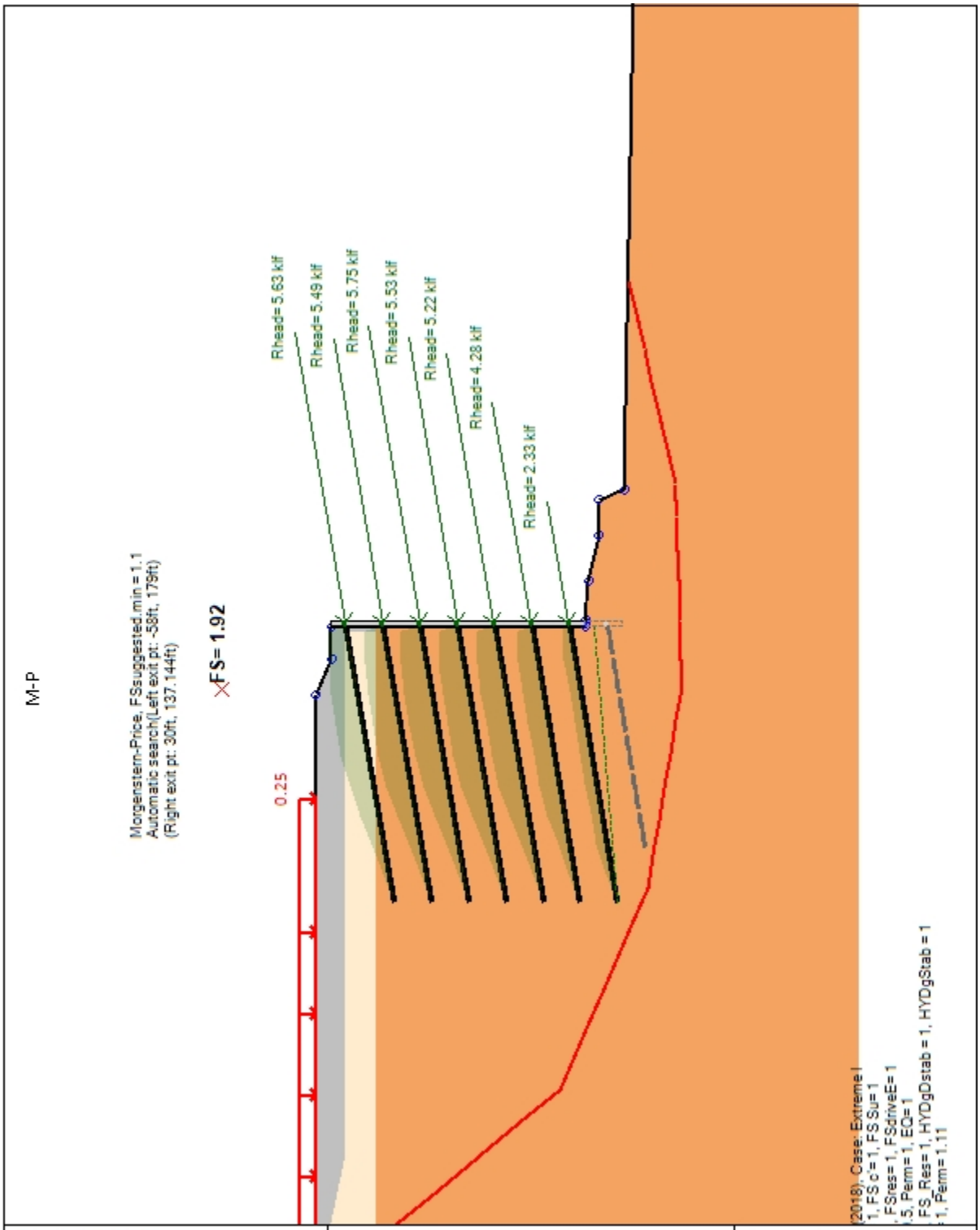

Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
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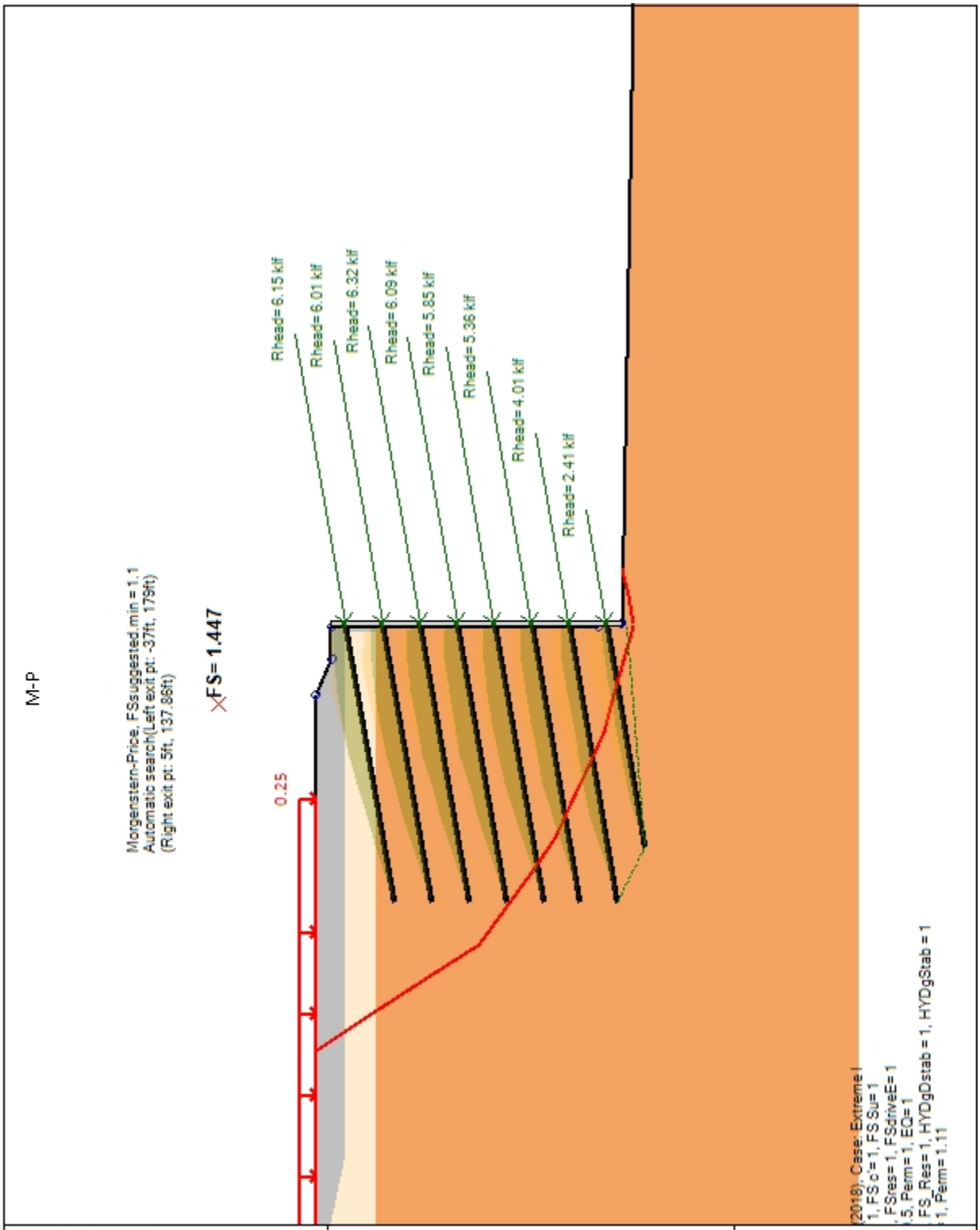

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..Files\3+80\New Stratigraphy\CS Sta 3+80 (Seismic, M-P) .SNLP		12/1/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 3+80 (Seismic, Bishop)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/1/2021 6:30:51 PM

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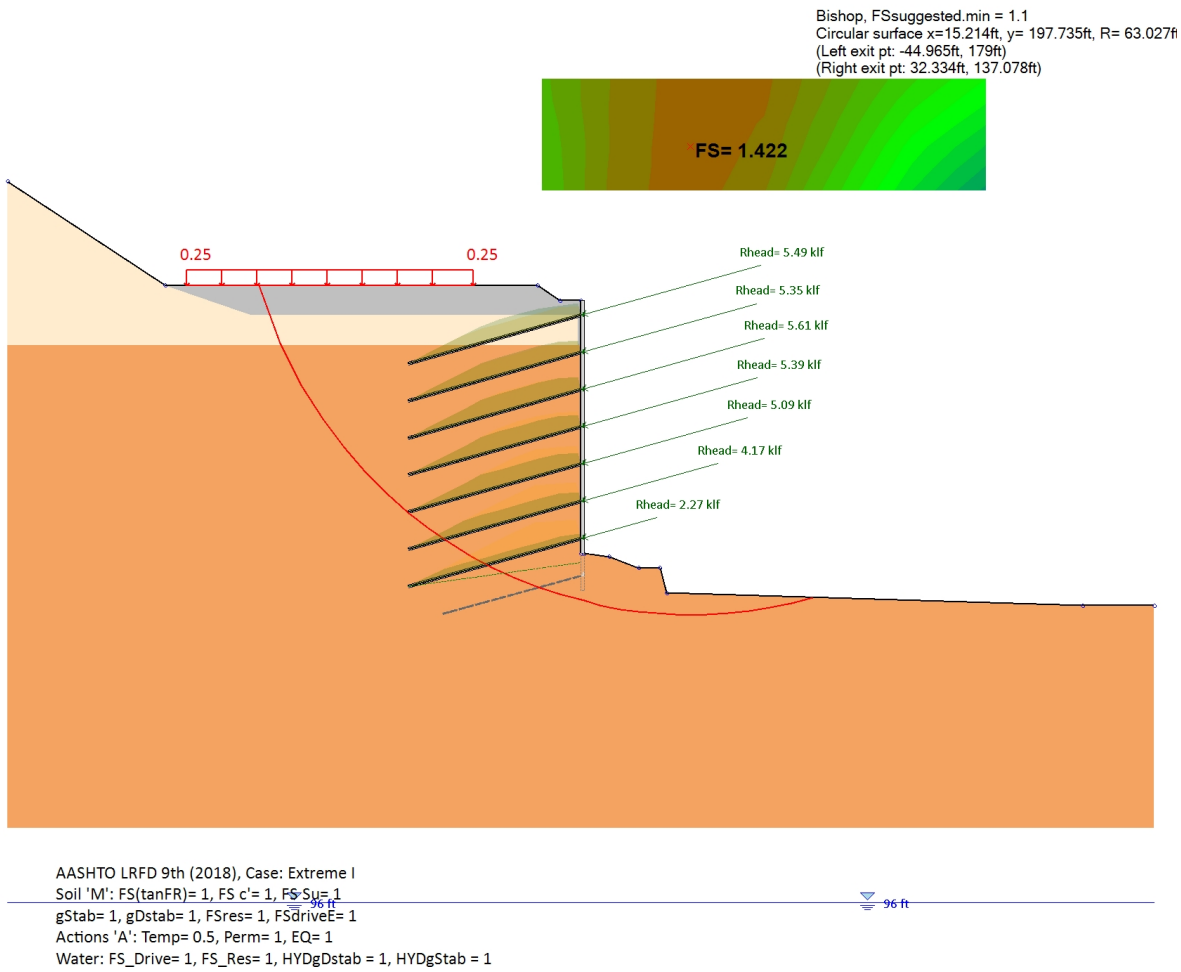
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\3+80\New Stratigraphy\CS Sta 3+80 (Seismic, Bishop).SNLP

Quick analysis summary for design section: Bishop

Bishop

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Existing	Calculated	2.736	31.5	22.34	31.69	0.444	0.573	0.274	No	Yes
Project Wall	Calculated	1.422	39.57	28.06	39.81	0.643	0.647	0.344	No	Yes
Project Wall	Calculated	1.754	39.57	28.06	39.81	0.643	0.647	0.344	No	Yes
Project Wall	Calculated	3.46	39.57	28.06	39.81	0.643	0.647	0.344	No	Yes
Forward Com	Calculated	2.537	43.63	30.94	43.9	0.709	0.714	0.379	No	Yes
Forward Com	Calculated	1.512	43.63	30.94	43.9	0.709	0.714	0.379	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	2.736	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.422	1.1	Circle	15.214	197.735	63.027	N/A	N/A
Project Wall	Yes	1.754	1.1	Circle	20.667	203	80.691	N/A	N/A
Project Wall	Yes	3.46	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	2.537	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.512	1.1	Circle	10.333	202	67.798	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
xL (-55 to -6)	xR (0.5 to 15)	N/A	AASHTO LRF	Extreme I	60.73	0.444	N/A	N/A	N/A
N/A	N/A	N/A	AASHTO LRF	Extreme I	60.68	0.643	909.517	0	1344.663
N/A	N/A	N/A	AASHTO LRF	Extreme I	29.66	0.643	0	0	3955.078
xL (-58 to -6)	xR (0.1 to 20)	N/A	AASHTO LRF	Extreme I	60.64	0.643	5999.319	0	-3279.594
xL (-58 to -6)	xR (0.1 to 20)	N/A	AASHTO LRF	Extreme I	59.94	0.709	4879.074	0	-4658.43
N/A	N/A	N/A	AASHTO LRF	Extreme I	60.2	0.709	966.546	0	1815.501

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Extreme I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	0.5
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	175	25	0	5	6.0184	30.09
N1	0: N1	15	0	170	25	0	5	5.8849	29.42
N2	0: N1	15	0	165	25	0	5	6.1876	30.94
N3	0: N1	15	0	160	25	0	5	5.9681	29.84
N4	0: N1	15	0	155	25	0	5	5.7374	28.69
N5	0: N1	15	0	150	25	0	5	5.2593	26.3
N6	0: N1	15	0	145	25	0	5	3.9358	19.68
Nail 1	0: N1	15	0	140	20	0	5	2.3607	11.8

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	193
2	-58	179
3	-6	179
4	-3	177
5	0	177
6	0	141
7	0.1	138
8	70	136
9	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1A	110	110	32	0	N/A	15	
ESU 4C	135	135	43	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
179	ESU 1A	1	0.47
171	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -55ft, xLmax= -6ft
Right search limits: xRmin= 0.5ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Circ

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 143ft
Radii search ends at point x= 0ft, z= 127ft
10 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 125ft
Radii search ends at point x= 0ft, z= 110ft
10 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Auto

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -58ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall-Auto

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -58ft, xLmax= -6ft
Right search limits: xRmin= 0.1ft, xRmax= 20ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

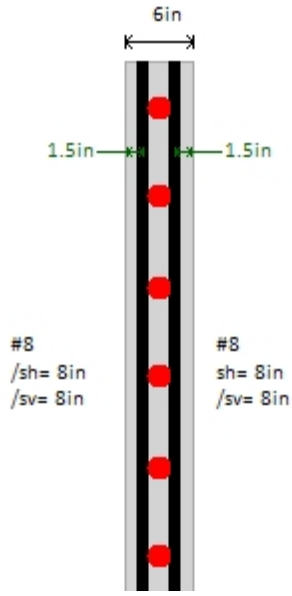
Slope stability assumptions: Forward Compatible-Circ

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.2g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Circular
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 138ft
Radii search ends at point x= 0ft, z= 123ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Bishop



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	Yes	177	136	N/A	6
Project Wall Height-Ci	Yes	177	143	N/A	6
Project Wall Height-G	Yes	177	143	N/A	6
Project Wall Height-A	Yes	177	143	N/A	6
Forward Compatible	Yes	177	136	N/A	6
Forward Compatible-	Yes	177	136	N/A	6

Soil nail input data for design section Bishop

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	175	25	0	5	1.27	6	75
N1	0: N1	15	0	170	25	0	5	1.27	6	75
N2	0: N1	15	0	165	25	0	5	1.27	6	75
N3	0: N1	15	0	160	25	0	5	1.27	6	75
N4	0: N1	15	0	155	25	0	5	1.27	6	75
N5	0: N1	15	0	150	25	0	5	1.27	6	75
N6	0: N1	15	0	145	25	0	5	1.27	6	75
Nail 1	0: N1	15	0	140	20	0	5	1.27	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	175	8	2.25	36	1	N/A	N/A	N/A
N1	170	8	2.25	36	1	N/A	N/A	N/A
N2	165	8	2.25	36	1	N/A	N/A	N/A
N3	160	8	2.25	36	1	N/A	N/A	N/A
N4	155	8	2.25	36	1	N/A	N/A	N/A
N5	150	8	2.25	36	1	N/A	N/A	N/A
N6	145	8	2.25	36	1	N/A	N/A	N/A
Nail 1	140	8	2.25	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Bishop

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= 15.214 z= 197.735 FS= 1.422

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	29.77	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	35.36	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	41.33	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	0	48.38	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	0	57.15	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	16.94	60.58	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	36.81	60.68	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= 20.667 z= 203 FS= 1.754

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
1: N1	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
2: N2	0	0	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	N/A
3: N3	0	1.99	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	0	10.27	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	0	19.52	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	0	29.66	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -5.37 z= 191.68 FS= 3.46

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	2.01	52.71	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	7.16	58.08	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	12.31	56.79	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	21.01	55.35	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	30.39	57.34	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	41.12	60.64	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	53.68	60.11	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -6.498 z= 192.1 FS= 2.537

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	52.56	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	58.32	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	57.14	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	5.07	55.96	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

4: N4	16.43	54.11	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	29.18	59.94	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	41.94	59.9	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	40.58	52.27	85.72	64.69	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= 10.333 z= 202 FS= 1.512

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	26.31	85.72	65.14	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
1: N1	0	29.86	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
2: N2	0	35.44	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
3: N3	0	41.43	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
4: N4	0	48.63	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
5: N5	0.42	57.31	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
6: N6	21.65	60.2	85.72	80.86	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO
7: Nail 1	31.33	52.62	85.72	64.69	0	42.86	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.13	0.2	N/A	N/A	GEO

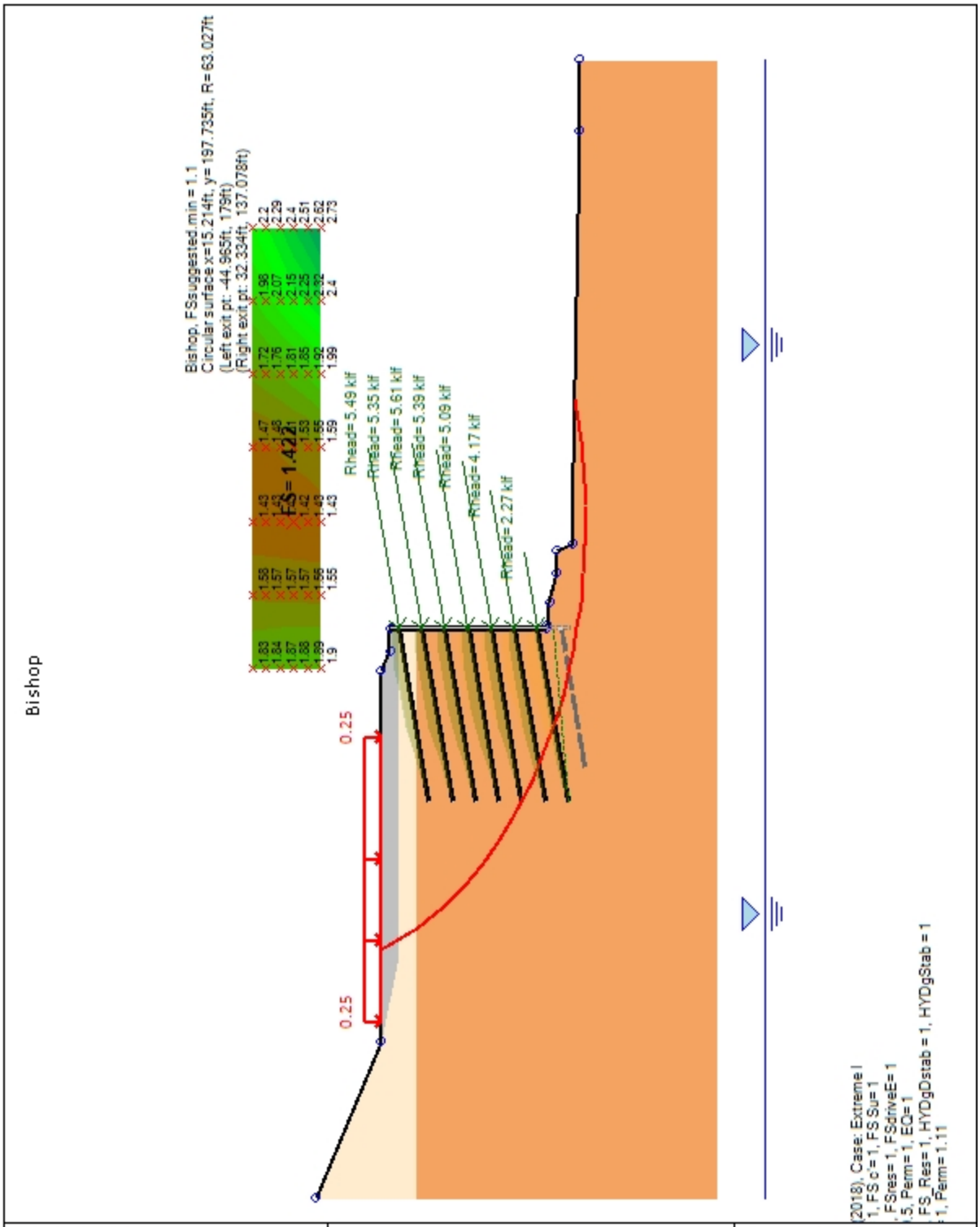
GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)

17/22



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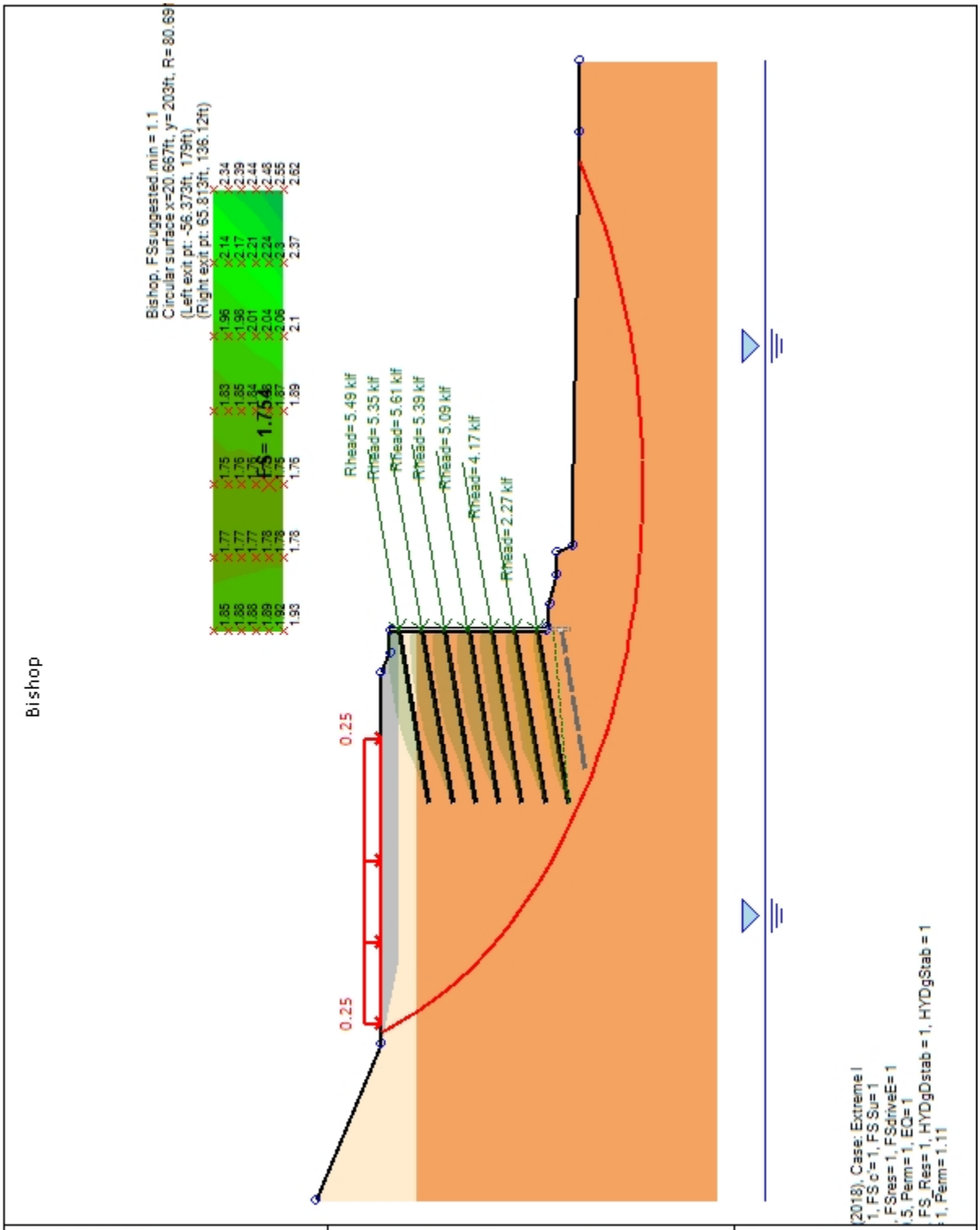

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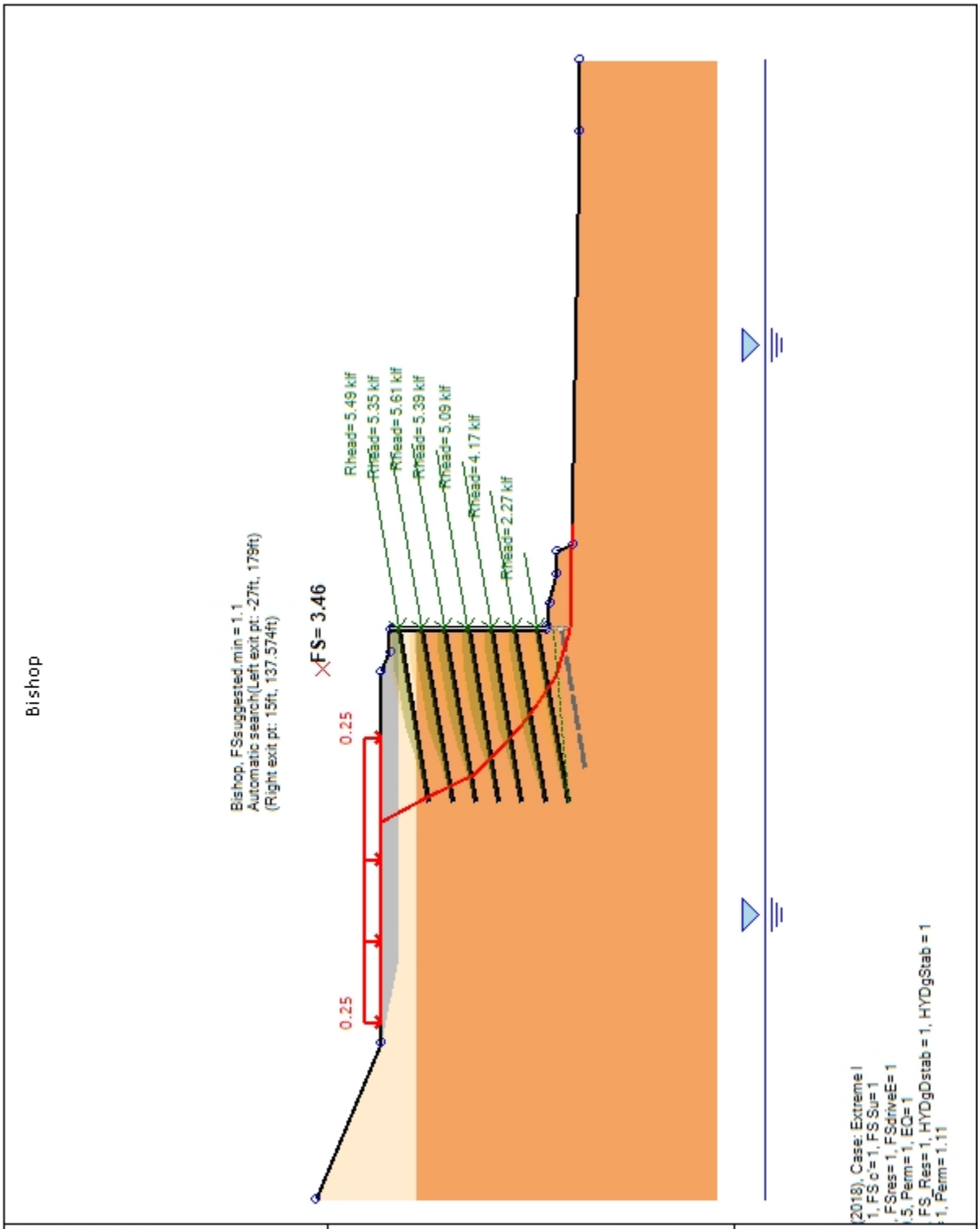

Company: Wood Engineer: DL	DS: 0, Project Wall Height-Auto	Deep Excavation LCC SnailPlus 2021
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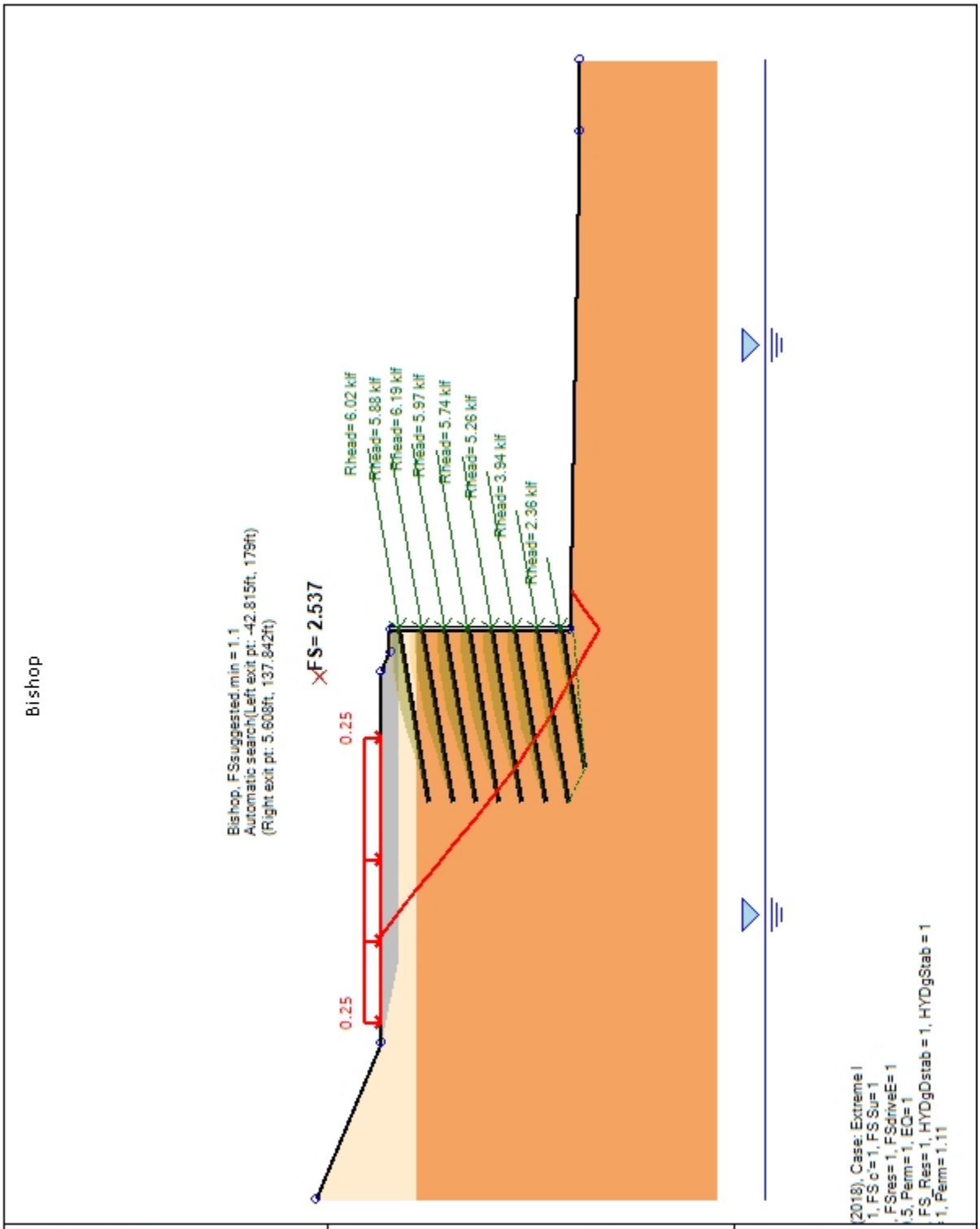

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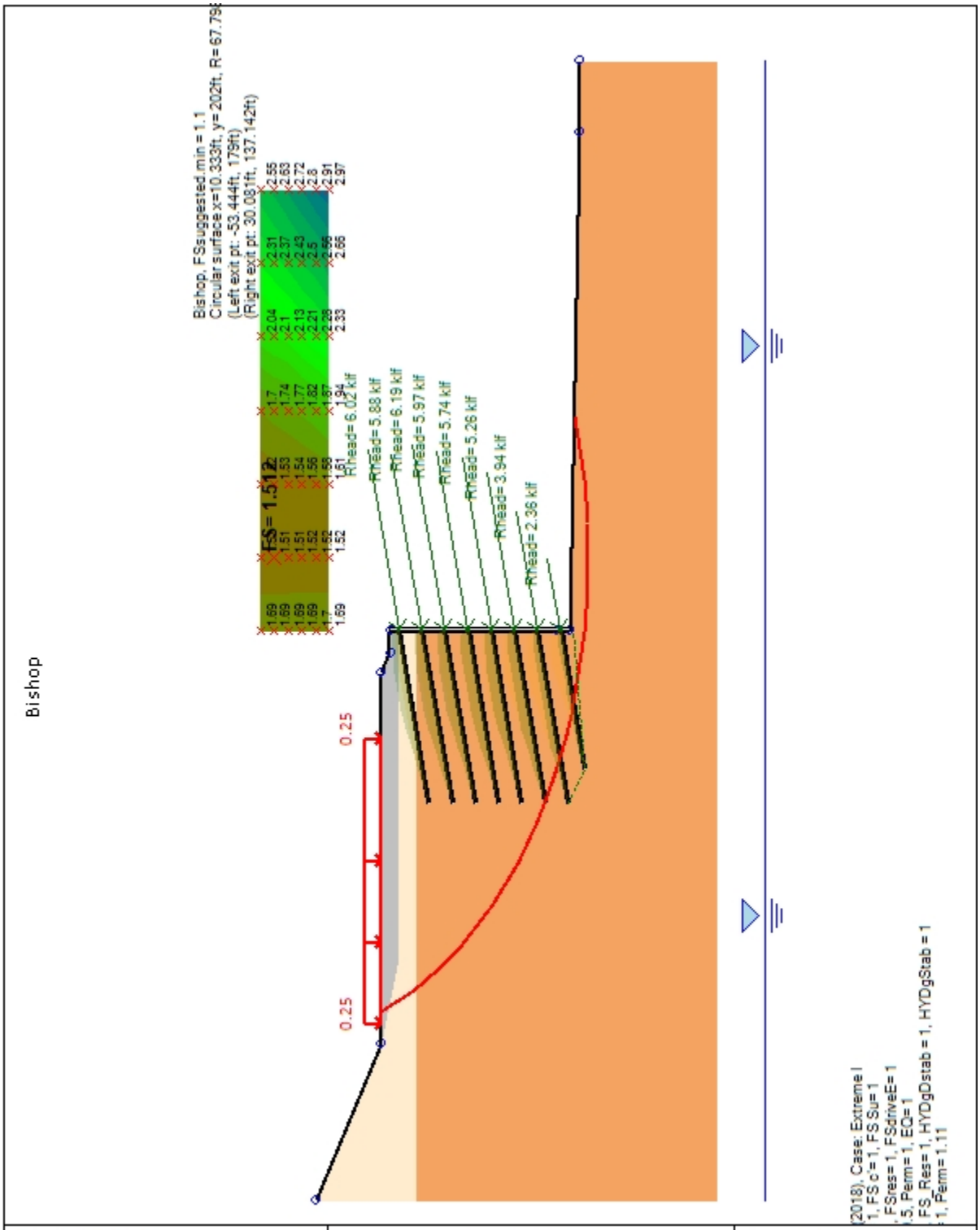

Company: Wood Engineer: DL	DS: 0, Forward Compatible-Circ	Deep Excavation LCC SnailPlus 2021
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SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 5+20 (Perm Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 8:10:54 AM

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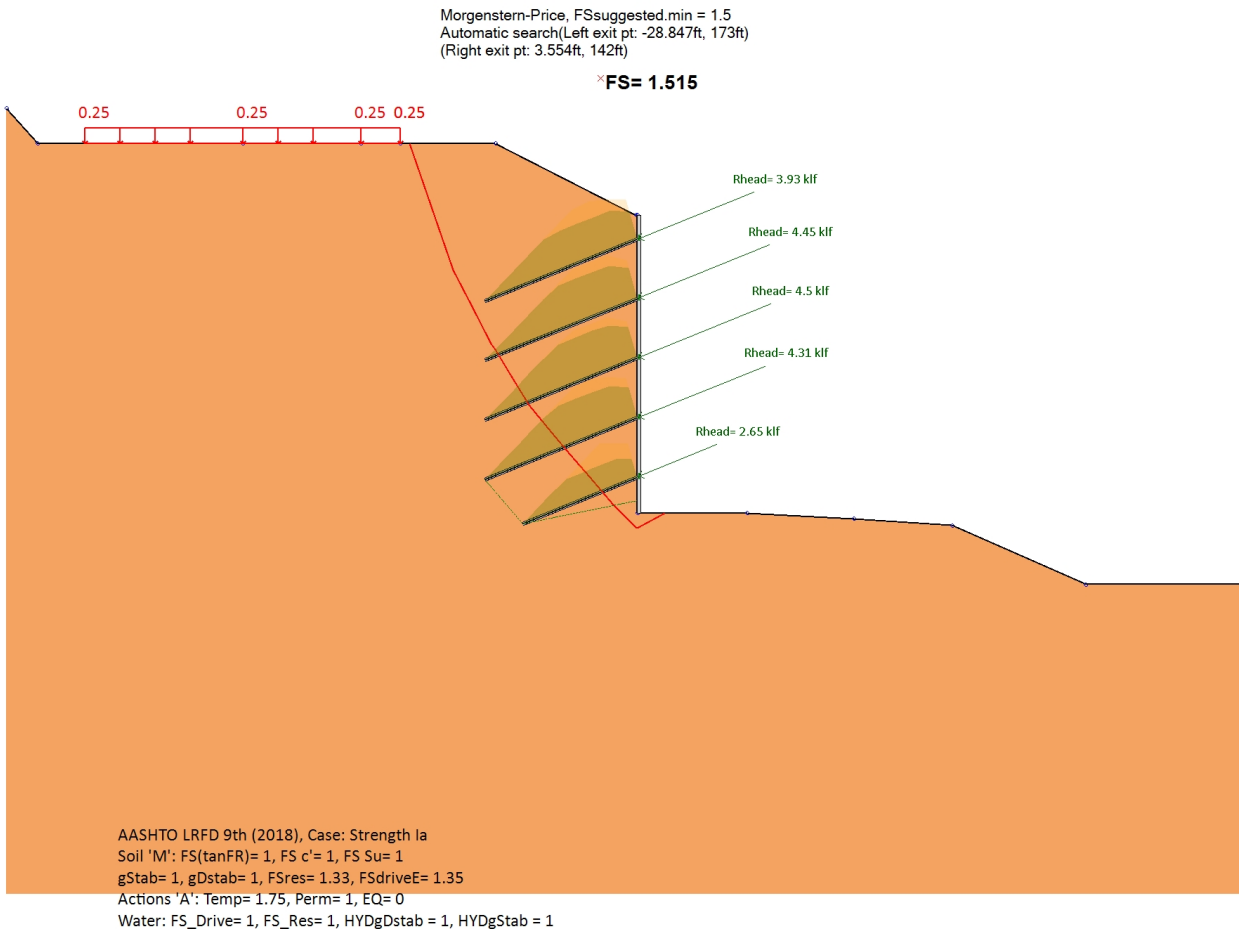
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\5+20\New Stratigraphy\CS Sta 5+20 (Perm Static, M-P).SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Existing	Calculated	1.528	0	0	0	0	0	0	No	Yes
Exc. 162 ft	Calculated	3.345	5.56	4.26	5.56	0.125	0.164	0.062	No	Yes
Exc. 157 ft	Calculated	2.584	13.11	10.04	13.11	0.295	0.387	0.146	No	Yes
Exc. 152 ft	Calculated	2.118	21.78	16.68	21.78	0.49	0.643	0.243	No	Yes
Project Wall	Calculated	1.806	28.43	21.77	28.43	0.64	0.84	0.318	No	Yes
Project Wall	Calculated	2.742	28.43	21.77	28.43	0.64	0.84	0.318	No	Yes
Forward Com	Calculated	1.515	35.3	27.03	35.3	0.794	1.043	0.394	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.528	1.5	Circle	57.348	200.796	49.703	N/A	N/A
Exc. 162 ft	Yes	3.345	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	2.584	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	2.118	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.806	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	2.742	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.515	1.5	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	43.95	0.125	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.295	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.49	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.64	N/A	N/A	N/A
xL (-80 to -45	xR (20 to 80)	N/A	AASHTO LRF	Strength Ia	0	0.64	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 15)	N/A	AASHTO LRF	Strength Ia	44.44	0.794	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	165	20	0	6	3.9258	23.55
N1	0: N1	15	0	160	20	0	6	4.4482	26.69
N2	0: N1	15	0	155	20	0	6	4.5047	27.03
N3	0: N1	15	0	150	20	0	6	4.3098	25.86
Nail 1	0: N1	15	0	145	15	0	6	2.6483	15.89

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	176
2	-76	173
3	-50	173
4	-35	173
5	-30	173
6	-18	173
7	-0.1	167
8	0	167
9	0	142
10	14	142
11	27.5	141.5
12	40	141
13	57	136
14	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1B	120	120	35	0	N/A	18	
ESU 1A	110	110	32	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
175	ESU 1B	1	0.43
170	ESU 1A	1	0.47
149	ESU 4C	1	0.32
139	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 20ft, z= 168ft
Radii search ends at point x= 20ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -45ft
Right search limits: xRmin= 20ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

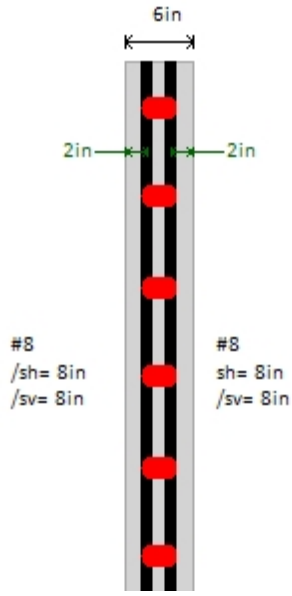
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	8
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 8 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	167	142	N/A	6
Exc. 162 ft	Yes	167	162	N/A	6
Exc. 157 ft	Yes	167	157	N/A	6
Exc. 152 ft	Yes	167	152	N/A	6
Project Wall Height	Yes	167	147	N/A	6
Project Wall Height-G	Yes	167	147	N/A	6
Forward Compatible	Yes	167	142	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	165	20	0	6	0.79	6	75
N1	0: N1	15	0	160	20	0	6	0.79	6	75
N2	0: N1	15	0	155	20	0	6	0.79	6	75
N3	0: N1	15	0	150	20	0	6	0.79	6	75
Nail 1	0: N1	15	0	145	15	0	6	0.79	6	75

Header plate data

15/24

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	165	6	1	36	1	N/A	N/A	N/A
N1	160	6	1	36	1	N/A	N/A	N/A
N2	155	6	1	36	1	N/A	N/A	N/A
N3	150	6	1	36	1	N/A	N/A	N/A
Nail 1	145	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 57.348 z= 200.796 FS= 1.528

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -2.834 z= 177.916 FS= 3.345

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	38.34	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -4.077 z= 178.333 FS= 2.584

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	13.7	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	33.98	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -3.868 z= 178.263 FS= 2.118

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	1.61	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	18.43	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	38.3	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -3.29 z= 178.069 FS= 1.806

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	13.61	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	29.49	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

3: N3	44.44	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	STR
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= 15.123 z= 177 FS= 2.742

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
1: N1	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
2: N2	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
3: N3	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 6

Soil nail results available for this stage.

