Foundation Investigation and Design Report

Embankment Settlements and Distortions

GWP 6310-10-00
Station 23+700, in Unsurvey Territory Block 492923
Highway 502, 66 km North of Highway 11
GeoCres No.: 52F-046

SUBMITTED TO:

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Part A - FOUNDATION INVESTIGATION REPORT

1 Part A Introduction

TBT Engineering Limited (TBTE) has been retained by MTO Northwestern Region (MTO) to provide a foundation investigation and design report to investigate ongoing settlement and distortion issues along an existing embankment at Station 23+700 (belly of the crescent cracking) along Highway 502, in Unsurvey Territory Block 492923. This work has been completed as a change order under WP 6310-10-00 Hwy 502 – 66 km North of Hwy 11 Northerly.

The embankment at this location has historically performed poorly and has exhibited crescent cracking and settlement within the south bound lane and has required numerous asphalt patching works to re-level the roadway surface.

This investigation consisted of advancing a total of five boreholes and two DMTs. Three boreholes were advanced at the left shoulder of the road way, and the remaining boreholes and DMTs were completed outside of the left side embankment toe. The boreholes were carried out to provide sub-surface data and collect soil samples to preform laboratory testing and to develop models for geotechnical analysis. This report (Part A) describes the subsurface conditions encountered during the investigation.

2 Site Description

The embankment is situated on a curve and a hill with the grade increasing down chainage. The poorly performing southbound lane is on the outside of the curve. The cracking exhibited in the south bound lane generally forms a series of crescent shapes over a length of approximately 60 m. The surrounding terrain is typically low lying cedar swamp along the left side toe with near vertical bedrock out crops along the right side of the embankment.

Over the 60 m long problem area, the right side of the embankment varies from 4 to 5 m in height with side slopes ranging from approximately 1 and 2 horizontal to 1 vertical. The left side of the road embankment varies in height from 4 to 7 m with side slopes ranging from approximately 2 and 1.5 horizontal to 1 vertical.

Photo 2.1 – Cracking Looking Down Chainage from Station 23+725 (approx.)

Photo 2.2 – Embankment at Center from Toe

3 Surficial Geology

Available surficial geology mapping (OGS NOEGTS Map 52FSE) indicates the site is located in a bedrock knob terrain unit comprised primarily bedrock with moderate local relief.

4 Investigation Procedures

A geotechnical site investigation was undertaken from October 7 to 15, 2015. The borehole and DMT locations are illustrated on the Borehole Location and Soil Strata Drawing found in Appendix C.

The investigation was completed using a CME 55 drill rig for the boreholes through the embankment, and a tripod set up (with cat head) for the boreholes at the embankment toe. An excavator was used to advance the DMTs. The CME 55 drill rig is equipped for geotechnical testing and sampling. Hollow stem auger, casing, and diamond core drilling methods were utilized for this project.

The borehole locations were identified in the field by TBTE personnel and service clearances were completed prior to mobilizing the drill rig to site.

Soil samples were obtained at the boreholes using a split spoon sampler as a part of the Standard Penetration Testing (SPT). The SPT involves driving a thick walled sampler into the soils under a standardized energy (63.5 kg, falling 760 mm). The number of blows required to drive the sampler 0.3 m is known as the SPT blow count (N). Refusal material was sampled using diamond coring techniques. Boreholes were backfilled in accordance with O. Reg. 903.

The flat plate dilatometer (DMT) consists of a blade shape probe which is pushed into the soil with minimal disturbance. At 200 mm intervals, the steel membrane within the blade is inflated laterally and the forces required to deform the soil are measured. The data obtained is interpreted based on published correlations to aide in the selection of engineering properties.

SPT “N” values reported on the borehole logs and referenced in Section 6 (Sub-Surface Conditions) are uncorrected field values.

A topographical survey was carried out utilizing a Trimble Model 3 RTK Survey Grade GPS System. The survey was conducted in North American Datum 1983 MTM Zone 16 and Canadian Geodetic Vertical Datum (CVD – 1928), 1978 Adjustment.

5 Laboratory Testing

Samples which were obtained during the field investigation were subjected to laboratory testing consisting of moisture content, grain size analysis, Atterberg limit tests, point load testing (rock cores), and direct shear testing. The results of these tests are shown on the Borehole Logs (Appendix A) and on the laboratory data reports (Appendix B).

6 Sub-Surface Conditions

Details of the subsurface conditions are provided on the borehole logs (Appendix A), laboratory reports (Appendix B) and on the Soil Strata Drawing (Appendix C).

The subsurface soils at this site typically consist of fills (granular and rock) through the embankment overlying sand and/or clay (with layers of sandy silt) followed by bedrock. Organic material was encountered at surface of Borehole 4 located at the toe of the embankment.

6.1 Asphalt

Asphalt was encountered at the surface of Boreholes 1, 2 and 3. The zone of asphalt varies in thickness from 0.1 to 0.5 m. The asphalt layering at Borehole 1 consists of a 0.2 m layer of asphalt at surface underlain by a 0.1 m layer of fill which is underlain by a second layer of asphalt 0.3 m thick.

6.2 Organic Material

Organic material was encountered at the ground surface of Borehole 4. The organic material is 0.6 m thick with a natural moisture content of 314 %.

6.3 Fill – Sand and Gravel

Embankment fill was encountered beneath the asphalt at Boreholes 1, 2 and 3. The fill varied in thickness from 0.9 to 3.8 m, and was encountered at elevations ranging from 416.1 to 417.0 m. This material is sand and gravel with trace amounts of silt. The test results (two tests) indicate a grain size distribution of 37 to 48 % gravel, 44 to 56 % sand, and 7 to 8 % silt/clay sized particles. The fill is loose to dense as indicated by “N” values ranging from 7 to 31 blows/0.3 m. During drilling at Borehole 1 at a depth of 1.5 m, the augers dropped 100 mm indicating the presence of a “void” within this material.

6.4 Rock Fill

Rock fill was encountered beneath the sand and gravel fill at Boreholes 1, 2, and 3. The rock fill varied in thickness from 1.5 to 3.3 m, and was encountered at elevations ranging from 413.2 to 418.2 m. The material is compact to very dense as indicated by an “N” value of 17 and numerous “N” values of 100+ (on cobbles and or boulders) blows/0.3 m.

6.5 Sand

Sand was encountered beneath the rock fill at Borehole 2, and at the ground surface of Borehole 5. The sand varied in thickness from 0.7 to 0.8 m, and was encountered at elevations of 411.0 (Borehole 2), and 411.9 m (Borehole 5). The sand layer at the surface of Borehole 5 contained significant organic material and trace amounts at Borehole 2. This material is in a loose condition as indicated by “N” values of 6 to 8 blows/0.3 m.

6.6 Clay

Clay with trace gravel and trace to some sand was encountered beneath the rock fill at Boreholes 1 and 2, beneath the organic material at Borehole 4, and beneath the sand at Borehole 5. Boreholes 2, 4 and 5 terminated within this material. At Borehole 1 this stratum was 2.3 m thick, and encountered at elevations ranging from 410.3 to 411.7 m. Within this clay stratum, two sandy silt layers were identified at Borehole 5 (as discussed below). Interpretation of DMTs 1 and 2 indicates the presence of clay with intermittent layers of silt to silty sand.

Nine grain size analysis indicates the material consists of 0 to 6 % gravel, 1 to 12 % sand, 35 to 49 % silt and 48 to 61 % clay sized particles. Based on nine Atterberg Limit tests, the clay is of medium plasticity with a natural moisture content generally approaching or slightly exceeding the liquid limit.

The clay has a soft to firm consistency based on “N” values ranging from 3 to 10 blows/0.3 m. Based on in situ field vane tests ranging from 81 to 100+ kPa the clay condition is stiff to very stiff. Interpretation of the of DMTs 1 and 2 indicate that the clay has a consistency generally ranging from firm to stiff with one thin very soft zone identified near the ground surface at DMT

2 and one soft reading near the ground surface of DMT 1. The clay is considered to be frost susceptible.

A set of consolidated drained direct shear tests was completed to estimate the residual effective stress strength parameters of the clay. The sample tested was from Borehole 1 at a depth of 6.7 m. The results of this testing indicate a residual shear strength of c' = 0 kPa and ϕ' = 30°.

6.7 Silt

Sandy silt with trace gravel was encountered intermittently within the clay at Borehole 5 and as interpreted at DMTs 1 and 2. The two silt layers encountered in Borehole 5 were at elevations 409.6 and 407.3 m, with thicknesses of 0.7 and 0.6 m respectively. Based on two grain size analysis the material consists of 0 to 1 % gravel, 24 to 29 % sand, and 70 to 76 % silt/clay sized particles. The silt is loose to compact as indicated by "N" values of 9 to 24 blows/0.3 m. This material is considered to be frost susceptible.