Critical point at x= -4.547 z= 178.49 FS= 1.515

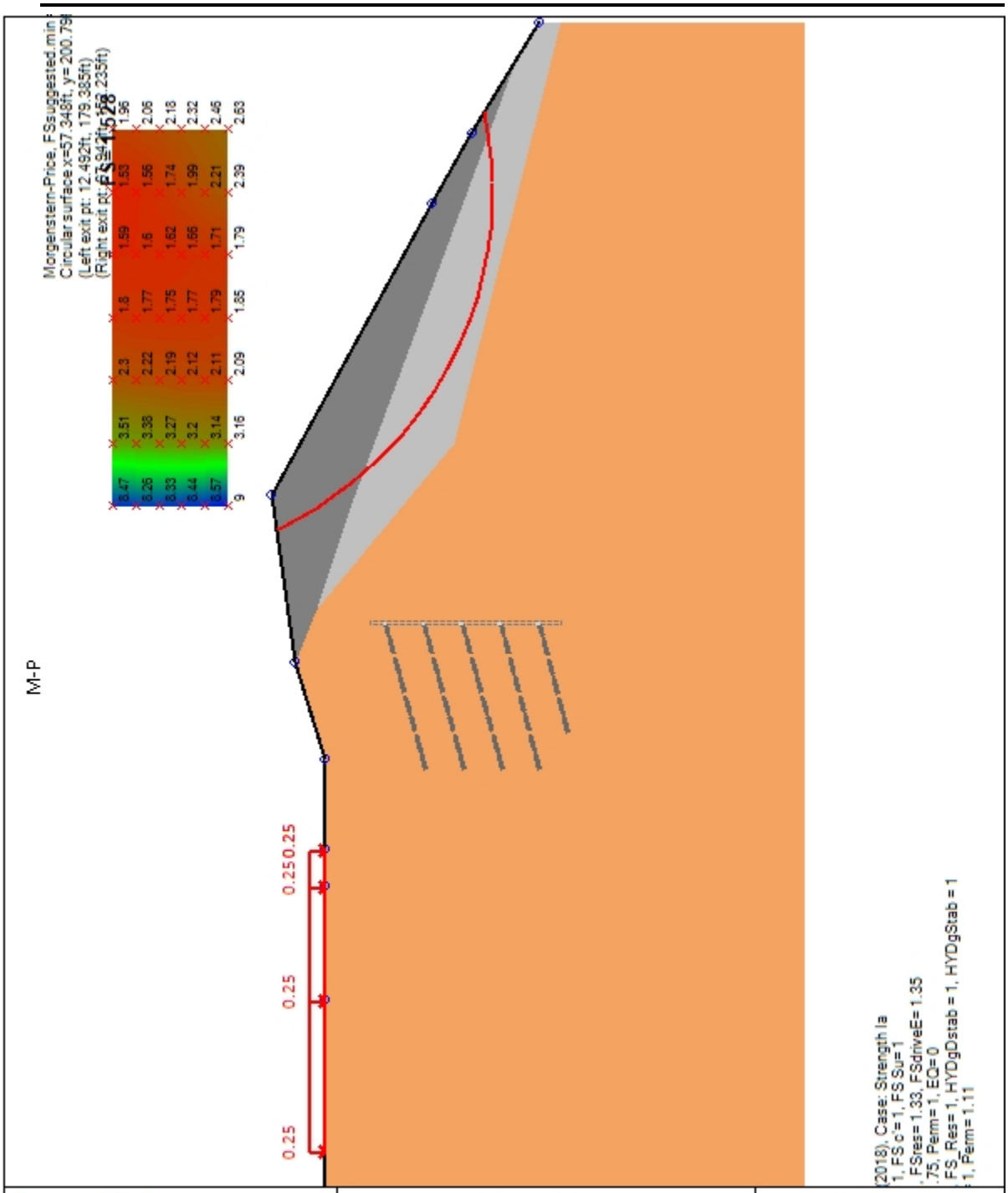
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	5.78	43.22	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	18.29	41.25	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	33.88	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	33.69	37.66	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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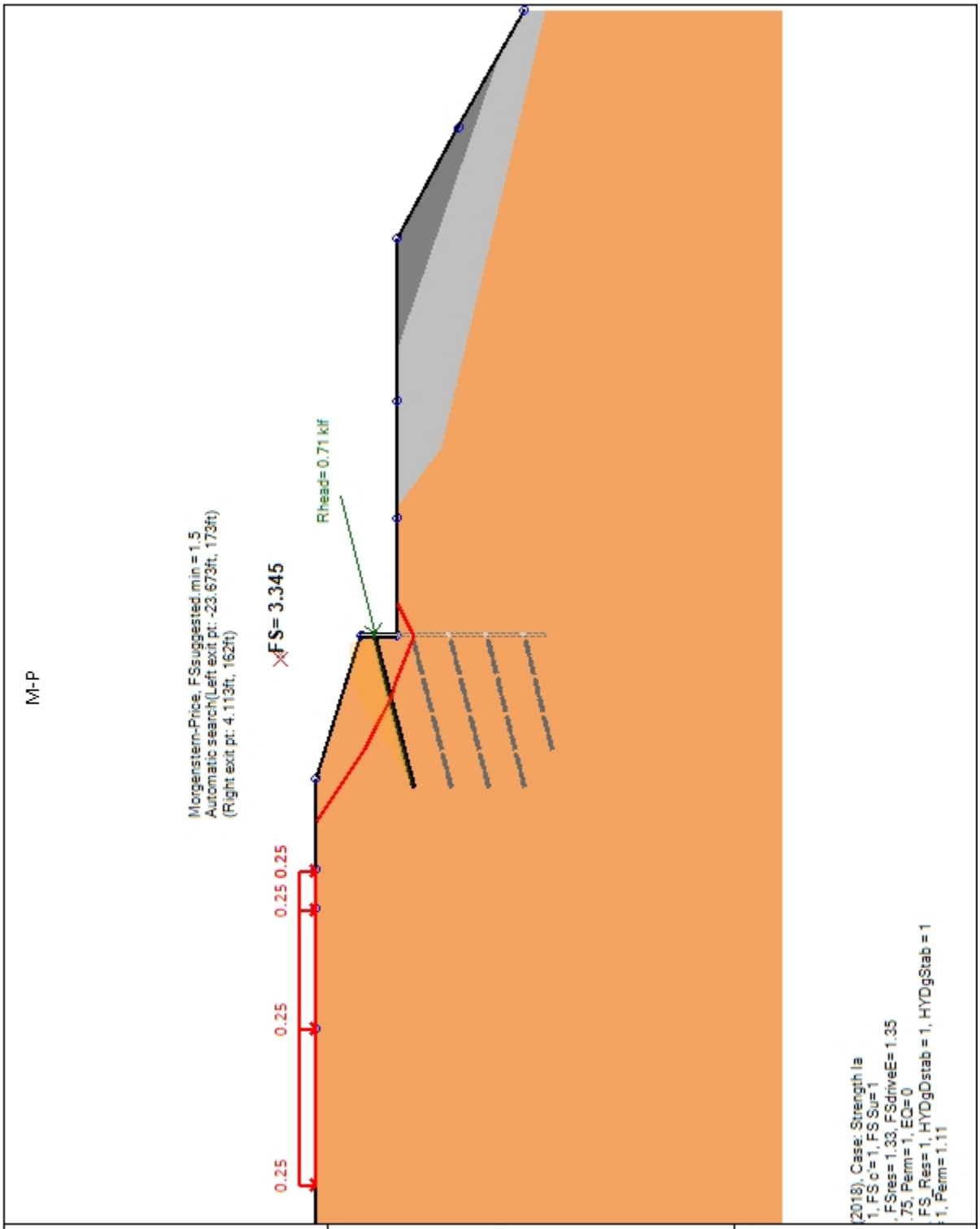

Company: Wood Engineer: DL	DS: 0, Exc. 162 ft	Deep Excavation LCC SnailPlus 2021
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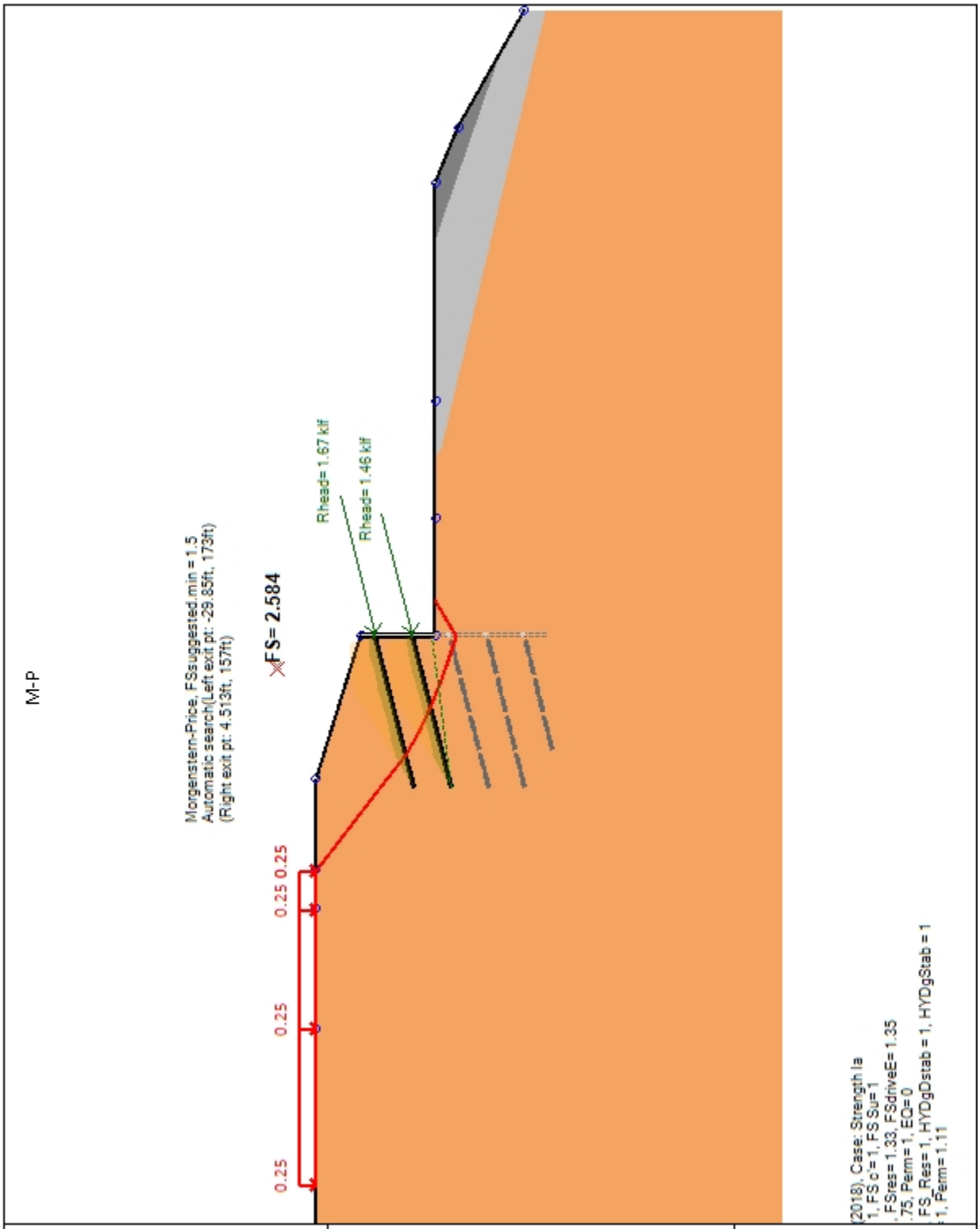

Company: Wood Engineer: DL	DS: 0, Exc. 157 ft	Deep Excavation LCC SnailPlus 2021
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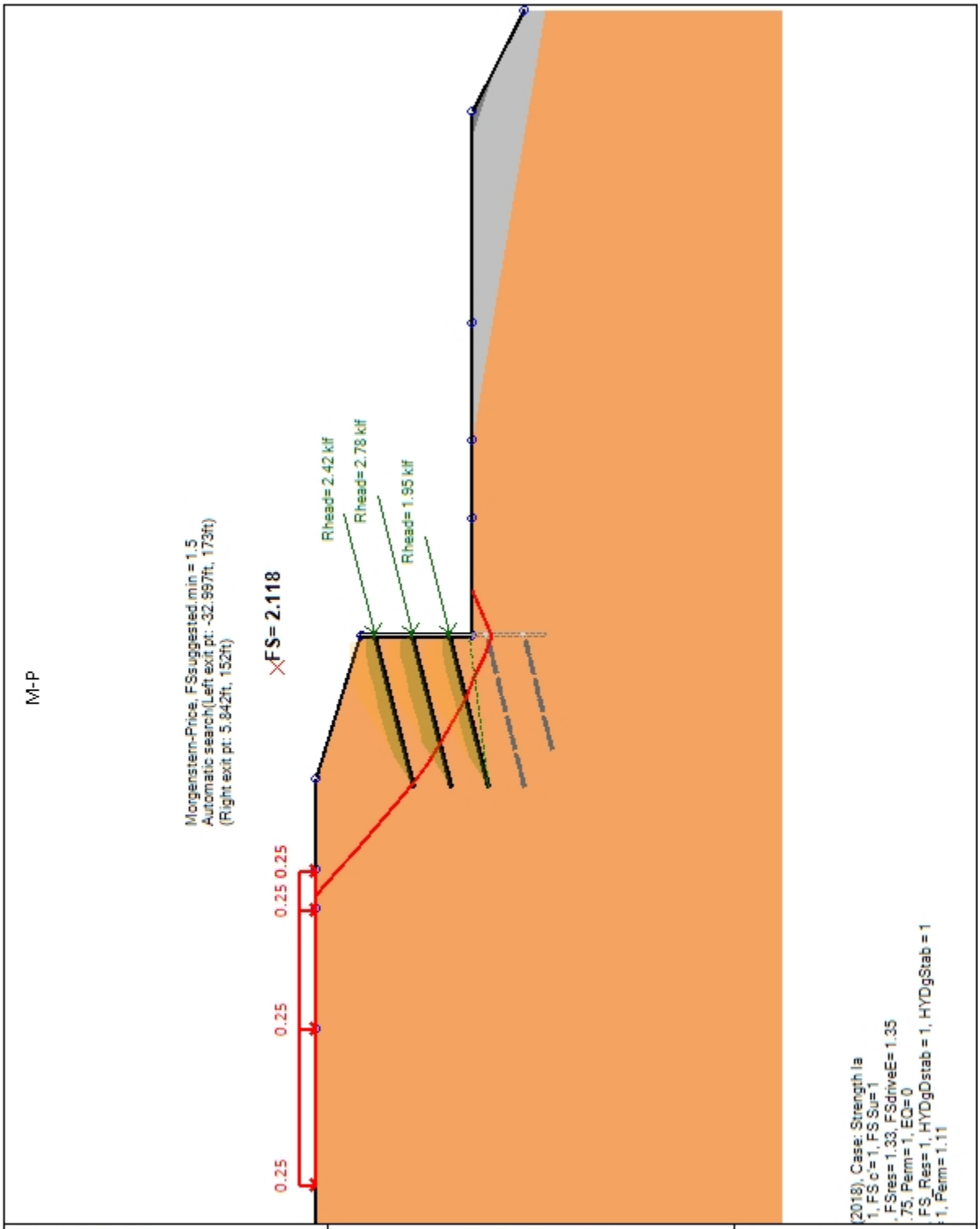
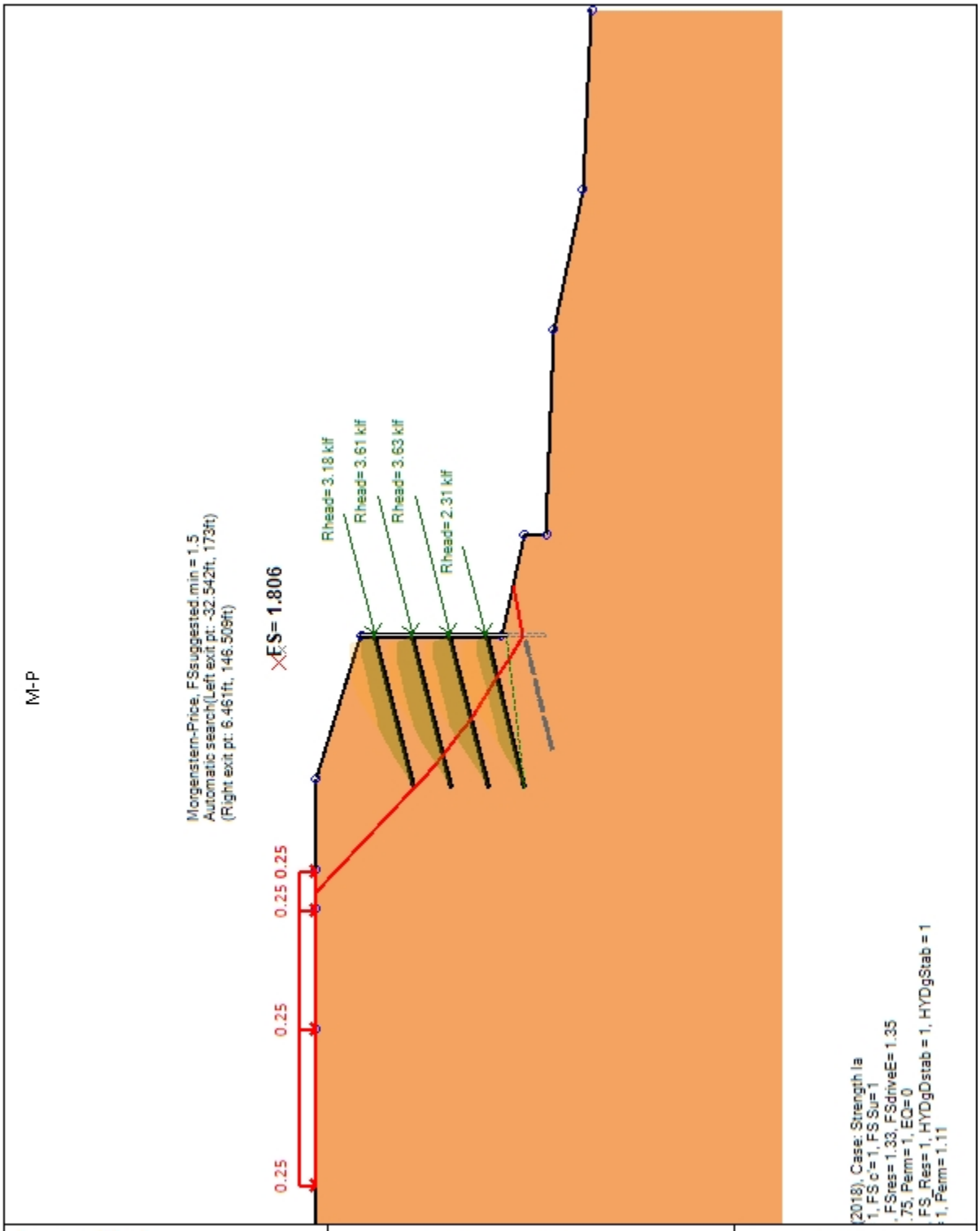
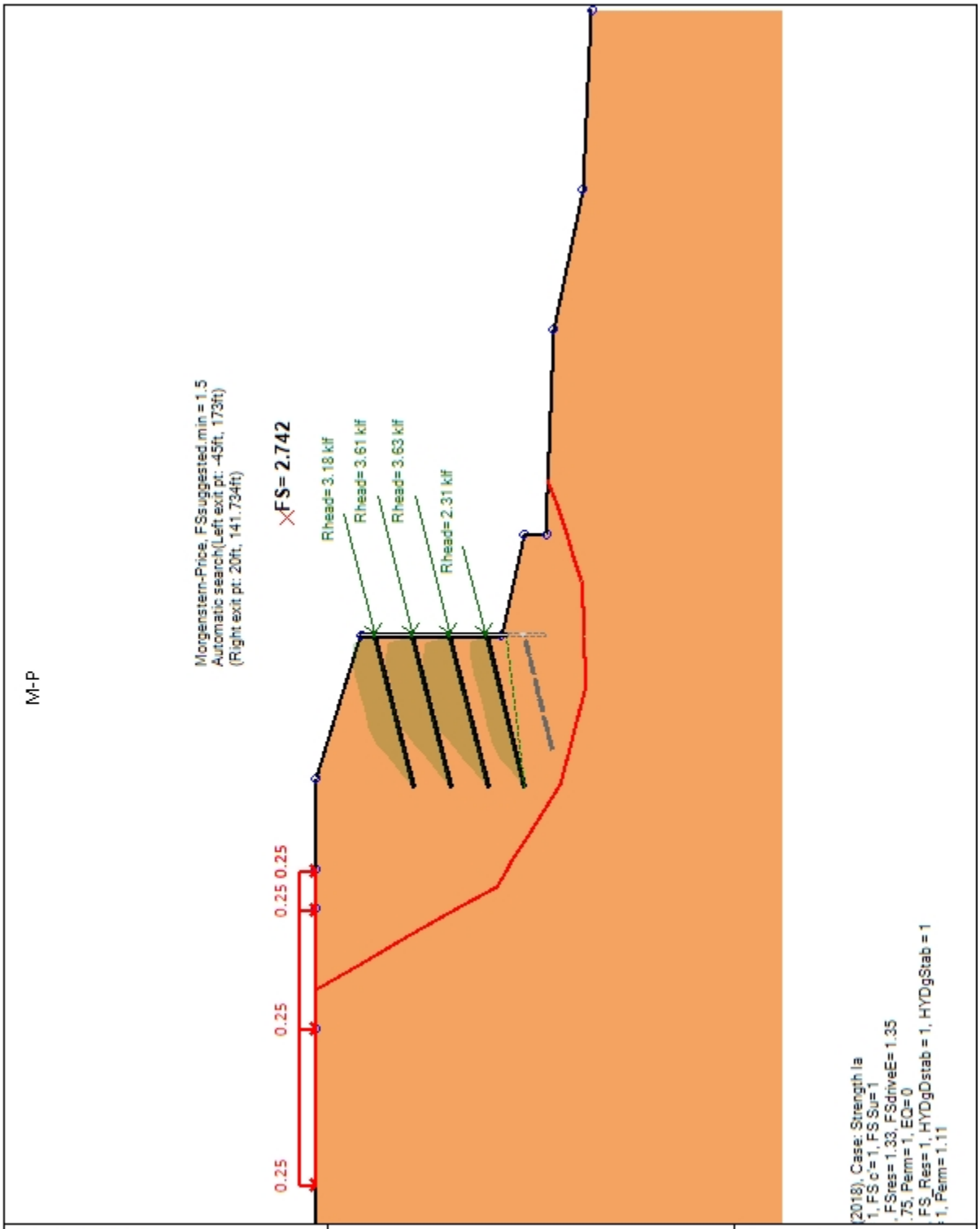


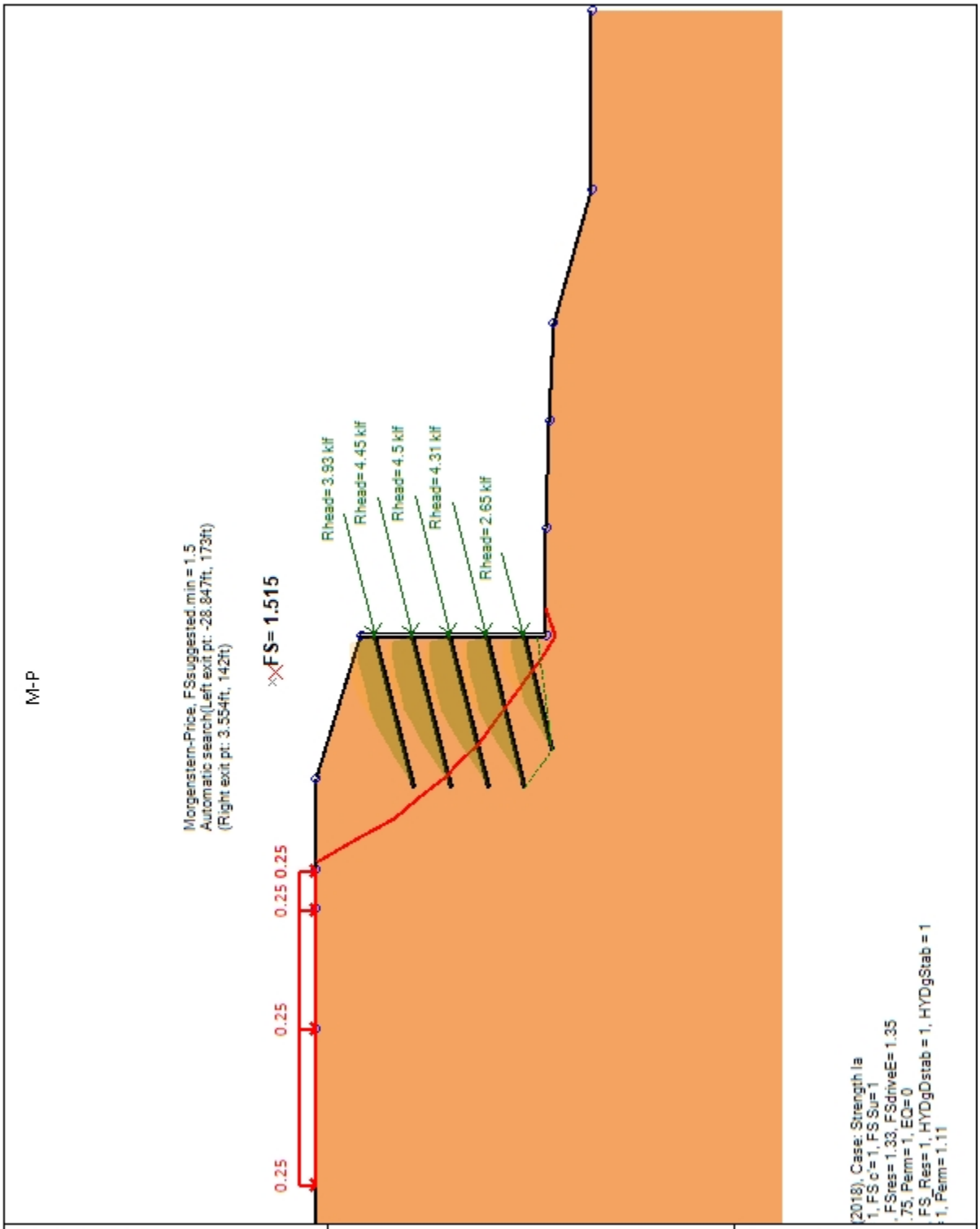
Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Perm Static, M-P).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Perm Static, M-P).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Perm Static, M-P).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
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SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 5+20 (Perm Static, Spencer)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 8:37:35 AM

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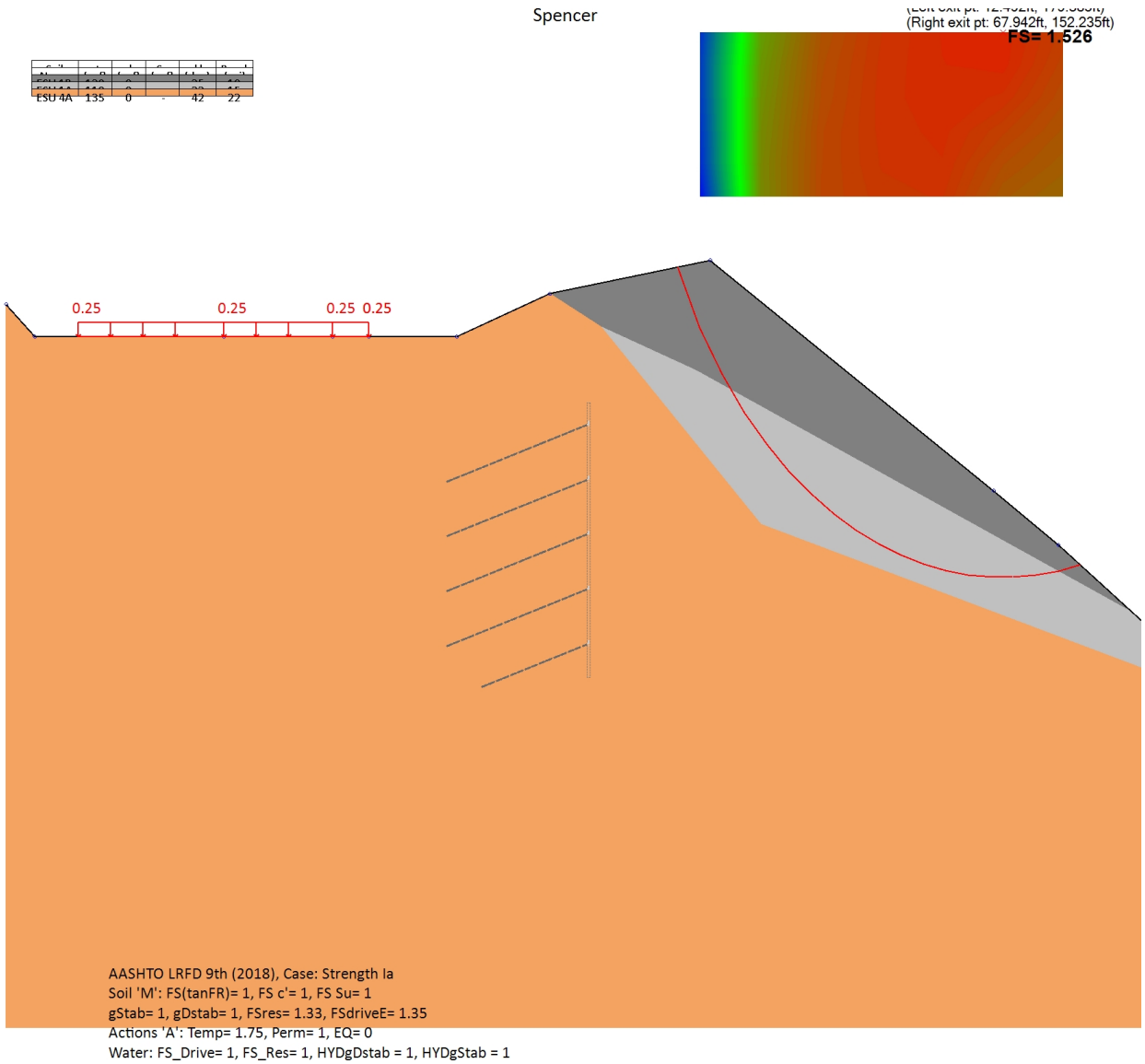
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\5+20\New Stratigraphy\CS Sta 5+20 (Perm Static, Spencer).SNLP

Quick analysis summary for design section: Spencer



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	1.526	0	0	0	0	0	0	No	Yes
Exc. 162 ft	Calculated	4.126	5.56	4.26	5.56	0.125	0.164	0.062	No	Yes
Exc. 157 ft	Calculated	2.65	13.11	10.04	13.11	0.295	0.387	0.146	No	Yes
Exc. 152 ft	Calculated	2.16	21.78	16.68	21.78	0.49	0.643	0.243	No	Yes
Project Wall	Calculated	1.821	28.43	21.77	28.43	0.64	0.84	0.318	No	Yes
Project Wall	Calculated	2.667	28.43	21.77	28.43	0.64	0.84	0.318	No	Yes
Forward Com	Calculated	1.573	35.3	27.03	35.3	0.794	1.043	0.394	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.526	1.5	Circle	57.348	200.796	49.703	N/A	N/A
Exc. 162 ft	Yes	4.126	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	2.65	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	2.16	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.821	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	2.667	1.5	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.573	1.5	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	43.95	0.125	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.295	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.49	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.64	N/A	N/A	N/A
xL (-80 to -45	xR (30 to 80)	N/A	AASHTO LRF	Strength Ia	0	0.64	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 15)	N/A	AASHTO LRF	Strength Ia	44.44	0.794	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	165	20	0	6	3.9258	23.55
N1	0: N1	15	0	160	20	0	6	4.4481	26.69
N2	0: N1	15	0	155	20	0	6	4.5047	27.03
N3	0: N1	15	0	150	20	0	6	4.3098	25.86
Nail 1	0: N1	15	0	145	15	0	6	2.6483	15.89

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	176
2	-76	173
3	-50	173
4	-35	173
5	-30	173
6	-18	173
7	-0.1	167
8	0	167
9	0	142
10	14	142
11	27.5	141.5
12	40	141
13	57	136
14	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1B	120	120	35	0	N/A	18	
ESU 1A	110	110	32	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
175	ESU 1B	1	0.43
170	ESU 1A	1	0.47
149	ESU 4C	1	0.32
139	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 20ft, z= 168ft
Radii search ends at point x= 20ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -45ft
Right search limits: xRmin= 30ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

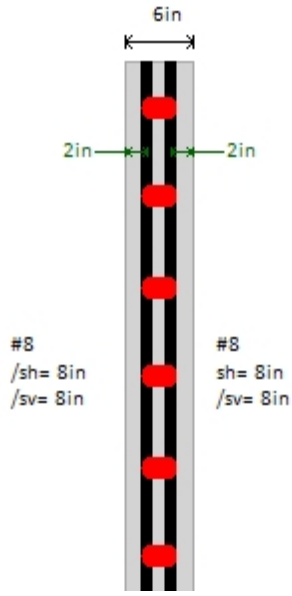
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Permanent structure long term
Min required FS	1.5
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Spencer



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	167	142	N/A	6
Exc. 162 ft	Yes	167	162	N/A	6
Exc. 157 ft	Yes	167	157	N/A	6
Exc. 152 ft	Yes	167	152	N/A	6
Project Wall Height	Yes	167	147	N/A	6
Project Wall Height-G	Yes	167	147	N/A	6
Forward Compatible	Yes	167	142	N/A	6

Soil nail input data for design section Spencer

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	165	20	0	6	0.79	6	75
N1	0: N1	15	0	160	20	0	6	0.79	6	75
N2	0: N1	15	0	155	20	0	6	0.79	6	75
N3	0: N1	15	0	150	20	0	6	0.79	6	75
Nail 1	0: N1	15	0	145	15	0	6	0.79	6	75

Header plate data

15/24

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	165	6	1	36	1	N/A	N/A	N/A
N1	160	6	1	36	1	N/A	N/A	N/A
N2	155	6	1	36	1	N/A	N/A	N/A
N3	150	6	1	36	1	N/A	N/A	N/A
Nail 1	145	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Spencer

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 57.348 z= 200.796 FS= 1.526

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -0.003 z= 177 FS= 4.126

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	38.53	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -1.641 z= 177.517 FS= 2.65

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	13.78	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	33.46	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= 1.884 z= 177 FS= 2.16

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0.65	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	16.47	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	36.07	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= 0.993 z= 177 FS= 1.821

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	13.04	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	28.51	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

3: N3	44.44	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	STR
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= 0.532 z= 177 FS= 2.667

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
1: N1	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
2: N2	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
3: N3	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 6

Soil nail results available for this stage.

Critical point at x= -0.918 z= 177.274 FS= 1.573

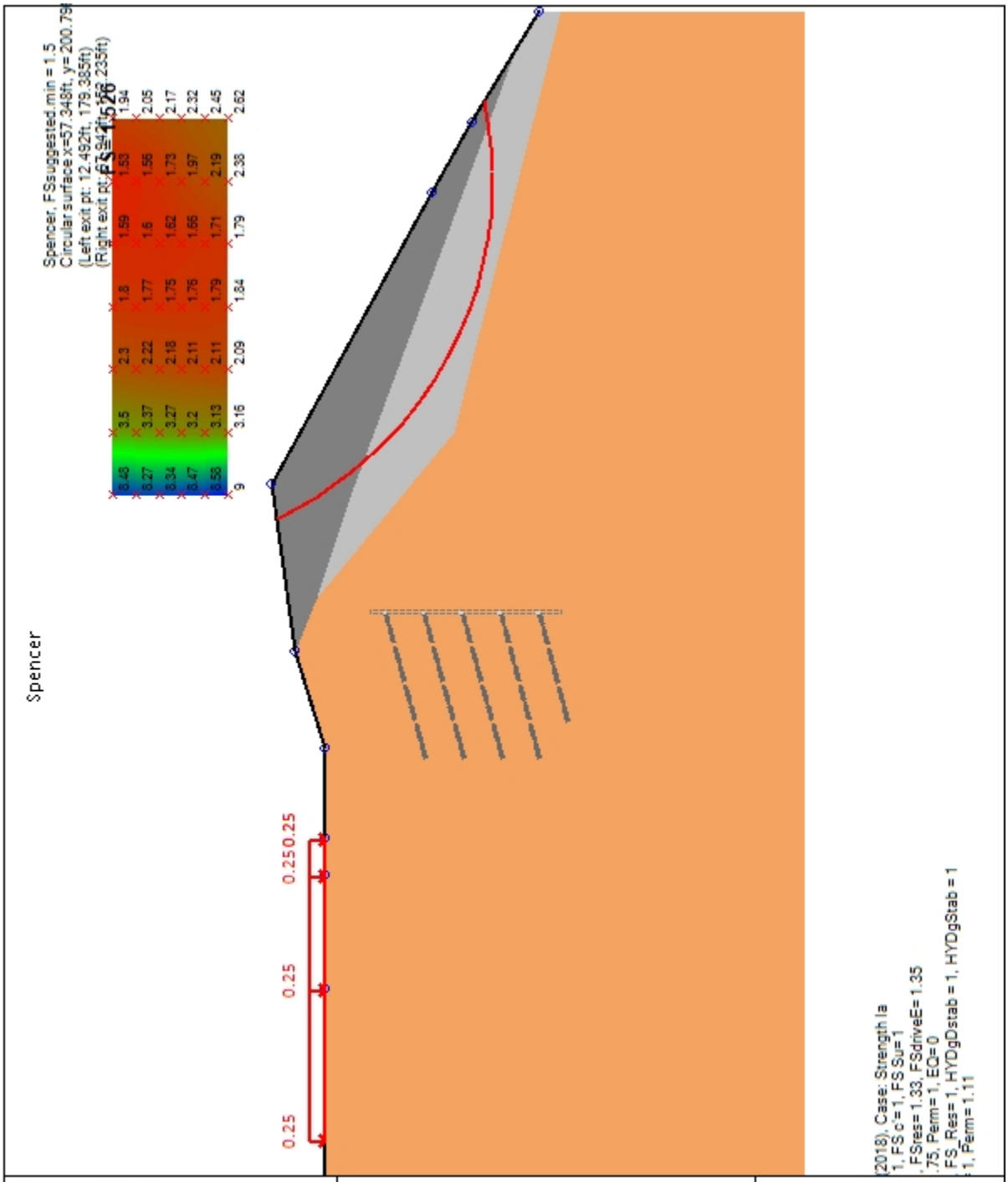
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	44.23	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	3.01	42.78	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	16.6	41.29	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	32.86	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	32.95	37.81	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



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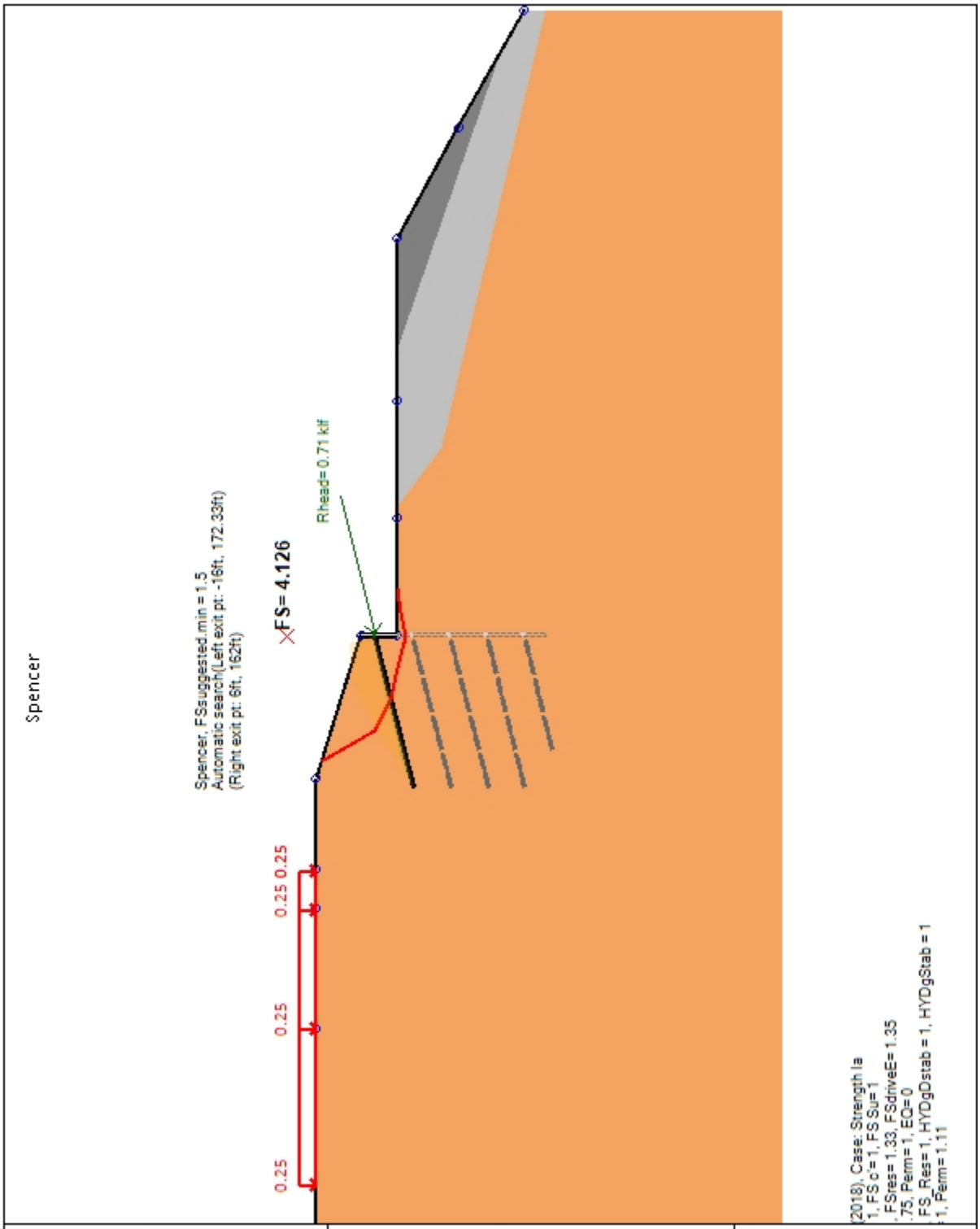

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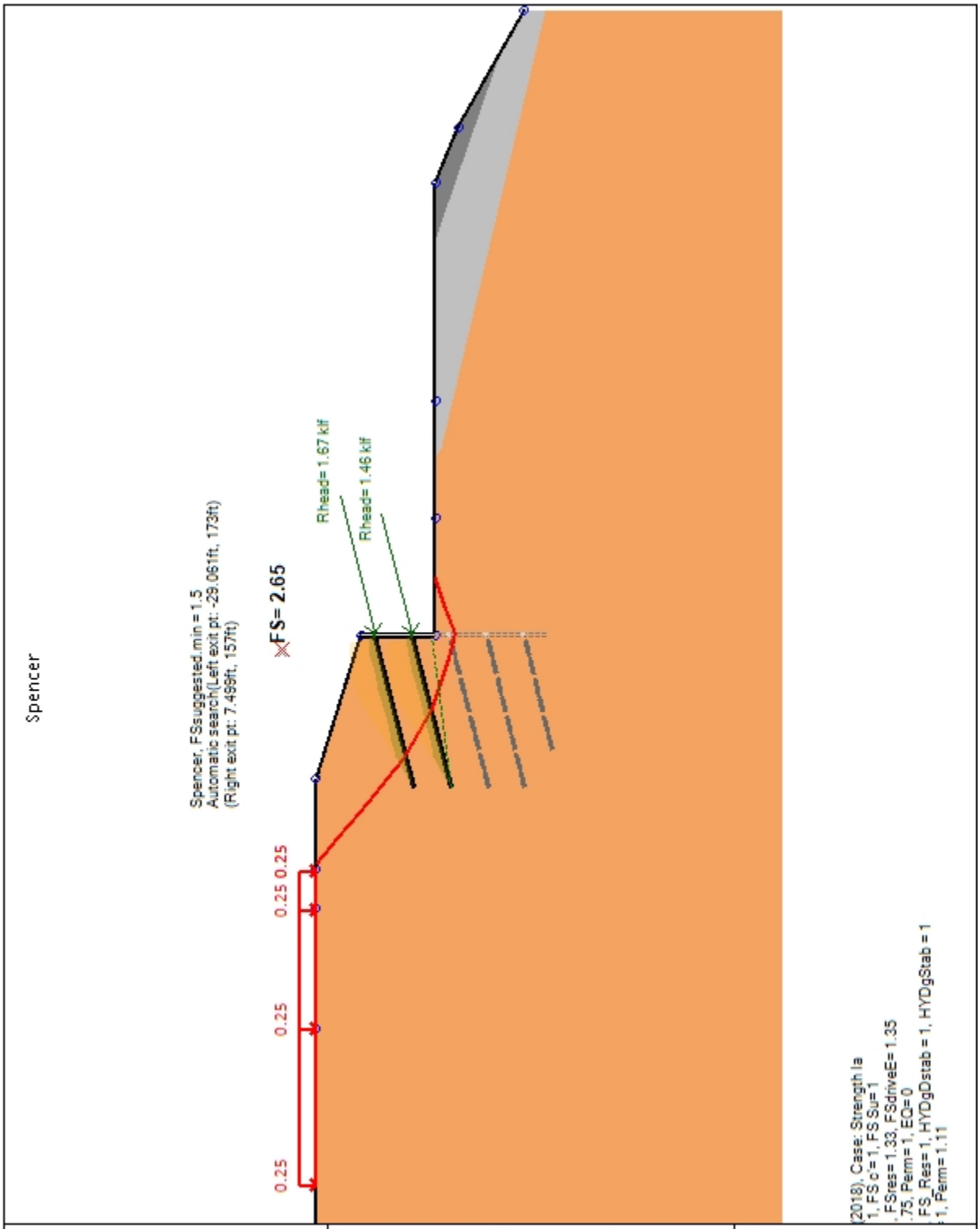