6.8 Bedrock

Bedrock was encountered within Boreholes 1 and 3 at depths of 8.2 and 3.6 m, respectively. The following table indicates the recorded bedrock elevation and depth at each borehole. Bedrock was sampled using diamond coring techniques. The bedrock is a fine to medium grained dark to green to grey mafic volcanic. Detailed core logs and photos of the rock cores are provided in Appendix A.

Table 6.1: Auger Refusal and Bedrock

Borehole Number	Bedrock Depth (m)	Bedrock Elevation
1	8.2	409.4
3	3.6	415.6

The rock quality designation (RQD) is an indirect measure of the number of fractures and the amount of jointing in the rock mass. The RQD is expressed as a percentage of the ratio of summed core lengths (greater than 100 mm) to the total length cored. The RQD index is used to provide a classification for the rock quality according to the following limits.

Table 6.2: RQD/ Rock Quality Correlation

RQD %	**ROCK QUALITY**
0 – 25	**Very Poor**
25 – 50	**Poor**
50 – 75	**Fair**
75 – 90	**Good**
90 – 100	**Excellent**

The RQD as presented on the borehole and core logs typically varies from 47 to 100 % indicating poor rock quality (2 of 5 cores), one fair core, one good core and one excellent core.

In order to classify the bedrock with respect to strength, point load tests were conducted on selected core samples. The test results are tabulated below.

Table 6.3: Estimated Uniaxial Compressive Strength

Borehole Number	Depth (m)	Elevation	*Estimated Uniaxial Compressive Strength (MPa)
1	8.6	409.0	193
	9.2	408.4	236
	10.2	407.4	240
3	5.1	414.1	21
	5.6	413.6	208
	7.7	411.5	199

* Estimated based on published correlations.

Based on the range in estimated uniaxial compressive strength, the intact bedrock is classified as very strong, with the exception of a single sample classified as weak.

6.9 Groundwater

Groundwater was not observed during drilling of the roadway boreholes, but was observed within 1 m of ground surface at the boreholes at the embankment toe. Groundwater levels will vary from season to season and from the effects of heavy precipitation events

Permeable materials were identified within the clay stratum. At times of high groundwater, or if they are connected to pressurized systems, artesian conditions may exist within these strata.

7 Miscellaneous

Laboratory testing was completed at the TBT Engineering Limited laboratory in Thunder Bay. The drill equipment for this investigation was operated by TBT Engineering. The field operations were supervised by Alan Finke. Laboratory testing was supervised by T. Fummerton C.E.T. This report was prepared by Steven Seller, P.Eng and Gordon Maki, P.Eng. and reviewed by W. Hurley, P.Eng (TBTE designated principal contact identified for MTO Foundation Engineering projects).

Part B - FOUNDATION DESIGN REPORT

8 Part B Introduction

TBT Engineering Limited (TBTE) has been retained by the Ministry of Transportation Northwest Region to provide foundation investigation and design services to address the ongoing settlement and distortion issues at the embankment at Station 23+700 on Highway 502, in in Unsurvey Territory Block 492923.

The foundation investigation as described in Part A, was carried out to investigate subsurface conditions at this site. The investigation consisted of five boreholes and two DMTs. The subsurface soils at this site typically consist of embankment fills (sand and gravel over rock fill) overlying sand and/or clay (with sandy silt layers) which is in turn underlain by bedrock.

The purpose of this section of the report (Part B) is to provide foundation design alternatives for the planning of the rehabilitation of the embankment. Varying degrees of additional investigations, studies and reporting may be required to finalize the chosen mitigation measure for the embankment.

Design alternatives are based on the existing site configuration, embankment configuration and the conditions encountered at the borehole locations and TBTE's interpretation of the subsurface conditions at the site.

9 Embankment Distortions and Settlements

The ongoing issues at Station 23+700 continue to cause settlements and cracking in the southbound lane over a 60 m long section of the highway. It is understood that the distortions/settlements have not been escalating, but have been an ongoing matter over an unknown period of time. The settlement of the south bound lane is apparent with the drastic distortion of the cable guide posts and multiple layers of increased asphalt thickness at the center of the series of crescent shaped pavement cracking. Until remediation measures can be implemented, it is recommend that the MTO visually inspect this embankment on a regular basis to monitor the road surface condition and ensure that any settlement/distortion does not begin to escalate.

The northbound lane's ditch should be inspected/reviewed to ensure that positive drainage (up chainage and away from the embankment) is provided to prohibit infiltration of surface water into the embankment.

9.1 Mechanisms Attributed to Ongoing Settlement and Distortions

Based on the available information and results of slope stability modeling, two possible mechanisms have been identified as contributing factors to the distortions/settlements. The mechanisms at work are believed, but potentially not limited to the following:

- Insufficient Embankment Stability:
  - Factors of safety (FoS) of less than 1.5 have been computed for the existing embankment configuration. Variations in the bedrock profile and groundwater levels were taken into consideration for the modeling.
  - An insufficient factor of safety against shear failure can be associated with creep movements, and could manifest in terms of the distortions/settlements observed.
- Internal Embankment Soil Migration:
  - Rock fill is present beneath the sand and gravel fill.
  - An improperly prepared rock fill surface would allow the migration of smaller particle size soil (granular fill) into void space of the rock fill.
  - Migration of the sand and gravel fill into the void space of the rock fill could manifest in as the distortions/settlements observed.
  - The void encountered in Borehole 1 within the sand and gravel fill is an indication that sand and gravel fill may be migrating into the void space of the rock fill.

10 Global Stability of Embankment

An assessment of global stability of the existing embankment configuration and mitigation measures were completed using Slope/W software and limit equilibrium analysis using the Morgenstern-Price method. Given the observed embankment movements, residual effective strength parameters were used for the clay. The soil properties established/estimated for the embankment and foundation soils are presented in Table 10.1.

Table 10.1: Stability Analyses Soil Properties

Soil	Effective Shear Strength Properties		Total Stress Shear Strength, Cu (kPa)	Unit Weight, γ (kN/m^3)
	Effective Angle of Internal Friction, φ' (degrees)	Effective Cohesion Intercept, C' (kPa)		
Embankment Fill	32	0	-	19
Weak Embankment Fill	28	0	-	19
Organics	28	0	-	12
Rock Fill	40	0	-	18
Native Clay	30	0	-	18
Clay/Bedrock Interface (1)	20	0	-	18
Fill/Bedrock Interface (2)	24	0	-	19
Rock Fill/Bedrock Interface (3)	28	0	-	19
Compacted Granular	35	0	-	20

The stability modeling was completed to assess the current factor of safety against shear failure for the existing embankment configuration and to determine measures to improve stability. A design traffic loading of 20 kPa was considered.

1. Existing Embankment Configuration
    - The geometry of this configuration was based on recent surveyed cross sections.
    - It is understood that additional fills were placed after initial construction to flatten the southbound lane side slope. The gradation of this material and its method of placement is unknown and has been modeled in a loose condition (weak embankment fill).
2. Proposed Stability Improvement Configuration
    - Existing embankment configuration incorporating a rock fill flanking berm and embankment widening was considered as one alternative.

- Reconstruction of the embankment leaving the existing rock fill in place and rebuilding with compacted granular fill or rock fill was considered as a second alternative.

Several variables were incorporated into the stability models to predict the response of the embankment under various conditions. The variables introduced are as follows:

1. Variations in Groundwater
    a. The models were subject to estimated high and low groundwater levels.
    b. The high groundwater level was estimated assuming a water level at 1 m above the northbound lane's ditch invert, or just above the high bedrock level.
    c. Given the presence of permeable rock fill at the base of the embankment, the estimated high groundwater level within the embankment is likely conservative. However, the zone of rock fill may not drain sufficiently during freezing conditions (with ice buildup), or if seepage is impeded due to soil infilling or placement of zones of less permeable fills within the rock fill.
2. Bedrock Profile
    a. Due to the high variability of the bedrock surface, estimations of the bedrock's profile were made.
    b. The profile of the bedrock slope and relative proximity to the surface of the embankment significantly influences stability.
    c. Where embankment fill and native clay are adjacent to the bedrock, a zone of reduced strength material (interface materials) were modelled to account for a reduced shear resistance along the bedrock surface.

10.1 Interpretation of the Slope Stability Analysis

The slope modeling indicates that the level of stability for the existing embankment, may be less than optimum (FoS < 1.5). The calculated FoS (considering the variables) range from 1.0 to 1.3.

The embankment will require modification to address the low FoS of stability. As requested, designs have been completed to provide minimum factors of safety of 1.3 and 1.5. To provide the increased stability of the embankment two approaches were analyzed; the addition of a flanking berm to the existing embankment, and reconstruction of the embankment. The embankment reconstruction alternative was considered to improve stability and to address the potential migration of the existing granular fills over the existing rock fill (as discussed in Section 11).