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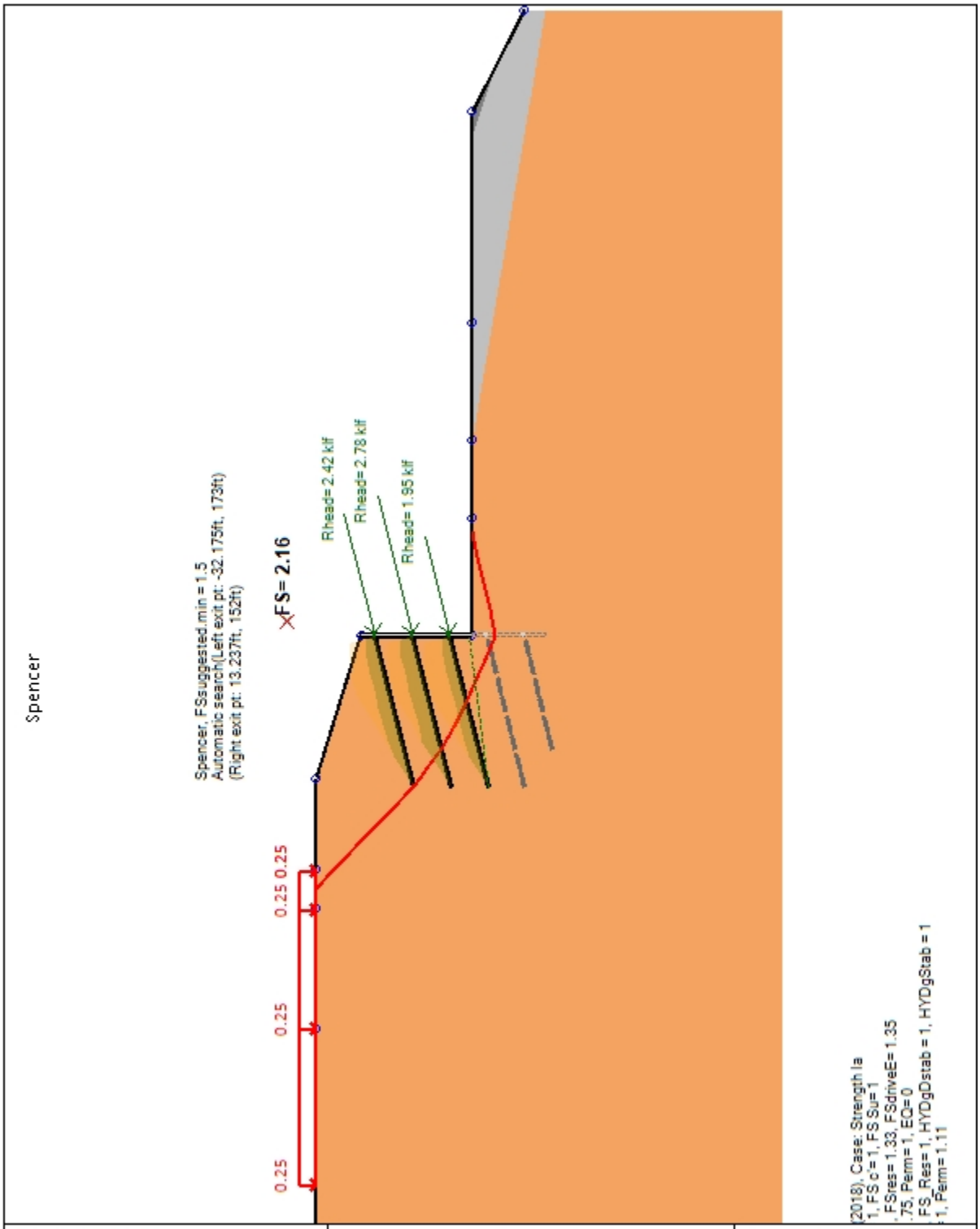

Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
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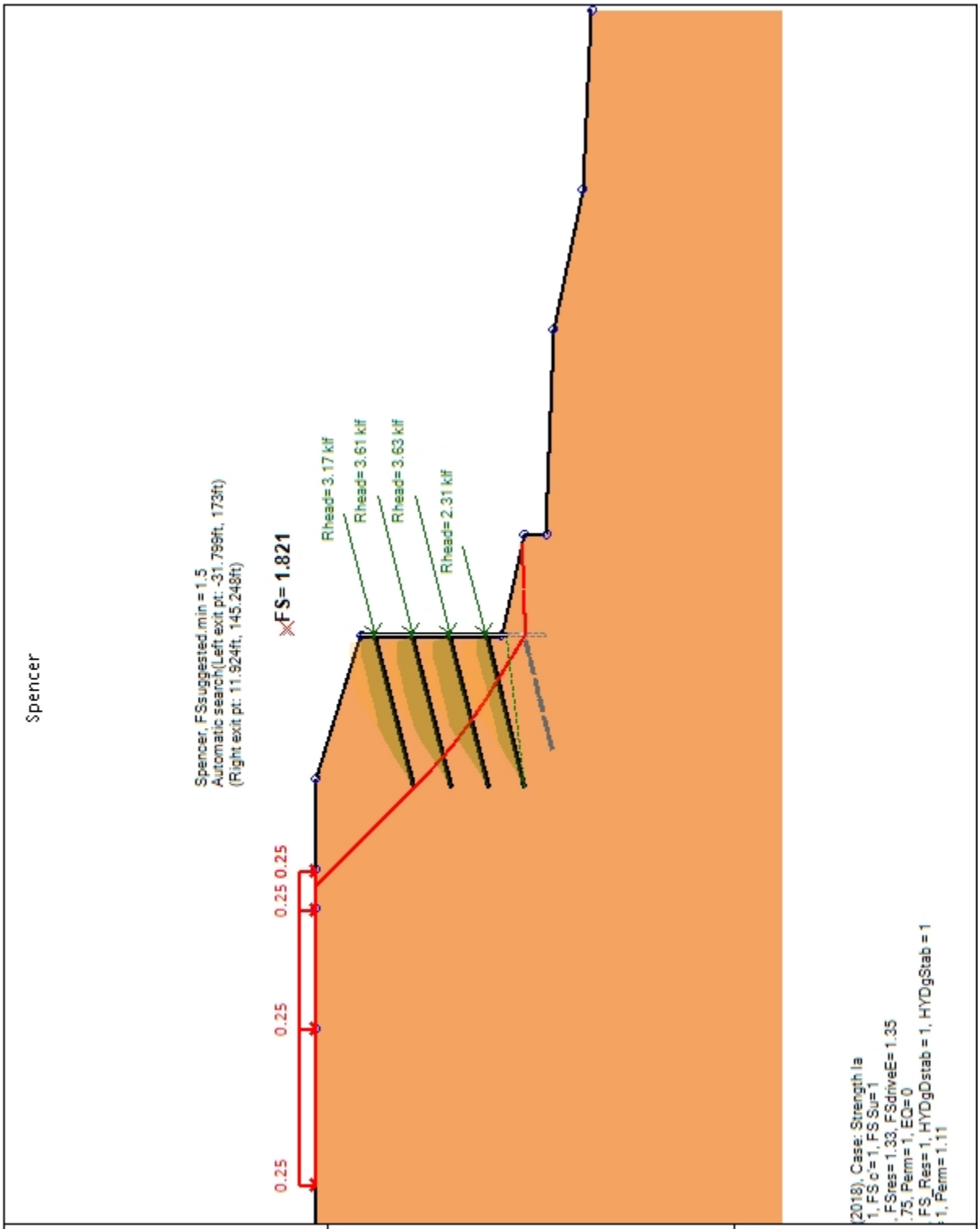

Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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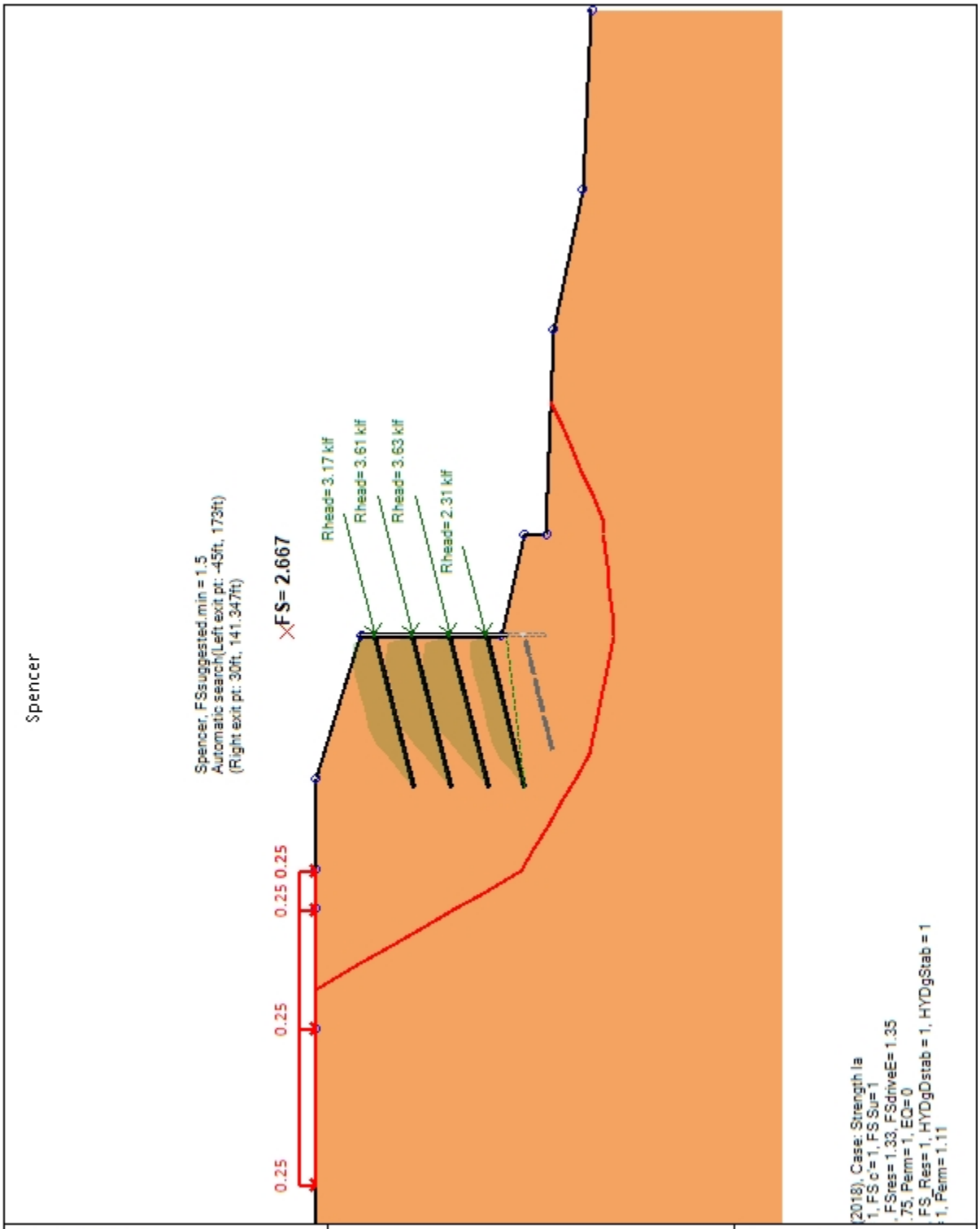

Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
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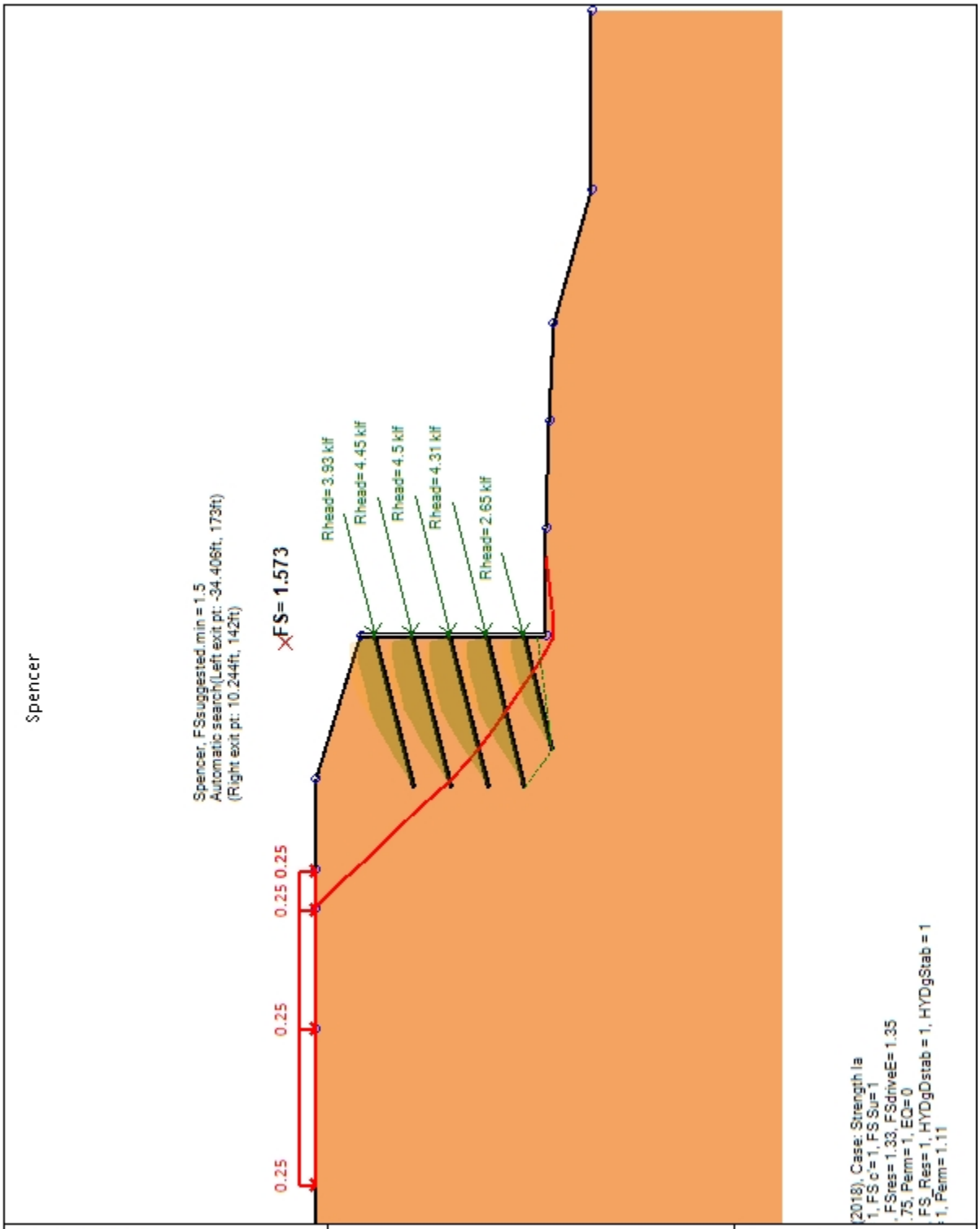

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..+20\New Stratigraphy\CS Sta 5+20 (Perm Static, Spencer).SNLP		12/2/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 5+20 (Temp Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 8:39:15 AM

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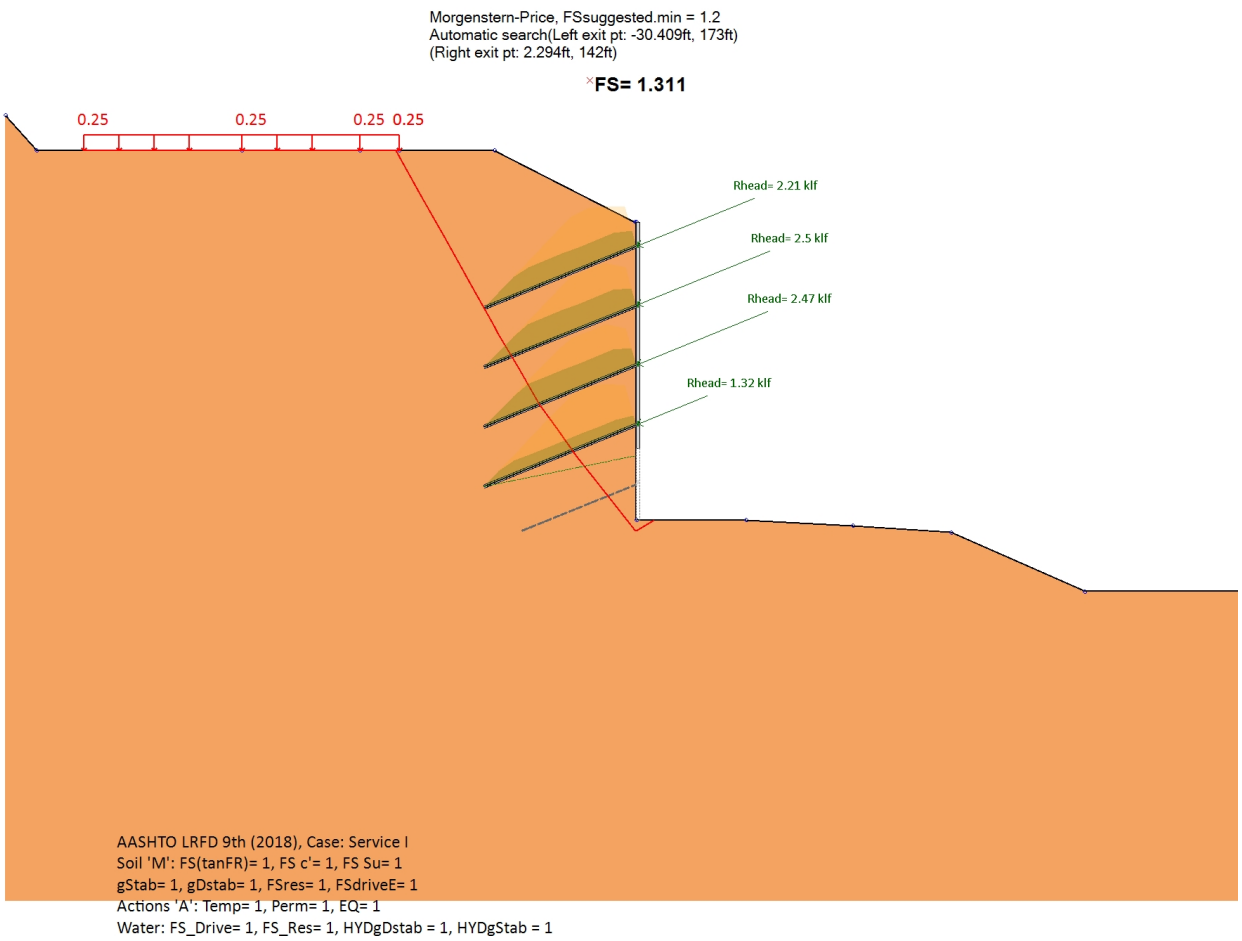
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	1.528	0	0	0	0	0	0	No	Yes
Exc. 162 ft	Calculated	3.214	0	0	0	0	0	0	No	Yes
Exc. 157 ft	Calculated	1.891	3.93	3.01	3.93	0.089	0.116	0.044	No	Yes
Exc. 152 ft	Calculated	1.737	9.46	7.25	9.46	0.213	0.28	0.106	No	Yes
Project Wall	Calculated	1.524	15.74	12.06	15.74	0.354	0.465	0.176	No	Yes
Forward Com	Calculated	1.311	19.62	15.02	19.62	0.441	0.58	0.219	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.528	1.2	Circle	57.348	200.796	49.703	N/A	N/A
Exc. 162 ft	Yes	3.214	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	1.891	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	1.737	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.524	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.311	1.2	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Service I	-	-	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 25)	N/A	AASHTO LRF	Service I	-	-	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Service I	43.95	0.089	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Service I	44.44	0.213	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Service I	44.44	0.354	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 15)	N/A	AASHTO LRF	Service I	44.44	0.441	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Service I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	1
Permanent loads	1
Temporary anchors	1
Permanent anchors	1
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	165	20	0	6	2.2089	13.25
N1	0: N1	15	0	160	20	0	6	2.5035	15.02
N2	0: N1	15	0	155	20	0	6	2.4662	14.8
N3	0: N1	15	0	150	20	0	6	1.3151	7.89
Nail 1	0: N1	15	0	145	15	0	6	0	0

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	176
2	-76	173
3	-50	173
4	-35	173
5	-30	173
6	-18	173
7	-0.1	167
8	0	167
9	0	142
10	14	142
11	27.5	141.5
12	40	141
13	57	136
14	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1B	120	120	35	0	N/A	18	
ESU 1A	110	110	32	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
175	ESU 1B	1	0.43
170	ESU 1A	1	0.47
149	ESU 4C	1	0.32
139	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 20ft, z= 168ft
Radii search ends at point x= 20ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

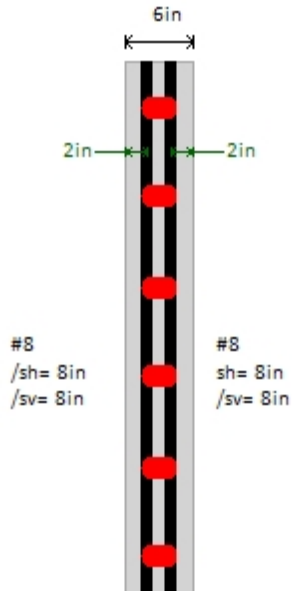
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Morgenstern-Price
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	167	142	N/A	6
Exc. 162 ft	No	167	162	N/A	6
Exc. 157 ft	Yes	167	162	N/A	6
Exc. 152 ft	Yes	167	157	N/A	6
Project Wall Height	Yes	167	152	N/A	6
Forward Compatible	Yes	167	148	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	165	20	0	6	0.79	6	75
N1	0: N1	15	0	160	20	0	6	0.79	6	75
N2	0: N1	15	0	155	20	0	6	0.79	6	75
N3	0: N1	15	0	150	20	0	6	0.79	6	75
Nail 1	0: N1	15	0	145	15	0	6	0.79	6	75

Header plate data

14/22

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	165	6	1	36	1	N/A	N/A	N/A
N1	160	6	1	36	1	N/A	N/A	N/A
N2	155	6	1	36	1	N/A	N/A	N/A
N3	150	6	1	36	1	N/A	N/A	N/A
Nail 1	145	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 57.348 z= 200.796 FS= 1.528

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -1.285 z= 177.397 FS= 3.214

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -3.672 z= 178.197 FS= 1.891

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	28.88	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -4.537 z= 178.487 FS= 1.737

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	11.35	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	27.19	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= -3.005 z= 177.974 FS= 1.524

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	13.86	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	29.93	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -5.882 z= 178.938 FS= 1.311

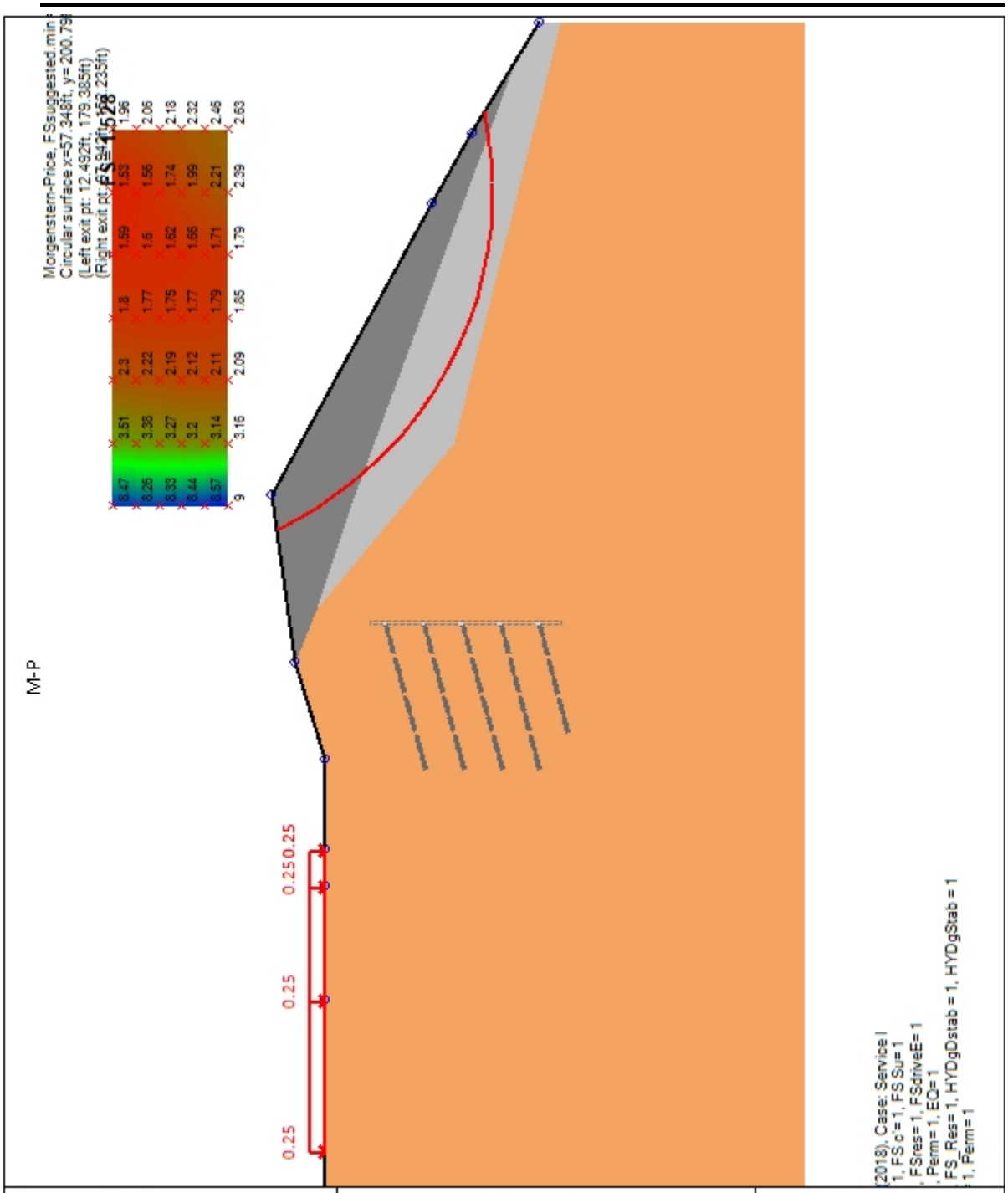
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	44.23	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	11.74	42.78	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	23.75	41.29	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	37.74	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GENERAL SOIL NAIL DATA

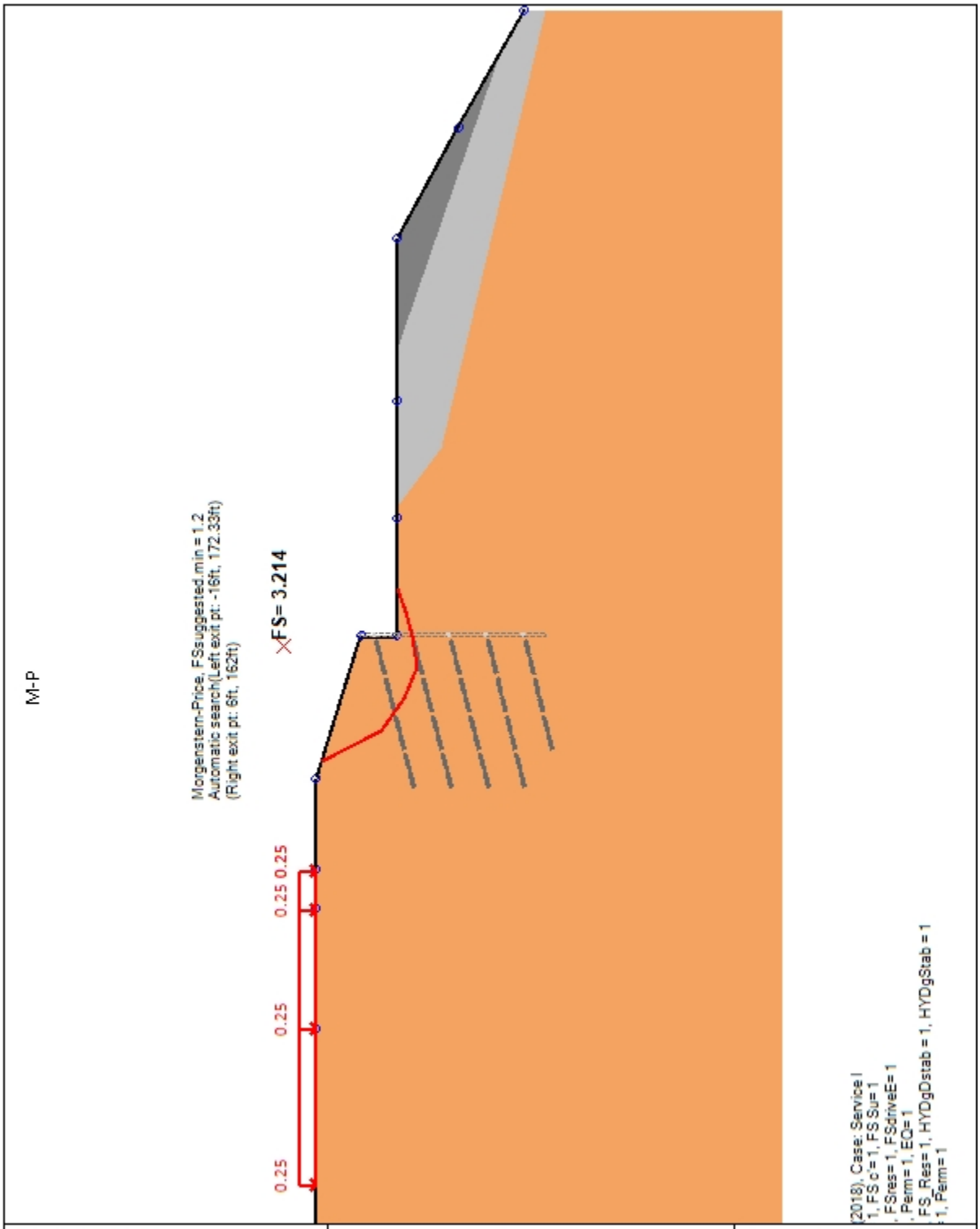
Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

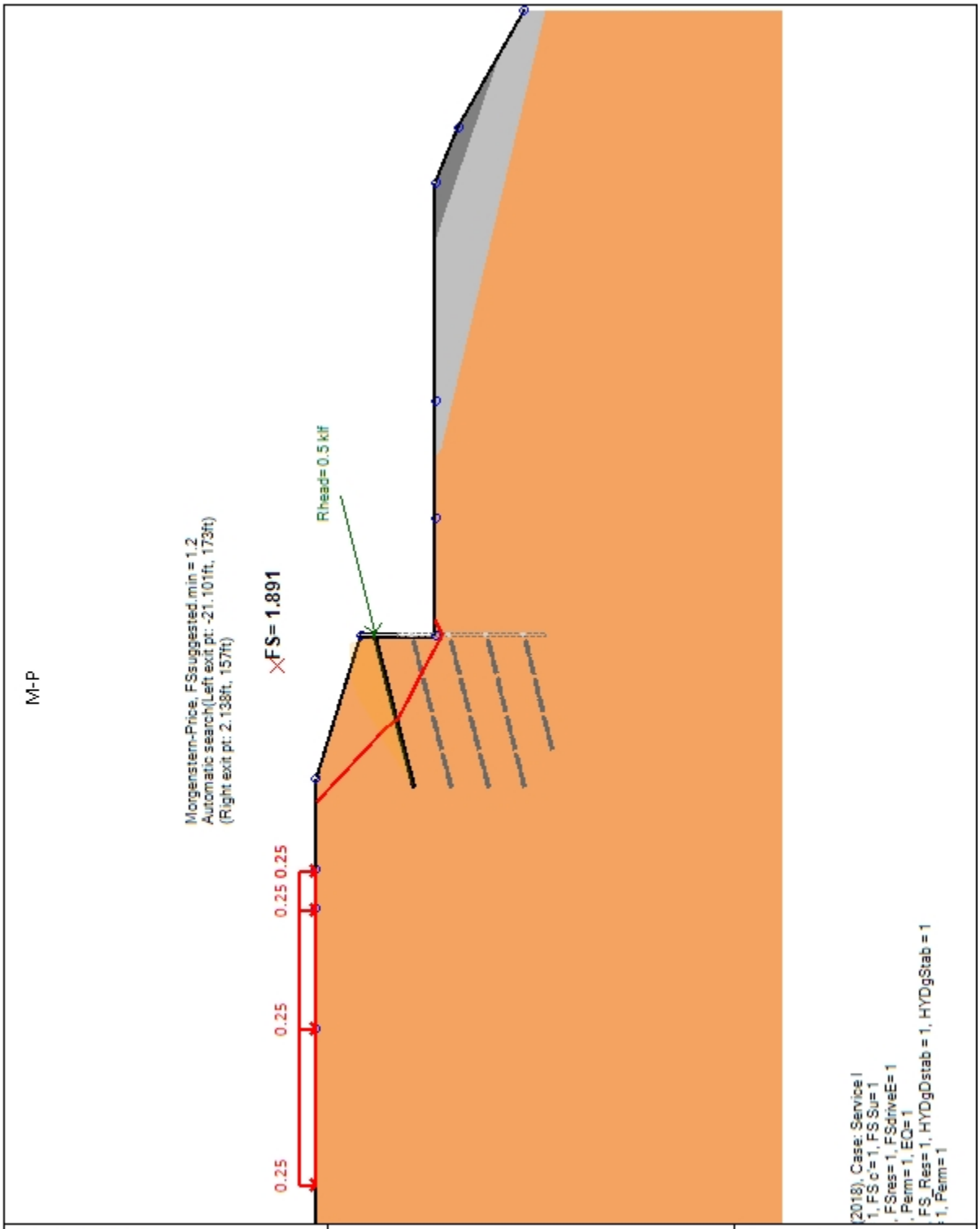
F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



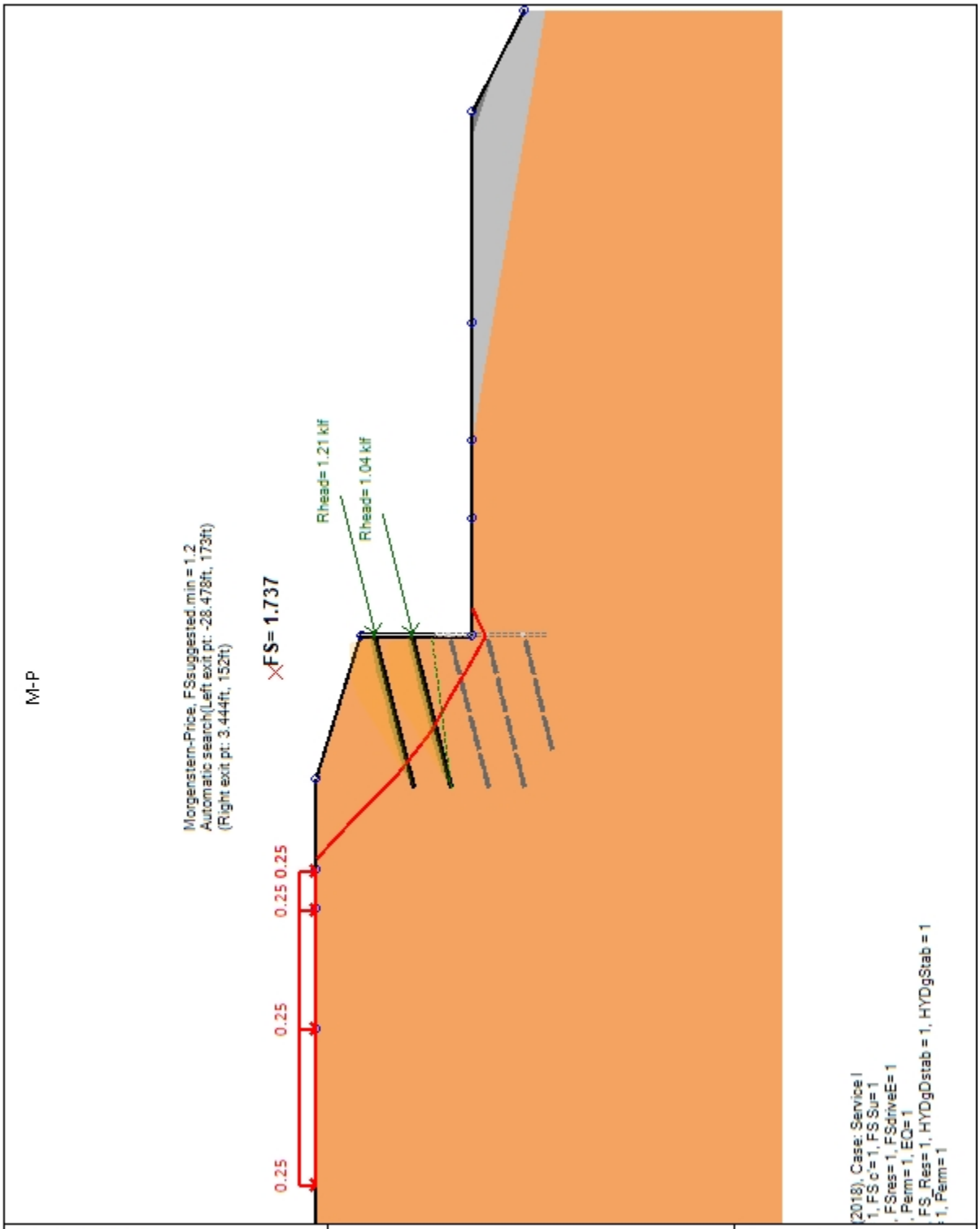
Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP		12/2/2021



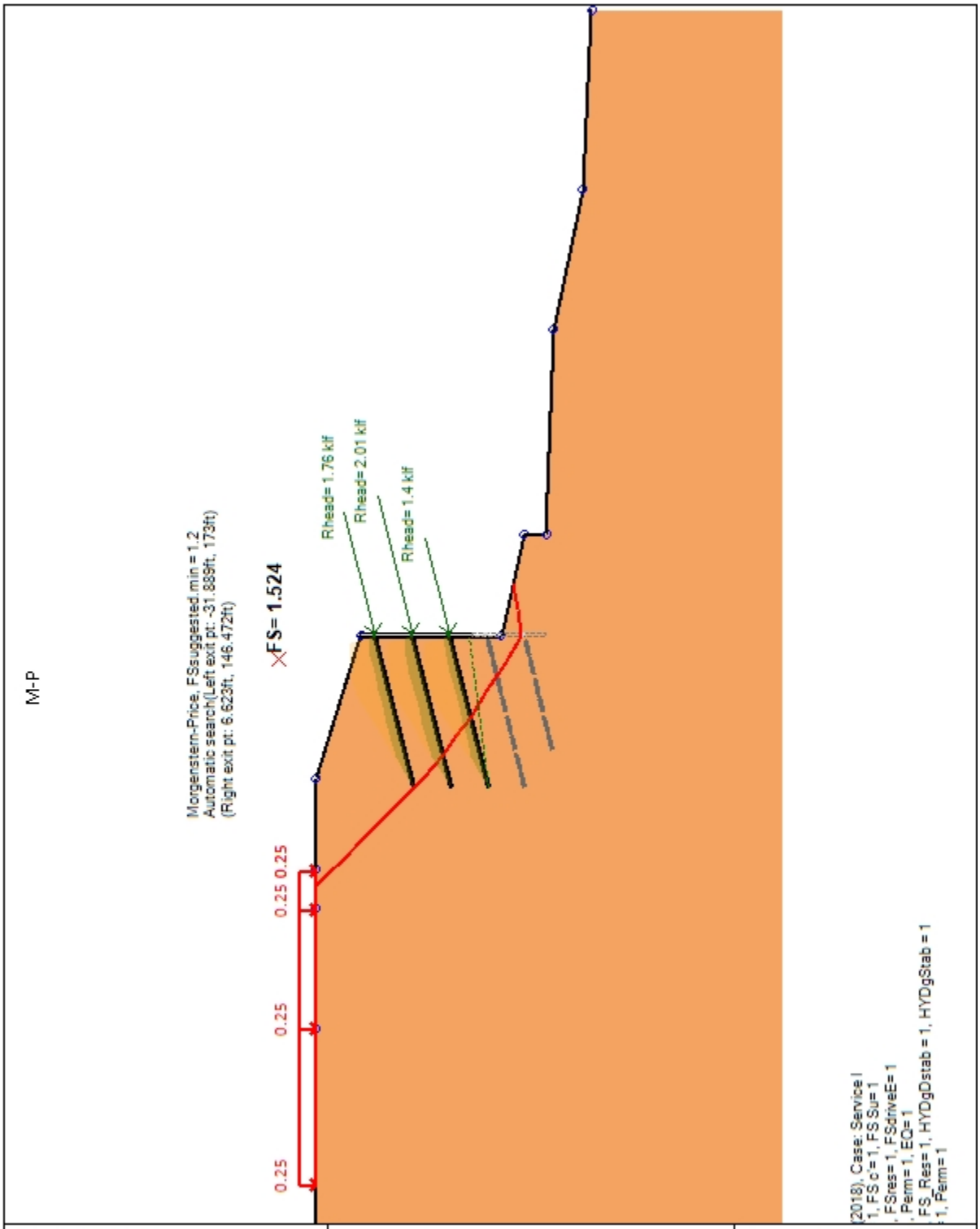
Company: Wood Engineer: DL	DS: 0, Exc. 162 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP		12/2/2021



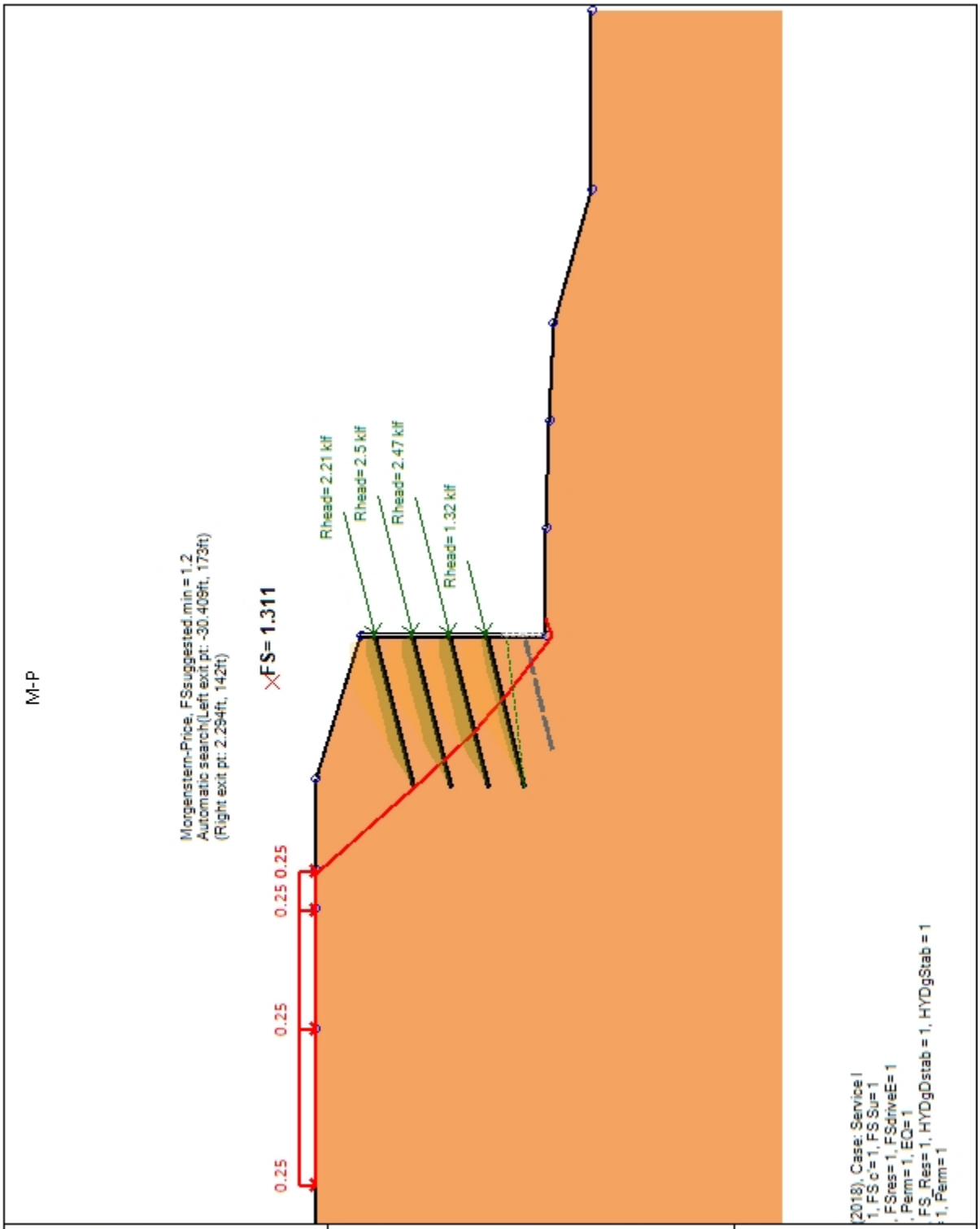
Company: Wood Engineer: DL	DS: 0, Exc. 157 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..es\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, M-P).SNLP		12/2/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 5+20 (Perm Static, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 8:40:39 AM

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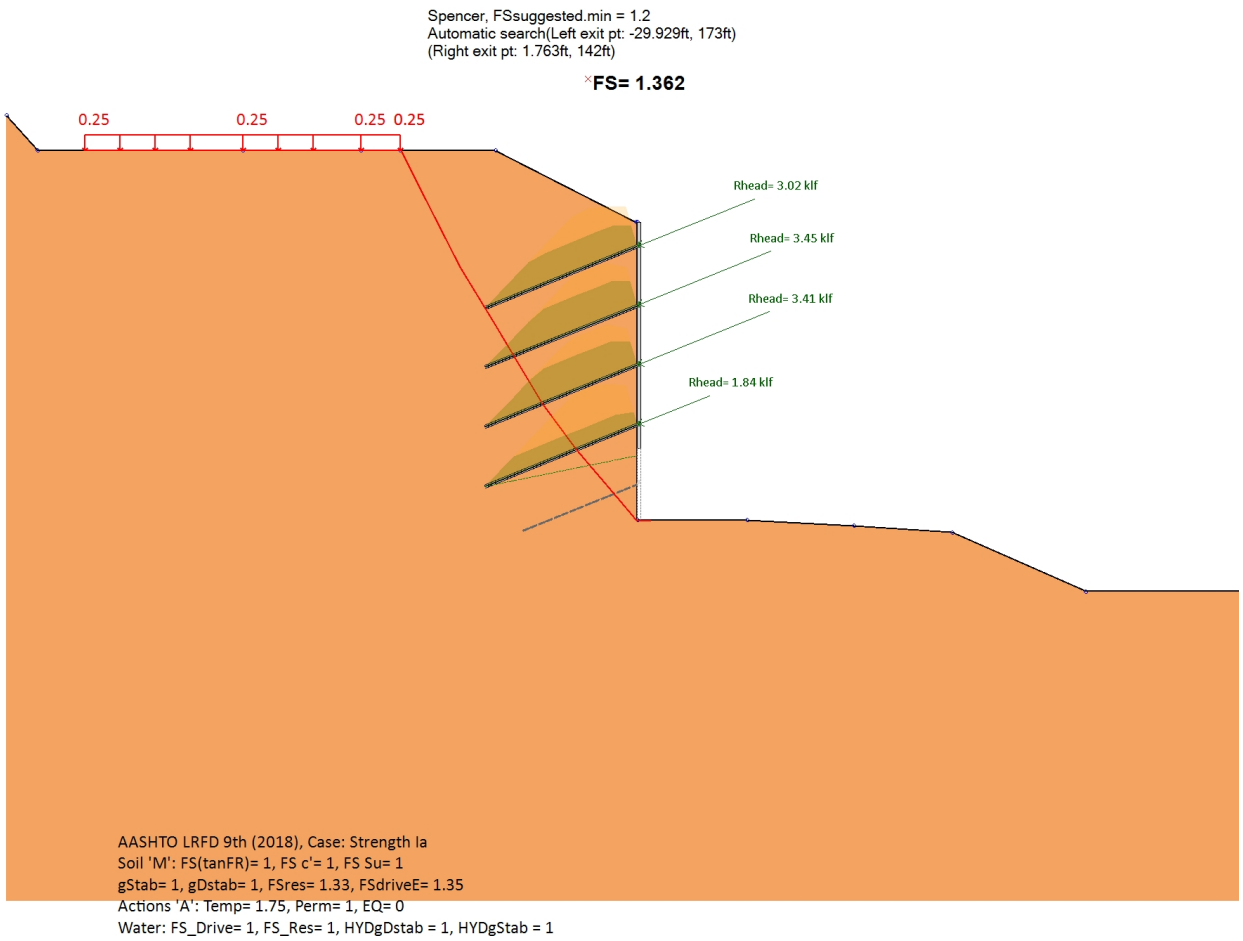
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\5+20\New Stratigraphy\CS Sta 5+20 (Temp Static, Spencer).SNLP