The results of the stability analysis are presented below, and examples of the modeling are provided in Appendix D:

Table 10.2: Stability Analyses Results

Configuration	Bedrock Profile	Groundwater	Target FoS	Computed FoS
Existing	Low	Low	1.5	1.3
		High		1.1
	High	Low	1.5	1.2
		High		1.0
Flanking Berm and Wideneing	Low	High	1.5	1.7
	High			1.5
	Low	High	1.3	1.6
	High			1.3
Reconstruction with Rock Fill	Low	High	1.5	1.6
	High			1.5
	Low	High	1.3	1.6
	High			1.3
Reconstruction with Compacted Granular	Low	High	1.5	1.7
	High			1.5
	Low	High	1.3	1.7
	High			1.3

11 Soil Migration

Soil migration between two granular soils occurs when soil particles of the finer graded soil are transported into or though the void space of the coarser graded soil. The transport of material is typically facilitated by gravity and/or movement of groundwater. Soil migration can result in surface settlements and distortions due to the resulting soil loss. The existing void identified within the sand and gravel fill may be attributed to soil migration of the sand and gravel into the underling rock fill.

Typical construction of sand and gravel fill over rock fill utilizes “chinking” of the rock surface or the use of graded or geotextile filter materials to reduce the risk of soil migration. There is no evidence of graded fill or geotextile filter being used. It is also unknown if chinking practices were used during original construction.

Potential treatment options to eliminate or reduce the risk of migration include the following:

- Grouting of the rock fill to infill the voids. This option is not recommended as grouting would be challenging to ensure all the voids are in filled. In addition, this will reduce the permeability of the rock fill and impact potential seepage gradients through the embankment.
- Construct a filter zone between the sand and gravel fill and rock fill. This can be accomplished by chinking the rock surface and/or placement of a filter material. This option will require excavation to the rock fill surface. The entire embankment would need to be reconstructed above the rock fill level.

12 Mitigation Options to Address Distortions and Settlements

Based on the above assessment of the potential mechanisms contributing to the settlements and distortions, the following options have been provided:

Option 1 - Highway Realignment:

This option involves realignment of the highway towards the north which would require a foundation investigation, and construction of a new portion of highway, allowing the existing portion of highway to remain in use during construction. The realignment could also be considered to straighten out the existing curve, but would still have to contend with the vertical alignment and bedrock out crops. The extent of the realignment has not been assessed as part of this scope of work. New property would be required to accommodate the new alignment.

This option would avoid the current problem area by discontinued use of the embankment. The new alignment would need to be designed to perform to MTO standards.

Option 2 – Reconstruction of the Embankment:

Reconstruction of the embankment may be considered to mitigate both soil migration and embankment stability. This would require the complete removal of the sand and gravel fill to expose the top of the rock fill. The new embankment would also utilize a flanking berm. The existing embankment should be reconstructed from Station 23+670 to Station 23+730.

For this option, the replacement of the material above the existing rock fill has been completed using either rock fill or compacted granular between the existing rock fill and the pavement structure. The rock surface would need to be chinked and potentially covered with a heavy non-woven geotextile. All organic material beyond the existing toe (below the foot print of the new flanking berm) should be stripped from the below the proposed reconstruction footprint. Inspection should be conducted to determine if organic material exists beneath the existing rock fill, if so it should be removed. In order to provide the minimum requested factors of safety the following configurations are required:

Illustration 12.1 – Reconstruction with Rock Fill FoS 1.5

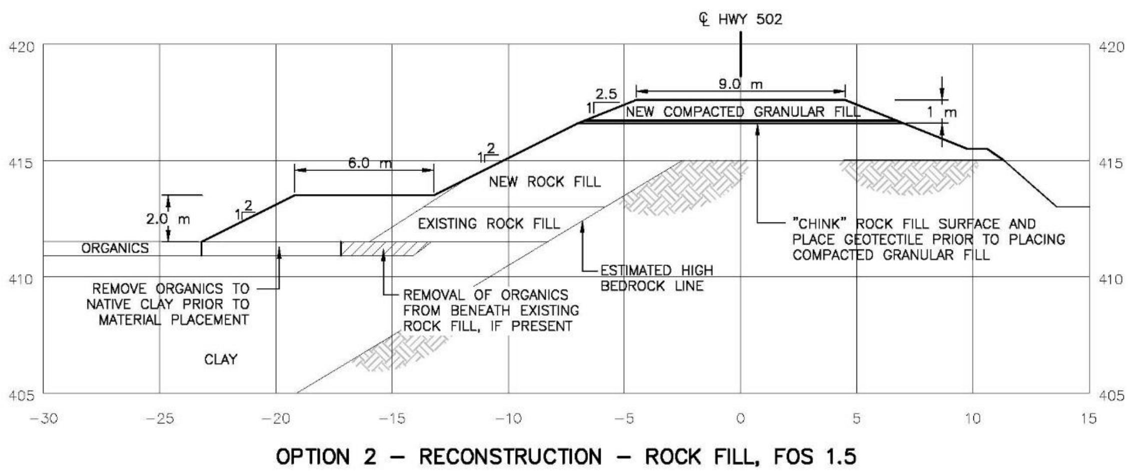
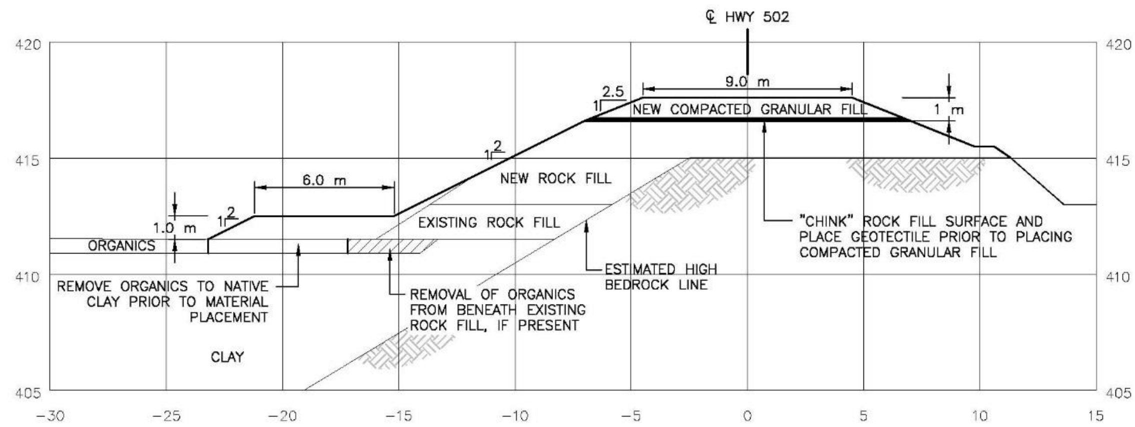
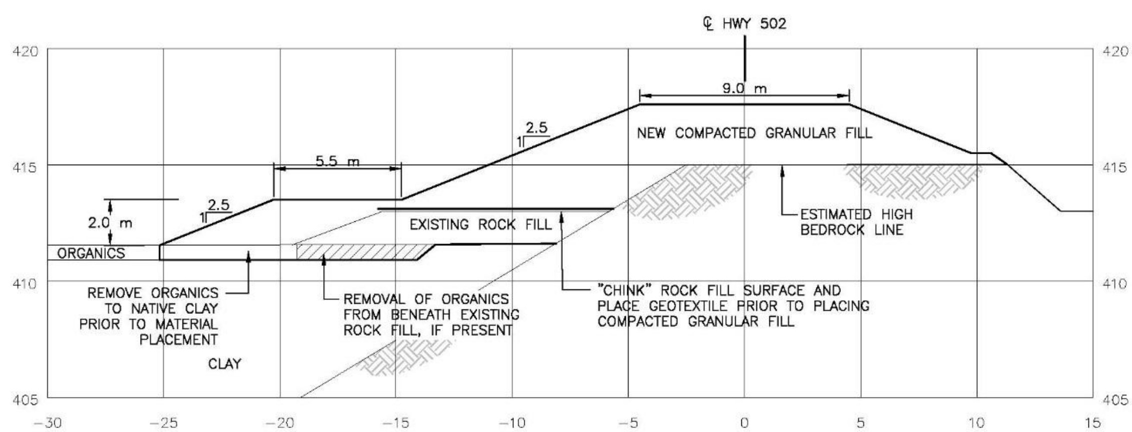


Illustration 12.2 – Reconstruction with Rock Fill FoS 1.3



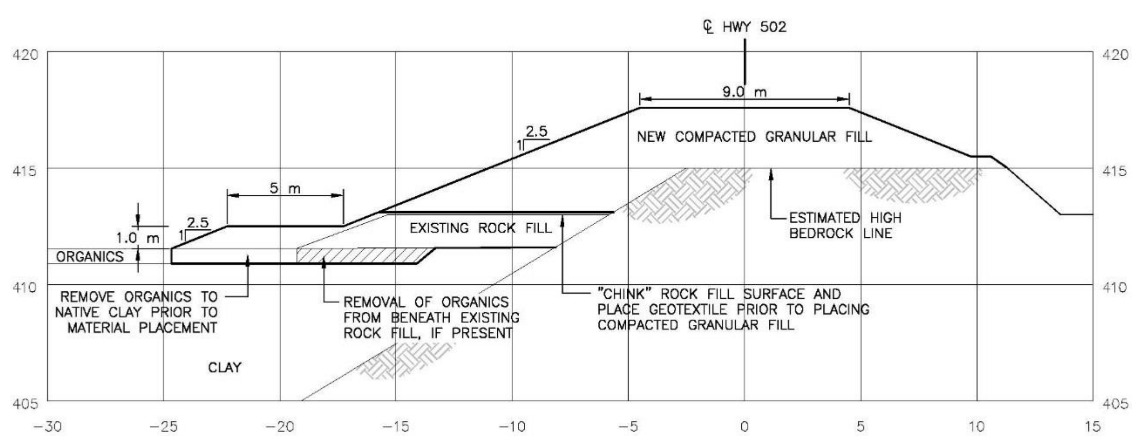
OPTION 2 – RECONSTRUCTION – ROCK FILL, FOS 1.3

Illustration 12.3 – Reconstruction with Compacted Granular FoS 1.5



OPTION 2 – RECONSTRUCTION – GRANULAR FILL, FOS 1.5

Illustration 12.4 – Reconstruction with Compacted Granular FoS 1.3



OPTION 2 – RECONSTRUCTION – GRANULAR FILL, FOS 1.3

A design factor of safety of 1.3 is considered suitable to reduce the risk of a sudden and extensive failure; however, given the uncertainty with respect to the bedrock profile and water levels within the embankment, a design FoS of 1.5 is recommended. It should be noted that at any time (pre to post construction) a 1.3 FoS remediation option can be “upgraded” to a 1.5 FoS remediation option. The “upgrade” would require additional materials, and potentially additional property and clearing.

The new configurations will induce new settlements along the existing roadway. The maximum estimated settlements at the edge of southbound lane, roadway centerline, and the edge of the northbound lane are less than 25 mm, less than 13 mm and less than 5 mm, respectively. Additional settlement of the embankment (rock fill option) will be experienced as the new rock fill settles. The amount of settlement is dependent on the amount (thickness) of the new rock fill placed, and will vary from 10 to 30 mm (in addition to that noted above) for compacted rock fill.

Embankment excavations (based on Borehole 1) could extend as deep as 4.4 m from roadway surface. The depth of excavation required, could pose problems in maintaining an open lane for traffic, a vertical staging program would have to be investigated to see if it can be practically completed. The narrow roadway and bedrock outcrop adjacent to the northbound lane complicates the construction of a widening at this location, and will probably require rock excavation. In lieu of a widening, a reroute, highway closure or full detour may be required in order to facilitate reconstruction. In order to design a detour or widening, additional investigations would be required, such as a foundation investigation, survey and highway design. Additional property will be required to accommodate the embankment reconstruction, and any potential detour.

During reconstruction of the embankment, the following measures/precautions should be adhered to:

- Removal of material to should be completed in a top down fashion.
- Inspection of the exposed rock fill surface must be completed to determine the extent of infilling of the rock fill.
- No material shall be stock pilled on the top of the embankment.
- All construction materials shall be brought to site at the base of the embankment and not delivered over the embankment edge.

- No construction or waste material shall be stockpiled on the embankment slope.
- Excavation of organic material should be completed is small strips (maximum width of 5 m) and replaced with construction material immediately. Excavations at the toe of the embankment should be backfilled at the end of each shift.
- Depending on potential staging requirements excavations should not be steeper than 2(H):1(V). If seepage is encountered within the granular fills flatter slopes or granular sheeting may be required.
- Any material considered for reuse should be separated, stockpiled and tested ensure the material meets specifications and does not become contaminated.

Option 3 – Construction of a Flanking Berm and Embankment Widening

Construction of a flanking berm and widening along the embankment slope for the south bound lane would only address the insufficient embankment stability. This option does not address potential soil migration issues at the site. As such, settlements and distortions may continue requiring continued maintenance. It is understood that as part of the overall project, this area will be resurfaced. During the resurfacing, once the asphalt has been removed, a large vibratory packer could be used on the existing sub-base material. This may aid in the removal of any potential voids within in the sand and gravel fill. The flanking berm should be constructed from Station 23+670 to Station 23+730.

In order to provide the requested factors of safety (1.3 and 1.5), two berm configurations have been designed.

All organic material should be stripped from the proposed flanking berm's footprint. Inspection should be conducted to determine if organic material exists beneath the existing rock fill. Removal of organic material beneath the existing rock fill may not be possible without destabilizing the slope, and appropriate measures/construction practices should be taken to ensure the stability of the embankment. Alternatively the organic material can be left in place and minor settlements from the consolidation of the organic material may be experienced.

In order to provide the minimum requested factors of safety, the following configurations are required.

Illustration 12.5 – Flanking Berm and Embankment Widening FoS 1.5

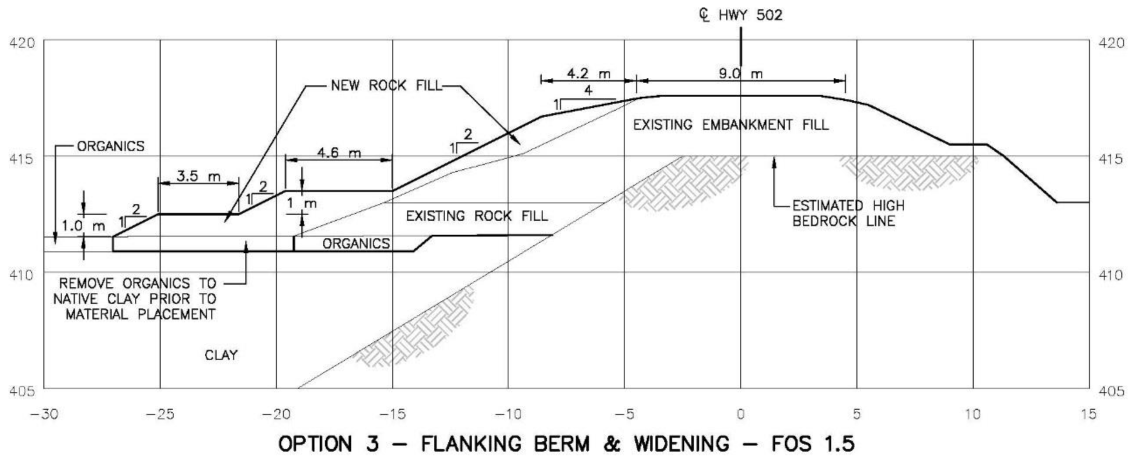
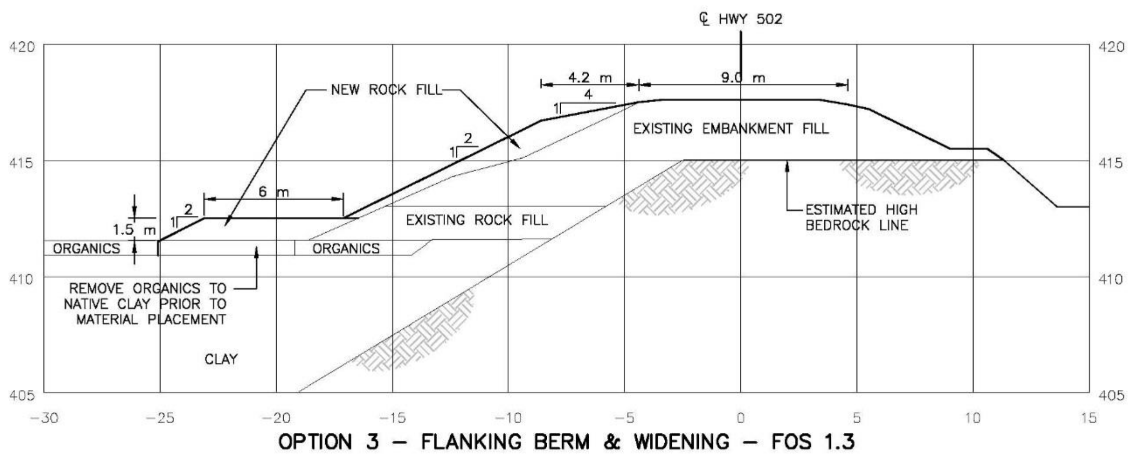


Illustration 12.6 – Flanking Berm and Embankment Widening FoS 1.3



A design factor of safety of 1.3 is considered suitable to reduce the risk of a sudden and extensive failure; however, given the uncertainty with respect to the bedrock profile and water levels within the embankment, a design FoS of 1.5 is recommended. It should be noted that at any time (pre to post construction) a 1.3 FoS remediation option can be “upgraded” to a 1.5 FoS remediation option. The “upgrade” would require additional materials, and potential additional property and clearing.