Quick analysis summary for design section: Spencer

Spencer

ESU 4A	135	0	-	42	22



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Existing	Calculated	1.526	0	0	0	0	0	0	No	Yes
Exc. 162 ft	Calculated	3.116	0	0	0	0	0	0	No	Yes
Exc. 157 ft	Calculated	1.967	5.56	4.26	5.56	0.125	0.164	0.062	No	Yes
Exc. 152 ft	Calculated	1.822	13.11	10.04	13.11	0.295	0.387	0.146	No	Yes
Project Wall	Calculated	1.547	21.78	16.68	21.78	0.49	0.643	0.243	No	Yes
Forward Com	Calculated	1.362	27.01	20.68	27.01	0.608	0.798	0.302	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Existing	Yes	1.526	1.2	Circle	57.348	200.796	49.703	N/A	N/A
Exc. 162 ft	Yes	3.116	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 157 ft	Yes	1.967	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Exc. 152 ft	Yes	1.822	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.547	1.2	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.362	1.2	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 25)	N/A	AASHTO LRF	Strength Ia	-	-	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	43.95	0.125	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.295	N/A	N/A	N/A
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Strength Ia	44.44	0.49	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 15)	N/A	AASHTO LRF	Strength Ia	44.44	0.608	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Strength Ia
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	0
Variable loads	1.75
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1.35, F_kA= 1.5
Earth favorable	1.33
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	165	20	0	6	3.0248	18.15
N1	0: N1	15	0	160	20	0	6	3.4471	20.68
N2	0: N1	15	0	155	20	0	6	3.4097	20.46
N3	0: N1	15	0	150	20	0	6	1.8353	11.01
Nail 1	0: N1	15	0	145	15	0	6	0	0

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	176
2	-76	173
3	-50	173
4	-35	173
5	-30	173
6	-18	173
7	-0.1	167
8	0	167
9	0	142
10	14	142
11	27.5	141.5
12	40	141
13	57	136
14	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1B	120	120	35	0	N/A	18	
ESU 1A	110	110	32	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
175	ESU 1B	1	0.43
170	ESU 1A	1	0.47
149	ESU 4C	1	0.32
139	ESU 4A	1	0.33

Slope stability assumptions: Existing

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 20ft, z= 168ft
Radii search ends at point x= 20ft, z= 155ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 162 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
Soil nail mobilization interaction factor Imob= 0.25
Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
Minimum soil nail mobilization factor SNmin.mob = 0
Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
Soil nail stability considers both external and internal stability (punching through facing).
Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 157 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Exc. 152 ft

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

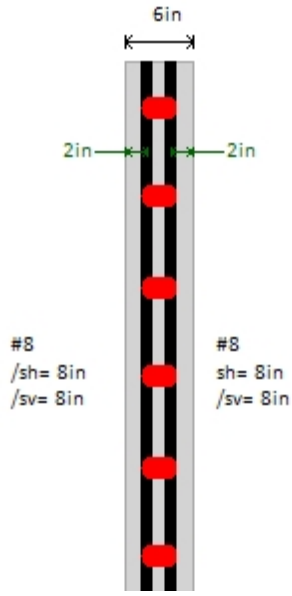
Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Short term 48hrs non-critical
Min required FS	1.2
Method	Spencer
Nail methods	Available shear
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.75
Φ.p nail pullout	0.65
Φ.ff facing bending	0.9
Φ.fp facing punching	0.9
Φ.ht on bolts	0.8
Φ.b on bearing	0.33

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Spencer



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Existing	No	167	142	N/A	6
Exc. 162 ft	No	167	162	N/A	6
Exc. 157 ft	Yes	167	162	N/A	6
Exc. 152 ft	Yes	167	157	N/A	6
Project Wall Height	Yes	167	152	N/A	6
Forward Compatible	Yes	167	148	N/A	6

Soil nail input data for design section Spencer

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	165	20	0	6	0.79	6	75
N1	0: N1	15	0	160	20	0	6	0.79	6	75
N2	0: N1	15	0	155	20	0	6	0.79	6	75
N3	0: N1	15	0	150	20	0	6	0.79	6	75
Nail 1	0: N1	15	0	145	15	0	6	0.79	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	165	6	1	36	1	N/A	N/A	N/A
N1	160	6	1	36	1	N/A	N/A	N/A
N2	155	6	1	36	1	N/A	N/A	N/A
N3	150	6	1	36	1	N/A	N/A	N/A
Nail 1	145	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Spencer

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 57.348 z= 200.796 FS= 1.526

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -1.285 z= 177.397 FS= 3.116

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -0.425 z= 177.109 FS= 1.967

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	29.1	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -0.387 z= 177.096 FS= 1.822

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	4	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	21.23	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= 0.712 z= 177 FS= 1.547

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0.01	43.95	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	13.27	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	29.08	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

3: N3	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -6.16 z= 179.031 FS= 1.362

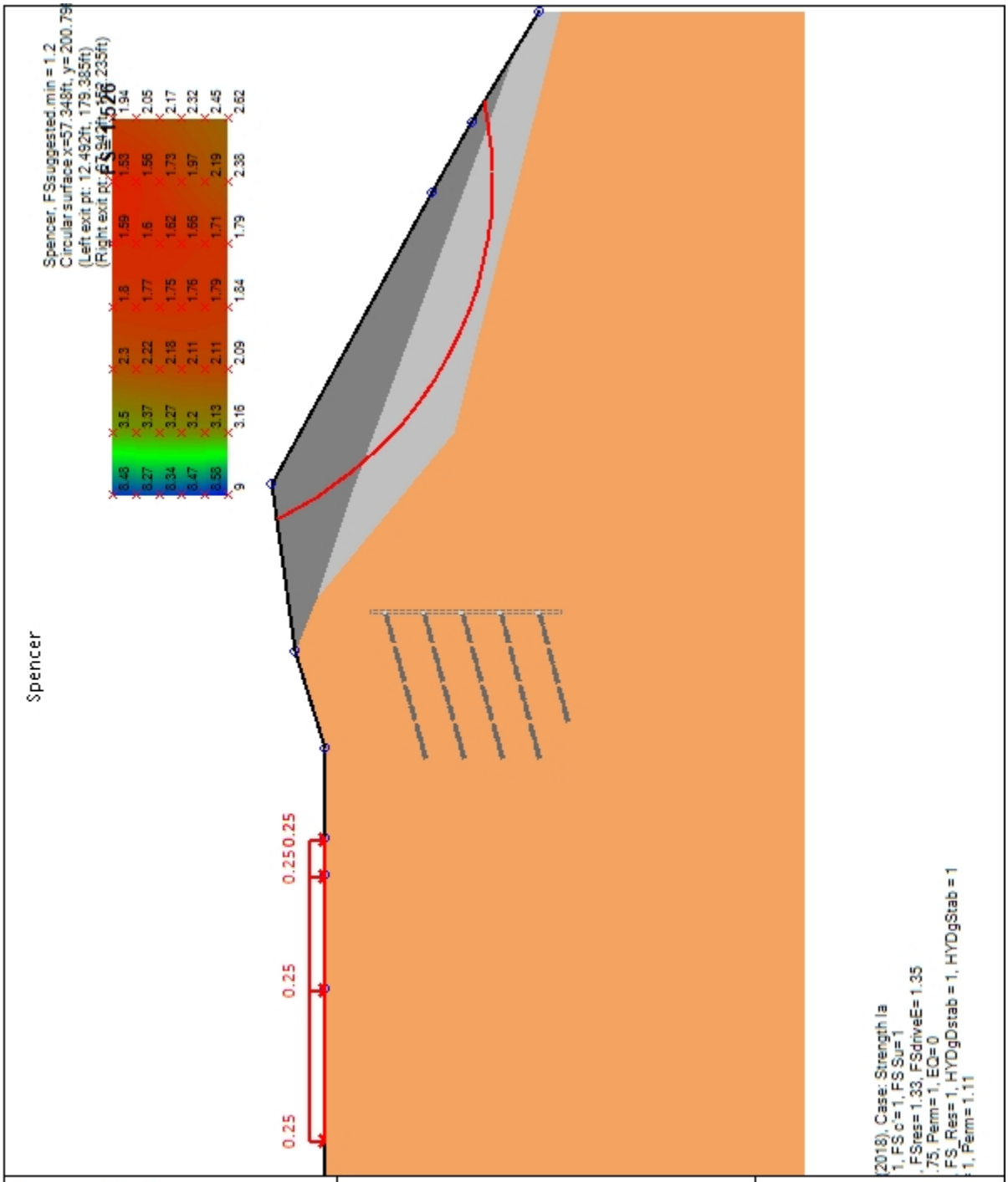
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	44.23	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	12.27	42.78	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	24.54	41.29	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	38.96	44.44	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Existing	Deep Excavation LCC SnailPlus 2021
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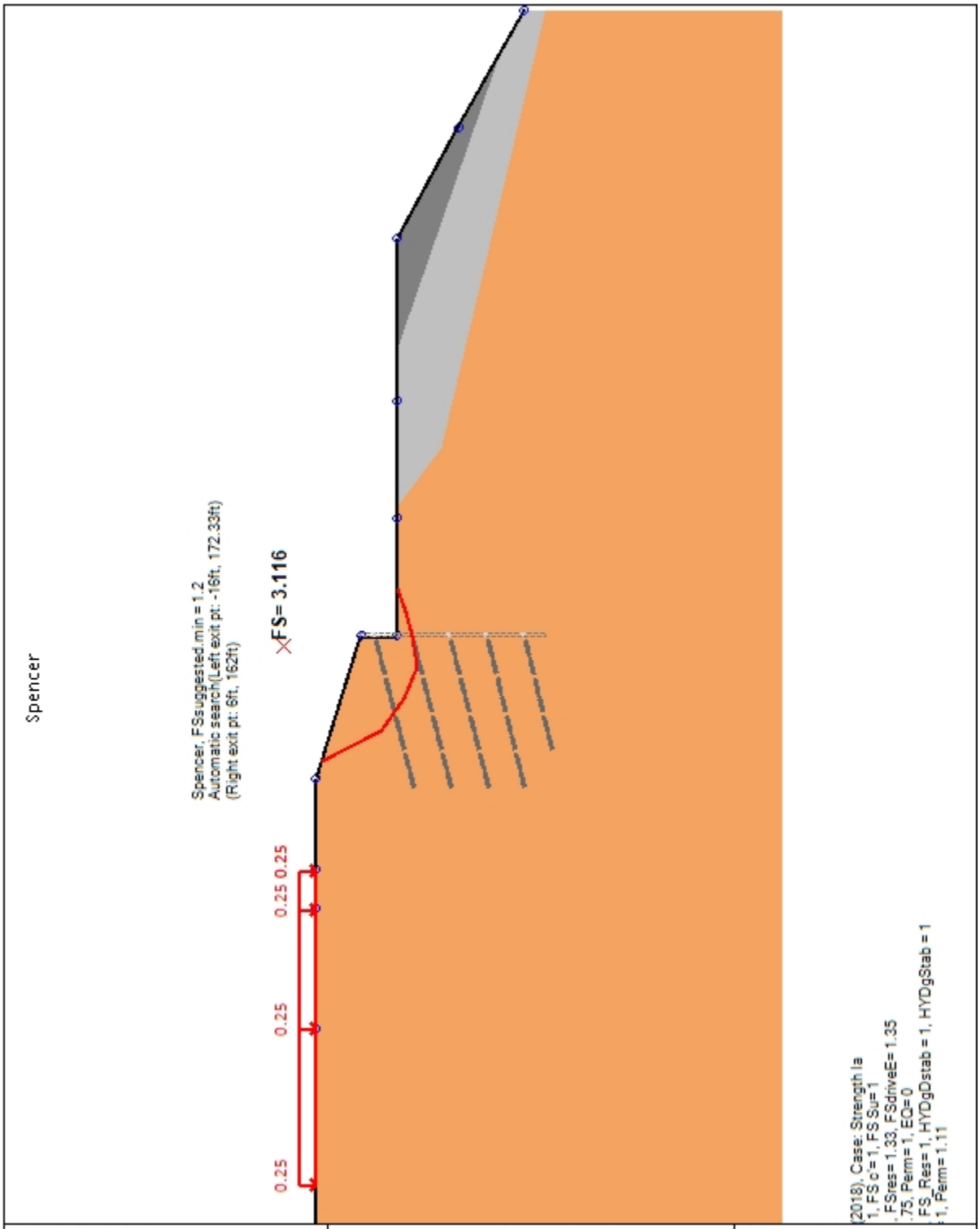

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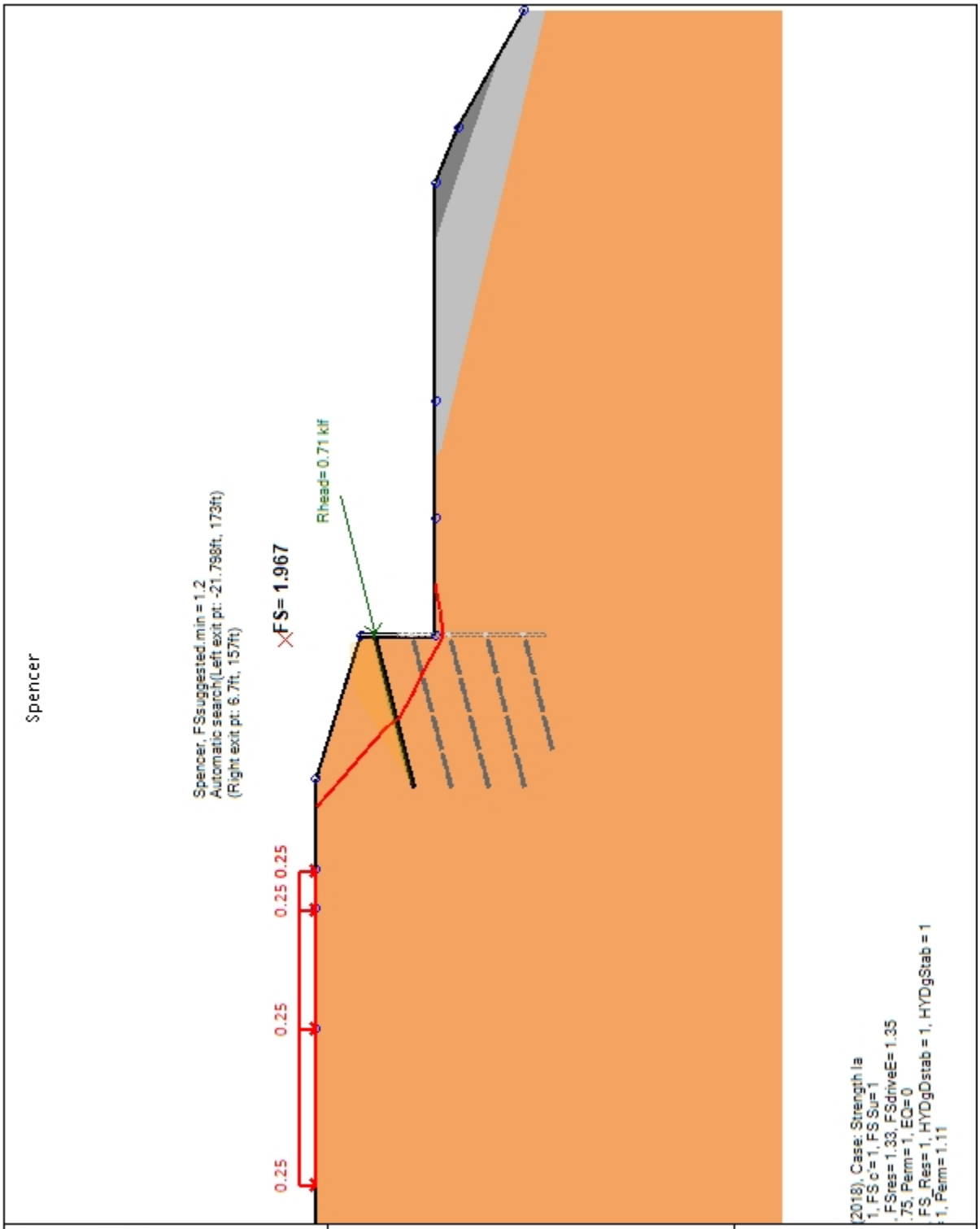

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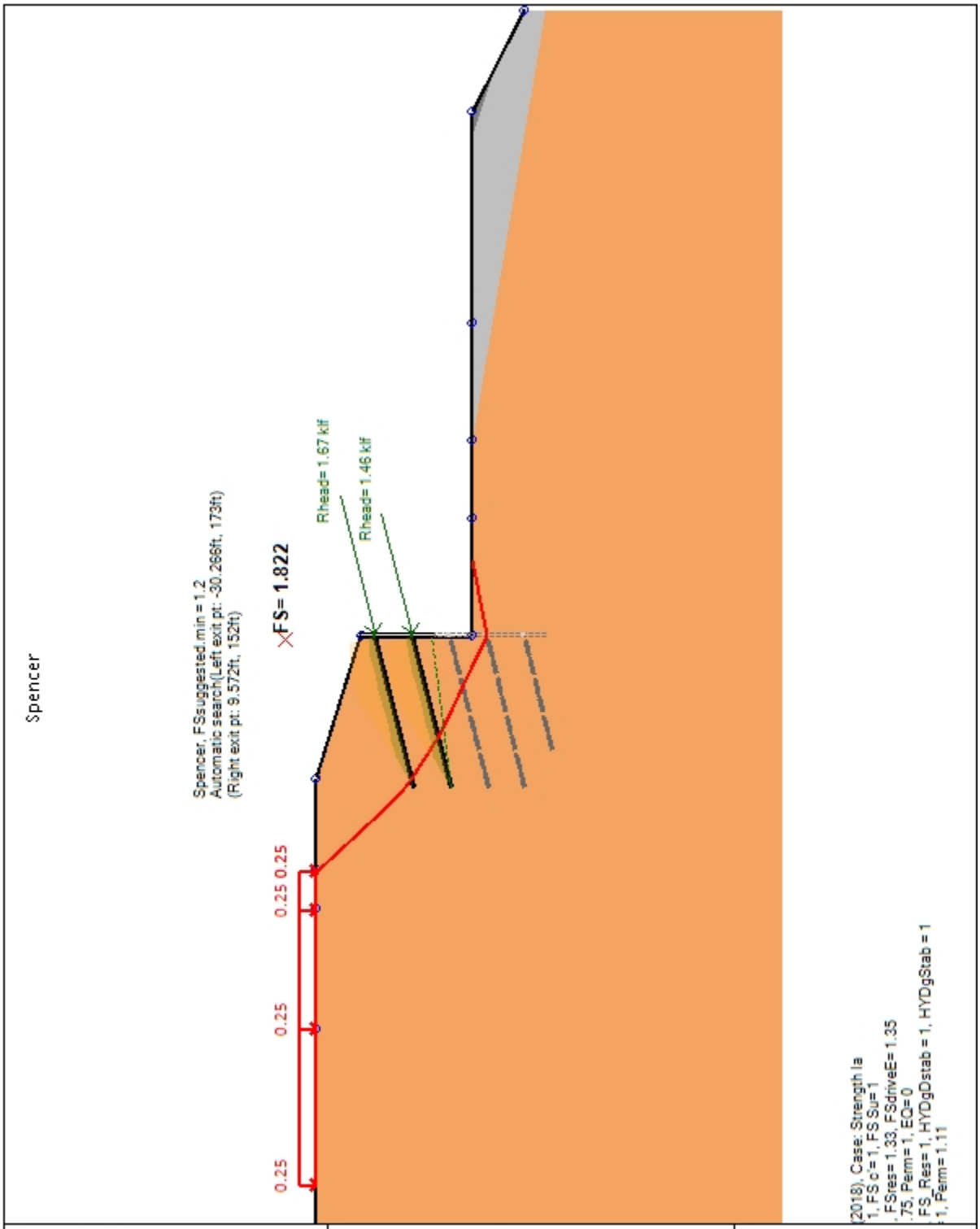

Company: Wood Engineer: DL	DS: 0, Exc. 152 ft	Deep Excavation LCC SnailPlus 2021
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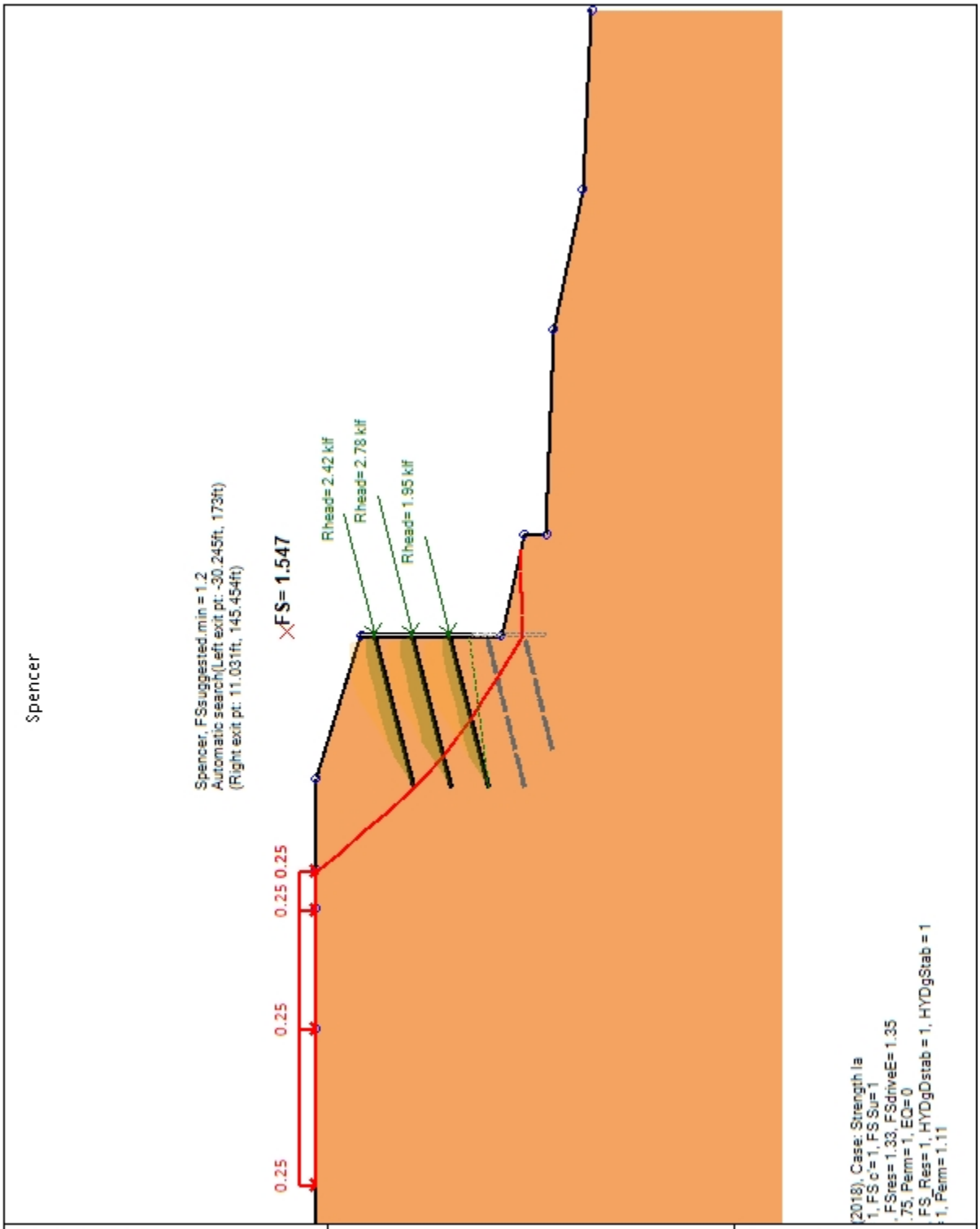
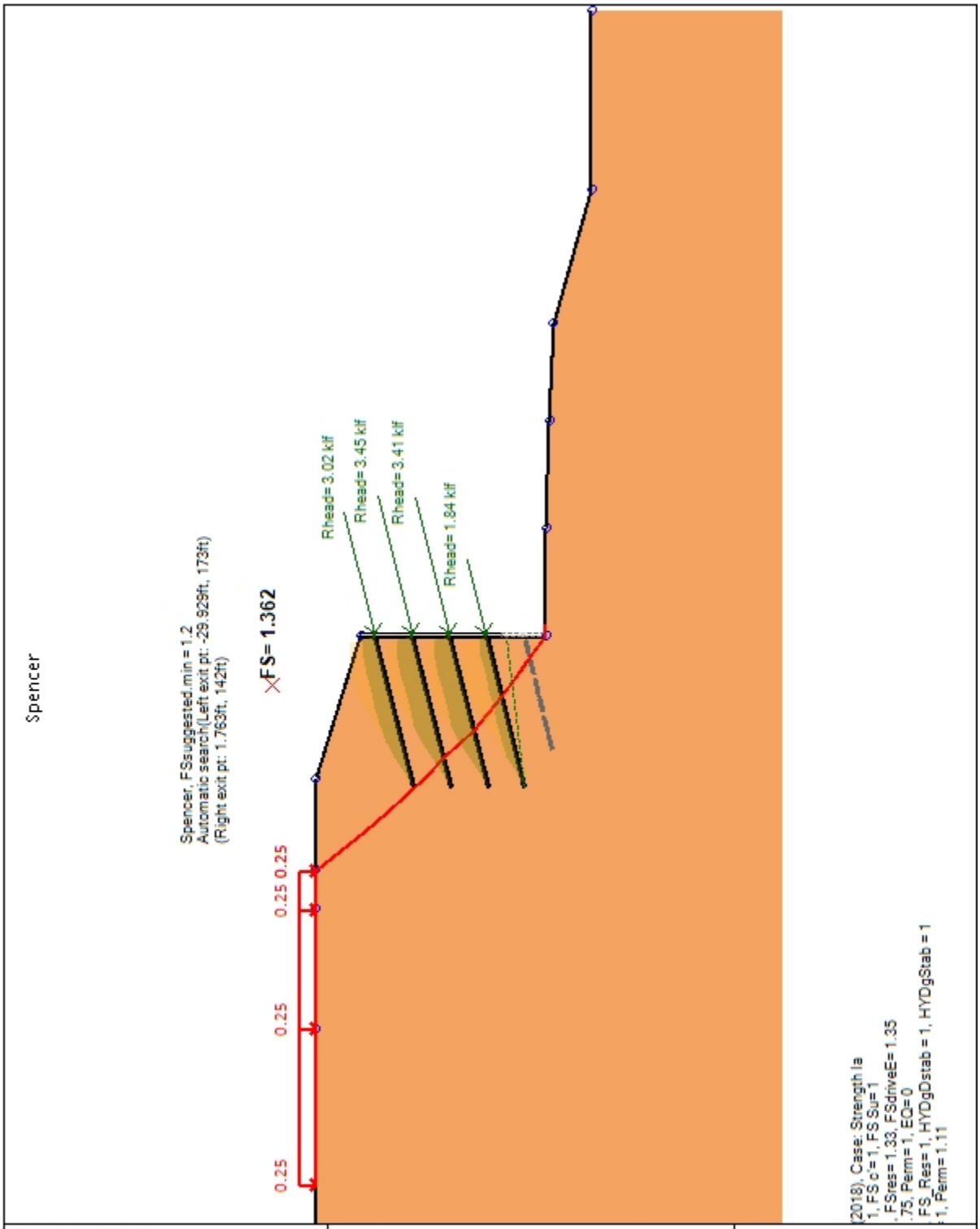


Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
C:\Us..+20\New Stratigraphy\CS Sta 5+20 (Temp Static, Spencer).SNLP		12/2/2021



Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us..+20\New Stratigraphy\CS Sta 5+20 (Temp Static, Spencer).SNLP		12/2/2021

SnailPlus 2021: Report Output

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Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 5+20 (Seismic, M-P)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 8:43:42 AM

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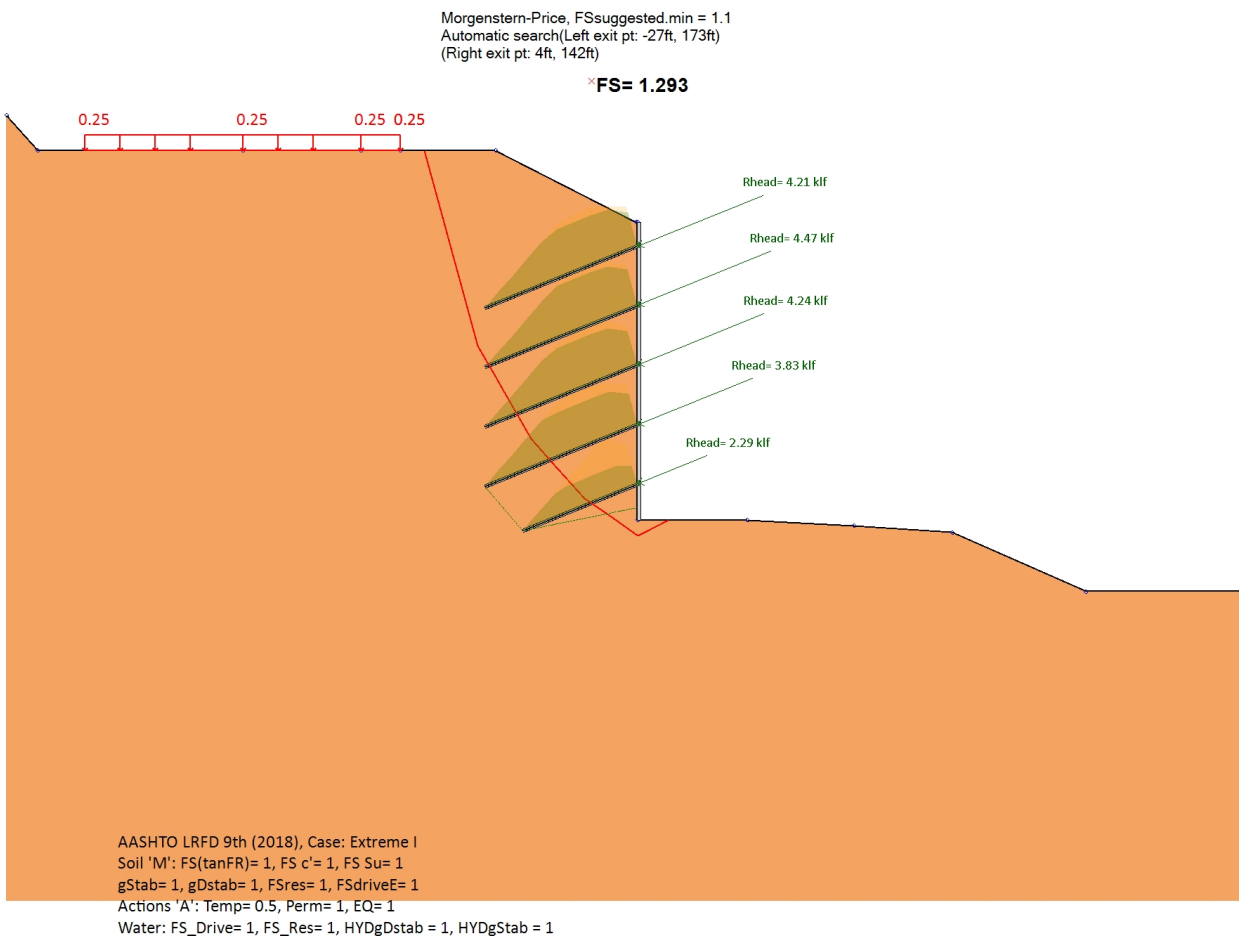
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\5+20\New Stratigraphy\CS Sta 5+20 (Seismic, M-P).SNLP

Quick analysis summary for design section: M-P

M-P

ESU 4A	135	0	-	42	22



Stage	Calculation	FS	Fmax.Nails	Fmax.Nails	Fmax.Mob	STR Check	STR Check	STR Chec	Max.	Min.
Section	Status	Slope	(k)	Head (k)	(k)	Nails	Plates	Facing	Reinf.	Reinf.
Project Wall	Calculated	1.41	29.22	22.38	29.22	0.759	0.777	0.326	No	Yes
Project Wall	Calculated	1.964	29.22	22.38	29.22	0.759	0.777	0.326	No	Yes
Forward Com	Calculated	1.293	35.03	26.83	35.03	0.91	0.931	0.391	No	Yes

Fmax Nails = Maximum axial nail force in analysis.
Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).

STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Project Wall	Yes	1.41	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	1.964	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.293	1.1	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Extreme I	38.51	0.759	N/A	N/A	N/A
xL (-80 to -45	xR (30 to 80)	N/A	AASHTO LRF	Extreme I	0	0.759	N/A	N/A	N/A
xL (-60 to -5)	xR (0.1 to 15)	N/A	AASHTO LRF	Extreme I	38.51	0.91	N/A	N/A	N/A

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Extreme I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	0.5
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	165	20	0	6	4.2144	25.29
N1	0: N1	15	0	160	20	0	6	4.471	26.83
N2	0: N1	15	0	155	20	0	6	4.2384	25.43
N3	0: N1	15	0	150	20	0	6	3.8339	23
Nail 1	0: N1	15	0	145	15	0	6	2.2949	13.77

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	176
2	-76	173
3	-50	173
4	-35	173
5	-30	173
6	-18	173
7	-0.1	167
8	0	167
9	0	142
10	14	142
11	27.5	141.5
12	40	141
13	57	136
14	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1B	120	120	35	0	N/A	18	
ESU 1A	110	110	32	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
175	ESU 1B	1	0.43
170	ESU 1A	1	0.47
149	ESU 4C	1	0.32
139	ESU 4A	1	0.33

Slope stability assumptions: Project Wall Height

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -45ft
Right search limits: xRmin= 30ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Morgenstern-Price
Nail methods	Available shear
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Force Tolerance	10%
Initial FS0	1
MP interslice factor m	1
MP interslice factor v	1
MP initial Lamda.0	0
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section M-P

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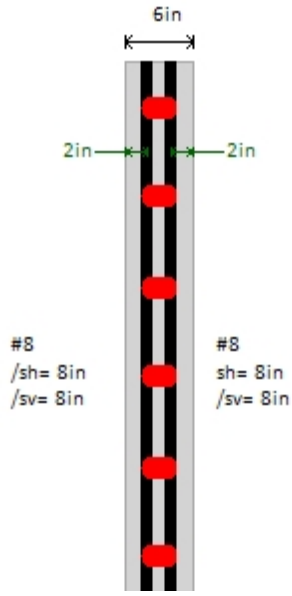

Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Project Wall Height	Yes	167	148	N/A	6
Project Wall Height-G	Yes	167	148	N/A	6
Forward Compatible	Yes	167	142	N/A	6

Soil nail input data for design section M-P

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	165	20	0	6	0.79	6	75
N1	0: N1	15	0	160	20	0	6	0.79	6	75
N2	0: N1	15	0	155	20	0	6	0.79	6	75
N3	0: N1	15	0	150	20	0	6	0.79	6	75
Nail 1	0: N1	15	0	145	15	0	6	0.79	6	75

Header plate data

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Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	165	6	1	36	1	N/A	N/A	N/A
N1	160	6	1	36	1	N/A	N/A	N/A
N2	155	6	1	36	1	N/A	N/A	N/A
N3	150	6	1	36	1	N/A	N/A	N/A
Nail 1	145	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: M-P

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= -5.192 z= 178.707 FS= 1.41

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	8.57	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	28.59	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	38.51	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	STR
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= -5.192 z= 178.707 FS= 1.964

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
1: N1	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
2: N2	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
3: N3	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -5.75 z= 178.894 FS= 1.293

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	1.78	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	13.6	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	27.75	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	28.93	37.81	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

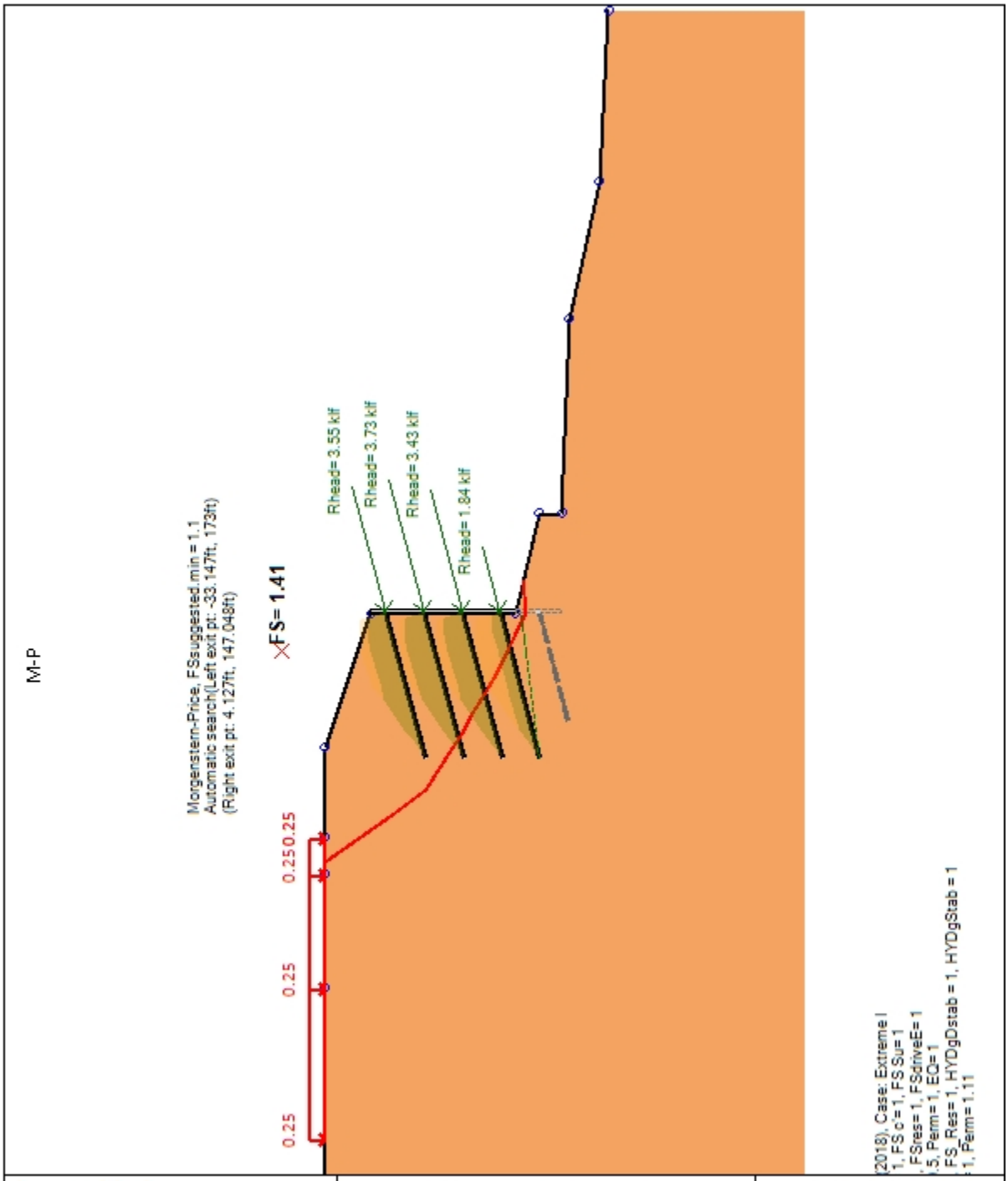
GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)

t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



Company: Wood Engineer: DL	DS: 0, Project Wall Height	Deep Excavation LCC SnailPlus 2021
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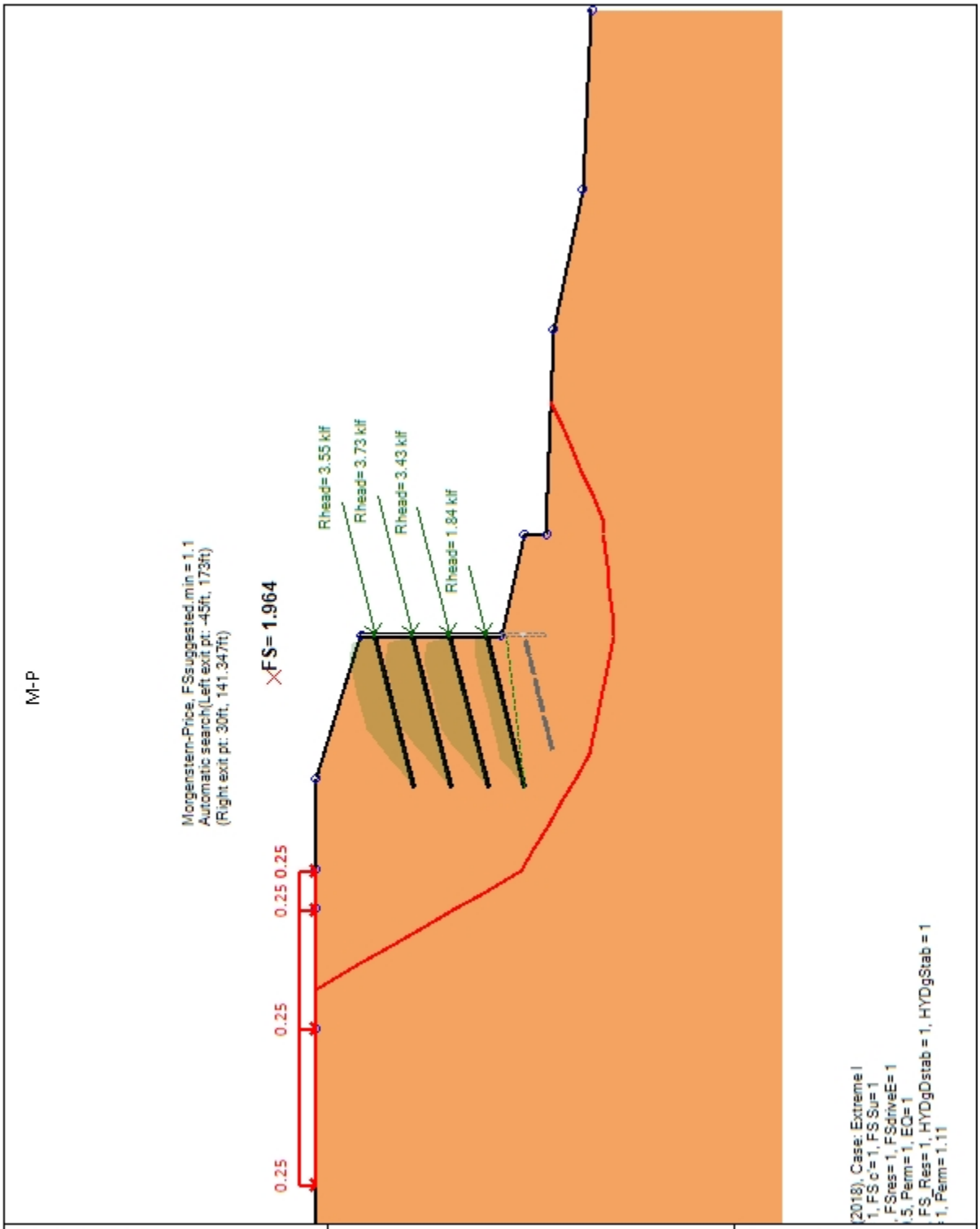