The new configurations will induce new settlements along the existing roadway. The maximum estimated settlements at the edge of southbound lane, roadway centerline, and the edge of the northbound lane are less than 25 mm, less than 13 mm and less than 5 mm, respectively. Additional settlement of the embankment (rock fill option) will be experienced as the new rock fill settles. The amount of settlement is dependent on the amount (thickness) of the new rock fill placed, and will vary from less than 10 to 20 mm (in addition to that noted above) for compacted rock fill.

During construction of the widening and flanking berm, the following measures/precautions should be adhered to:

- The existing embankment should be benched prior to placement of the widening material as per OPSD 208.010, using a maximum of 0.5 m high benches. Minor sloughing of the benches may occur during excavation.
- Removal of material to complete benches should be completed in a top down fashion.
- No material shall be stock pilled on the top of the embankment and construction traffic should be limited within the south bound lane.
- All construction materials shall be brought to site at the base of the embankment and not delivered over the embankment edge.
- No construction or waste material shall be stockpiled on the embankment slope.
- Excavation of organic material should be completed is small strips (5 m wide maximum) and replaced with construction material immediately. Excavations at the toe of the embankment should be backfilled at the end of each shift.

Construction of the flanking berm could be completed while maintaining the northbound lane open of traffic, pending the development of a staging/construction program. Additional property is required for the flanking berm.

Table 12.1 - Mitigation Options Comparison Table

Option	Advantages	Relative Cost	Additional Investigations	Property Required	Maintaining Traffic	Addresses all Identified Mechanisms
Option 1 New Alignment	Newly engineered embankment and roadway. Free of any pre-existing conditions. Potential benefits to highway engineering.	High	Foundation Survey Geotechnical Environmental Highway	Yes. Potentially extensive	Traffic can remain on existing roadway during construction of new alignment.	Yes.
Option 2 Reconstruction	Newly engineered embankment slopes provides a stable embankment. Construction of a barrier or filter will eliminate internal soil migration.	Moderate to High	Foundation – Detour/ Widening Survey Highway	Yes. Enough to accommodate flattened slopes, berms and potential detour lane.	Widening the north bound lane may be possible but will require detailed design to confirm. A detour could impact the relative cost.	Yes.
Option 3 Flanking Berm	Could be quickly implemented. Addresses insufficient stability.	Low	Survey	Yes. Enough to accommodate flanking berm.	Partial lane closure required.	No. Potential maintenance required to address settlement from soil migration.

12.1 Mitigation Measures Summary

The ongoing settlement and distortion of the embankment at Station 27+300 along Highway 502 can be mitigated through several actions. These vary from realigning the highway (Option 1), rebuilding of the existing embankment with a flanking berm (Option 2), to a partial remedy (flanking berm and widening only) which may require ongoing maintenance (Option 3). TBTE recommends Option 1 as the most comprehensive alternative to solve all foundation issues, and eliminate any concern over the potential uncertainties at the existing site. Although Option

1 will be the option with the highest estimated relative cost the elimination of all the foundation issues and the potential benefit to the overall highway may outweigh the actual additional cost. In the event that budgetary constraints do not allow for the implementation of Option 1, Option 3 offers the best manageable solution (in financial and constructability terms).

Option 1, realignment, offers the opportunity to potentially straighten a portion of Highway 502, and to construct a well performing embankment avoiding the problem area. While the new alignment is being investigated and ultimately constructed, the existing roadway can be maintained and left open to traffic. Although this option may carry a significant cost above the other options, there may be other benefits to the overall project and should be considered.

Option 2, reconstruction, will address both mechanisms which are contributing to the distortion/settlement. However, construction staging and maintaining traffic through the corridor may prove problematic, and will require additional investigations and design. If the existing corridor must be maintained then this option is recommended.

Option 3, slope flattening and flanking berm only, will address only one of the two mechanisms which are expected to be contributing to the distortion/settlement. Future ongoing maintenance of the roadway surface may be required since soil migration may continue. As work is being completed, the northbound lane should be available to maintain traffic while the southbound lane will require closure to facility the construction. This option would have the smallest relative cost, and may be considered where ongoing future maintenance cost can be tolerated to address possible future distortions and settlements.

13 Limitations

Conclusions and recommendations presented in this report are based on the information determined at the borehole locations. Subsurface and groundwater conditions between and beyond these locations may differ from those encountered. Conditions may become apparent during construction that were not detected and could not be anticipated at the time of the site investigation.

The comments given in this report on potential construction problems and possible methods of construction are intended only for the guidance of the designer.

Groundwater levels indicated are based on the information described within the report. The presence of all conditions that could affect the type and scope of dewatering procedures which may be considered cannot readily be determined from boreholes. These include local and seasonal fluctuations of the groundwater level, changes in soil conditions between test locations, thin and/or discontinuous layers of highly permeable soils, etc.

The information contained within this report in no way reflects any environmental aspect of the site or soil.

14 Closure

We trust the above addresses your project requirements at this time. Should you have any questions or comments, please do not hesitate the contact us at your convenience.

Yours truly,
For TBT ENGINEERING

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APPENDIX A

Borehole Logs

Ministry of Transportation
Ontario

Foundation Design

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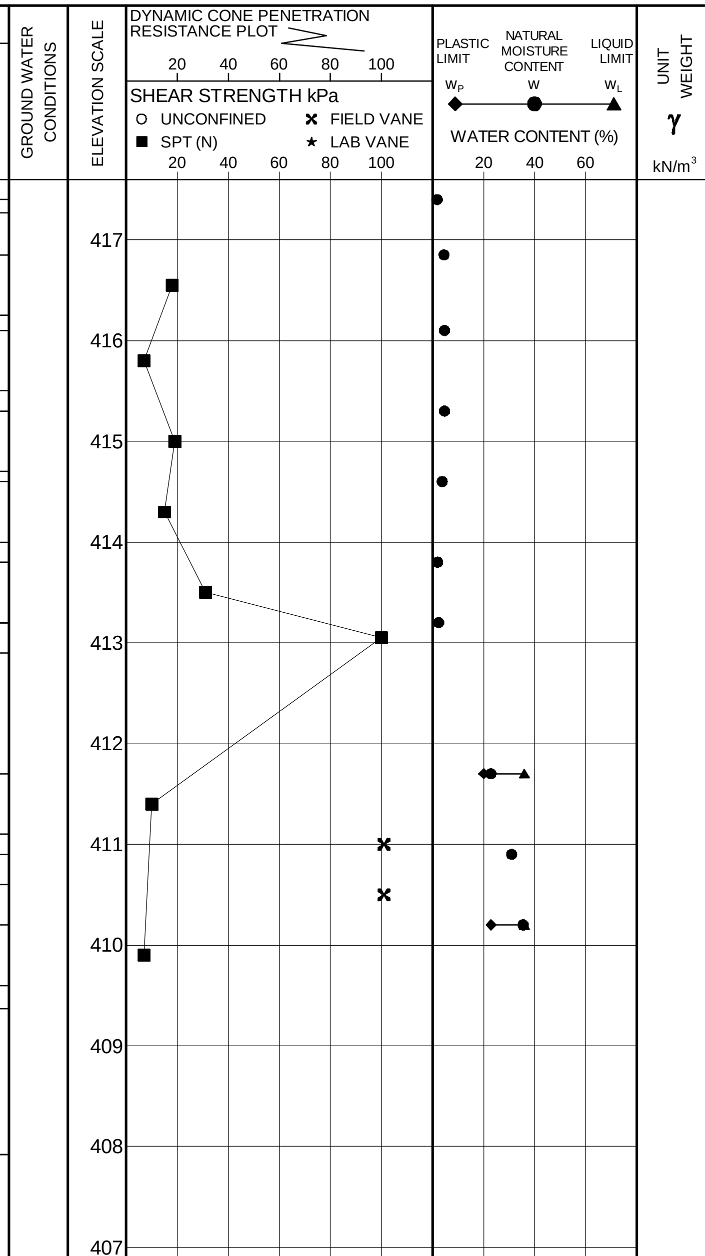
RECORD OF Borehole No 1

METRIC

W.P. **6310-10-00**	PROJECT **Highway 502 Resurfacing**	SITE	ORIGINATED BY **AF**
DIST **61** HWY **502**	LOCATION **STA 23+698 o/s 2.7 Lt**	TBTE JOB# **15-011**	COMPILED BY **JRM**
DATE **October 7, 2015**	BOREHOLE TYPE **Hollow Stem Auger**	DATUM **Geodetic**	CHECKED BY **SS**

SOIL PROFILE / SAMPLES

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
417.6					
417.4 / 0.0	ASPHALT				
417.3 / 0.2	FILL - SAND & GRAVEL	1	AS		
417.0 / 0.3	ASPHALT				
0.6	FILL - Sand & Gravel, trace silt, loose to dense, occasional cobbles, brown	2	SS	18	
		3	SS	7	- Auger dropped 100mm suring SPT, possible void. 48 44 (8)
		4	SS	19	
		5	SS	15	
	- - - - - - grey	6	SS	31	
413.2 / 4.4	ROCK FILL	7	SS	100+	- On cobble. Advanced using "N" casing.
411.7 / 5.9	CLAY - trace sand, trace gravel, brown, very stiff				1 8 40 51
		8	SS	10	
		9	TW		
					1 3 49 48
		10	SS	7	
409.4 / 8.2	BEDROCK Mafic Volcanic - Fine to medium grained, dark green-grey	1	RC		RC # 1 REC = 97% RQD = 80%
		2	RC		RC # 2 REC = 73% RQD = 58%
406.8 / 10.8	End of Borehole @ 10.8 m.				