Company: Wood Engineer: DL	DS: 0, Project Wall Height-Global	Deep Excavation LCC SnailPlus 2021
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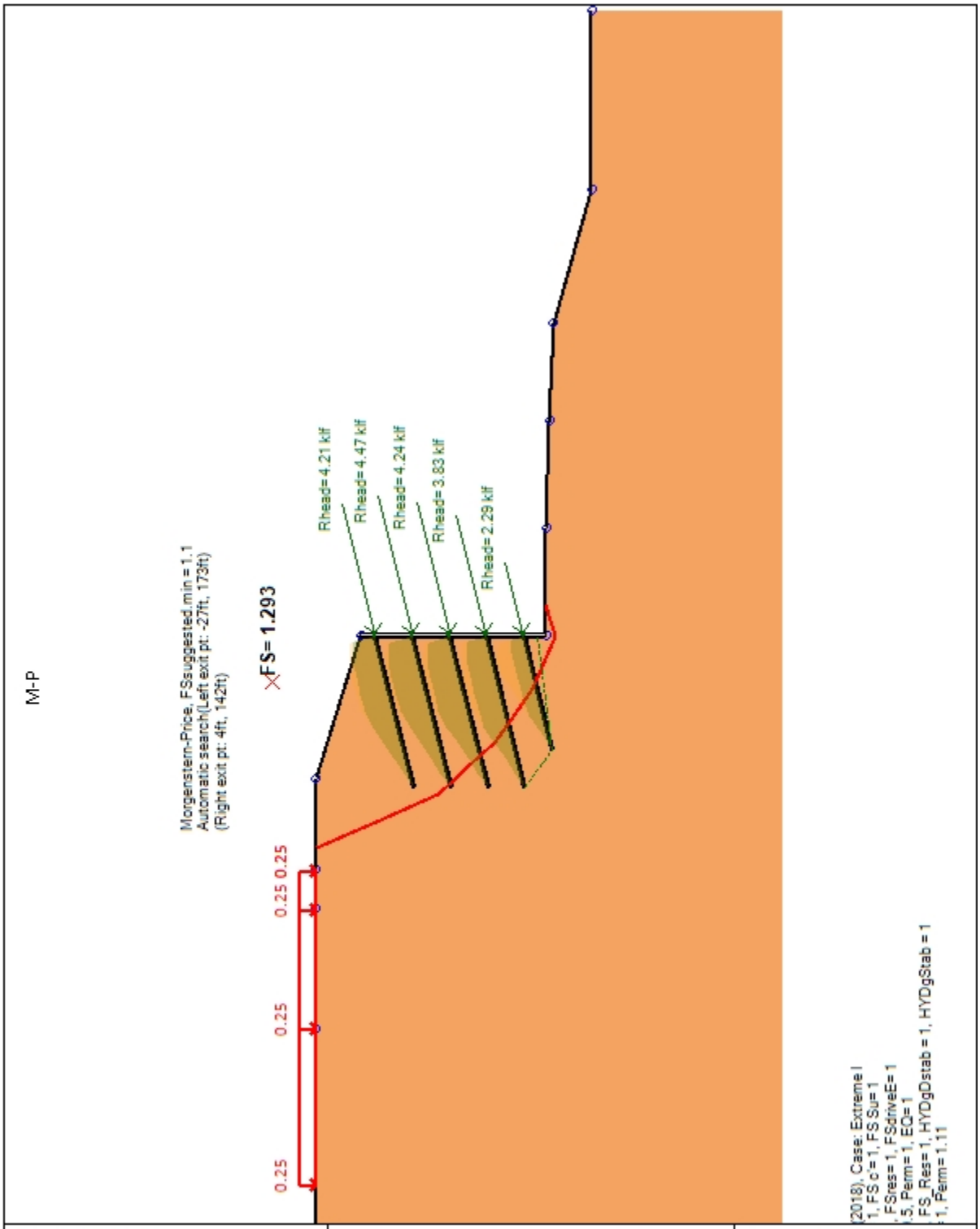

Company: Wood Engineer: DL	DS: 0, Forward Compatible Wall	Deep Excavation LCC SnailPlus 2021
C:\Us.. Files\5+20\New Stratigraphy\CS Sta 5+20 (Seismic, M-P).SNLP		12/2/2021

SnailPlus 2021: Report Output

Copyright@2009 - 2020 Deep Excavation LLC: www.deepexcavation.com A program for the evaluation of soil nail walls. Deep Excavation LLC, Astoria, New York, www.deepexcavation.com

Project: WSDOT I-405 R2B - Wall 9.05R-B, CS Sta 5+20 (Seismic, Bishop)

Company: Wood
Prepared by engineer: AP
File number: 1
Time: 12/2/2021 8:48:59 AM

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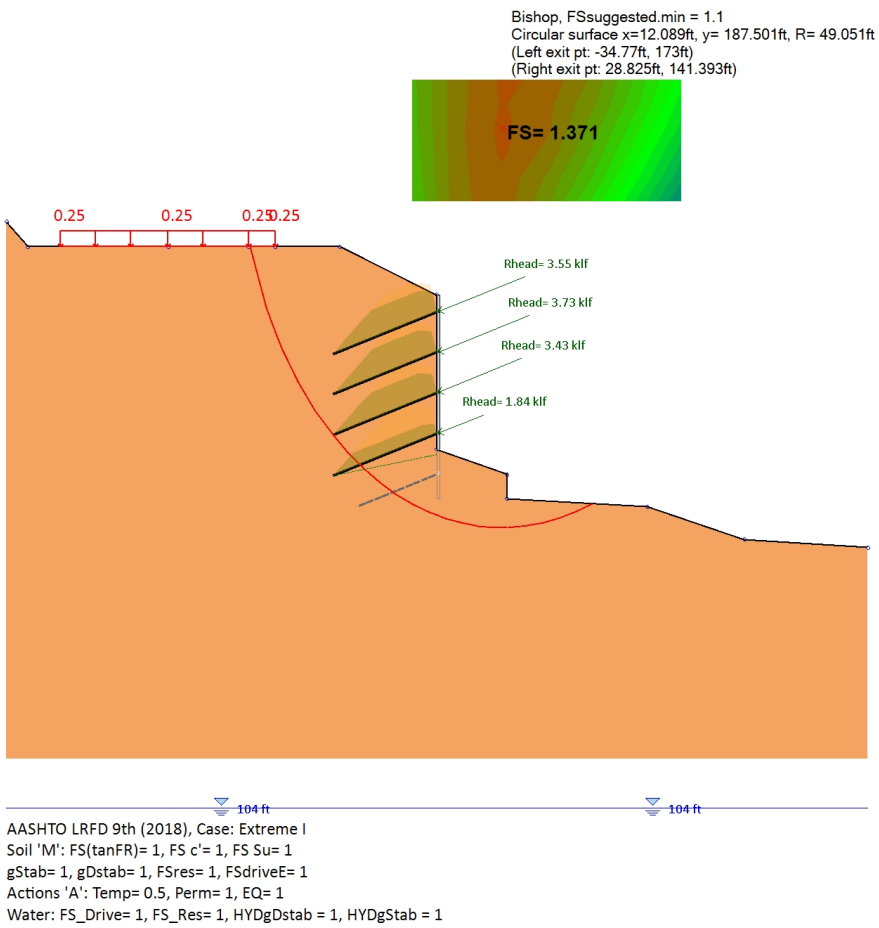
File: C:\Users\Anthony.Pusic\OneDrive - Wood PLC\Projects\I 405\Walls\9.05R-B\Snail Files\5+20\New Stratigraphy\CS Sta 5+20 (Seismic, Bishop).SNLP

Quick analysis summary for design section: Bishop

Bishop

ESU 4A	135	0	-	42	22



Stage Section	Calculation Status	FS Slope	Fmax.Nails (k)	Fmax.Nails Head (k)	Fmax.Mob (k)	STR Check Nails	STR Check Plates	STR Chec Facing	Max. Reinf.	Min. Reinf.
Project Wall	Calculated	1.371	29.22	22.38	29.22	0.759	0.777	0.326	No	Yes
Project Wall	Calculated	1.556	29.22	22.38	29.22	0.759	0.777	0.326	No	Yes
Project Wall	Calculated	3.19	29.22	22.38	29.22	0.759	0.777	0.326	No	Yes
Project Wall	Calculated	6.264	29.22	22.38	29.22	0.759	0.777	0.326	No	Yes
Forward Com	Calculated	1.418	35.03	26.83	35.03	0.91	0.931	0.391	No	Yes
Forward Com	Calculated	3.096	35.03	26.83	35.03	0.91	0.931	0.391	No	Yes

Fmax Nails = Maximum axial nail force in analysis.

Fmax Nail@head = Maximum axial nail force at facing (To).
Fmax.Mob = Maximum mob axial nail force from To/Tmax ratio Clouterre (Tmax)
STR Nails= Stress check for nails, Design load/Design Capacity (maintain below 1 for good design).
STR Plates= Stress check for nail plates (punching and bending).
STR Facing= Stress check for facing, Design load/Design Capacity.

Table: Analysis summary for all stages, Part 1

Stage	Analyzed	FS min	FS req. code	Type	Xc (ft)	Zc (ft)	R (ft)	Active (deg)	Passive (deg)
Project Wall	Yes	1.371	1.1	Circle	12.089	187.501	49.051	N/A	N/A
Project Wall	Yes	1.556	1.1	Circle	18.333	196	63.695	N/A	N/A
Project Wall	Yes	3.19	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Project Wall	Yes	6.264	1.1	Automatic	Auto	Auto	N/A	N/A	N/A
Forward Co	Yes	1.418	1.1	Circle	10.917	197	57.064	N/A	N/A
Forward Co	Yes	3.096	1.1	Automatic	Auto	Auto	N/A	N/A	N/A

Table: Analysis summary for all stages, Part 2

Point 1	Point 2	Crack (ft)	Design Appro	Design Case	Nail force (k)	Nail check	Support Mre	Wall Mres(k-	MEQ seismic
N/A	N/A	N/A	AASHTO LRF	Extreme I	38.51	0.759	184.676	0	779.566
N/A	N/A	N/A	AASHTO LRF	Extreme I	33.36	0.759	0	0	1790.601
xL (-60 to -5)	xR (0 to 25)	N/A	AASHTO LRF	Extreme I	38.51	0.759	3187.43	0	-1850.864
xL (-80 to -40	xR (25 to 80)	N/A	AASHTO LRF	Extreme I	0	0.759	0	0	-5149.032
N/A	N/A	N/A	AASHTO LRF	Extreme I	38.51	0.91	493.284	0	962.815
xL (-60 to -5)	xR (0.1 to 15)	N/A	AASHTO LRF	Extreme I	38.51	0.91	2690.196	0	-2400.644

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Table: Standard design approach or load combination by code

Code	AASHTO LRFD 9th (2018)
Case	Extreme I
Parameter	Safety Factor
Slope Fres	1
Seismic multiplier	1
Variable loads	0.5
Permanent loads	1
Temporary anchors	1
Permanent anchors	1.11
tan(friction angle)	1
Eff. cohesion c'	1
Shear strength Su	1
Earth unfavorable	1
Earth favorable	1
Water unfavorable	1
Water favorable	1
HYDraulic unfavorable	1
HYDraulic favorable	1
UPLift unfavorable	1
UPLift favorable	1
Used FS wall STR	Service

Table: Nails & max mobilized head forces

Name	Nail	α	x	El.	Lfix	Lfree	Space	Fhead	Fhead
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(k/ft)	(k)
N0	0: N1	15	0	165	20	0	6	4.2144	25.29
N1	0: N1	15	0	160	20	0	6	4.471	26.83
N2	0: N1	15	0	155	20	0	6	4.2384	25.43
N3	0: N1	15	0	150	20	0	6	3.8339	23
Nail 1	0: N1	15	0	145	15	0	6	2.2949	13.77

Fhead= Mobilized force at nail head (facing), determined from pressures at facing.

Table: Surface point coordinates for last stage

Point	x (ft)	El. (ft)
1	-80	176
2	-76	173
3	-50	173
4	-35	173
5	-30	173
6	-18	173
7	-0.1	167
8	0	167
9	0	142
10	14	142
11	27.5	141.5
12	40	141
13	57	136
14	80	136

Soil type property data

Name	γtot	γdry	Φ'	c'	Su	qBond	Color
	(pcf)	(pcf)	(deg)	(psf)	(psf)	(psi)	
ESU 1B	120	120	35	0	N/A	18	
ESU 1A	110	110	32	0	N/A	15	
ESU 4A	135	135	42	0	N/A	22	

γtot = Total unit weight below water table
γdry = Bulk unit weight above water table
c' = Effective cohesion (in drained state for clays)
Φ' = Effective friction (in drained state for clays)
Su = Undrained shear strength (for clays in undrained condition)
qBond = Ultimate bond resistance for soil nails

Name: Boring 1, pos: (50, 0)

Top elev.	Soil type	OCR	Ko
177.68	ESU 1B	1	0.43
174.86	ESU 4A	1	0.33

Slope stability assumptions: Project Wall Height-Circ

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 149ft
Radii search ends at point x= 0ft, z= 134ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Circ-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 135ft
Radii search ends at point x= 0ft, z= 120ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Auto

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0ft, xRmax= 25ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Project Wall Height-Auto-Global

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -80ft, xLmax= -40ft
Right search limits: xRmin= 25ft, xRmax= 80ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Slope stability assumptions: Forward Compatible Wall-Circ

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Circular search method applied
Search Limits from top left corner of wall
Left = -1 ft, Right = 20 ft, Horizontal intervals = 6
Top = 177 ft, Bottom = 0 ft, Vertical intervals = 6
Radii search starts from point x= 0ft, z= 144ft
Radii search ends at point x= 0ft, z= 129ft
5 radii intervals are used
Active angle limit is not used.
Passive angle limit is not used.
Service Support Capacities are included in slope stability.
Wall shear capacity is included for stability surfaces intersecting the wall (note: soldier pile wall = 0)
Shear and lateral force on vertical start and end faces is based on at-rest conditions
Number of intervals on vertical start and end faces = 30
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

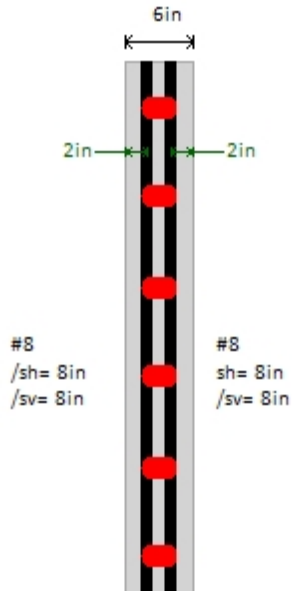
Slope stability assumptions: Forward Compatible-Auto

Table: Basic analysis assumptions last stage

Stage conditions	Extreme event, flood or seismic
Min required FS	1.1
Method	Bishop
Earthquake	ax= 0.22g, az= 0g
Seismic pressures	Mononobe-Okabe
Surface search	Automatic
Left limits	-60ft to -5ft
Right limits	0.1ft to 15ft
Number of points	5
Min. slice width	3ft
Tolerance	1%
Soil nail analysis	Same settings on all nails
Nail stability	External-Internal
Nail shear	Ignored
Φ.t nail STR strength	0.65
Φ.p nail pullout	0.65
Φ.ff facing bending	1
Φ.fp facing punching	1
Φ.ht on bolts	0.75
Φ.b on bearing	0.43

Maximum number of Iterations = 100, Tolerance = 0.01%
Maximum slice width = 3 ft
Analysis performed with automatic search, with 5 points.
Left search limits: xLmin= -60ft, xLmax= -5ft
Right search limits: xRmin= 0.1ft, xRmax= 15ft
Initial search grid: DXi= 0.5ft, DYi= 0.5ft
Force tolerance: 10%
Mobilized soil nail axial force distribution calculated with back analysis for FS=1.0
  Soil nail mobilization interaction factor Imob= 0.25
  Imob= 0 means that FX.mobilized = FX.nail for FS=1.0, Imob= 1 means that FX.mobilized = FX.nail ultimate
  Minimum soil nail mobilization factor SNmin.mob = 0
  Fx.mob = Fx(FS=1.0) + Imob x (Fx.ULT -Fx(FS=1.0)) >= SNmin.mob x Fx.ULT
Global mode parameters applied for slope stability analysis.
  Soil nail stability considers both external and internal stability (punching through facing).
  Soil nail shear is ignored in the analysis.

Shotcrete facing data design section Bishop



Facing Thickness D= 6in

Concrete strength Fc'= 4ksi

Rebar and mesh yield strength Fy= 75ksi

Back face hor. reinforcement (or mesh) #8@8in area a.bh=1.185 in^2/ft

Back face vertical reinforcement (or mesh) #8@8in area a.bv=1.185 in^2/ft

Front face reinforcement (if used in permanent section)

Front face hor. reinforcement (or mesh) #8@8in area a.fh=1.185 in^2/ft

Front face vertical reinforcement (or mesh) #8@8in area a.fv=1.185 in^2/ft

Stage	Active	Top El.	Bottom El.	Two stage facing	Thickness
Name	Yes/No	(ft)	(ft)	-	(in)
Project Wall Height-Ci	Yes	167	148	N/A	6
Project Wall Height-Ci	Yes	167	148	N/A	6
Project Wall Height-A	Yes	167	148	N/A	6
Project Wall Height-A	Yes	167	148	N/A	6
Forward Compatible	Yes	167	142	N/A	6
Forward Compatible-	Yes	167	142	N/A	6

Soil nail input data for design section Bishop

Name	Nail	α	x	El.	Lfix	Lfree	Space	Asteel	Dfix	Fy
-	Section	deg	(ft)	(ft)	(ft)	(ft)	(ft)	(in^2)	(in)	(ksi)
N0	0: N1	15	0	165	20	0	6	0.79	6	75
N1	0: N1	15	0	160	20	0	6	0.79	6	75
N2	0: N1	15	0	155	20	0	6	0.79	6	75
N3	0: N1	15	0	150	20	0	6	0.79	6	75
Nail 1	0: N1	15	0	145	15	0	6	0.79	6	75

Header plate data

Nail	El.	Width	Thick	Fy	D open.	Studs	c studs	Waler
Number	(ft)	(in)	(in)	(ksi)	(in)	Studs	c studs	Bars
N0	165	6	1	36	1	N/A	N/A	N/A
N1	160	6	1	36	1	N/A	N/A	N/A
N2	155	6	1	36	1	N/A	N/A	N/A
N3	150	6	1	36	1	N/A	N/A	N/A
Nail 1	145	6	1	36	1	N/A	N/A	N/A

SLOPE STABILITY ANALYSIS: SOIL NAIL RESULTS ALL STAGES

Soil nail results for design section: Bishop

Soil nail results Stage: 0

Soil nail results available for this stage.

Critical point at x= 12.089 z= 187.501 FS= 1.371

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	0	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	0.06	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	16.85	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 1

Soil nail results available for this stage.

Critical point at x= 18.333 z= 196 FS= 1.556

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	11.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	0	17.75	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	0	25.11	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	0	33.36	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 2

Soil nail results available for this stage.

Critical point at x= -5.408 z= 178.779 FS= 3.19

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	6.2	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	18.63	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	33.31	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	38.51	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	STR
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 3

Soil nail results available for this stage.

Critical point at x= -3.763 z= 178.228 FS= 6.264

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
1: N1	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
2: N2	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
3: N3	0	0	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	N/A
4: Nail 1	Not ac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Soil nail results Stage: 4

Soil nail results available for this stage.

Critical point at x= 10.917 z= 197 FS= 1.418

	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	26.36	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	0	33.18	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	0	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

3: N3	15.38	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	23.48	38.51	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

Soil nail results Stage: 5

Soil nail results available for this stage.

Critical point at x= -5.75 z= 178.894 FS= 3.096

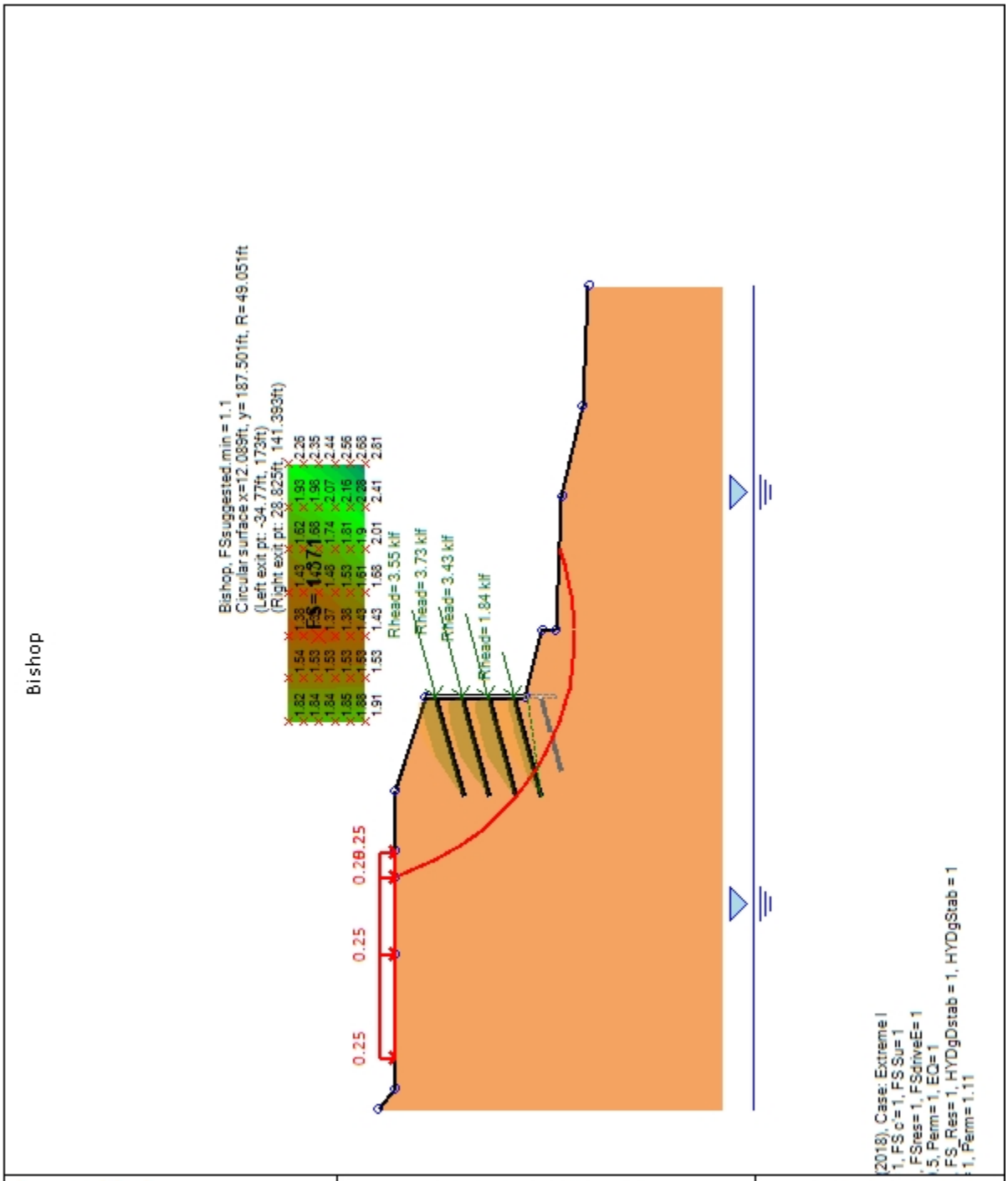
	F	Fmax	CAP S	CAP G	Tcap G	TC1 ST	TC2	TC3	TC4	TC4 C4	ks	Po	Pu	lo	IxxCalc	SxxCal	t. loss	% STR	Mode
Nail/Uni	k	k	k	k	k	k	k	k	k	k	ksf	ksf	ksf	ft	in4	in3	in	%	Crit
0: N0	0	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
1: N1	3.24	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
2: N2	15.52	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
3: N3	31.21	38.51	53.32	64.69	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO
4: Nail 1	33.11	37.81	53.32	48.52	0	26.66	Not in	Not in	Not in	Not in	N/A	N/A	N/A	N/A	0.08	0.14	N/A	N/A	GEO

GENERAL SOIL NAIL DATA

Soil nails are concidered only when a slope stability analysis is performed.

TABLE DATA (major parameters)

F = Soil nail axial tension force for critical failure surface (may not be the greatest)
Fmax = Maximum soil nail tension from all analyzed critical failure surfaces
CAP STR = Tensile structural design capacity for soil nail
CAP GEO = Tensile geotechnical pull out resistance for soil nail
TcapGEO = Critical shear resistance for soil nail (min TC1, TC2, TC3, TC4)
TC1 = Structural soil nail shear resistance
TC2 = Shear resistance according to Clouterre TC2 criterion
TC3 = Shear resistance according to Clouterre TC3 criterion
TC4 = Shear resistance according to Clouterre TC4 criterion
TC4 C4 = Shear resistance according to Clouterre TC4 criterion for limit equilibrium approach
kS = Soil subgrade modulus reaction at failure surface-soil nail intersection point
Po = Soil lateral pressure at failure surface-soil nail intersection point
Pu = Ultimate lateral pressure at failure surface-soil nail intersection point
Lo = Flexure length for shear calculations
IxxCalc = Nail moment of inertia (adjusted for corrosion loss if assumed etc)
SxxCalc = Nail section modulus (adjusted for corrosion loss if assumed)
t.loss = Structural thickness loss (if assumed by the user)
%STR = Structural capacity loss as a percentage (if assumed by the user)



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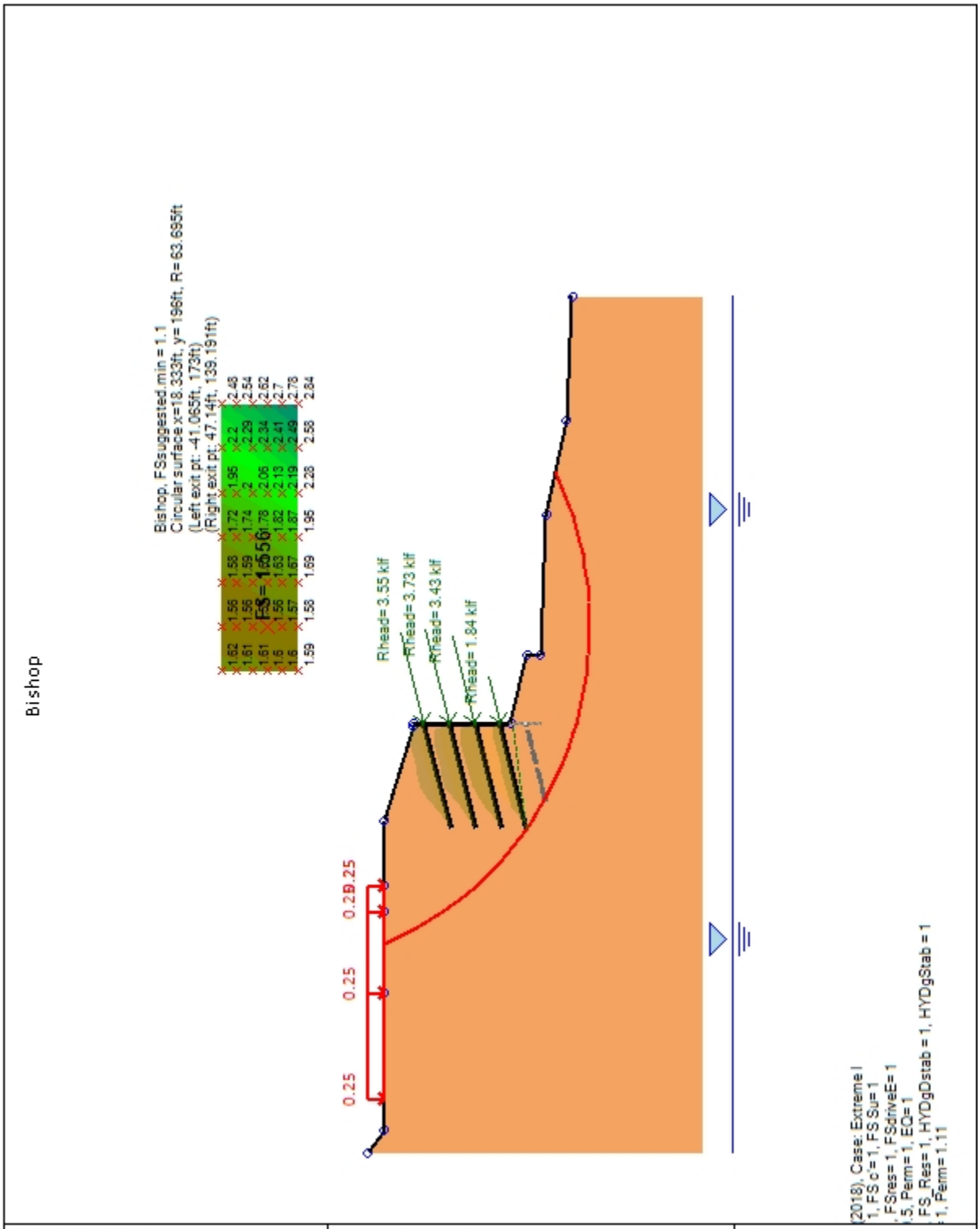

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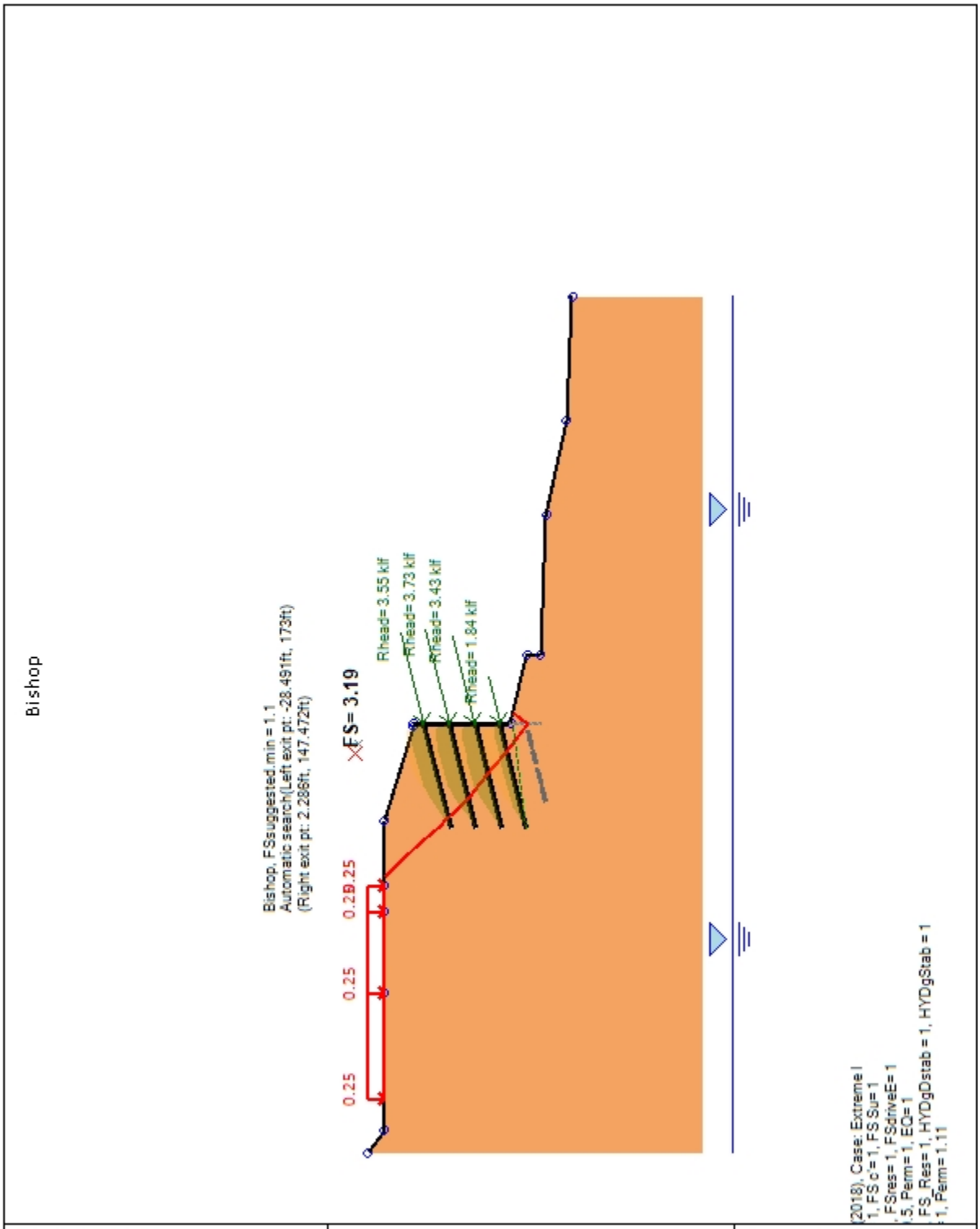

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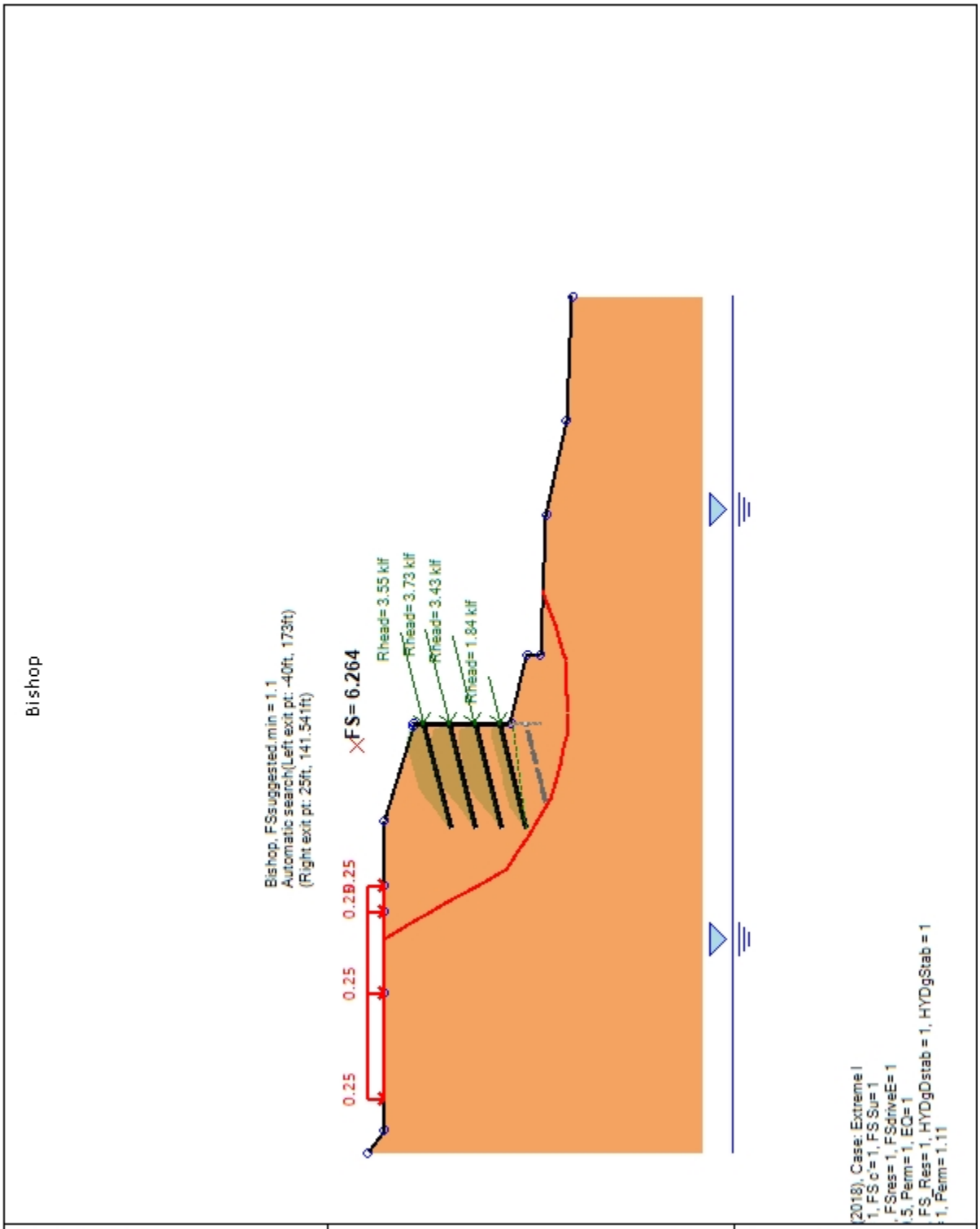

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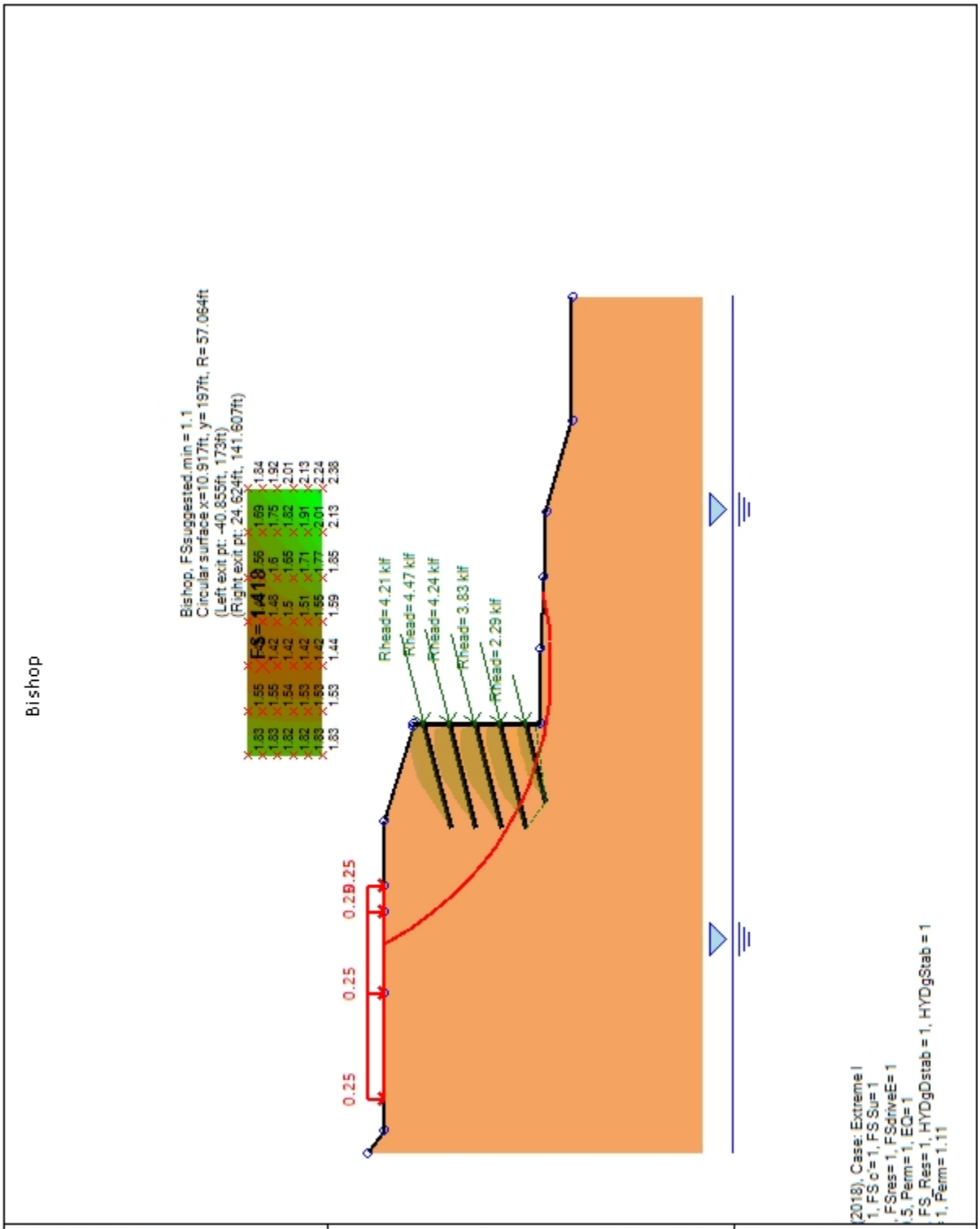

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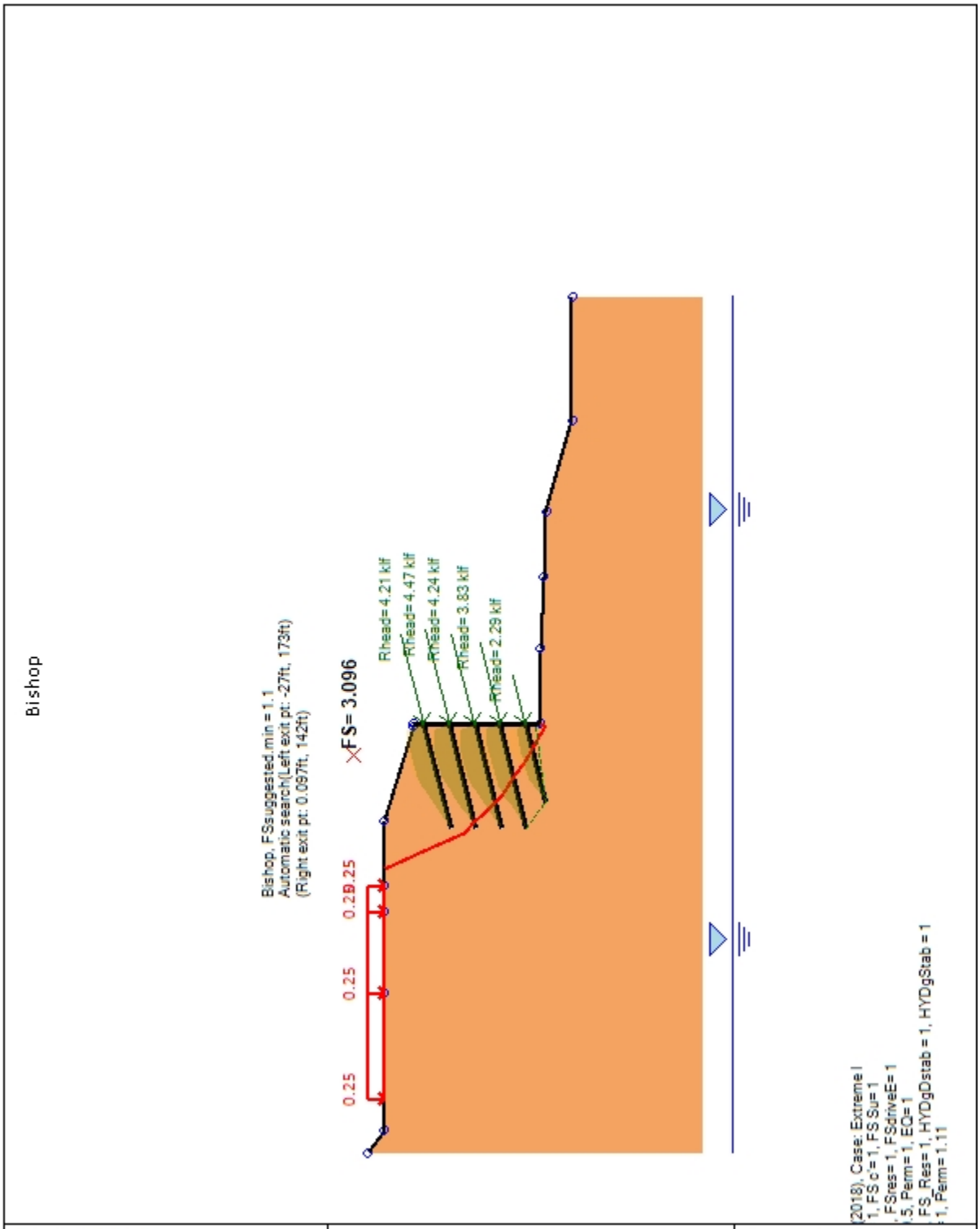

Company: Wood Engineer: DL	DS: 0, Forward Compatible-Auto	Deep Excavation LCC SnailPlus 2021
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In Association with

Appendix G
Soil Nail Verification Test Results

Appendix G – Soil Nail Verification Test Results

Verification Test Procedures

In accordance with project plans and specifications, verification nail installation and testing was performed to evaluate the design load transfer (DLT) value proposed for use in design of the soil nail wall. The verification nails and verification tests of those nails was performed in general accordance with Washington State Department of Transportation Standard Specifications 6-15.3(6) and 6-15.3(8)A, respectively. As discussed in Section 1.1 of this report, multiple rounds of verification nail installation and testing were performed due to inconsistent results from testing. All of the test nails were drilled using a hollow-stem auger and gravity grouted. The sequence of events for the verification testing was as follows:

- 2021-03-16: Two test pits were excavated for stand-up tests of the site soils.
- 2021-03-22: Two verification nails were installed (VN-1 and VN-2).
- 2021-03-26: Verification nail testing was performed on VN-1 and VN-2. Testing indicated that VN-1 met the creep criteria at 150 percent of DLT and achieved the required verification load (200 percent DLT). However, VN-2 failed while attempting to increase the loading to 150 percent of DLT.
- 2021-05-26: Two additional verification nails were installed (VN-3 and VN-4).
- 2021-06-02: Verification nail testing was performed on VN-3 and VN-4. Testing indicated that VN-3 passed the creep criteria while holding at 150 percent of DLT but failed while attempting to increase the load from 150 to 175 percent of DLT. VN-4 met the creep criteria at 150 percent of DLT and achieved the required verification load of 200 percent DLT.
- 2021-07-13: Two additional verification nails were installed (VN-5 and VN-6).
- 2021-07-20: Verification nail testing was performed on VN-6 with testing indicating that the verification nail met the required creep criteria at 150 percent of DLT and achieved the required verification load of 200 percent of DLT.
- 2021-07-21: Verification nail testing was performed on VN-5 with testing indicating that the verification nail met the required creep criteria at 150 percent of DLT but failed when attempting to increase the load to 175 percent of DLT.

Verification Nail No.	Wall Station	Elevation (feet)	Design Load Transfer (plf)	Bond Length (feet)	Maximum Test Load Achieved (plf)	Verification Test Result
VN-1	2+12	151	1,700	10	3,400	Pass
VN-2	4+53	174	2,500	10	3,750	Fail
VN-3	4+48	171	2,500	10	4,120	Fail
VN-4	4+06	175	2,500	10	5,000	Pass
VN-5	4+42	172	2,500	10	4,600	Fail
VN-6	4+67	170	2,500	10	5,000	Pass

Abbreviations:
plf = pounds per linear foot

The minimum pullout resistance was at least 3,400 pounds per linear foor (plf) and the maximum was at least 5,000 plf. The average pullout resistance was 4,275 plf, assuming that the maximum load tested at 200 percent of DLT is the ultimate pullout resistance.

Revised Design Load Transfer and Soil-Grout Bond Stress

For constructability, the contractor requested revising the design to use the lowest test result, which was 3,400 plf, for the upper three rows of the soil nails. Thus:

200 percent of DLT = 3,400 plf; therefore DLT = 1,700 plf.

Since the drill hole diameter is 6 inches, the ultimate soil-grout bond stress is:

3,400plf / πd or 3,400 plf / 3.14*0.5 = 2,155psf = 15 pounds per square inch.