×³, ★³: Numbers refer to Sensitivity
O ³% STRAIN AT FAILURE
NP Non Plastic

TBT Engineering Consulting Group

RECORD OF Borehole No 2

METRIC

W.P. **6310-10-00**	PROJECT **Highway 502 Resurfacing**	SITE	ORIGINATED BY **AF**
DIST **61** HWY **502**	LOCATION **STA 23+729 o/s 3.3 Lt**	TBTE JOB# **15-011**	COMPILED BY **JRM**
DATE **October 8, 2015**	BOREHOLE TYPE **Hollow Stem Auger**	DATUM **Geodetic**	CHECKED BY **SS**

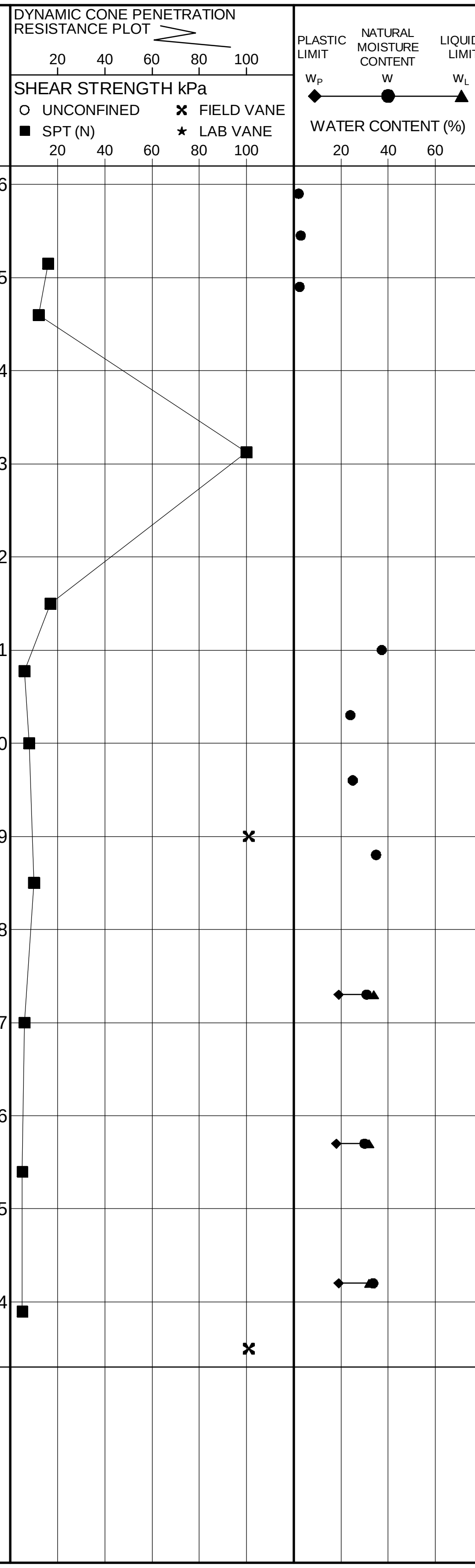
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT
416.2		
416.0 / 0.1	ASPHALT	
	FILL - SAND & GRAVEL, trace silt, occasional cobbles, brown, compact	
414.3 / 1.9	ROCK FILL	
411.0 / 5.2	SAND - Silty, trace organic, grey, loose	
410.3 / 5.9	CLAY - trace to some silt, brown, very stiff - - - - - - grey	
403.3 / 12.9	End of Borehole @ 12.9 m.	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	AS		
2	SS	16	37 56 (7)
3	SS	12	
			- N casing advanced
4	SS	100+	- On cobble
5	SS	17	
6	SS	6	
7	SS	8	
8	TW		
9	SS	10	
			0 4 45 50
10	SS	6	
			0 12 37 50
11	SS	5	
			0 1 47 53
12	SS	5	

GROUND WATER CONDITIONS | ELEVATION SCALE | UNIT WEIGHT γ kN/m³



×³, ★³: Numbers refer to Sensitivity

O³% STRAIN AT FAILURE

NP Non Plastic

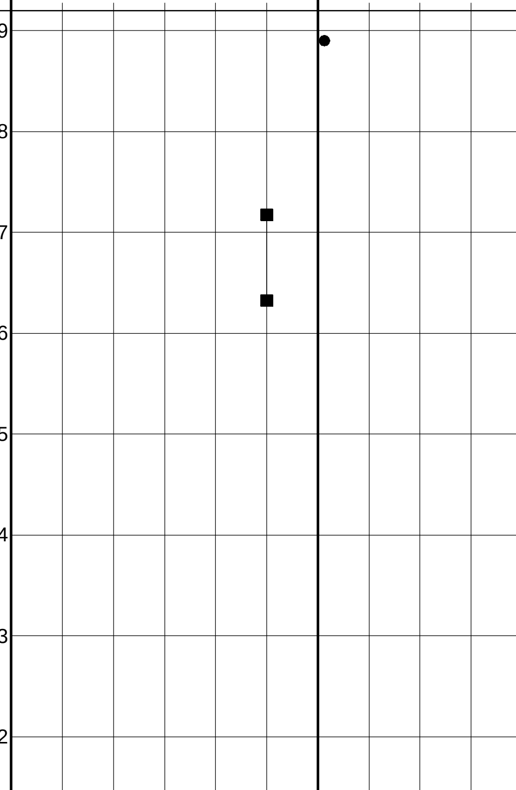
TBT Engineering Consulting Group

RECORD OF Borehole No 3

METRIC

W.P.	**6310-10-00**	PROJECT	**Highway 502 Resurfacing**	SITE	
ORIGINATED BY	**AF**				
DIST	**61** HWY **502**	LOCATION	**STA 23+668 o/s 2.7 Lt**	TBTE JOB#	**15-011**
COMPILED BY	**JRM**				
DATE	**October 8, 2015**	BOREHOLE TYPE	**Hollow Stem Auger**	DATUM	**Geodetic**
CHECKED BY	**SS**				

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
419.2						
419.1 / 0.1	ASPHALT				419	
	FILL - SAND & GRAVEL	1	AS			
418.2 / 1.0	ROCK FILL				418	
		2	SS	100+	417	- On cobble
		3	SS	100+	416	- On cobble
415.6 / 3.6	BEDROCK Mafic Volcanic - Fine to medium grained, dark green-grey				415	
		1	RC		414	RC # 1 REC = 95% RQD = 56%
		2	RC		413	RC # 2 REC = 100% RQD = 80%
		3	RC		412	RC # 3 REC = 99% RQD = 99%
411.4 / 7.8	End of Borehole @ 7.8 m.					



UNIT WEIGHT γ kN/m³ · GR SA SI CL · GROUND WATER CONDITIONS · STRAT PLOT

3, 3: Numbers refer to Sensitivity
O 3% STRAIN AT FAILURE
NP Non Plastic

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Ontario

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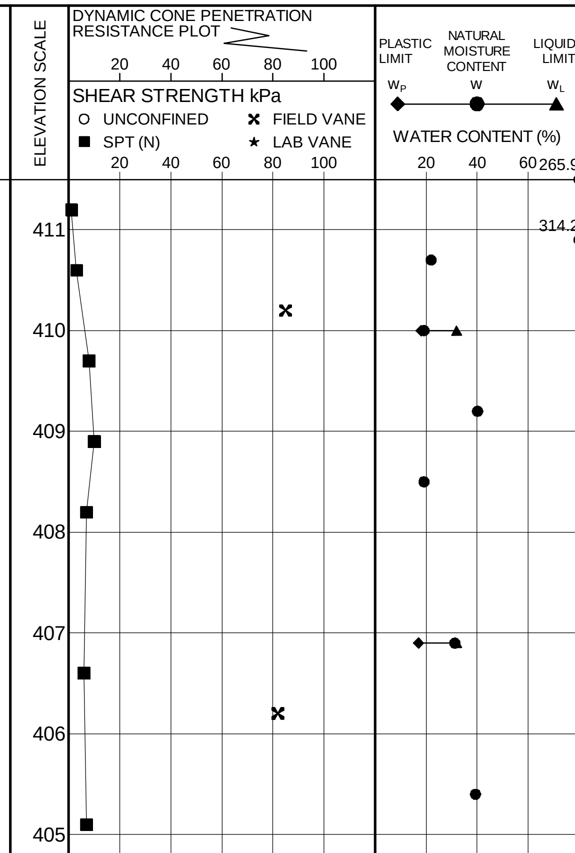
RECORD OF Borehole No 4

METRIC

W.P. **6310-10-00** PROJECT **Highway 502 Resurfacing** SITE ORIGINATED BY **AF**
DIST **61** HWY **502** LOCATION **STA 23+710 o/s 19.1 Lt** TBTE JOB# **15-011** COMPILED BY **JRM**
DATE **October 9, 2015** BOREHOLE TYPE **Hand Auger** DATUM **Geodetic** CHECKED BY **SS**

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
411.5 / 0.0	ORGANIC MATERIAL - brown	1	SS	1	
410.9 / 0.6	CLAY - trace sand, brown, stiff	2	SS	3	
					0 9 35 56
		3	SS	8	
		4	SS	10	
	- - - - - - grey	5	SS	7	
					0 5 45 49
		6	SS	6	
		7	SS	7	
404.8 / 6.7	End of Borehole @ 6.7 m.				