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Kirkland, WA 98033 Fax (425) 368-1001

Special Inspection Report

PROJECT NAME WSDOT I-405 Renton to Bellevue Design Build		PROJECT NO. PS19-203160-0	FIELD REPORT NO. 2021-03-22~SDS SNW 9.05R-B
ADDRESS 9.05R-B: Temp Soil Nail Wall		DATE March 22, 2021	PAGE 1 OF 5
CITY OR COUNTY Renton, WA	PERMIT NO.	ARRIVAL TIME 9:15AM	DEPARTURE TIME 1:00PM
CLIENT WSDOT	WOOD ENGINEER OF RECORD/PHONE NO. Dong-Soo Lee / (425) 330-3082		
GENERAL CONTRACTOR FLJV/ Billy Myers (360) 515-8657	WOOD FIELD REPRESENTATIVE/ MOBILE NO. Sierra Sirmans / (253) 652-9062		
SUBCONTRACTOR Drill Tech Drilling and Shoring Inc./Bill Creger (510) 598-0609	WEATHER Overcast Slight Rain, Mid 50's		
TYPE OF WORK PERFORMED Wall 9.05R-B: Drilling/installation of Verification Test Nails VN-1, VN-2			
EQUIPMENT USED DTDS: Klemm KR8063D track-mounted drill rig w/ 6-inch dia. auger			

COMMENTS

Wall 9.05R-B: Proof Test Nails

Wood was onsite to observe the installation of two verification test nails, VN-1 and VN-2. Upon arrival DTDS began setup at STA 2+14. The first proof test nail installed, VN-1, is indicated on the plan sheet on page two at approximate STA 2+14. The drill rig was positioned roughly perpendicular to the wall face with the drill mast inclined at 15 degrees. An open-hole, auger drilling technique with 6-inch diameter, continuous flight hollow stem auger was used to advance the hole. Drilling disclosed loose to medium dense sand to silty sand with the auger advanced to approximately 16 feet. Once the cuttings had been removed by repeated passes with the auger, 19 ft, #9-solid (threaded) bar nail with properly placed centralizers was installed after drilling. 3.5 FT of the nail bar projects out of the face of the drilled hole, see Photograph One.

The second verification test nail installed, VN-2, was at STA 4+50. The placement of this proof test nail was first called to be at STA 4+16, however DTDS indicated that the marked location (vertical cut with red marking paint) was at STA 4+50. Verification calls were made by DTDS to Bill Creger and by Wood to Bill Lockard to confirm the location. The verification test was confirmed to be installed at Sta 4+50 to be in a location that would lie within glacial till that is exposed in the adjacent test pit. The drilling and installation proceeded at STA 4+50 as described above. The hole was drilled to an approximate depth of 16 feet and a 19FT, #9-solid (threaded) bar nail with properly placed centralizers was installed after drilling. 3.8 FT of the nail bar projects out of the face of the drilled hole, see Photograph Two.

☒ The contents of this field report were discussed with the contractor's on-site representative.

☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

Sierra Sirmans
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD ENGINEER OF RECORD

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Daily field report

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-03-22~SDS SNW 9.05R-B
ADDRESS	DATE	PAGE
Renton, WA	2021-03-22	2 OF 5

COMMENTS

After both verification test nails were installed, DTDS mixed and pumped neat cement grout into VN-1. Wood confirmed a ten-foot bond zone was completed by DTDS. VN-2 was then filled with grout and was also confirmed to have a ten-foot bond zone.

Table 1: Soil Nail Record

Verification Soil Nails (VN-#)					
Nail No.	**Station (STA)**	**Row**	**Bar Length (ft)**	**Bond Length (ft)**	**No Load Length (ft)**
VN-1	2+14	NA	19	10	5.5
VN-2	4+50	NA	19	10	5.2

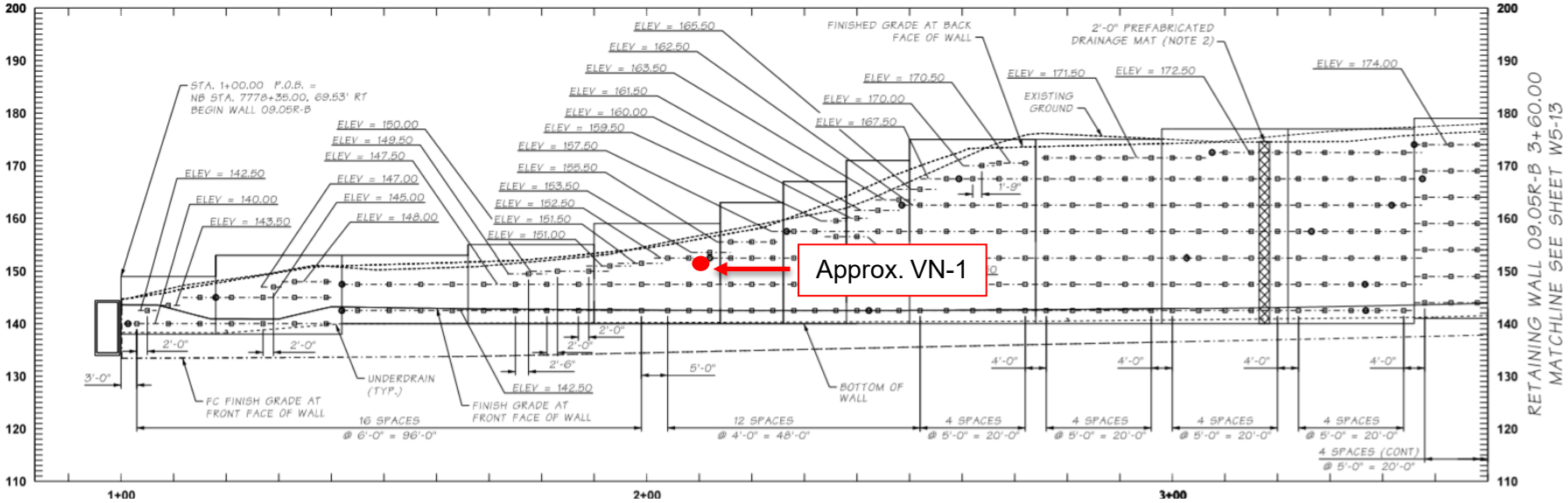
Test Pits:

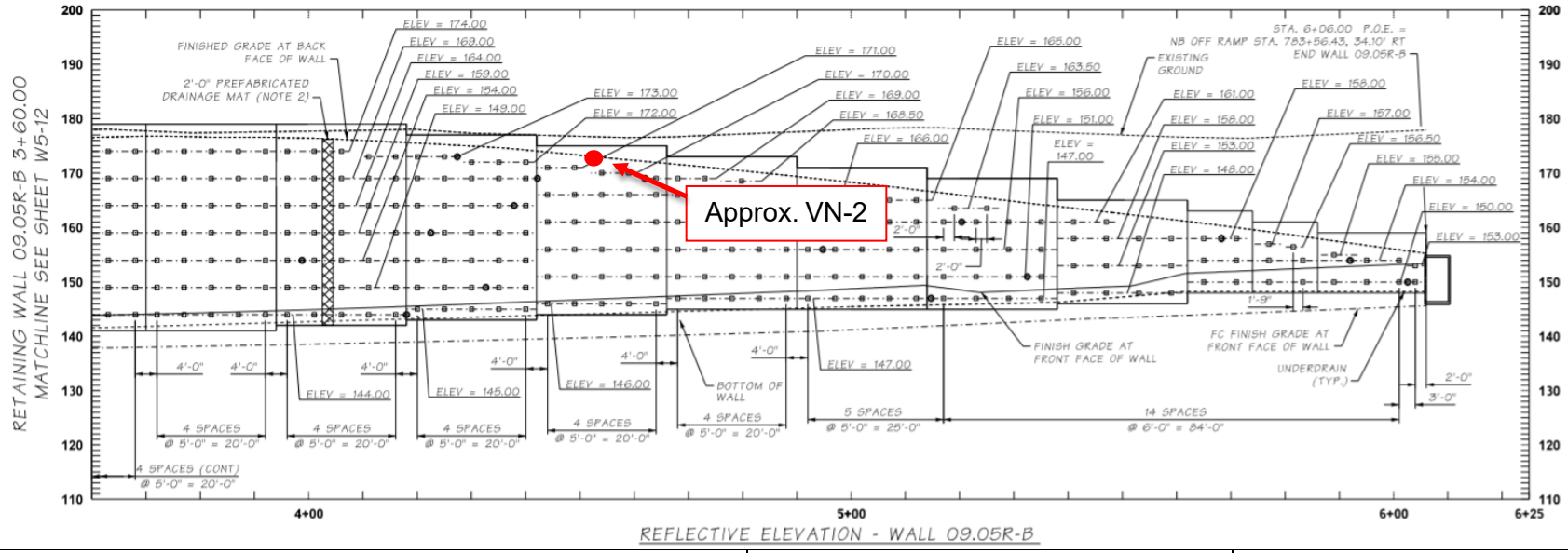
Two test pits were observed on site adjacent to the south side of either VN-1 and VN-2. Photograph three shows the test pit south of VN-1, photograph four shows the test pit south of VN-2. Neither test pit had significant accumulation of material and no indication of caving or cracking on the face.

Sierra Siemans
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD ENGINEER OF RECORD

Site Plan 1 & 2: Proof Test Soil Nail Locations

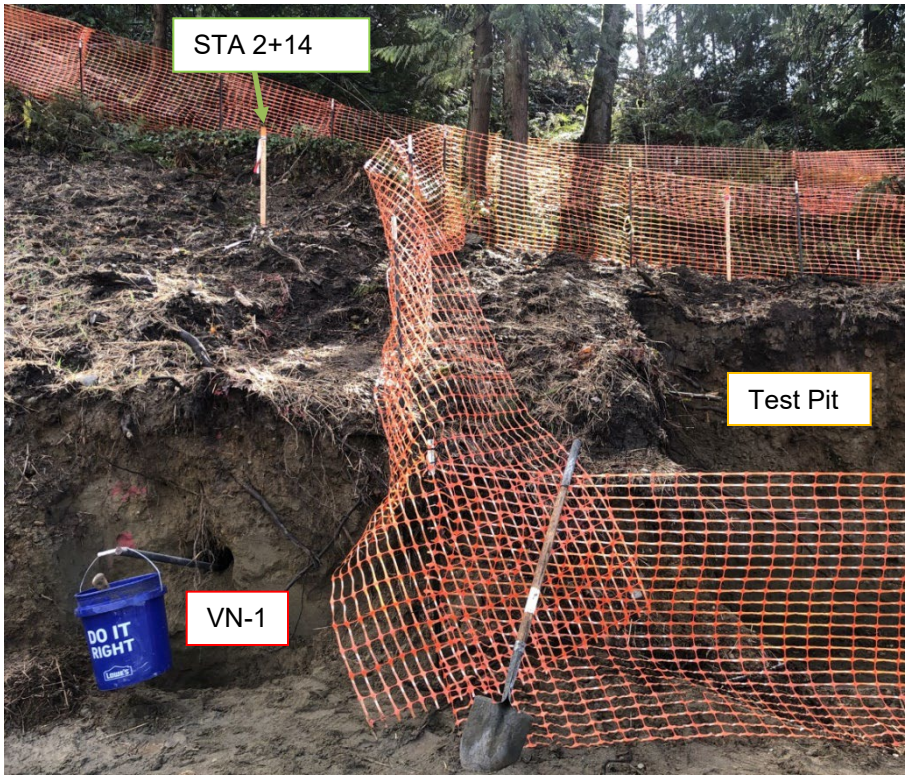




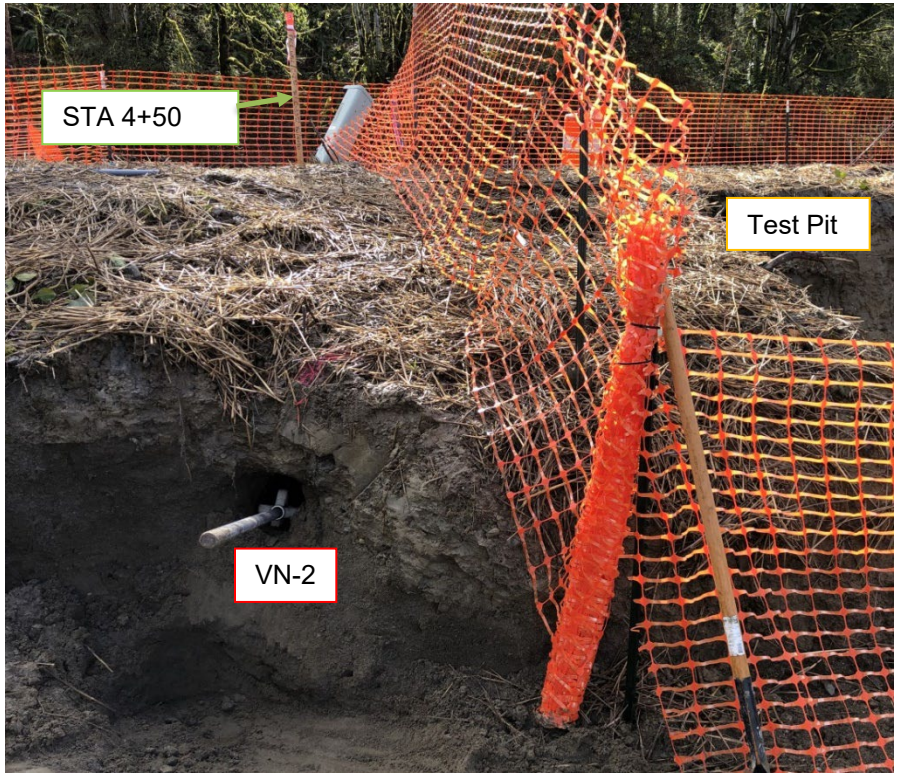
REFLECTIVE ELEVATION - WALL 09.05R-B

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-22~SDS SNW 9.05R-B
DESCRIPTION	DATE	PAGE
Approximate Location of Verification Soil Nails	March 22, 2021	3 OF 5

Site Photographs:



Photograph One – VN-1



Photograph Two – VN-2

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-22~SDS SNW 9.05R-B
DESCRIPTION	DATE	PAGE
VN-1, VN-2 Photographs	March 22, 2021	4 OF 5

Site Photographs:

Photograph Three - Test Pit adjacent to VN-1

Photograph Four - Test Pit adjacent to VN-2

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-22~SDS SNW 9.05R-B
DESCRIPTION	DATE	PAGE
Test Pit Photographs, Centralizer placement	March 22, 2021	5 OF 5

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Special Inspection Report

PROJECT NAME		PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build		PS19-203160-0	2021-03-26~SDS_ SNW 9.05R
ADDRESS		DATE	PAGE
07.10R: Temp Soil Nail Wall		March 26, 2021	1 OF 5
CITY OR COUNTY	PERMIT NO.	ARRIVAL TIME	DEPARTURE TIME
Renton, WA		8:00AM	2:45PM
CLIENT	WOOD PROJECT MANAGER/PHONE NO.		
WSDOT	Milan Radic / (425) 589-4202		
GENERAL CONTRACTOR	WOOD FIELD REPRESENTATIVE/ MOBILE NO.		
FLJV/ Ken Horton (360) 630-3553	Sierra Sirmans / (253) 652-9062		
SUBCONTRACTOR	WEATHER		
DTDS Inc./ Bill Creger (510) 598-0609	Overcast, mid 40's		
TYPE OF WORK PERFORMED			
Wall 9.05 R: Soil Nail Wall, Soil Nail Verification Stressing			
EQUIPMENT USED			
DTDS: Power Team RH605 Ram & pump, McDaniel 316SS gauge, GeoKon 1000-200-2 load cell, GeoKon GK-502 load cell readout, generator			

COMMENTS

Wall 9.05 R: Soil Nail Verification Stressing

Wood Environmental & Infrastructure Solutions Inc. (Wood) was onsite to observe verification nail testing of the two verification test soil nails previously installed on 03/22/21. Upon arrival DTDS began setup on VN-1 at STA 2+14. Four wood planks and a ½-inch plate were positioned against the vertical cut on the wall to stabilize the material around then soil nail. A GeoKon load cell was placed between two ½-inch steel plates. A dial gage was then positioned on the second plate, oriented parallel with the nail and direction of pull. (See photographs 1 & 2 for a detail view of the testing setup).

For each proof nail tested today DTDS began applying incremental loads on the nail while monitoring the movement of the nail by the dial gage. Loading applied by the ram was monitored by the pressure gauge and by the load cell. Each incremental load held varied from 10 minutes to 1 hour and Wood monitored the changes on the dial gauge and kps on the load cell readout GK-502, along with; DTDS, and Kleinfelder reps recorded the movement of the nail at the beginning and end of the hold period along with the load information. For VN-1, at the 150% DTL, the load was held for 60 minutes. After the 60 minutes, we increased to 175% DTL for ten minutes, followed by 200% DTL for ten minutes. Finally, the load was slowly released down to the alignment load and held until the movement recording was taken. The loading was then released and DTDS began disassembling the testing setup.

☒ The contents of this field report were discussed with the contractor's on-site representative.

☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

Sierra Sirmans
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD PROJECT MANAGER

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Special Inspection report

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-03-26~SDS_ SNW 9.05R
ADDRESS	DATE	PAGE
Renton, WA	2021-03-26	2 OF 5

COMMENTS

DTDS then moved the testing equipment to VN-2 and set it up in a similar manner previously described and performed the verification testing on VN-2. The test for VN-2 was called off during the 150% DTL after three minutes when DTDS observed the dial gauge "max out." The equipment remained untouched while DTDS reps attempted to stabilize the load and search for any disruptions in the system. At ten minutes, a recording was taken however the load test was assumed failed after only three minutes at 150% DTL.

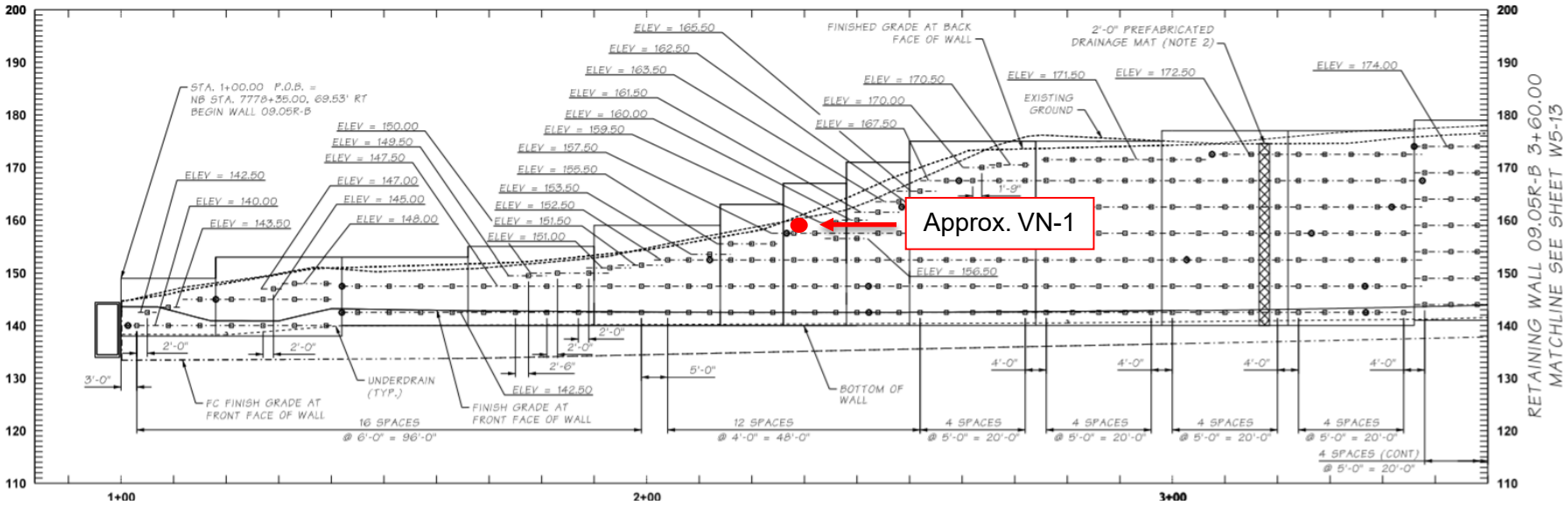
Measurements recorded for VN-1 and VN-2 are on pages five and six.

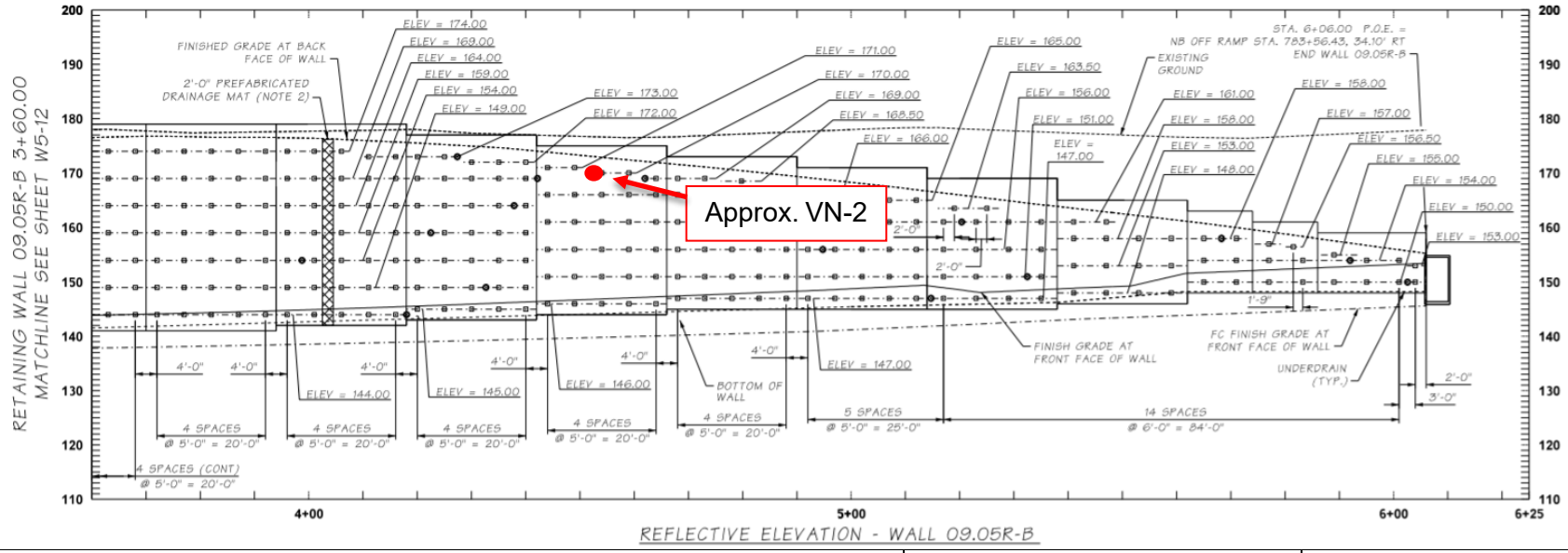
After the equipment was taken down at VN-2, Wood departed around 2:45pm.

Sierra Siemans
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD PROJECT MANAGER

Site Plan 1 & 2: Proof Test Soil Nail Locations





REFLECTIVE ELEVATION - WALL 09.05R-B

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-26~SDS_ SNW 9.05R
DESCRIPTION	DATE	PAGE
Soil Nail Plan	March 26, 2021	3 OF 5

Photograph 1:

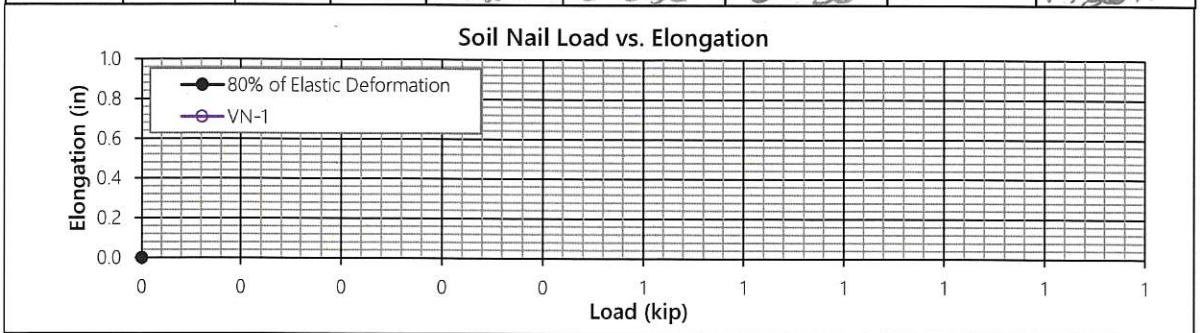
Detail of powerpack w/pressure gauge, hydraulic ram, load cell and dial gage setup on VN-1

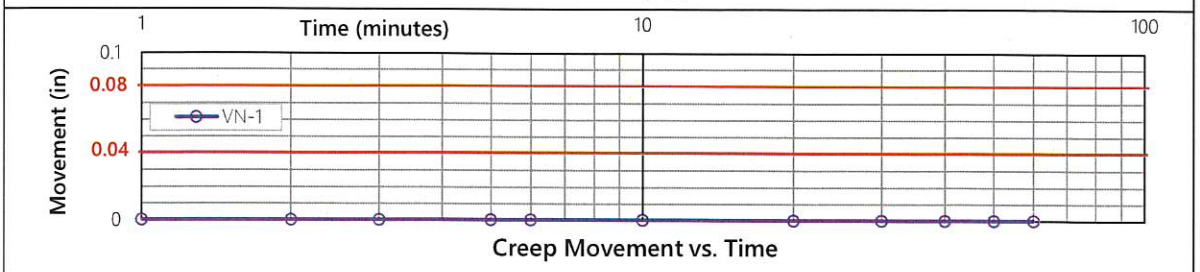
Photograph 2: Setting up on VN-2

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-03-26~SDS_ SNW 9.05R
DESCRIPTION	DATE	PAGE
Site photos	March 26, 2021	4 OF 5

Wood.	Soil Nail Verification Stressing Record		Page 1 of 1
Soil Nail Number:	VN-1	Wall Number:	09.05R-B
Project Number:	PS19-20316-0	Design Load (kip):	17
Project Name:	I-405 RTB Widening	Design Lockoff Load (kip):	N/A
Wood's Observer:	Carlos M	Actual Lockoff Load (kip):	N/A
Date:	3/26/21	Total Length (feet):	19
Contractor:	Drill Tech	Bond Length (feet):	10
Ram:	Power Team RH605	Unbond Length (feet):	6.3
Ram Serial #:	JS6013	Stressing Length w/ Tail (feet):	3.4
Pressure Gage:	McDaniel, Model 316SS	Bar Size:	No. 9
Gage Serial #:	DT-60-5-2A	Bar Area (in^2):	1.00
Calibration Date:	2/24/2021	Bar Grade (ksi):	75
Certificate #:	359828174	Bar Modulus (ksi):	29,000

Soil Nail Load		Gage (psi)		Load	Observed Elongation (in)		Hold Time	Enter Start
%DL	kip	Design	Actual	kip	Start	End		Time
AL	1.5	150	150	3.63 (0.3)	Ø	Ø	until stable	9:15AM
0.25 (DL)	4.25	374	400	5.94 (0.3)	0.015	0.014	10 min	9:25AM
0.50 (DL)	8.5	720	750	9.75 (0.3)	0.057	0.062	10 min	9:35AM
0.75 (DL)	12.75	1,066	1050	14.30 (0.3)	0.102	0.105	10 min	9:45AM
1.00 (DL)	17	1,412	1400	17.60 (0.3)	0.197	0.210	10 min	9:55AM
1.25 (DL)	21.25	1,758	1750	22.15 (0.3)	0.262	0.271	10 min	10:05AM
1.50 (DL)	25.5	2,104	2100	26.60 (0.3)	0.361	0.360	1 min	10:07AM
1.50 (DL)	25.5	2,104	2100	26.60 (0.3)	0.363	0.363	2 min	10:09AM
1.50 (DL)	25.5	2,104	2100	26.60 (0.3)	0.363	0.363	3 min	10:10AM
1.50 (DL)	25.5	2,104	2050	26.23 (0.3)	0.362	0.362	5 min	10:11AM
1.50 (DL)	25.5	2,104	2050	26.16 (0.3)	0.362	0.362	6 min	10:12AM
1.50 (DL)	25.5	2,104	2000	25.70 (0.3)	0.360	0.360	10 min	10:17AM
1.50 (DL)	25.5	2,104	2000	26.23 (0.3)	0.365	0.365	20 min	10:27AM
1.50 (DL)	25.5	2,104	2000	25.90 (0.3)	0.362	0.362	30 min	10:37AM
1.50 (DL)	25.5	2,104	2000	25.80 (0.3)	0.360	0.360	40 min	10:47AM
1.50 (DL)	25.5	2,104	2000	25.76 (0.3)	0.361	0.361	50 min	10:57AM
1.50 (DL)	25.5	2,104	2000	25.71 (0.3)	0.361	0.361	60 min	11:07AM
1.75 (DL)	29.75	2,450	2450	30.00 (0.3)	0.433	0.445	10 min	11:08AM
2.00 (DL)	34	2,796	2800	36.00 (0.3)	0.538	0.544	10 min	11:18AM
AL	1.5	150	150	2.22 (0.3)	0.236	0.238	until stable	11:30AM





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wood.

Special Inspection report

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-03-26~SDS_ SNW 9.05R
ADDRESS	DATE	PAGE
Renton, WA	2021-03-26	5 OF 5

Wood.	Soil Nail Verification Stressing Record			Page 1 of 1
Soil Nail Number:	VN-2 (4750)	Wall Number:	09.05R-B	
Project Number:	PS19-20316-0	Design Load (kip):	25	
Project Name:	I-405 RTB Widening	Design Lockoff Load (kip):	N/A	
Wood's Observer:	SIERRA SIEMANS	Actual Lockoff Load (kip):	N/A	
Date:	3/26/2021	Total Length (feet):	19	
Contractor:	Drill Tech	Bond Length (feet):	10	
Ram:	Power Team RH605	Unbond Length (feet):	6.6	
Ram Serial #:	JS6013	Stressing Length w/ Tail (feet):	1.8(6.6)	
Pressure Gage:	McDaniel, Model 316SS	Bar Size:	No. 9	
Gage Serial #:	DT-60-5-2A	Bar Area (in^2):	1.00	
Calibration Date:	2/24/2021	Bar Grade (ksi):	75	
Certificate #:	359828174	Bar Modulus (ksi):	29,000	

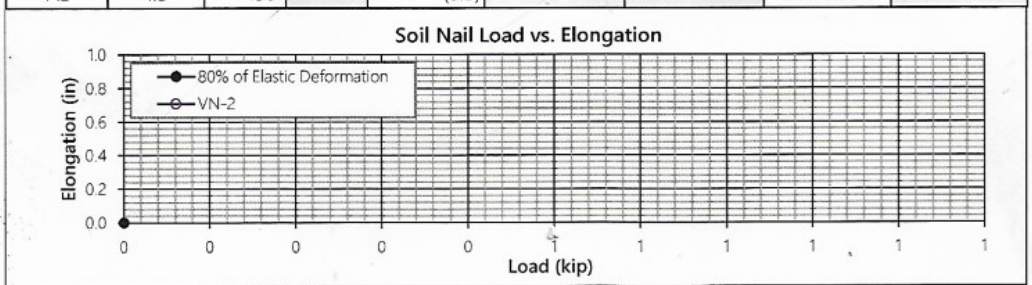
Soil Nail Load		Gage (psi)		Load	Observed Elongation (in)		Hold Time	Enter Start Time
%DL	kip	Design	Actual	kip	Start	End		
AL	1.5	150	200	5.47 (0.3)	0	0	until stable	12:27
0.25 (DL)	6.25	537	500	10.98 (0.3)	0.002	0.002	10 min	12:28
0.50 (DL)	12.5	1,046	1,050	19.66 (0.3)	0.008	0.007	10 min	12:29
0.75 (DL)	18.75	1,555	1550	27 (0.3)	.054	0.59	10 min	12:40
1.00 (DL)	**25**	2,064	2010	34.50 (0.3)	0.139	0.132	10 min	1:00
1.25 (DL)	31.25	2,573	2500	39.60 (0.3)	0.355	0.353	10 min	1:12
1.50 (DL)	37.5	3,081	3,000	44.50 (0.3)	0.718	0.718	1 min	1:24
1.50 (DL)	37.5	3,081	3,100	44.60 (0.3)			2 min	1:26
1.50 (DL)	37.5	3,081	2,900	(0.3)			3 min	1:27
1.50 (DL)	37.5	3,081		(0.3)			5 min	
1.50 (DL)	37.5	3,081		(0.3)			6 min	
1.50 (DL)	37.5	3,081	2,900	45.46 (0.3)	1.173	1.173	10 min	1:36
1.50 (DL)	37.5	3,081		(0.3)			20 min	
1.50 (DL)	37.5	3,081		(0.3)			30 min	
1.50 (DL)	37.5	3,081		(0.3)			40 min	
1.50 (DL)	37.5	3,081		(0.3)			50 min	
1.50 (DL)	37.5	3,081		(0.3)			60 min	
1.75 (DL)	43.75	3,590		(0.3)			10 min	
2.00 (DL)	50	4,099		(0.3)			10 min	
AL	1.5	150		(0.3)			until stable	

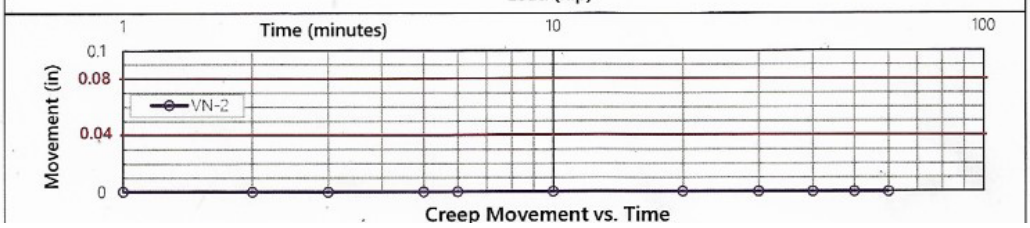
creeping down below 3,000 psi

stabilizing

During 1.50 hold, we exceeded 0.08" cycle of time of creep

At 2:06 we reset dial gauge, visually observed nail move at 3,000 psi.





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Special Inspection Report

PROJECT NAME WSDOT I-405 Renton to Bellevue Design Build		PROJECT NO. PS19-203160-0	FIELD REPORT NO. 2021-05-26~PLR-SNW-9.05R
ADDRESS Wall 9.05R Soil Nail Wall		DATE May 26, 2021	PAGE 1 OF 3
CITY OR COUNTY Renton, WA	PERMIT NO.	ARRIVAL TIME 7:00 AM	DEPARTURE TIME 11:30PM
CLIENT WSDOT	WOOD ENGINEER OF RECORD/PHONE NO. Dong-Soo Lee / (425) 330-3082		
GENERAL CONTRACTOR FLJV/ Billy Myers (360) 515-8657	WOOD FIELD REPRESENTATIVE/ MOBILE NO. Pat Reed / (206) 391-6609		
SUBCONTRACTOR Drill Tech Drilling and Shoring Inc./ Bill Creger (510) 598-0609	WEATHER Partly Sunny Mid 50s		
TYPE OF WORK PERFORMED W9.05R Soil Nail Wall Additional Verification Nails			
EQUIPMENT USED FLJV: John Deere 135G Excavator, DrillTech: Cat C235 Track-mounted Soil Nail Drill (ID# KR-2510) w/ 4x10ft drill stem & 6-inch dia drag bit, Air Compressor 750-3 (AC153), Grout mix plant w/ pump.			

COMMENTS

09.05R: Temporary Soil Nail Wall

As requested by general contractor, Wood Environmental & Infrastructure Solutions Inc. (Wood) was onsite to observe drilling and installation of two additional Verification Nails (VN) VN-3 and VN-4. This activity was in support of construction of permanent wall 09.05R. Prior to our arrival, an operator for Flat Iron Joint Venture (FLJV) used a large bulldozer to place fill from STA 4+50 to 3+50 (approximately) to create access for the drilling rig. The ground surface was near 170 feet in elevation at both of the boring locations. Upon our arrival Drill Tech Drilling and Shoring Inc. (DTDS) drilled VF-3 at STA 4+48 and VF-4 at STA 4+06. Both borings were drilled in 17 feet at an inclination of 15 degrees. DTDS utilized an open-hole drilling method (uncased) by means of the KR-2510 excavator mounted, continuous flight auger drill rig with four 10-foot-long sections. During drilling Wood observed soil conditions to consist of dry, light brown, silty SAND. The auger was inserted and withdrawn to clean out the boring.

Shortly after drilling, DTDS installed the soil nail tendons consisting of #9 (1 1/8th inches) Dwyidag threaded tendons, without corrosion protection (bare) with five centralizers, one at 1.5-foot and 7.5-foot off center after that (measured from the tip of the nail). The bars were inserted to 17 feet back from the face, leaving three feet in front of the face for jacking. Wood observed insertion of the tendons into the drilled holes noting nail tendons went in smoothly. DTDS placed a tremie into the bottom of each hole and monitored the grout installation using a flashlight, halting the flow when the bottom ten feet of the bar was covered.

☒ The contents of this field report were discussed with the contractor's on-site representative.

☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD ENGINEER OF RECORD

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Daily field report

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-05-26~PLR-SNW-9.05R
ADDRESS	DATE	PAGE
Renton, WA	2021-05-26	2 OF 3

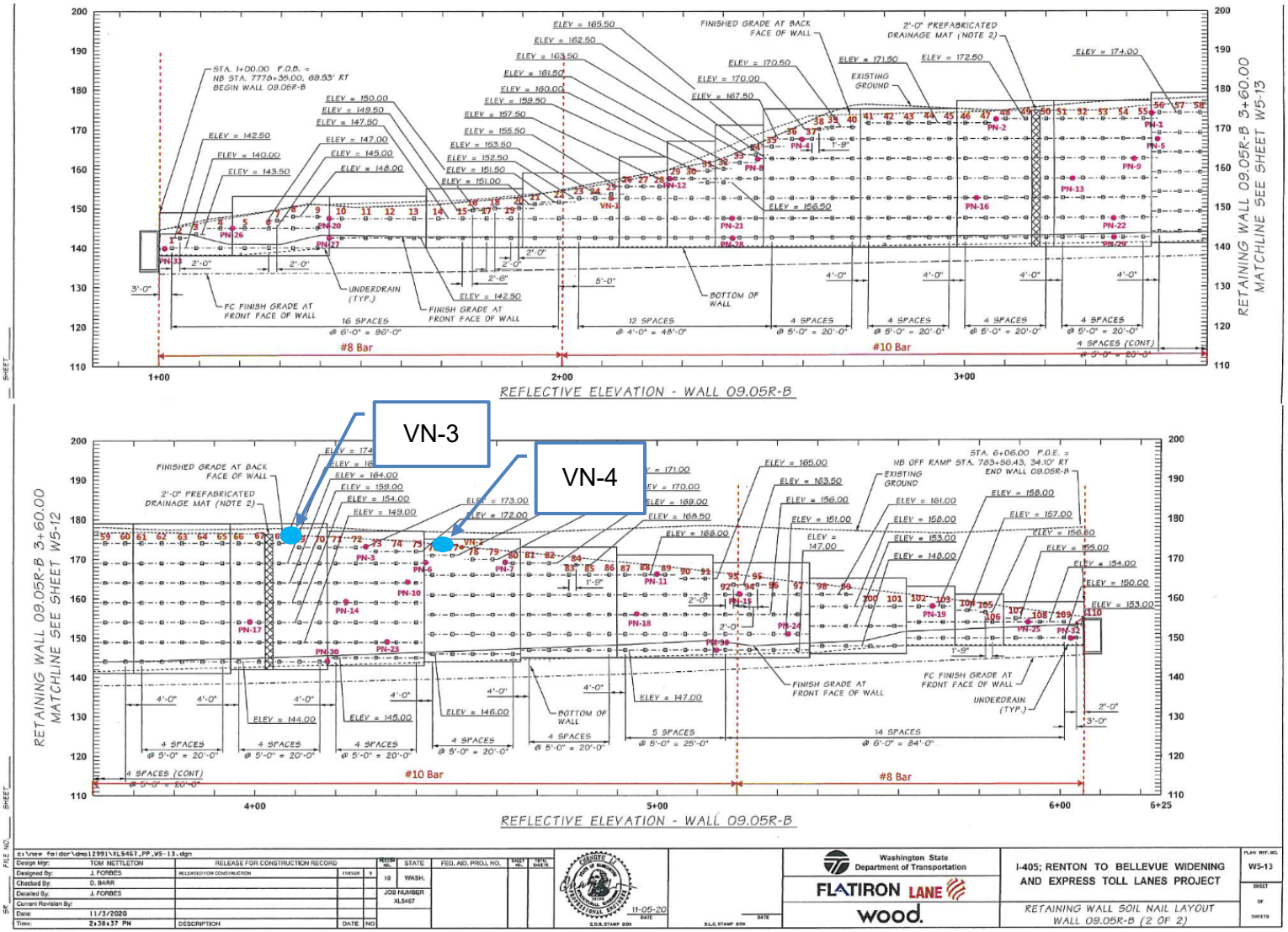
COMMENTS

Table 1- Soil Nail Summary Information

Nail No.	Row	Bar Length (ft)	Bond Length (ft)	No Load Length (ft)
VF-3	NA	20	10	10
VF-4	NA	20	10	10

Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD ENGINEER OF RECORD



PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-05-26~PLR-SNW-9.05R
DESCRIPTION	**DATE**	**PAGE**
Approximate Location of Verification Soil Nails	May 26, 2021	3 OF 3

Wood Environment & Infrastructure Solutions, Inc.
4020 Lake Washington Blvd. NE, Suite 200 Tel (425) 368-1000
Kirkland, WA 98033 Fax (425) 368-1001

Special Inspection Report

PROJECT NAME		PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build		PS19-203160-0	2021-06-02~PLR-SNW-9.05R
ADDRESS		DATE	PAGE
Wall 9.05R Soil Nail Wall		June 2, 2021	1 OF 4
CITY OR COUNTY	PERMIT NO.	ARRIVAL TIME	DEPARTURE TIME
Renton, WA		7:00 AM	2:00 PM
CLIENT	WOOD ENGINEER OF RECORD/PHONE NO.		
WSDOT	Dong-Soo Lee / 425-330-3082		
GENERAL CONTRACTOR	WOOD FIELD REPRESENTATIVE/ MOBILE NO.		
FLJV/ Billy Myers (360) 515-8657	Pat Reed / (206) 391-6609		
SUBCONTRACTOR	WEATHER		
Drill Tech Drilling and Shoring Inc./ Bill Creger (510) 598-0609	Sunny 80 degrees		
TYPE OF WORK PERFORMED			
W9.05R Soil Nail Wall Additional Verification Nails			
EQUIPMENT USED			
FLJV: John Deere 135G Excavator, DrillTech: Cat C235 Track-mounted Soil Nail Drill (ID# KR-2510) w/ 4x10ft drill stem & 6-inch Dia. drag bit, Air Compressor 750-3 (AC153), Grout mix plant w/ pump.			

COMMENTS

09.05R: Soil Nail Wall

As requested by general contractor, Wood Environmental & Infrastructure Solutions Inc. (Wood) was onsite to observe the verification testing of Verification Nails (VN-3 and 4). The ground surface was near 170 feet in elevation at both of the boring locations. Upon our arrival Drill Tech Drilling and Shoring Inc. (DTDS) set up the testing apparatus on VN-3. The cut behind the nail was approximately three feet high. Several 4 x 6 timbers were placed vertically against the wall surface, and covered with a steel plate 2 x 2 feet in area, approximately one half inch in thickness, with a hole in the center for the bar to be tested. A 50-ton jack cylinder (DT50-6-9) was placed on the bar, followed by another plate, a load cell, and a final plate (photo, page 4). The Load Cell reports on a separate unit in lbs of force applied. A feeler gauge was set up on a tripod independent of the jack and pile. The dial was set at 0. The pump and pressure gauge corresponded to the DTDS DT50-6-9A calibration sheet. The bars were Number 9 (1 1/8 inch) DWIDAG steel. A nut was used to secure the bar to the jack. The depth to the grout was confirmed to be 10 feet. The bar of VN-3 was measured 33 inches from the wall to the tip. VN-4 measured 36 inches in front of the wall. The overall length of the bars was 20 feet. The stressing length was 9 feet during both tests. During the drilling of VN-3 Wood observed soil conditions to consist of dry, light brown, silty SAND along the entire boring. The other test nail, VN-4 was installed in gravelly silty SAND that was similar to glacial till.

DTDS began to add pressure to the system, as shown on the reports for VN-3 and 4. The load, PSI, and stepped increase in pressure were verified by both Wood and DTDS prior to the start of the test. The timber and steel plate were pushed

☒ The contents of this field report were discussed with the contractor's on-site representative.

☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD ENGINEER OF RECORD

Wood Environment & Infrastructure Solutions, Inc. (Wood)
4020 Lake Washington Blvd. NE, Suite 200 Tel (425) 368-1000
Kirkland, WA 98033 Fax (425) 368-1001

wood.

Daily field report

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-06-02~PLR-SNW-9.05R
ADDRESS	DATE	PAGE
Renton, WA	2021-06-02	2 OF 4

COMMENTS

back approximately 4 to 6 inches during the test loading on both piles. The crew needed to add more pressure during some of the test holds to keep the same load. This is a function of both the hydraulic system of the test equipment and the movement of the timbers back into the slope. The creep test (change in rate of motion over time) test was successful for both nails. The sequence of load increases is shown in the attached PDFs of the test results.