Columns: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; UNIT WEIGHT γ kN/m³

×3, ★3: Numbers refer to Sensitivity
O 3% STRAIN AT FAILURE
NP Non Plastic

ON_MOT_BH_MTM DIST 15-011 MTO.GPJ ON_MOT.GDT 2/26/16

Ministry of Transportation
Ontario

TBT Engineering Consulting Group

RECORD OF Borehole No 5

METRIC

W.P.	6310-10-00	PROJECT	Highway 502 Resurfacing	SITE	
ORIGINATED BY	TP	DIST	61	HWY	502
LOCATION	STA 23+680 o/s 20.2 Lt	TBTE JOB#	15-011	COMPILED BY	JRM
DATE	October 14, 2015	BOREHOLE TYPE	Hand Auger	DATUM	Geodetic
CHECKED BY	SS				

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
411.9 / 0.0	SAND - Silty, organics, black, loose	1	SS	8		
411.2 / 0.8	CLAY - stiff	2	SS	9		
	- - - - - - trace gravel	3	SS	10		
409.6 / 2.3	SILT - Sandy, trace gravel, brown, compact	4	SS	24		1 29 (70)
408.9 / 3.0	CLAY - some sand, trace gravel, grey, stiff	5	SS			3 12 36 50
407.3 / 4.6	SILT - Sandy, grey, loose	6	SS	9		0 24 (76)
406.7 / 5.2	CLAY - trace sand, grey, stiff	7	SS	8		0 1 39 61
405.8 / 6.1	End of Borehole @ 6.1 m.					

Elevation scale: 411, 410, 409, 408, 407, 406

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; ✕ FIELD VANE; ■ SPT (N); ★ LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60 239.3

UNIT WEIGHT γ kN/m³

✕3, ★3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE
NP Non Plastic

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Strength (MPa)
VH = Very High = >200
H = High = 50-200
M = Medium = 15-50
L = Low = 4-15
VL = Very Low = 1-4

Discontinuity type
B = Bedding joint
J = Cross Joint
F = Fault
S = Shear Plane

Roughness
RU = Rough undulating
RP = Rough planar
SU = Smooth undulating
SP = Smooth planar
LU = Slicken sided undulating
LP = Slicken sided planar

Orientation
F = Flat (0-20°)
D = Dipping (20-50°)
V = Near Vertical (>50°)

Aperture
O = Open
C = Closed
F = Filled

Weathering
U = Unweathered (No signs)
S = Slightly (Oxidized)
M = Moderately (Discoloured)
H = Highly (Friable)
C = Completely (Soil-like)

Spacing
VW = Very wide = >3m
W = Wide = 1-3m
M = Moderate = 0.3-1m
C = Close = 5-30cm
VC = Very close = <5cm

Filling
T = Tight, hard
O = Oxidized
SA = Slightly altered, clay free
S = Sandy, Clay free
Si = Sandy, silty, minor clay
NC = Non-softening clay
SC = Swelling, softening clay
N= No filling

ROCK CORE LOG	Page 1 of 1	
Project #: 15-011	BH1	Lab# 16515
Client: MTO HWY 502	Logger: Jason Arnold	
Site: HWY 502, BH1	Date: Wednesday, Oct 14, 2015	

DEPTH (m)	BOX/RUN	% REC (m)	% RQD (m)	GENERAL DESCRIPTION (Rock type(s), %, colour, texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES # OF SETS	TYPE(S)	Orientation	SPACING	Roughness	APERTURE	FILLING	OCCASIONAL FEATURES
From 8.23 To 9.68	1/1	97.0% (1.40)	80.0% (1.16)	**fine to medium grain, dark grey-green mafic volcanic with trace-1% pyrite disseminated throughout. Volcanics are possibly pillowed flows.**		U	1	J	D	C	SP	O	O	Carbonate filled fracture planes.
From 9.68 To 10.72	1/2 1/3	73.0% (0.80)	58.0% (0.63)	**fine to medium grain, dark grey-green mafic volcanic with trace-1% pyrite disseminated throughout. Volcanics are possibly pillowed flows.**										No Joint sets observed, run is broken and blocky.
From To														
From To														

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Strength (MPa)
VH = Very High = >200
H = High = 50-200
M = Medium = 15-50
L = Low = 4-15
VL = Very Low = 1-4

Discontinuity type
B = Bedding joint
J = Cross Joint
F = Fault
S = Shear Plane

Orientation
F = Flat (0-20°)
D = Dipping (20-50°)
V = Near Vertical (>50°)

Roughness
RU = Rough undulating
RP = Rough planar
SU = Smooth undulating
SP = Smooth planar
LU = Slicken sided undulating
LP = Slicken sided planar

Aperture
O = Open
C = Closed
F = Filled

Weathering
U = Unweathered (No signs)
S = Slightly (Oxidized)
M = Moderately (Discoloured)
H = Highly (Friable)
C = Completely (Soil-like)

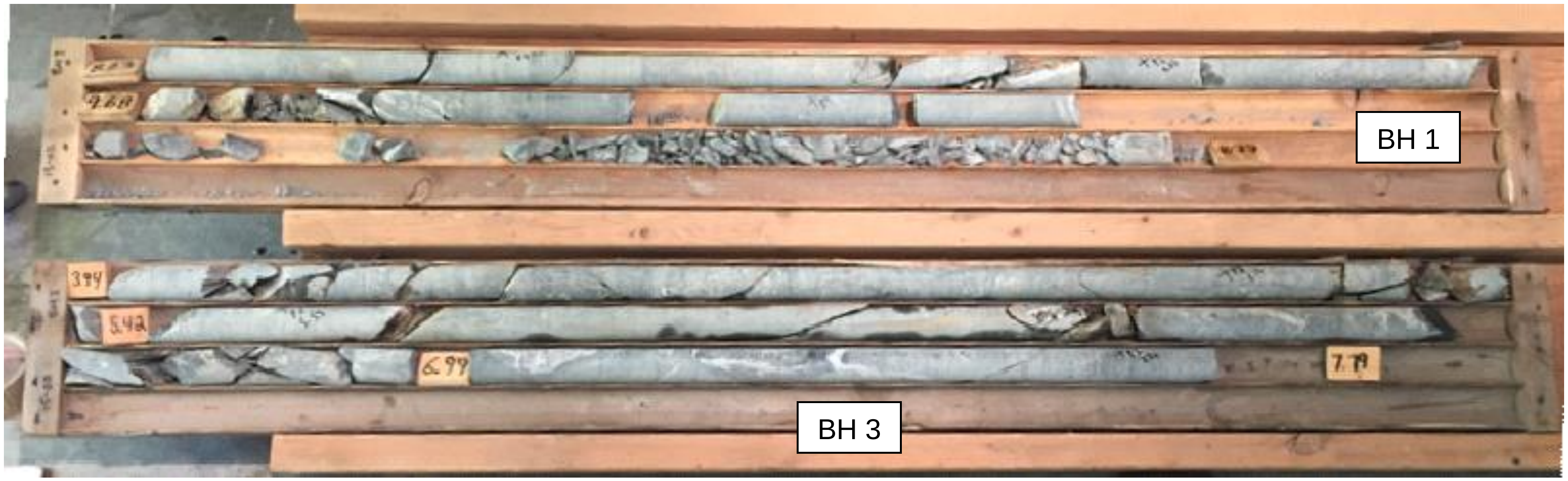
Spacing
VW = Very wide = >3m
W = Wide = 1-3m
M = Moderate = 0.3-1m
C = Close = 5-30cm
VC = Very close = <5cm

Filling
T = Tight, hard
O = Oxidized
SA = Slightly altered, clay free
S = Sandy, Clay free
Si = Sandy, silty, minor clay
NC = Non-softening clay
SC = Swelling, softening clay
N= No filling