After the hour hold for the creep test at 150% the test called for an increase of the load to 175 and 200% of the design load. VN-3 failed Just above 150% (at 4000 psi/41.2 kips). The bar popped out, knocking over the movement gauge. VN-4 performed well but was brought to a top load of 45.3 kips rather than 50 because the timbers were splitting and moving, creating a safety issue. The Soil Nail test reports are in 3.1 Design\Geotechnical\CONSTRUCTION\ Inspection Observation Records\09.05R-B Soil Nail Installation Logs\

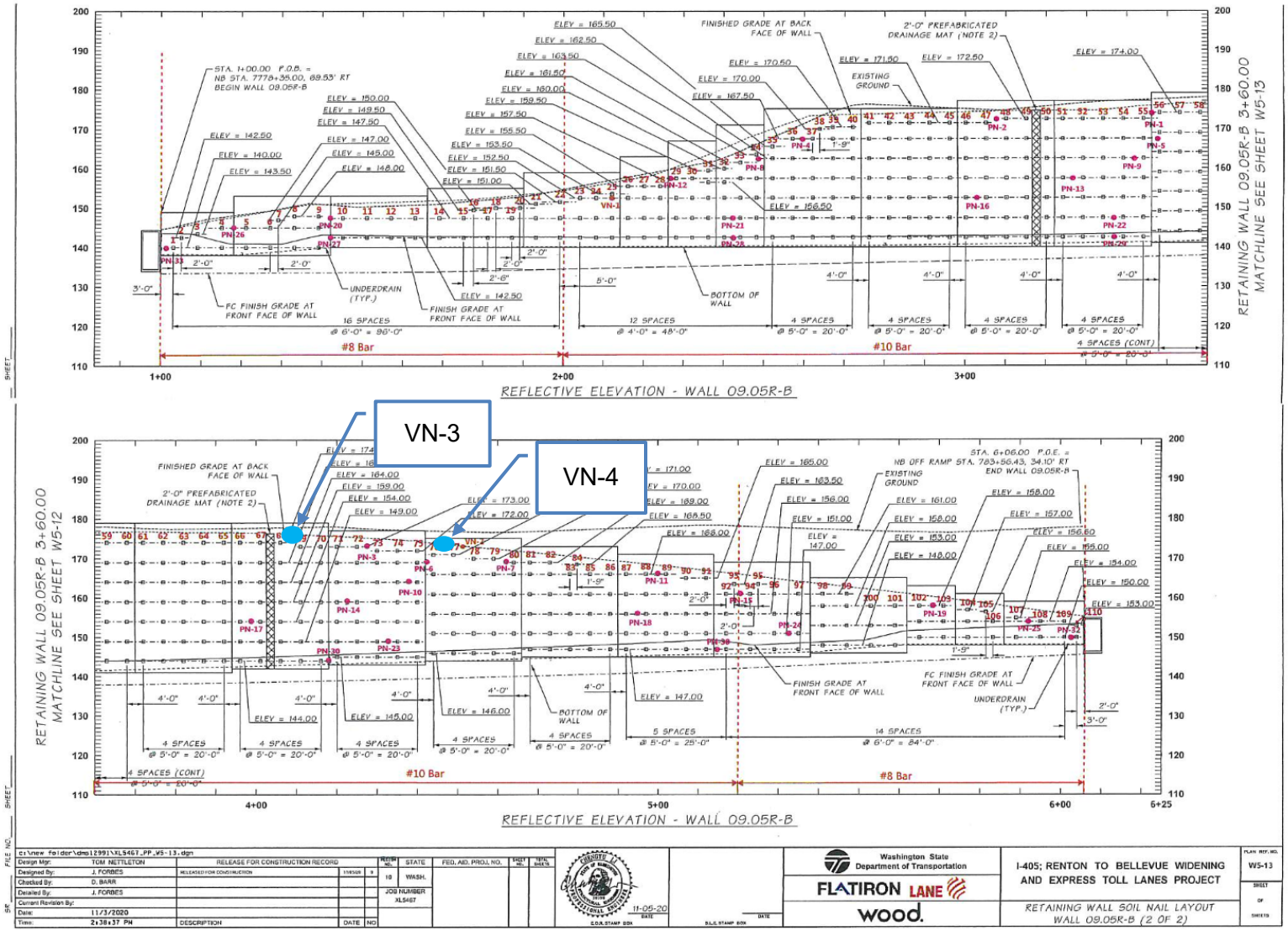
Table 1- Soil Nail Summary Information

Nail No.	Pass/Fail	Average Creep Rate (in/min)	Maximum Elongation (in)	Bond Length (ft)
VF-3	Fail	0.006	Pulled out	10
VF-4	Pass	0.003	0.576	10

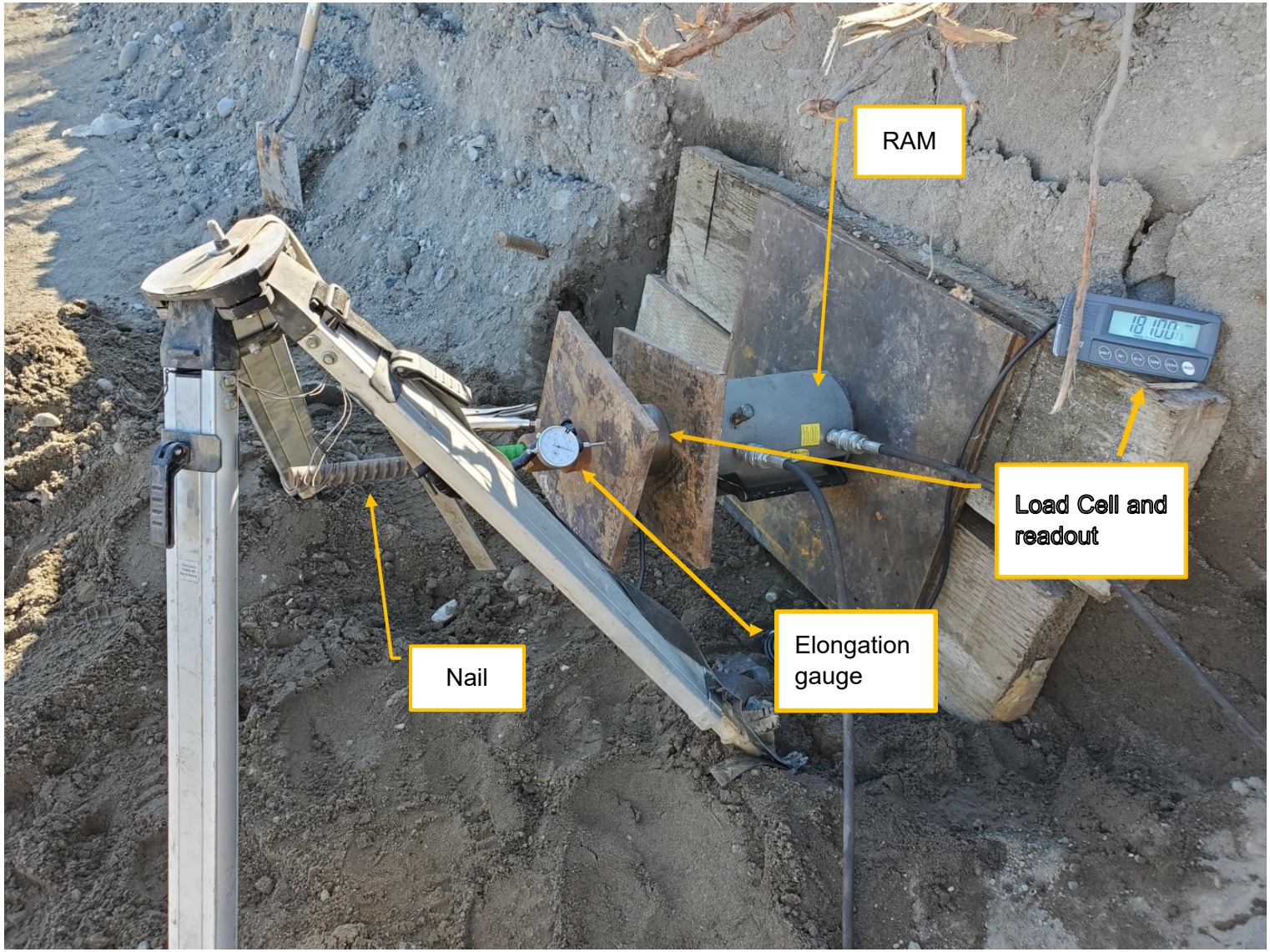
P

Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Lee, Dong Soo
WOOD ENGINEER OF RECORD



PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-06-02~PLR-SNW 9.05R
DESCRIPTION	**DATE**	**PAGE**
Approximate Location of Verification Soil Nails	June 2, 2021	3 OF 4



PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-06-02~PLR-SNW 9.05R
DESCRIPTION	DATE	PAGE
Photograph of load testing gauge at VN-3	June 2, 2021	4 OF 4

Wood Environment & Infrastructure Solutions, Inc.
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Kirkland, WA 98033 Fax (425) 368-1001

Special Inspection Report

PROJECT NAME WSDOT I-405 Renton to Bellevue Design Build		PROJECT NO. PS19-203160-0	FIELD REPORT NO. 2021-07-13_PLR_SNW 09.05R-B
ADDRESS Soil Nail Wall 09.05R-B		DATE July 13, 2021	PAGE 1 OF 4
CITY OR COUNTY Renton, WA	PERMIT NO.	ARRIVAL TIME 7:00 AM	DEPARTURE TIME 10:30 AM
CLIENT WSDOT	WOOD ENGINEER OF RECORD/PHONE NO. Todd Wentworth / (425) 864-0517		
GENERAL CONTRACTOR FLJV/ Ken Horton (360) 630-3553	WOOD FIELD REPRESENTATIVE/ MOBILE NO. Patricia L Reed/206-391-6609		
SUBCONTRACTOR DTDS/ Bill Creger (510)598-0609	WEATHER Sunny, 70 degrees F		
TYPE OF WORK PERFORMED Installation of two additional test nails – VN-5 and VN-6			
EQUIPMENT USED Klemm-style drilling rig with 8-inch auger, kettle-type grout plant on a lowboy, pickup with water tank on trailer			

COMMENTS

Soil Nail Wall 09.05R

Wood Environmental & Infrastructure Solutions Inc. (Wood) was onsite to observe the installation of two additional verification soil nails. The nails are "9-bar" uncoated steel. According to Bill Creger with DTDS, the production nails are #8 and #10 nails; the bars used for the verification testing are #9 because the #8 bars will not take the DTL of 50 kips, and the #10 bars are epoxy-coated. The centralizers placed on the bars were at 1.5 and 8.4 feet from the bottom end. Each was doubled (see photo) because they only had 6-inch centralizers and the bars were sinking into the sand. The additional centralizers lifted the bars further off the bottom of the boring.

VN-5 was drilled at STA 4+42, about 15 feet west of the site boundary, at an estimated elevation of 172 feet. It was drilled to 17 feet from the slope face. The subgrade was yellowish brown poorly graded SAND with trace gravel in a moist condition. The nail was placed without difficulty and set on the extra centralizers and a rock at the upper end of the nail. It was drilled at 08:06 hours and grouted at 09:58 due to issues with the grout plant. Kleinfelder did collect a sample of the grout for laboratory analysis. The grout was brought up to cover the centralizer at 8.4 feet to a depth of 10 feet, leaving 10 feet unbonded. The upper three feet of the nails was exposed at the slope face. DTDS added grout in 15 minute intervals after observing and measuring the grout depth from the face of the slope.

VN-6 was drilled at STA 4+67, about 20 feet west of the site boundary, at an estimated elevation of 165 feet. It was drilled

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☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Todd Wentworth
WOOD ENGINEER OF RECORD

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Daily field report

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-07-13_PLR_SNW 09.05R-B
ADDRESS	DATE	PAGE
Renton, WA	July 13, 2021	2 OF 4

COMMENTS

to 17 feet from the slope face. The subgrade was yellowish brown poorly graded SAND in a moist condition. The nail was placed without difficulty and set on the extra centralizers and a rock at the upper end of the nail. It was drilled at 08:24 hours and grouted at 10:01 due to issues with the grout plant. Kleinfelder did collect a sample of the grout for laboratory analysis. The grout was brought up to cover the centralizer at 8.4 feet to a depth of 10 feet, leaving 10 feet unbonded. The upper three feet of the nails was exposed at the slope face. DTDS added grout in 15-minute intervals after observing and measuring the grout depth from the face of the slope.

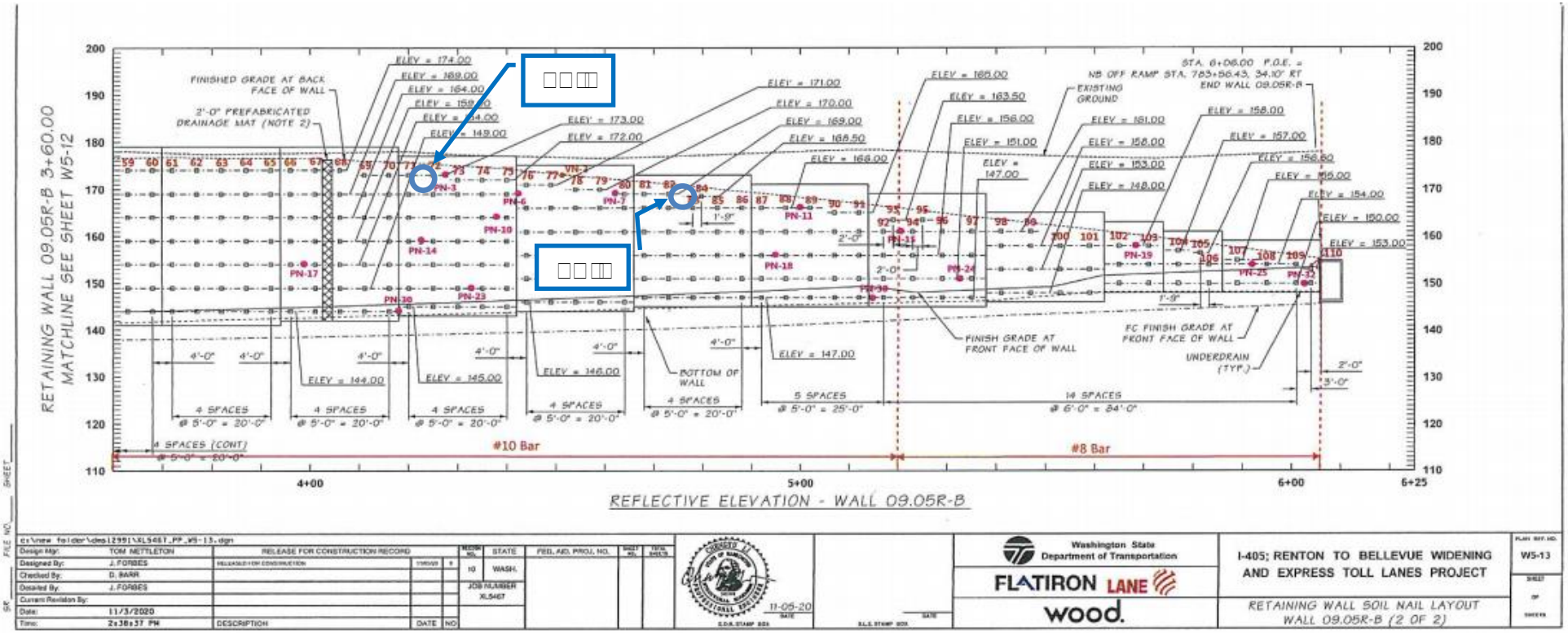
Patricia L. Reed

WOOD FIELD REPRESENTATIVE

Todd Nentwerth

WOOD ENGINEER OF RECORD

Site Plan 1: Verification Nail Installations



Washington State Department of Transportation
FLATIRON LANE
wood.

I-405; RENTON TO BELLEVUE WIDENING AND EXPRESS TOLL LANES PROJECT

RETAINING WALL SOIL NAIL LAYOUT WALL 09.05R-B (2 OF 2)

W5-13

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-07-13_PLR_SNW 09.05R-B
DESCRIPTION	DATE	PAGE
Soil Nail Wall 09.05R-B	July 13, 2021	3 OF 4

Photo Sheet 1: Verification Nail Installation

Second centrali□er attached to botto□ of the first.

PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-07-13_PLR_SNW 09.05R-B
DESCRIPTION	DATE	PAGE
Soil Nail Wall 09.05R-B Photo	July 13, 2021	4 OF 4

~~6-25-21~~

~~1290 On site. Checked lines.~~

~~Checked flags at NE & NW.~~
~~Damp SAND, yellowish brown.~~

~~Sent red-marked plans to Jimmi~~

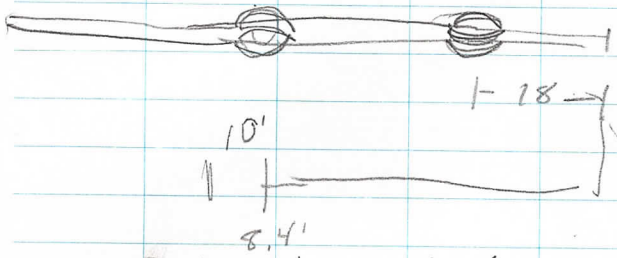
7-13-21

0650 On site at Wall 09. ~~DR~~ OSR 1
Drillers are here. Scott says they need to switch the rig to 8", which will take ~20 min. Weather is sunny, 70°, clouds on the horizon.
0750 Located VF-5 at 4+42, ~172' elevation. Using #9 bar. 8" holes. Uncased. Started drilling at.
0806 Damp @ 3' SP with trace fine gravel, olive brown. Bill Craig is here.
0818 Bar placed. Drilled to ~17'
Bar has 3' Sil. VF-5

VF-6 0824 Start @ 4+67 ~161'
14-15 fine gravel (trace) A-SA.
0834 Done. Bill C leaves for meeting.
0845 Starting grouting set up. Using 2-kettle on the truck. Jimmi leaves.
0900 Jimmi back. DTDS having difficulty with grout plant.
At VF-6
VF-5 is ~15' from wall
VF-6 is ~20' "

Rite in the Rain

7/13/21



0945 Grouting VF-6. Tremie to the bottom. 0949 Done. Grout at
0958 Grouting VF-5. Tremied. Pumping @ 1001. Topping off. PVC tremie broke @ ~6'. Grout at 10 ft bond.
1035 Lv. site for office.

Rite in the Rain

Wood Environment & Infrastructure Solutions, Inc.
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Kirkland, WA 98033 Fax (425) 368-1001

Special Inspection Report

PROJECT NAME WSDOT I-405 Renton to Bellevue Design Build		PROJECT NO. PS19-203160-0	FIELD REPORT NO. 2021-07-20-PLR-SNW 9.05R-B
ADDRESS Wall 9.05R-B Soil Nail Wall		DATE July 20, 2021	PAGE 1 OF 3
CITY OR COUNTY Renton, WA	PERMIT NO.	ARRIVAL TIME 7:30 AM	DEPARTURE TIME 10:30 AM
CLIENT WSDOT	WOOD ENGINEER OF RECORD/PHONE NO. Todd Wentworth / (425) 864-0517		
GENERAL CONTRACTOR FLJV/ Billy Myers (360) 515-8657	WOOD FIELD REPRESENTATIVE/ MOBILE NO. Pat Reed / (206) 391-6609		
SUBCONTRACTOR Drill Tech Drilling and Shoring Inc./ Bill Creger (510) 598-0609	WEATHER Cloudy, light mist, 65 degrees		
TYPE OF WORK PERFORMED W9.05R Soil Nail Wall Additional Verification Nails VN-5 and VN-6			
EQUIPMENT USED Soil Nail Testing Equipment			

COMMENTS

Wood's representative was on site to observe the Verification Testing of two additional soil nails, VN-5 and VN-6. Both nails were installed on July 13, 2021. DTDS installed VN-5 in an area where the native subgrade consisted of poorly graded medium sand with gravel. The other nail, VN-6 was installed in an area of poorly graded medium sand without gravel. Both nails were installed at an inclination of 15 degrees. The difference from previous test nail installations was the use of an 8-inch diameter drill.

The measurements of the grout level today were both 7-feet from the native soil wall back to the grout. DTDS placed several 4 by 6-inch timber boards (6-feet long) behind a 3 by 3-inch steel plate. The ram of a 50-ton jack was placed on the nail. A load cell was placed next, and then a 6 by 6-inch steel plate and a nut. The tip of the nail was 25.5-inches from the front of the timber cribbing. The Gauge used was DT50-6-9A, the pump was OTC-4.

The test of VN-6 met project specifications. The creep was within parameters, and the elongation was also within parameters. The test for VN-5 was set and started, however as testing progressed it was noted that the cribbing began to push a block of soil up the slope behind the wall face when at about 75% of the design load. Further loading would move the sand rather than testing the design of the nails. We discussed options with DTDS (Scott Brown) and agreed to install two Eco blocks against the slope to provide a wider distribution of the pressure. Scott Brown said that he needed to locate two Eco blocks and bring in their excavator to place the blocks. He estimated that it would take until tomorrow morning about 10 AM to prepare the location. Test data is attached as Attachment #1

☒ The contents of this field report were discussed with the contractor's on-site representative.

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Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Todd Wentworth
WOOD ENGINEER OF RECORD

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Daily field report

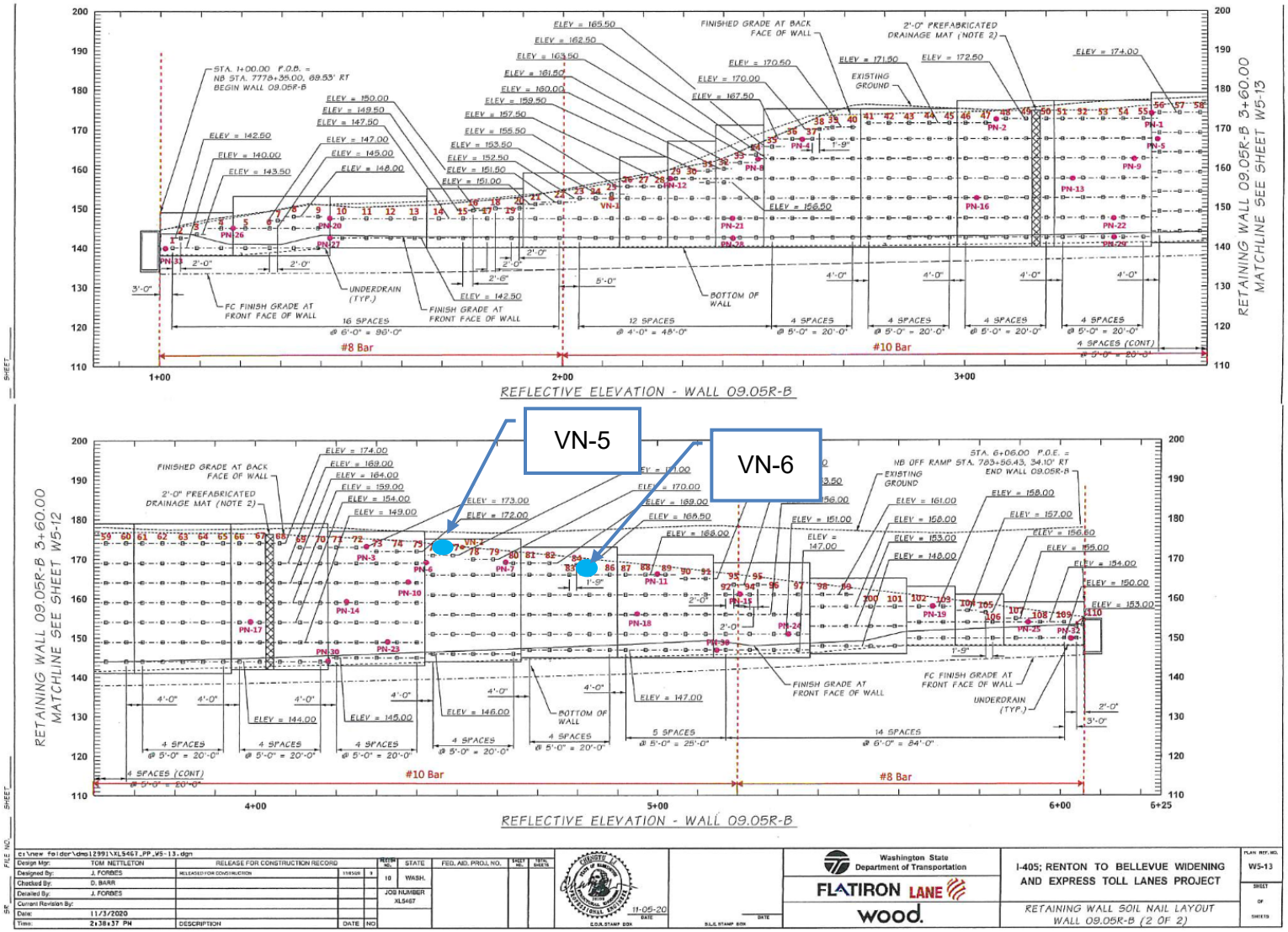
PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-07-20-PLR-SNW 9.05R-B
ADDRESS	DATE	PAGE
Renton, WA	2021-07-20	2 OF 3

COMMENTS

Patricia L. Reed

WOOD FIELD REPRESENTATIVE

WOOD ENGINEER OF RECORD



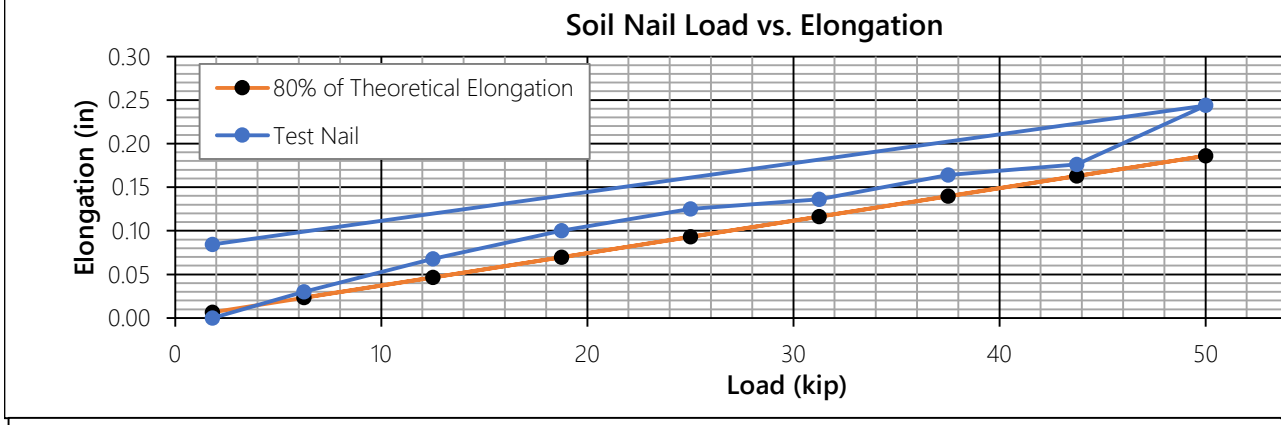
PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-07-20-PLR-SNW 9.05R-B
DESCRIPTION	**DATE**	**PAGE**
Approximate Location of Verification Soil Nails	July 20, 2021	3 OF 3

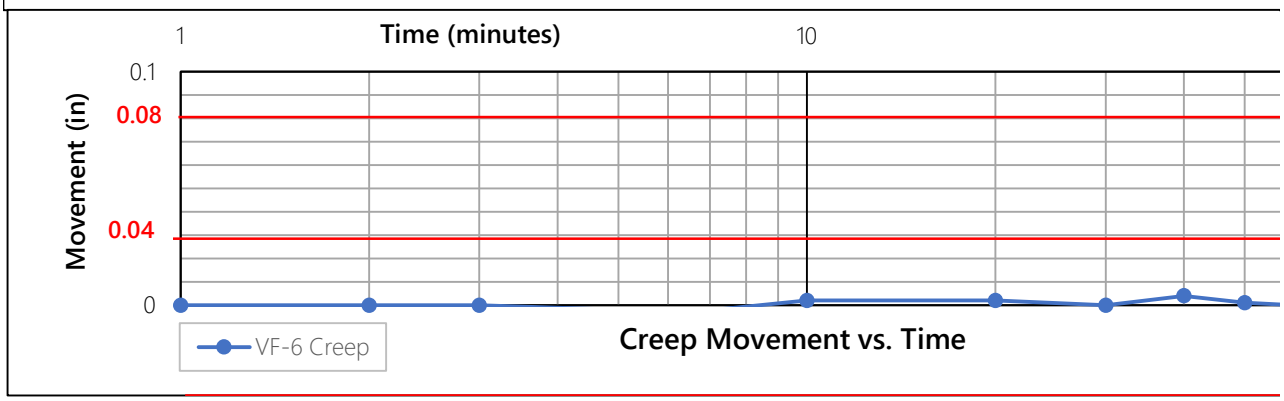
Wood.	Soil Nail Verification Testing Record		
Soil Nail Number:	VN-6	Wall Number:	09.05R
Project Number:	PS19-20316-0	Design Load (kip):	25
Project Name:	I-405 RTB Widening	Design Lockoff Load (kip):	N/A
Wood's Observer:	Patricia Reed	Actual Lockoff Load (kip):	N/A
Date:	7/20/2021	Total Bar Length (feet):	20
Contractor:	Drill Tech	Bond Length (feet):	10
Ram:	Orbit ORDH506	Unbond Length (feet):	10
Ram Serial #:	DT50-6-9B	Stressing Length w/ Tail (feet):	7
Pressure Gauge:	McDaniel, Model 316SS	Bar Size:	9
Gauge Serial #:	DT50-6-9A	Bar Area (in^2):	1.00
Calibration Date:	5/19/2021	Bar Grade (ksi):	75
Certificate #:	359828275	Bar Modulus (ksi):	29,000

Soil Nail Load		Gage (psi)		Load	Observed Elongation (in)		Hold Time
%DL	kip	Design	Actual	kip	Start	End	
AL	1.8	37	**3,750**	37.0	**0.000**	**0.000**	until stable
0.25 (DL)	6.25	477	**600**	6.1	**0.030**	**0.030**	5 min‡
0.50 (DL)	12.5	1,096	**1,100**	11.1	**0.068**	**0.068**	5 min‡
0.75 (DL)	18.75	1,714	**1,800**	18.2	**0.100**	**0.101**	10 min
1.00 (DL)	**25**	2,332	**2,450**	24.8	**0.125**	**0.126**	10 min
1.25 (DL)	31.25	2,950	**3,050**	30.8	**0.136**	**0.136**	10 min
1.50 (DL)	37.5	3,568	**3,600**	36.4	**0.164**	**0.169**	1 min
1.50 (DL)	37.5	3,568	**3,600**		**0.164**	**0.163**	2 min
1.50 (DL)	37.5	3,568	**3,600**		**0.164**	**0.162**	3 min
1.50 (DL)	37.5	3,568	**3,600**		**0.162**	**0.160**	5 min
1.50 (DL)	37.5	3,568	**3,600**		**0.160**	**0.166**	6 min
1.50 (DL)	37.5	3,568	**3,600**		**0.166**	**0.166**	10 min
1.50 (DL)	37.5	3,568	**3,600**		**0.166**	**0.166**	20 min
1.50 (DL)	37.5	3,568	**3,600**		**0.164**	**0.165**	30min
1.50 (DL)	37.5	3,568	**3,600**		**0.168**	**0.168**	40 min
1.50 (DL)	37.5	3,568	**3,600**		**0.165**	**0.165**	50 min
1.50 (DL)	37.5	3,568	**3,600**		**0.164**	**0.164**	60 min
1.75	43.75	4,187	**4,250**	43.0	**0.176**	**0.175**	**10 min**
2	50	4,805	**4,850**	49.0	**0.244**	**0.260**	**10 min**
AL	1.8	37			**0.084**	**0.083**	**until stable**

* Jack pressure was declining over time. Pressure increased back to test load.

‡ Time reduced based on stability of elongation.





A proof tested nail is acceptable if:

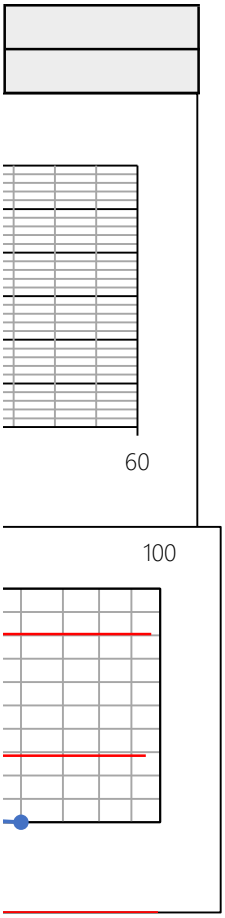
1. The nail carries the maximum load with less than 0.04 inches of movement between 1 and 10 minutes, unless the load hold extended to 60 minutes, in which case the nail would be acceptable if the creep rate does not exceed 0.08 inches per log cycle of time.
2. The total movement at the maximum load exceeded 80 percent of the theoretical elastic elongation of the non-bonded length.
3. The creep rate is not increasing with time during the load hold period.

The acceptance criterion requires that:

- No pullout occurs at loads less than 1.0 PTL.
- The total soil nail movement (Δ_{PTL}) measured at PTL is greater than 80 percent of the theoretical elastic elongation of the unbonded length, as defined below.
- The creep movement does not exceed the criteria presented in Section 9.4.5.

$$\Delta_{PTL} > 0.8 \frac{PTL\ L_{UB}}{E\ A_t}$$

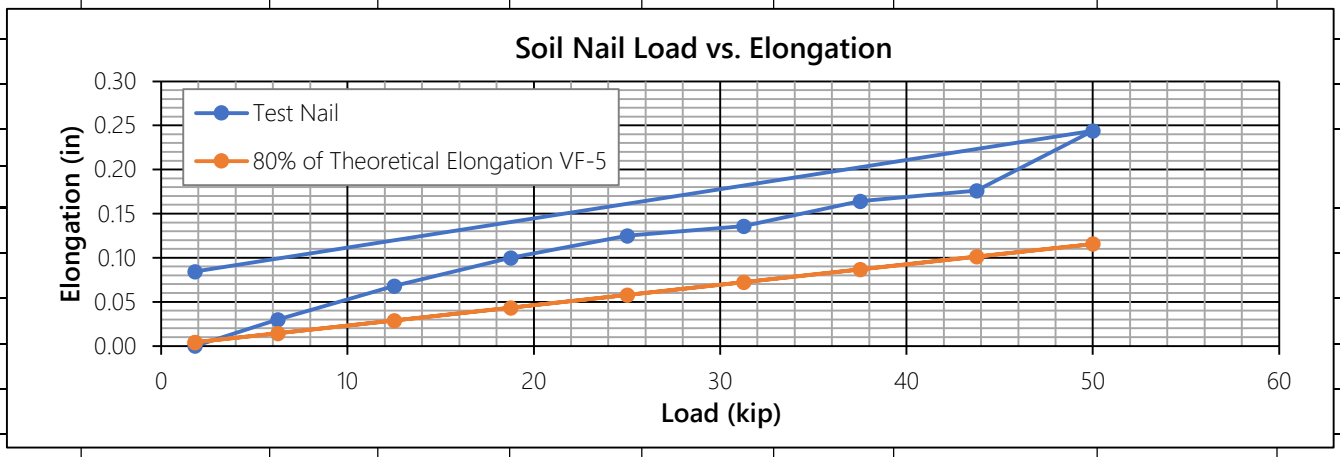
Enter Start Time
7:48

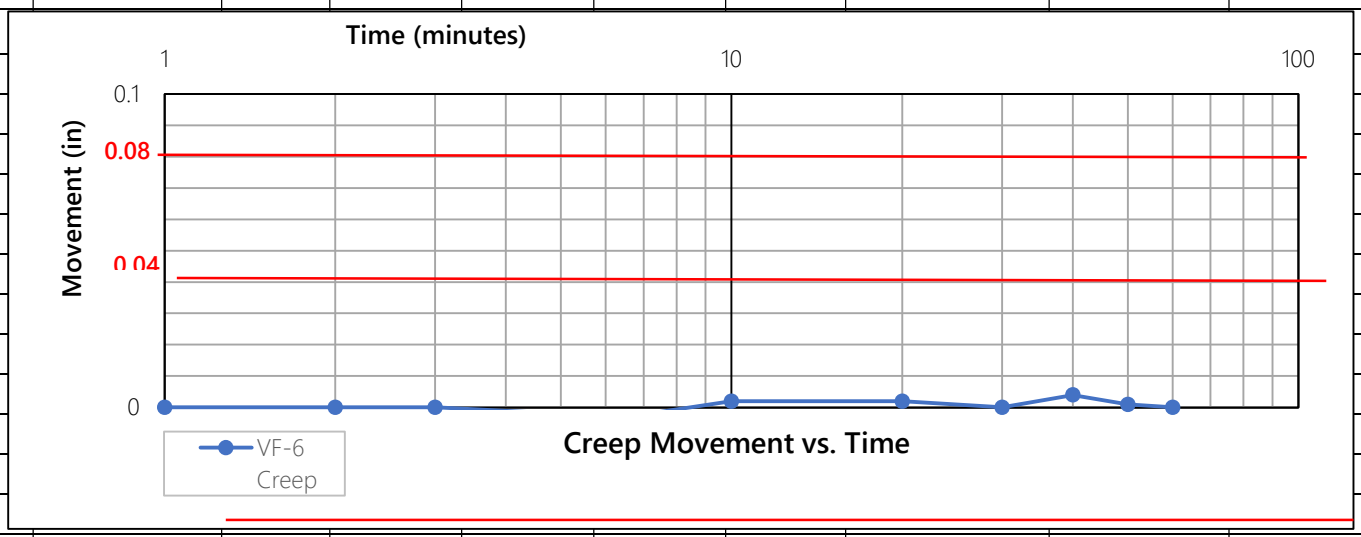

60
100

	Wood.	**Soil Nail Verification Testing Record**						Page 1 of 2	
	Soil Nail Number:	**VN-6**			Wall Number:		09.05R		
	Project Number:	**PS19-20316-0**			Design Load (kip):		25		
	Project Name:	**I-405 RTB Widening**			Design Lockoff Load (kip):		N/A		
	Wood's Observer:	**Patricia Reed**			Actual Lockoff Load (kip):		N/A		
	Date:	**7/20/2021**			Total Bar Length (feet):		20		
	Contractor:	**Drill Tech**			Bond Length (feet):		10		
	Ram:	**Orbit ORDH506**			Unbond Length (feet):		10		
	Ram Serial #:	**DT50-6-9B**			Stressing Length w/ Tail (feet):		7		
	Pressure Gauge:	**McDaniel, Model 316SS**			Bar Size:		9		
	Gauge Serial #:	**DT50-6-9A**			Bar Area (in^2):		1.00		
	Calibration Date:	**5/19/2021**			Bar Grade (ksi):		75		
	Certificate #:	**359828275**			Bar Modulus (ksi):		29,000		
	Soil Nail Load		Gage (psi)		Load	Observed Elongation (in)		Hold Time	Enter Start Time
	%DL	kip	Design	Actual	kip	Start	End		
	AL	1.8	37	300	3.0	0.000	0.000	until stable	7:48
	0.25 (DL)	6.25	477	600	6.1	0.030	0.030	5 min‡	
	0.50 (DL)	12.5	1,096	1,100	11.1	0.068	0.068	5 min‡	
	0.75 (DL)	18.75	1,714	1,800	18.2	0.100	0.101	10 min	
	1.00 (DL)	**25**	2,332	2,450	24.8	0.125	0.126	10 min	
	1.25 (DL)	31.25	2,950	3,050	30.8	0.136	0.136	10 min	
	1.50 (DL)	37.5	3,568	3,600	36.4	0.164	0.169	1 min	
	1.50 (DL)	37.5	3,568	3,600		0.164	0.163	2 min	
	1.50 (DL)	37.5	3,568	3,600		0.164	0.162	3 min	
	1.50 (DL)	37.5	3,568	3,600		0.162	0.160	5 min	
	1.50 (DL)	37.5	3,568	3,600		0.160	0.166	6 min	
	1.50 (DL)	37.5	3,568	3,600		0.166	0.166	10 min	
	1.50 (DL)	37.5	3,568	3,600		0.166	0.166	20 min	
	1.50 (DL)	37.5	3,568	3,600		0.164	0.165	30min	
	1.50 (DL)	37.5	3,568	3,600		0.168	0.168	40 min	
	1.50 (DL)	37.5	3,568	3,600		0.165	0.165	50 min	
	1.50 (DL)	37.5	3,568	3,600		0.164	0.164	60 min	
	1.75	43.75	4,187	4,250	43.0	0.176	0.175	10 min	
	2	50	4,805	4,850	49.0	0.244	0.260	10 min	
	AL	1.8	37			0.084	0.083	until stable	

* Jack pressure was declining over time. Pressure increased back to test load.

ǂ Time reduced based on stability of elongation.





5-28-21 Jack 300-8

3800 On site PSI Air

	Kips	Dial 1	Dial 2	PSI	Air
10%	30	0.991	.993	379	1490
	1	0.991	.993		
	2	0.990	.993		
	4	0.990	.990		
9%					
(10) 60	720	758	30 sec	2277	216 2300
	720	758	1 min		
	720	758	2		
	720	758	4		
40	742	775		1518	144 1500
	742	775			
	742	775			
	742	775			
20	772	801		760	72 750
	772	801			
	772	801			
	772	801			
5	798	821		190	12.2 200
	798	821			
	798	821			
	798	821			
	1005	Done			

CFA pile test 1

7-20-21 On wall 0905

Jack RAM 50T Raining VF-6

Gauge DT50-6-9A

Pump OTC-4

Load Cell LC-50T-1

VN-6 2' in front of soil wall

25½" in front of plate 7'SL 4+6647

10' to grout from end of bar 0748

VN-6	Kips	Gauge	Actual	Start	End
AL	1.8	137	~~200~~ 3750	Ø	
5) 25	6.25	477	600/650	0.030	0.030
5) 50	12.75	1096	120	0.068	0.068
10) 75	18.75	1714	1800/18	0.100	0.101
10) 100	25	2332	2450/	0.125	0.126
10) 125	31.25	2950	3050/	0.136	0.136
1 150	37.5	3568	365	0.167	0.165
2	Gauge	Creeping	3650	0.164	0.163
3	and load	Settling	3580	0.164	0.162
5	Cell don't	agree	3543	0.162	0.160
6		0 PSI 3650	bumped	0.160	0.166
10			to 35.10	0.166	0.166
20			bump	0.166	0.166
30	0.003			0.165	0.165
40			35.4 tons PSI	0.168	0.168
50			3650	0.165	0.165
60			3625	0.164	0.164

Rain or Rain

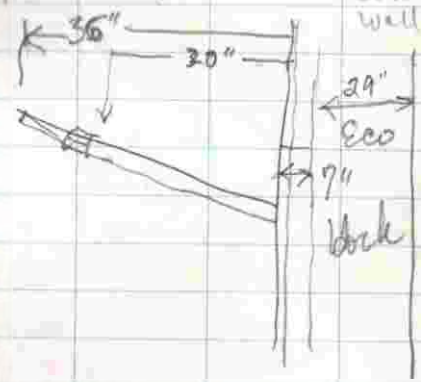
7-20-21

					0.175
175	43.75	4189	4250	0.176	40.4 (10)
200	50	4805	4850	0.244	0.240 (10)
~~300~~		300 PSI	300 PSI	37 10	0.893 0.084
		0			Done @ 1016

0.244
.172
.069

0.408
.132
.276

11:47 3' behind well



7-20-21

VF-55 Test 1 7' SL 10' BZ 31" 12½"

AL	DIDS	Actual PSI	Start Lbs	1050	@4+42
	~~450~~	300			
5) 25	~~600~~ 600	0.010	0.010	6.2 tons	600 psi
5) 50	1200	0.045	0.045	13.9 tons	1200
10) 75	1800 1850	0.082	0.082	18.75 Tons	
10) 100	2450 2500	0.121	0.120	24.8 tons	10
125	3050	0.167	0.169	cribbing	settled
150	3650	0.230	1		
		0.233	2		
		0.233	3	4	0.233
		0.233	5		
		0.232	6		
		0.238	10		
		0.238	20		
		0.242	30	37	
		0.242	40	3610	
		0.242	50	3600	
		0.246	60	3700	
~~175~~	4250	4000	0.623 → 0.627	0.623 @ 4000	
~~200~~	4850			.6227 4000	

@1238 Could ~~4500~~ be pulled out

12:16 to Culvert ERC project

@ 300 1.308 Final

Rite in the Rain

7-~~10~~ 20-21
8.13 Pipe SG
Photos RFI
Lv. 13:0

Wood Environment & Infrastructure Solutions, Inc.
4020 Lake Washington Blvd. NE, Suite 200 Tel (425) 368-1000
Kirkland, WA 98033 Fax (425) 368-1001

Special Inspection Report

PROJECT NAME WSDOT I-405 Renton to Bellevue Design Build		PROJECT NO. PS19-203160-0	FIELD REPORT NO. 2021-07-21-PLR-SNW 9.05R-B
ADDRESS Wall 9.05R-B Soil Nail Wall		DATE July 21, 2021	PAGE 1 OF 2
CITY OR COUNTY Renton, WA	PERMIT NO.	ARRIVAL TIME 10:30 AM	DEPARTURE TIME 12:30 PM
CLIENT WSDOT	WOOD ENGINEER OF RECORD/PHONE NO. Todd Wentworth / (425) 864-0517		
GENERAL CONTRACTOR FLJV/ Billy Myers (360) 515-8657	WOOD FIELD REPRESENTATIVE/ MOBILE NO. Pat Reed / (206) 391-6609		
SUBCONTRACTOR Drill Tech Drilling and Shoring Inc./ Bill Creger (510) 598-0609	WEATHER Sun, 75 degrees		
TYPE OF WORK PERFORMED W9.05R-B Soil Nail Wall Additional Verification Nail VN-5			
EQUIPMENT USED Soil Nail Testing Equipment			

COMMENTS

Wood's representative was on site yesterday and today to observe the Verification Testing of two additional soil nails, VN-5 and VN-6. Both nails were installed on July 13, 2021. DTDS installed VN-5 in an area where the native subgrade consisted of poorly graded medium sand with gravel. The other nail, VN-6 was installed in an area of poorly graded medium sand without gravel. Both nails were installed at an inclination of 15 degrees. The difference from previous test nail installations was the use of an 8-inch diameter drill rather than a 6-inch. Yesterday VN-6 met project requirements, passing both the creep and elongation parts of the test. We utilized the PSI values provided by DTDS on both tests. The test of VF-5 was halted yesterday due to collapse of the ground behind the testing rig.

The measurement of the grout level today on VN-5 was 7-feet from the native soil wall back to the grout. DTDS placed four Eco-blocks around the nail. They then laid several 4 by 6-inch timber boards (6-feet long) behind a 3 by 3-inch steel plate. The ram of a 50-ton jack was placed on the nail. A load cell was placed next, and then a 6 by 6-inch steel plate and a nut. The tip of the nail was 35-inches from the front of the timber cribbing. The Gauge used was DT50-6-9A, the pump was OTC-4.

The test of VN-5 did not meet project specifications. The creep at 150% of DTL was within parameters, and the elongation was also within parameters, but the nail began to pull out at a load of 4100 psi (just under 175% of DTL).
Test data is attached as Attachment #1

☒ The contents of this field report were discussed with the contractor's on-site representative.

☐ A preliminary copy of this field report was left on site. All recommendations contained herein are subject to change pending review by the WOOD Engineer of Record.

Patricia L. Reed
WOOD FIELD REPRESENTATIVE

Todd Wentworth
WOOD ENGINEER OF RECORD

Wood Environment & Infrastructure Solutions, Inc. (Wood)
4020 Lake Washington Blvd. NE, Suite 200 Tel (425) 368-1000
Kirkland, WA 98033 Fax (425) 368-1001

Daily field report

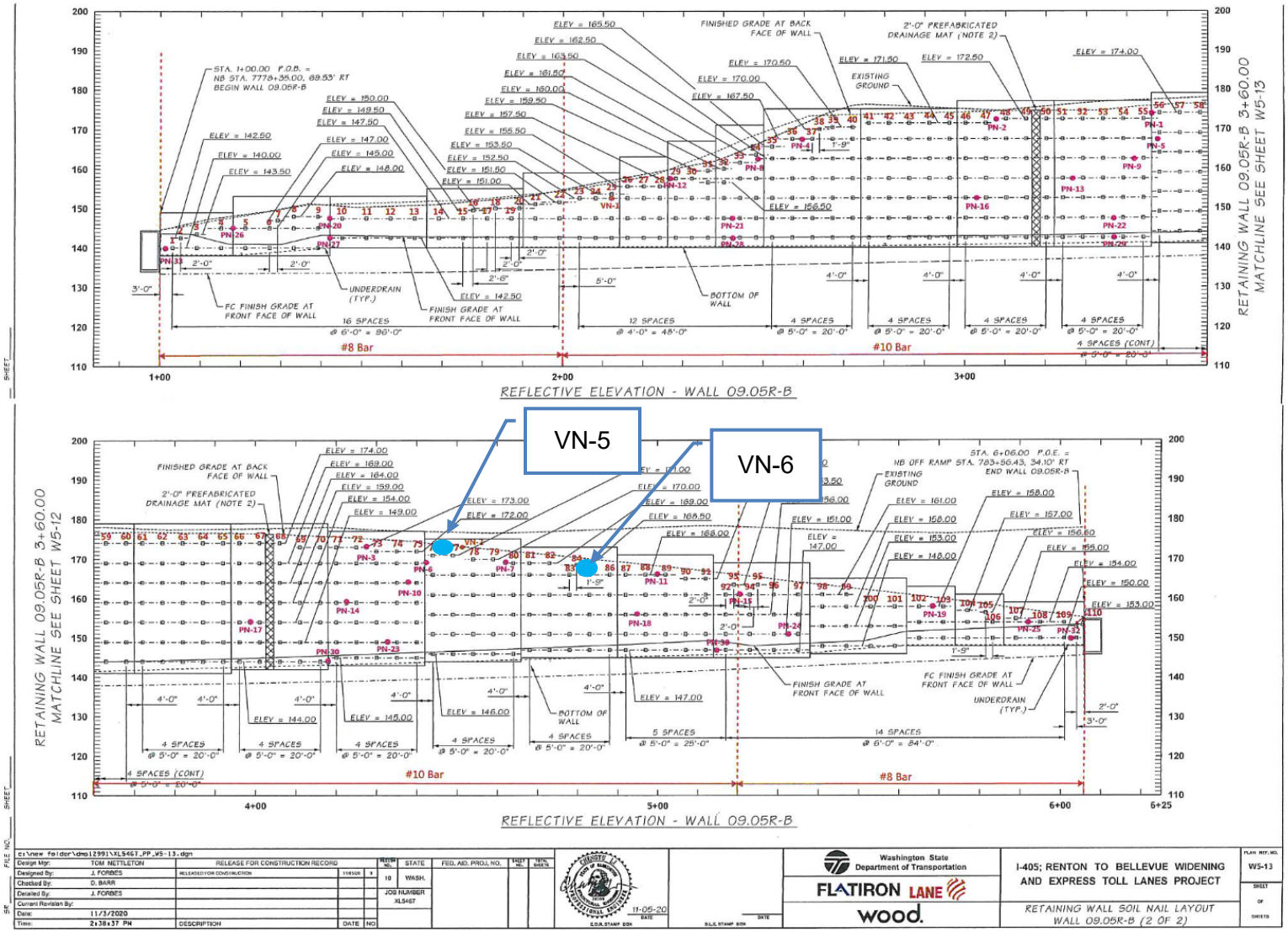
PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-203160-0	2021-05-26~PLR T. Soil Nail 07.10R
ADDRESS	DATE	PAGE
Renton, WA	2021-05-26	2 OF 3

Patricia L. Reed

WOOD FIELD REPRESENTATIVE

Todd Heatherworth

WOOD ENGINEER OF RECORD

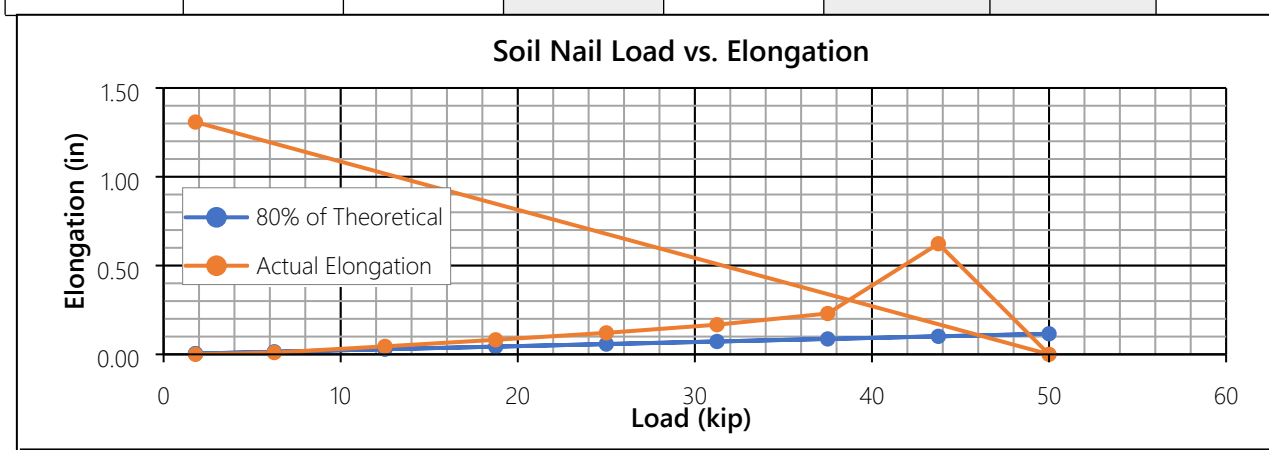


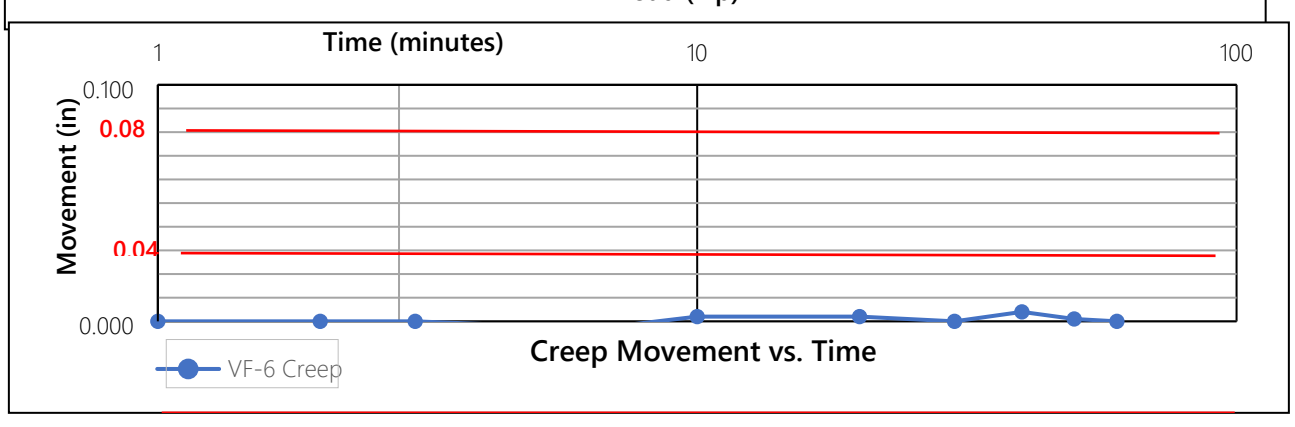
PROJECT NAME	PROJECT NO.	FIELD REPORT NO.
WSDOT I-405 Renton to Bellevue Design Build	PS19-20316-0	2021-07-21-PLR-SNW 9.05R-B
DESCRIPTION	**DATE**	**PAGE**
Approximate Location of Verification Soil Nails	July 21, 2021	2 OF 2

Wood.	Soil Nail Verification Testing Record			Page 1 of 1
Soil Nail Number:	VN-5	Wall Number:	09.05R	
Project Number:	PS19-20316-0	Design Load (kip):	25	
Project Name:	I-405 RTB Widening	Design Lockoff Load (kip):	N/A	
Wood's Observer:	Patricia Reed	Actual Lockoff Load (kip):	N/A	
Date:	7/21/2021	Total Bar Length (feet):	20	
Contractor:	Drill Tech	Bond Length (feet):	10	
Ram:	Orbit ORDH506	Unbond Length (feet):	10	
Ram Serial #:	DT50-6-9B	S.length with tail (feet)	7	
Pressure Gauge:	McDaniel, Model 316SS	Bar Size:	9	
Gauge Serial #:	DT50-6-9A	Bar Area (in^2):	1.00	
Calibration Date:	5/19/2021	Bar Grade (ksi):	75	
Certificate #:	359828275	Bar Modulus (ksi):	29,000	

Soil Nail Load		Gage (psi)		Load	Observed Elongation (in)		Hold Time	Enter Start Time
%DL	kip	Design	Actual	kip	Start	End		
AL	1.8	37	**300**	37.0	**0.000**	**0.000**	until stable	**10:50**
0.25 (DL)	6.25	477	**600**	6.1	**0.010**	**0.010**	5 min‡	
0.50 (DL)	12.5	1,096	**1,200**	12.1	**0.045**	**0.045**	5 min‡	
0.75 (DL)	18.75	1,714	**1,850**	18.7	**0.082**	**0.082**	10 min	
1.00 (DL)	**25**	2,332	**2,500**	25.3	**0.121**	**0.121**	10 min	
1.25 (DL)	31.25	2,950	**3,050**	30.8	**0.167**	**0.167**	10 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.230**		1 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.233**		2 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.233**		3 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.233**		5 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.232**		6 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.238**		10 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.242**		20 min	
1.50 (DL)	37.5	3,568	**3,700**	37.4	**0.242**		30min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.242**		40 min	
1.50 (DL)	37.5	3,568	**3,650**	36.9	**0.242**		50 min	
1.50 (DL)	37.5	3,568	**3,700**	37.4	**0.246**		60 min	
1.75	43.75	4,187	**4,100**	41.5	**0.623**	**0.627**	10 min	
2	50	4,805	**4,850**				10 min	
AL	1.8	37	**300**		**1.308**		until stable	

‡ Time reduced based on stability of elongation.





Wood.	Soil Nail Verification Testing Record	Page 1 of 1

Soil Nail Number:	VN-5 ~~VT-5~~	Wall Number:	09.05R
Project Number:	PS19-20316-0	Design Load (kip):	25
Project Name:	I-405 RTB Widening	Design Lockoff Load (kip):	N/A
Wood's Observer:	Patricia Reed	Actual Lockoff Load (kip):	N/A
Date:	7/21/21	Total Bar Length (feet):	20
Contractor:	DTDS Drill Tech	Bond Length (feet):	10
Ram:	Orbit ORDH 506	Unbond Length (feet):	10
Ram Serial #:	DT 50-6-98	S.length with tail (feet)	7
Pressure Gauge:	McDaniel Model	Bar Size:	9
Gauge Serial #:	DT50-6-9A 31655	Bar Area (in^2):	1.0
Calibration Date:	5/19/21	Bar Grade (ksi):	75
Certificate #:	359828275	Bar Modulus (ksi):	29,000

FAIL

Soil Nail Load		Gage (psi)		Load	Observed Elongation (in)		Hold Time	Enter Start Time
%DL	kip	Design	Actual	kip	Start	End		
AL	1.8	37	300	37.0	0.000	0.000	until stable	10:50
0.25 (DL)	6.25	477	600	6.1	0.010	0.010	5 min‡	
0.50 (DL)	12.5	1096	1200	12.1	0.045	0.045	5 min‡	
0.75 (DL)	18.75	1714	1850	18.7	0.082	0.082	10 min	
1.00 (DL)	25	2332	2500	25.3	0.121	0.121	10 min	
1.25 (DL)	31.25	2950	3050	30.8	0.167	0.167	10 min	
1.50 (DL)	37.5	3568	3650	36.9	0.230		1 min	
1.50 (DL)					0.233		2 min	
1.50 (DL)					0.233		3 min	
1.50 (DL)					0.233		5 min	
1.50 (DL)					0.233		6 min	
1.50 (DL)					0.238		10 min	
1.50 (DL)					0.242		20 min	
1.50 (DL)					0.242		30min	
1.50 (DL)					0.242		40 min	
1.50 (DL)					0.242		50 min	
1.50 (DL)					0.246		60 min	
1.75	43.75	4187	4100	41.5	0.623	0.627	10 min	held
2	50.0	4885	—	Couldn't	get	there	10 min	
AL	1.8						until stable	

‡ Time reduced based on stability of elongation.

I-405 Renton to Bellevue Widening & ETL Project

Contract No. 9242

RW 9.05R-B Soil Nail Verification Test Results (Revision 1)

Reference FLJV Submittal Nos. 0431 and 0477

Corrected the Mis-Labeled RW on the V1 Test Sheet

Date: April 14, 2021

Owner: Washington State Department of Transportation (WSDOT)

General Contractor: Flatiron Lane JV

Submittal Author: Bill Creger

Specification References

Section 6-15 Soil Nail Walls per:

WSDOT 2018 Standard Specifications with Revisions, dated 01/07/19

Renton to Bellevue General Special Provisions, dated 12/19/18

I-405, Renton to Bellevue Widening & and Express Toll Lanes Project

DOCUMENT REVIEW

- ☐ APPROVED, NO EXCEPTION TAKEN
- ☐ APPROVED AS NOTED
- ☐ RESUBMIT, REVISE AS NOTED
- X REVIEWED COMMENTS PROVIDED IF ANY

REVIEWED BY: B. Bell DATE: 4/19/21

Review is for general conformance with contract or design documents. Sole responsibility for correctness of dimensions, details, quantities, materials, and safety during fabrication and erection shall remain with the contractor

This Type 1 Working Drawing is confirming receipt and has been routed to the GSI for their information.

2200 Wymore Way – Antioch, CA 94509-8548 – (925) 978-2060 – Fax: (925) 978-2063

DRILLTECH DRILLING & BORING, INC.
2200 Wymore Way, Antioch, CA 94509
Office: (925)978-2060 // Fax: (925)978-2063

Project:	I-405 Renton to Bellevue Widening & Express Toll Lanes		
Location:	Renton to Bellevue, WA		
Foreman:	Scott Brown		
Date:	03/26/21	Job No.	20018

Sheet 1

Soil Nail Verification Test

STA 4+53.29, Elev 173.83

Soil Nail No: V2 North
Embedment Length (ft.) 10
Retaining Wall No: RW 9.05R-B

TEST LOAD	
Lb (ft):	10
Qd (kips/ft):	2.5
DTL (kips):	25

Verification test nail failed

Ram Information
Ram No.: 60-5-2
Gauge No.: 60-5-2A
Calibr. Date 2/24/2021

Testing Schedule

Load Level	Load (kips)	60-5-2A (psi)	Elongation (Inches) 1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	10 min.	20 min.	30 Min.	40 Min.	50 Min.	60 Min.
AL (0.10 DTL)	2.50	200	0.000											
0.25 DTL	6.25	500	0.002	Reading at beginning of 10-minute hold					0.002					
0.50 DTL	12.50	1000	0.008	Reading at beginning of 10-minute hold					0.007					
0.75 DTL	18.75	1500	0.054	Reading at beginning of 10-minute hold					0.059					
1.00 DTL	25.00	2050	0.139	Reading at beginning of 10-minute hold					0.132					
1.25 DTL	31.25	2550	0.355	Reading at beginning of 10-minute hold					0.353					
1.50 DTL (Creep*)	37.50	3050	0.718	Work to stabilize pressure from 2-minutes to 10-minutes					1.173					
1.75 DTL	43.75	3550		Reading at beginning of 10-minute hold										
2.00 DTL (MTL)	50.00	4050		Reading at beginning of 10-minute hold										
AL (0.10 DTL)	2.50	200												

AL = Alignment Load; DTL = Design Test Load

*Hold the load to within 2 percent and measure and record soil nail movement at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes

Verification Test Acceptance Criteria:

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1) Creep rate does not exceed 0.08 inch from 1-min to 60-minutes.

2) Total movement measured at the Maximum Test Load (MTL=2.00 DTL) exceeds 80 percent of theoretical elastic elongation of the non-bonded length.

Elongation Calculations

MTL =	50.00 kips		Lu (Unbonded Length) =	5 ft.	
E =	29000 ksi		A (X-Section Area) =	1.000 sq. in	#9 Bar
Theoretical Elongation	=	0.0983	inches		
80% Theoretical Elongation	=	0.0786	inches		
Actual Elongation	=		inches	FAILED Creep Test	

Ram Load	Load Cell Reading
2.50	5.97
6.25	10.98
12.50	19.66
18.75	27.00
25.00	34.50
31.25	39.60
37.50	44.50
43.75	
50.00	
2.50	

Total Creep Movement From 1- to 60-minutes: _____ > 0.08-inches FAIL

Started creep test at 1:24p
On creep test - 2 to 10 minutes used to stabilize pressure and stopped test due to exceeding 0.08-inches.
Tried loading again to 1.50 DL and visibly pulling out at 3,000 psi

DRILLTECH DRILLING & BORING, INC.
2200 Wymore Way, Antioch, CA 94509
Office: (925)978-2060 // Fax: (925)978-2063

Project:	I-405 Renton to Bellevue Widening & Express Toll Lanes		
Location:	Renton to Bellevue, WA		
Foreman:	Scott Brown		
Date:	03/26/21	Job No.	20018

Sheet 1

Soil Nail Verification Test

STA 2+11.68, Elev 150.76

Soil Nail No: V1 South End
Embedment Length (ft.) 10
Retaining Wall No: 9.05R-B

TEST LOAD	
Lb (ft):	10
Qd (kips/ft):	1.7
DTL (kips):	17

Ram Information
Ram No.: 60-5-2
Gauge No.: 60-5-2A
Calibr. Date 2/24/2021

Testing Schedule

Load Level	Load (kips)	60-5-2A (psi)	Elongation (Inches) 1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	10 min.	20 min.	30 Min.	40 Min.	50 Min.	60 Min.
AL (0.10 DTL)	1.70	150	0.000											
0.25 DTL	4.25	350	0.015	Reading at beginning of 10-minute hold					0.014					
0.50 DTL	8.50	650	0.057	Reading at beginning of 10-minute hold					0.062					
0.75 DTL	12.75	1000	0.102	Reading at beginning of 10-minute hold					0.105					
1.00 DTL	17.00	1350	0.197	Reading at beginning of 10-minute hold					0.210					
1.25 DTL	21.25	1700	0.262	Reading at beginning of 10-minute hold					0.271					
1.50 DTL (Creep*)	25.50	2050	0.361	0.363	0.363	0.362	0.362	0.362	0.360	0.365	0.362	0.360	0.361	0.361
1.75 DTL	29.75	2400	0.433	Reading at beginning of 10-minute hold					0.445					
2.00 DTL (MTL)	34.00	2750	0.538	Reading at beginning of 10-minute hold					0.544					
AL (0.10 DTL)	1.70	150	0.238											

AL = Alignment Load; DTL = Design Test Load

*Hold the load to within 2 percent and measure and record soil nail movement at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes

Verification Test Acceptance Criteria:

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1) Creep rate does not exceed 0.08 inch per log cycle of time and is linear or decreasing through the creep test load-hold period.

2) Total movement measured at the Maximum Test Load (MTL=2.00 DTL) exceeds 80 percent of theoretical elastic elongation of the non-bonded length.

Elongation Calculations

MTL =	34.00 kips		Lu (Unbonded Length) =	5 ft.	
E =	29000 ksi		A (X-Section Area) =	1.000 sq. in	#9 Bar
Theoretical Elongation	=	0.0668	inches		
80% Theoretical Elongation	=	0.0535	inches		
Actual Elongation	=	0.3060	inches	Pass	

Ram Load	Load Cell Reading
1.70	3.63
4.25	5.82
8.50	9.75
12.75	14.30
17.00	17.60
21.25	22.15
25.50	26.60
29.75	30.00
34.00	33.60
1.70	2.22

Total Creep Movement From 1- to 60-minutes: 0.000 inches Pass

I-405 Renton to Bellevue Widening & ETL Project

Contract No. 9242

RW 9.05R-B Soil Nail Verification Test Results VN3 and VN4 (Revision 0)

Reference FLJV Submittal Nos. 0431 and 0477

Date: June 3, 2021

Owner: Washington State Department of Transportation (WSDOT)

General Contractor: Flatiron Lane JV

Submittal Author: Bill Creger

Specification References

Section 6-15 Soil Nail Walls per:

WSDOT 2018 Standard Specifications with Revisions, dated 01/07/19

Renton to Bellevue General Special Provisions, dated 12/19/18

I-405, Renton to Bellevue Widening & and Express Toll Lanes Project

DOCUMENT REVIEW

- ☐ APPROVED, NO EXCEPTION TAKEN
- ☐ APPROVED AS NOTED
- ☐ RESUBMIT, REVISE AS NOTED
- ☒ REVIEWED COMMENTS PROVIDED IF ANY

REVIEWED BY: B. Bell DATE: 6/9/21

Review is for general conformance with contract or design documents. Sole responsibility for correctness of dimensions, details, quantities, materials, and safety during fabrication and erection shall remain with the contractor

This Type 1 Working Drawing is confirming receipt and has been routed to the GSI for their information.

2200 Wymore Way – Antioch, CA 94509-8548 – (925) 978-2060 – Fax: (925) 978-2063

DRILLTECH DRILLING & BORING, INC.
2200 Wymore Way, Antioch, CA 94509
Office: (925)978-2060 // Fax: (925)978-2063

Project:	I-405 Renton to Bellevue Widening & Express Toll Lanes		
Location:	Renton to Bellevue, WA		
Foreman:	Scott Brown		
Date:	6/2/2021	Job No.	20018

Sheet 1

Soil Nail Verification Test

Failed Test - Verification nail pulled out at 4,000 psi. Passed creep test.

	Approx. STA 4+48
Soil Nail No:	VN3
Embedment Length (ft.)	10
Retaining Wall No:	RW 9.05R-B

TEST LOAD	
Lb (ft):	10
Qd (kips/ft):	2.5
DTL (kips):	25

Ram Information
Ram No.: 50-6-9
Gauge No.: 50-6-9A
Calibr. Date 5/19/2021

Testing Schedule

Load Level	Load (kips)	50-6-9A (psi)	Elongation (Inches) 1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	10 min.	20 min.	30 Min.	40 Min.	50 Min.	60 Min.
AL (0.10 DTL)	2.50	250	0.024											
0.25 DTL	6.25	600	0.051	Reading at beginning of 10-minute hold					0.055					
0.50 DTL	12.50	1200	0.103	Reading at beginning of 10-minute hold					0.108					
0.75 DTL	18.75	1800	0.163	Reading at beginning of 10-minute hold					0.163					
1.00 DTL	25.00	2450	0.212	Reading at beginning of 10-minute hold					0.212					
1.25 DTL	31.25	3050	0.260	Reading at beginning of 10-minute hold					0.260					
1.50 DTL (Creep*)	37.50	3650	0.304	0.305	0.305	0.305	0.305	0.305	0.311	0.315	0.315	0.316	0.316	0.316
1.75 DTL	43.75	4250	NR	Pull-out began at approximately 4,000 psi.					NR					
2.00 DTL (MTL)	50.00	4850	NR	Reading at beginning of 10-minute hold					NR					
AL (0.10 DTL)	2.50	250	1.025											

AL = Alignment Load; DTL = Design Test Load

*Hold the load to within 2 percent and measure and record soil nail movement at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes

Verification Test Acceptance Criteria:

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1) Creep rate does not exceed 0.08 inch from 1-min to 60-minutes.

2) Total movement measured at the Maximum Test Load (MTL=2.00 DTL) exceeds 80 percent of theoretical elastic elongation of the non-bonded length.

Elongation Calculations

MTL =	50.00 kips		Lu (Unbonded Length) =	6 ft.	
E =	29000 ksi		A (X-Section Area) =	1.000 sq. in	#9 Bar
Theoretical Elongation	=	0.1179	inches		
80% Theoretical Elongation	=	0.0943	inches		
Actual Elongation	=	NR	inches	Nail pulled out at 4,000 psi	

Ram Load	Load Cell Reading
2.50	4.40
6.25	6.85
12.50	12.30
18.75	18.15
25.00	24.00
31.25	30.25
37.50	35.50
43.75	NR
50.00	NR
2.50	NR

Total Creep Movement From 1- to 60-minutes: 0.012 inches Pass

Test failed when verification nail pulled out at approximately 4,000 psi. Passed the creep test and failed at before reaching next test increment at 1.75 DTL.

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Project:	I-405 Renton to Bellevue Widening & Express Toll Lanes		
Location:	Renton to Bellevue, WA		
Foreman:	Scott Brown		
Date:	6/2/2021	Job No.	20018

Sheet 1

Soil Nail Verification Test

	Approx. STA 4+06
Soil Nail No:	VN4
Embedment Length (ft.)	10
Retaining Wall No:	RW 9.05R-B

TEST LOAD	
Lb (ft):	10
Qd (kips/ft):	2.5
DTL (kips):	25

Ram Information
Ram No.: 50-6-9
Gauge No.: 50-6-9A
Calibr. Date 5/19/2021

Testing Schedule

Load Level	Load (kips)	50-6-9A (psi)	Elongation (Inches) 1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	10 min.	20 min.	30 Min.	40 Min.	50 Min.	60 Min.
AL (0.10 DTL)	2.50	250	0.032											
0.25 DTL	6.25	600	0.052	Reading at beginning of 10-minute hold					0.052					
0.50 DTL	12.50	1200	0.120	Reading at beginning of 10-minute hold					0.120					
0.75 DTL	18.75	1800	0.180	Reading at beginning of 10-minute hold					0.180					
1.00 DTL	25.00	2450	0.251	Reading at beginning of 10-minute hold					0.254					
1.25 DTL	31.25	3050	0.329	Reading at beginning of 10-minute hold					0.329					
1.50 DTL (Creep*)	37.50	3650	0.410	0.411	0.412	0.411	0.411	0.411	0.410	0.412	0.412	0.416	0.416	0.416
1.75 DTL	43.75	4250	0.486	Reading at beginning of 10-minute hold					0.496					
2.00 DTL (MTL)	50.00	4850	0.576	Reading at beginning of 10-minute hold					0.578					
AL (0.10 DTL)	2.50	250	0.236											

AL = Alignment Load; DTL = Design Test Load

*Hold the load to within 2 percent and measure and record soil nail movement at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes

Verification Test Acceptance Criteria:

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1) Creep rate does not exceed 0.08 inch from 1-min to 60-minutes.

2) Total movement measured at the Maximum Test Load (MTL=2.00 DTL) exceeds 80 percent of theoretical elastic elongation of the non-bonded length.

Elongation Calculations

MTL =	50.00 kips		Lu (Unbonded Length) =	6 ft.	
E =	29000 ksi		A (X-Section Area) =	1.000 sq. in	#9 Bar
Theoretical Elongation	=	0.1179	inches		
80% Theoretical Elongation	=	0.0943	inches		
Actual Elongation	=	0.3420	inches	**> 80% Theoretical - Pass**	

Ram Load	Load Cell Reading
2.50	3.45
6.25	6.05
12.50	11.80
18.75	17.50
25.00	23.50
31.25	29.00
37.50	34.10
43.75	39.70
50.00	45.00
2.50	NR

Total Creep Movement From 1- to 60-minutes: 0.006 inches Pass

JACKING SOLUTIONS LLC

Rentals · Rebuilt Equipment · New Sales · Testing

5/19/2021

Calibration Results

CYLINDER		
	Manufacturer:	**Orbit**
	Model:	**ORDH506**
	S/N:	**DT50-6-9**

Effective Area
10.3

Certificate No: 359828275

Date: 5/19/2021

PUMP		
	Manufacturer:	**Power Team**
	Model:	**PE554**
	S/N:	**310053**

GAUGE		
	Manufacturer:	**McDaniel**
	Model:	**316SS**
	S/N:	**DT50-6-9A**

Test Data

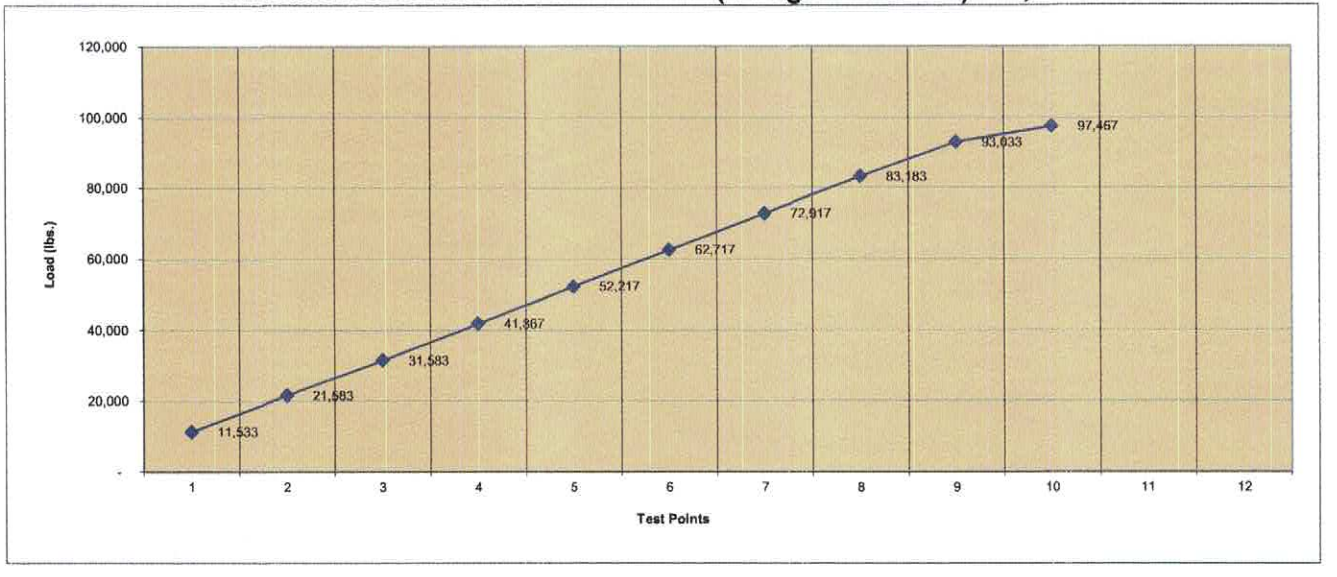
Gauge Pressure	Verified Actual Average Load	Calculated Load	Percent of Error
1000	11,533	10,300	10.69%
2000	21,583	20,600	4.55%
3000	31,583	30,900	2.16%
4000	41,867	41,200	1.59%
5000	52,217	51,500	1.37%
6000	62,717	61,800	1.46%
7000	72,917	72,100	1.12%
8000	83,183	82,400	0.94%
9000	93,033	92,700	0.36%
9500	97,467	97,850	-0.39%

Jacking Solutions LLC hereby certifies that the above described instrument(s) met or exceeded all published specifications at the time of calibration specified on attached Calibration Report. The instrument(s) has been calibrated using standards whose accuracies are traceable to the national Institute of Standards and Technology (NIST) within the limitations of the Institute's calibration services.

Tested by: _____

David Lilyblade
Jacking Solutions LLC

Calculation Curve: Load = 10.11 x (Gauge Pressure) + 1,423.12



10210 Auburn Black Diamond Rd · Auburn, WA 98092 · 206.595.2847 · Fax: 253.737.4102

JACKING SOLUTIONS LLC

Rentals • Rebuilt Equipment • New Sales • Testing

Certificate of Calibration Report

Certificate Number 359828275

Information

Customer:	Drill Tech Inc.
Contact:	Bill Creger
Address:	14201 SE Petrovitsky Rd. A3-302 Renton, WA. 98058
Phone:	510-598-0609
Fax:	

Calibrated Equipment

RAM	Manufacturer:	Orbit
	Model:	ORDH506
	S/N	DT50-6-9
PUMP	Manufacturer:	Power Team
	Model:	PE554
	S/N	310053
GAUGE	Manufacturer:	McDaniel
	Model:	316SS
	S/N	DT50-6-9A

Calibration Statistics

Date:	5/19/2021
Time:	12:05 pm
Temperature:	53 degrees
Humidity:	57 %

Results

Pass?:	Yes
Seals OK?:	Yes
Action Taken:	n/a

Standards used for Certification

Manufacturer:	National Scale	Date of Calibration	04/27/2021
Model:	1100083-660	Next Calibration Due	04/27/2022
S/N	39451		
Description:	compression load cell		

JACKING SOLUTIONS LLC

Rentals · Rebuilt Equipment · New Sales · Testing

5/19/2021

Calibration Results

CYLINDER		
	Manufacturer:	**Orbit**
	Model:	**ORDH506**
	S/N:	**DT50-6-9**

Effective Area
10.3

Certificate No: 359828276

Date: 5/19/2021

PUMP		
	Manufacturer:	**Power Team**
	Model:	**PE554**
	S/N:	**310053**

GAUGE		
	Manufacturer:	**McDaniel**
	Model:	**316SS**
	S/N:	**DT50-6-9B**

Test Data

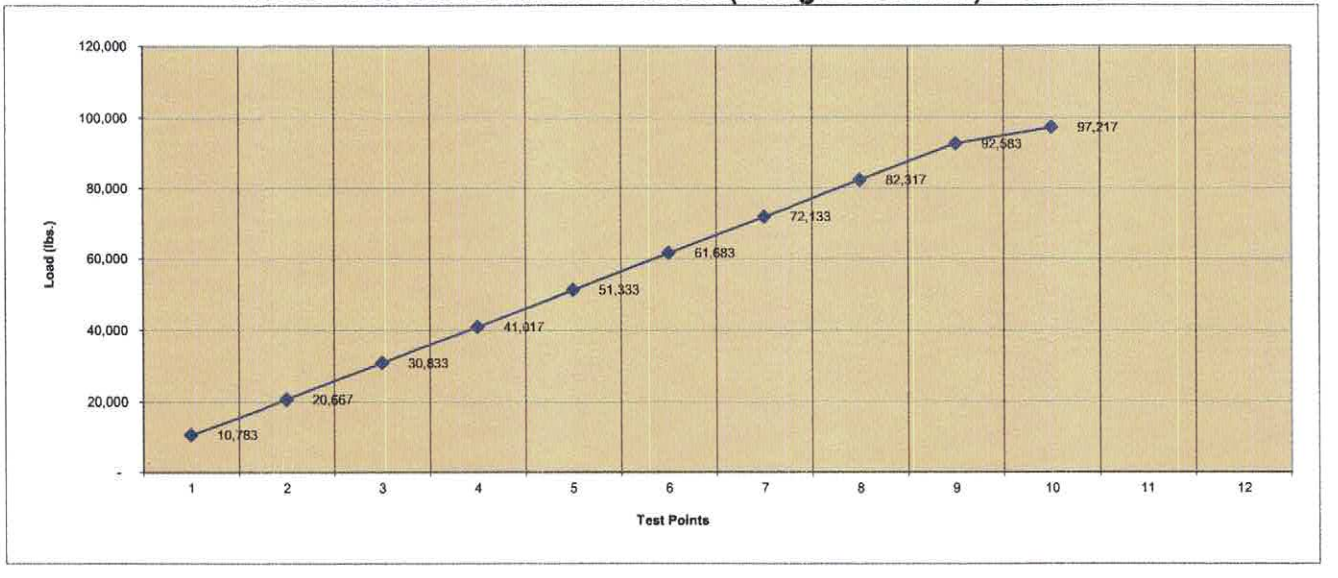
Gauge Pressure	Verified Actual Average Load	Calculated Load	Percent of Error
1000	10,783	10,300	4.48%
2000	20,667	20,600	0.32%
3000	30,833	30,900	-0.22%
4000	41,017	41,200	-0.45%
5000	51,333	51,500	-0.33%
6000	61,683	61,800	-0.19%
7000	72,133	72,100	0.05%
8000	82,317	82,400	-0.10%
9000	92,583	92,700	-0.13%
9500	97,217	97,850	-0.65%

Jacking Solutions LLC hereby certifies that the above described instrument(s) met or exceeded all published specifications at the time of calibration specified on attached Calibration Report. The instrument(s) has been calibrated using standards whose accuracies are traceable to the national Institute of Standards and Technology (NIST) within the limitations of the Institute's calibration services.

Tested by: _____

David Lilyblade
Jacking Solutions LLC

Calculation Curve: Load = 10.17 x (Gauge Pressure) + 614.29



JACKING SOLUTIONS LLC

Rentals • Rebuilt Equipment • New Sales • Testing

Certificate of Calibration Report

Certificate Number 359828276

Information

Customer:	Drill Tech Inc.
Contact:	Bill Creger
Address:	14201 SE Petrovitsky Rd. A3-302 Renton, WA. 98058
Phone:	510-598-0609
Fax:	

Calibrated Equipment

RAM	Manufacturer:	Orbit
	Model:	ORDH506
	S/N	DT50-6-9
PUMP	Manufacturer:	Power Team
	Model:	PE554
	S/N	310053
GAUGE	Manufacturer:	McDaniel
	Model:	316SS
	S/N	DT50-6-9B

Calibration Statistics

Date:	5/19/2021
Time:	2:29 pm
Temperature:	55 degrees
Humidity:	56 %

Results

Pass?:	Yes
Seals OK?:	Yes
Action Taken:	n/a

Standards used for Certification

Manufacturer:	National Scale	Date of Calibration	04/27/2021
Model:	1100083-660	Next Calibration Due	04/27/2022
S/N	39451		
Description:	compression load cell		

I-405 Renton to Bellevue Widening & ETL Project

Contract No. 9242

RW 9.05R-B Soil Nail Verification Test Results VN5 and VN6 (Revision 0)

Reference FLJV Submittal Nos. 0431 and 0477

Date: July 27, 2021

Owner: Washington State Department of Transportation (WSDOT)

General Contractor: Flatiron Lane JV

Submittal Author: Bill Creger

Specification References

Section 6-15 Soil Nail Walls per:

WSDOT 2018 Standard Specifications with Revisions, dated 01/07/19

Renton to Bellevue General Special Provisions, dated 12/19/18

I-405, Renton to Bellevue Widening & and Express Toll Lanes Project

DOCUMENT REVIEW

- ☐ APPROVED, NO EXCEPTION TAKEN
- ☐ APPROVED AS NOTED
- ☐ RESUBMIT, REVISE AS NOTED
- ☒ REVIEWED COMMENTS PROVIDED IF ANY

REVIEWED BY: J. Horton DATE: 8/9/21

Review is for general conformance with contract or design documents. Sole responsibility for correctness of dimensions, details, quantities, materials, and safety during fabrication and erection shall remain with the contractor

This Type 1 Working Drawing is confirming receipt and has been routed to the GSI for their information.

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DRILLTECH DRILLING & BORING, INC.
2200 Wymore Way, Antioch, CA 94509
Office: (925)978-2060 // Fax: (925)978-2063

Project:	I-405 Renton to Bellevue Widening & Express Toll Lanes		
Location:	Renton to Bellevue, WA		
Foreman:	Scott Brown		
Date:	7/20/2021	Job No.	20018

Sheet 1

Soil Nail Verification Test

8-inch Diameter Hole

Approx. STA 4+42, Approx Elev 170

Soil Nail No: VN6
Embedment Length (ft.) 10
Retaining Wall No: RW 9.05R-B

TEST LOAD	
Lb (ft):	10
Qd (kips/ft):	2.5
DTL (kips):	25

Ram Information
Ram No.: 50-6-9
Gauge No.: 50-6-9A
Calibr. Date 5/19/2021

Testing Schedule

Load Level	Load (kips)	50-6-9A (psi)	Elongation (Inches) 1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	10 min.	20 min.	30 Min.	40 Min.	50 Min.	60 Min.
AL (0.10 DTL)	2.50	300	0.000											
0.25 DTL	6.25	600	0.030	Reading at beginning of 10-minute hold					0.030					
0.50 DTL	12.50	1200	0.680	Reading at beginning of 10-minute hold					0.068					
0.75 DTL	18.75	1800	0.100	Reading at beginning of 10-minute hold					0.101					
1.00 DTL	25.00	2450	0.125	Reading at beginning of 10-minute hold					0.126					
1.25 DTL	31.25	3050	0.136	Reading at beginning of 10-minute hold					0.136					
1.50 DTL (Creep*)	37.50	3650	0.164	0.164	0.164	0.164	0.162	0.166	0.166	0.166	0.164	0.168	0.165	0.164
1.75 DTL	43.75	4250	0.176	Reading at beginning of 10-minute hold					0.175					
2.00 DTL (MTL)	50.00	4850	0.244	Reading at beginning of 10-minute hold					0.260					
AL (0.10 DTL)	2.50	300	0.084											

AL = Alignment Load; DTL = Design Test Load

*Hold the load to within 2 percent and measure and record soil nail movement at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes

Verification Test Acceptance Criteria:

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1) Creep rate does not exceed 0.08 inch from 1-min to 60-minutes.

2) Total movement measured at the Maximum Test Load (MTL=2.00 DTL) exceeds 80 percent of theoretical elastic elongation of the non-bonded length.

Elongation Calculations

MTL =	50.00 kips	Lu (Unbonded Length) =	7 ft.		
E =	29000 ksi	A (X-Section Area) =	1.000 sq. in	#9 Bar	
Theoretical Elongation	=	0.1376	inches		
80% Theoretical Elongation	=	0.1101	inches		
Actual Elongation	=	0.1760	inches	**> 80% Theoretical - Pass**	

Ram Load	Load Cell Reading
2.50	3.75
6.25	7.00
12.50	12.30
18.75	18.30
25.00	24.10
31.25	29.80
37.50	35.25
43.75	41.50
50.00	45.50
2.50	3.70

Total Creep Movement From 1- to 60-minutes: 0.000 inches Pass

DRILLTECH DRILLING & MINING, INC.
2200 Wymore Way, Antioch, CA 94509
Office: (925)978-2060 // Fax: (925)978-2063

Project:	I-405 Renton to Bellevue Widening & Express Toll Lanes		
Location:	Renton to Bellevue, WA		
Foreman:	Scott Brown		
Date:	7/20/2021	Job No.	20018

Sheet 1

Soil Nail Verification Test

Approx. STA 4+67, Approx Elev 172

Soil Nail No: VN5
Embedment Length (ft.) 10
Retaining Wall No: RW 9.05R-B

TEST LOAD	
Lb (ft):	10
Qd (kips/ft):	2.5
DTL (kips):	25

8-inch Diameter Hole

Nail pulled out at 4,500 psi (approx 46 kips). Once is started moving the nail would only hold at 4,000 psi (approx 41 kips)

Ram Information
Ram No.: 50-6-9
Gauge No.: 50-6-9A
Calibr. Date 5/19/2021

Testing Schedule

Load Level	Load (kips)	50-6-9A (psi)	Elongation (Inches) 1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	10 min.	20 min.	30 Min.	40 Min.	50 Min.	60 Min.
AL (0.10 DTL)	2.50	300	0.000											
0.25 DTL	6.25	600	0.010	Reading at beginning of 10-minute hold					0.010					
0.50 DTL	12.50	1200	0.045	Reading at beginning of 10-minute hold					0.045					
0.75 DTL	18.75	1800	0.082	Reading at beginning of 10-minute hold					0.082					
1.00 DTL	25.00	2450	0.121	Reading at beginning of 10-minute hold					0.120					
1.25 DTL	31.25	3050	0.167	Reading at beginning of 10-minute hold					0.169					
1.50 DTL (Creep*)	37.50	3650	0.230	0.233	0.233	0.233	0.233	0.232	0.238	0.238	0.242	0.242	0.242	0.246
1.75 DTL	43.75	4250	0.623						0.627					
2.00 DTL (MTL)	50.00	4850	NA	Reading at beginning of 10-minute hold					NA					
AL (0.10 DTL)	2.50	250	1.308											

AL = Alignment Load; DTL = Design Test Load

*Hold the load to within 2 percent and measure and record soil nail movement at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes

Verification Test Acceptance Criteria:

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1) Creep rate does not exceed 0.08 inch from 1-min to 60-minutes.

2) Total movement measured at the Maximum Test Load (MTL=2.00 DTL) exceeds 80 percent of theoretical elastic elongation of the non-bonded length.

Elongation Calculations

MTL =	50.00 kips	Lu (Unbonded Length) =	6 ft.		
E =	29000 ksi	A (X-Section Area) =	1.000 sq. in	#9 Bar	
Theoretical Elongation	=	0.1179	inches		
80% Theoretical Elongation	=	0.0943	inches		
Actual Elongation	=	#VALUE!	inches	FAIL, didn't reach 2xDLT	

Ram Load	Load Cell Reading
2.50	4.70
6.25	7.45
12.50	13.50
18.75	18.00
25.00	24.60
31.25	NA
37.50	NA
43.75	NA
50.00	NA
2.50	NA

Total Creep Movement From 1- to 60-minutes: 0.016 inches Pass