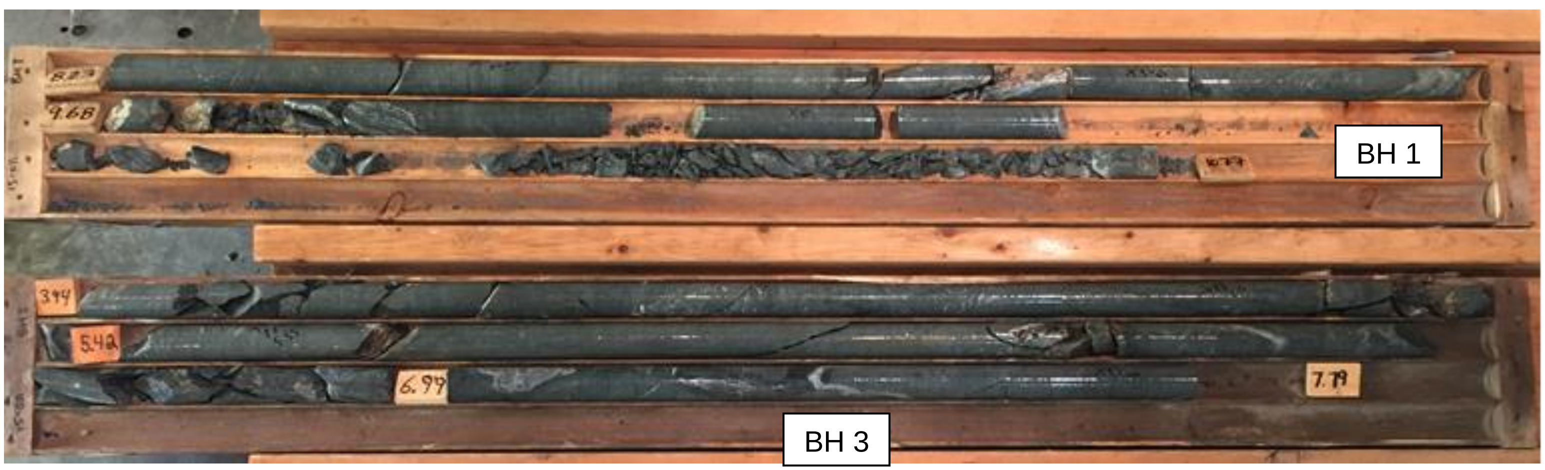
ROCK CORE LOG	Page 1 of 1	
Project #: 15-011	BH3	Lab# 16516
Client: MTO HWY 502	Logger: Jason Arnold	
Site: HWY 502, BH3	Date: Wednesday, Oct 14, 2015	

DEPTH (m)	BOX/RUN	% REC (m)	% RQD (m)	GENERAL DESCRIPTION (Rock type(s), %, colour, texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES # OF SETS	TYPE(S)	Orientation	SPACING	Roughness	APERTURE	FILLING	OCCASIONAL FEATURES
From 3.94 To 5.42	1/1	95.0% (1.40)	56.0% (0.83)	**fine to medium grain, dark grey-green mafic volcanic with trace-1% pyrite disseminated throughout. Volcanics are possibly pillowed flows.**		S	4	J	D	C	SP	O	N	
From 5.42 To 6.99	1/2 1/3	100.0% (1.57)	80.0% (1.26)	**fine to medium grain, dark grey-green mafic volcanic with trace-1% pyrite disseminated throughout. Volcanics are possibly pillowed flows.**		S	4	J	D	C	SP	O	N	
From 6.99 To 7.79	1/3	99.0% (0.79)	99.0% (0.79)	**fine to medium grain, dark grey-green mafic volcanic with trace-1% pyrite disseminated throughout. Volcanics are possibly pillowed flows.**										
From To														

Full Rock Core Dry



Full Rock Core Wet



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DMT 1

Reference No.: **15-125**
Project: **Hwy 502 Slip Failure**
Client: **MTO**

Ground Surface Elevation: 411.900 m
Water Table Depth: 0 m
Depth of DMT: 6 m

INPUT PARAMETERS

A	DMT A reading	bars
B	DMT B reading	bars
γ	Bulk Unit Weight	kN/m^3
Po	Effective overb. press.	kPa
U	Pore pressure	kPa
Id	Material Index	
Kd	Horizontal Stress Index	
Ed	Dilatometer Modulus	MPa
	Depth and Elevation	m

INTERPRETED GEOTECHNICAL PARAMETERS

γ	Bulk Unit Weight of Soil	kN/m^3
M	Constrained (oedometer) modulus	MPa
Ko	Coefficient of earth pressure insitu	
OCR	Overconsolidation ratio Pc/Po	
Pc	Preconsolidation pressure	kPa
q	Pc-Po	kPa
Cu	Undrained cohesion (cohesive)	kPa
Phi	Friction angle (cohesionless)	°
	Soil Description	

DEPTH	Elev.	A	B	A'	B'	γ	Po	U	Kd	Ed	M	Ko	OCR	Pc	q	Cu	Phi	Soil Description	
m	m	bars	bars	bars	bars	kN/m^3	kPa	kPa		MPa	MPa			kPa	kPa	kPa	degrees		
0.8	411.1	0.65	2.3	0.67	1.40	16.0	2	8	29.9	2.5	9.0						32	Sandy SILT	Very Loose
1.0	410.9	0.75	2.65	0.75	1.75	16.0	3	10	20.5	3.5	11.0						32	Sandy SILT	Very Loose
1.2	410.7	1.15	2.45	1.18	1.55	16.0	4	12	24.0	1.3	4.2	3.08	48.20	214	210	22		CLAY	Soft
1.4	410.5	1.4	3	1.42	2.10	16.0	6	14	22.5	2.4	7.7	2.97	43.75	249	243	26		Silty CLAY	Firm
1.6	410.3	1.55	3.75	1.54	2.85	16.0	7	16	20.0	4.5	14.3						29	SILT	Very Loose
1.8	410.1	2.7	7.65	2.55	6.75	17.0	8	18	28.4	14.5	50.7						33	Sandy SILT	Loose
2.0	409.9	2.75	10	2.49	9.10	19.0	10	20	22.4	22.9	74.7						37	Silty SAND	Compact
2.2	409.7	2.75	10	2.49	9.10	19.0	12	22	18.8	22.9	71.0						36	Silty SAND	Compact
2.4	409.5	4.35	13.80	4.00	12.40	19.0	14	24	27.1	29.1	100.1						35	Silty SAND	Compact
2.6	409.3	2.55	8.95	2.33	8.05	19.0	16	25	13.2	19.8	54.7						35	Silty SAND	Compact
2.8	409.1	5.10	16.20	4.67	14.80	20.0	18	27	24.7	35.1	117.7						35	Silty SAND	Compact
3.0	408.9	4.10	13.40	3.76	12.00	19.0	20	29	17.7	28.5	86.7						34	Silty SAND	Compact
3.2	408.7	3.70	14.00	3.31	12.60	19.0	21	31	14.0	32.2	90.5						36	Silty SAND	Compact
3.4	408.5	3.55	10.00	3.33	9.10	19.0	23	33	12.9	20.0	54.7						32	Silty SAND	Compact
3.6	408.3	5.25	14.20	4.93	12.80	18.0	25	35	18.3	27.2	83.8						32	Sandy SILT	Compact
3.8	408.1	7.30	18.80	6.85	17.40	19.5	27	37	24.1	36.5	121.7						33	Sandy SILT	Compact
4.0	407.9	4.10	6.40	4.08	5.50	17.0	28	39	13.0	4.9	13.5	2.16	18.63	527	499	65		Silty CLAY	Stiff
4.2	407.7	4.45	7.50	4.40	6.60	18.0	30	41	13.3	7.6	21.1	2.19	19.22	576	546	70		Silty CLAY	Stiff
4.4	407.5	4.70	7.80	4.64	6.90	18.0	32	43	13.3	7.8	21.7	2.19	19.29	609	578	74		Silty CLAY	Stiff
4.6	407.3	4.45	8.45	4.35	7.55	18.0	33	45	11.7	11.1	29.4	2.03	15.79	525	491	67		Clayey SILT	Stiff
4.8	407.1	4.25	10.00	4.06	9.10	18.0	35	47	10.3	17.4	44.1						30	Sandy SILT	Compact
5.0	406.9	4.75	7.40	4.72	6.50	18.0	37	49	11.6	6.2	16.3	2.01	15.47	565	528	72		Silty CLAY	Stiff
5.2	406.7	4.95	12.60	4.69	11.20	18.0	38	51	11.0	22.5	58.3						30	Sandy SILT	Compact
5.4	406.5	4.60	6.45	4.61	5.55	17.0	40	53	10.3	3.3	8.3	1.87	12.89	510	471	68		CLAY	Stiff
5.6	406.3	4.45	7.00	4.42	6.10	17.0	41	55	9.4	5.8	14.2	1.77	11.25	461	420	63		Silty CLAY	Stiff
5.8	406.1	5.80	7.00	5.84	6.10	16.0	42	57	12.5	0.9	2.5	2.11	17.37	734	692	92		CLAY	Stiff
6.0	405.9	6.00	8.85	5.96	7.95	18.0	44	59	12.2	6.9	18.6	2.08	16.85	740	696	93		Silty CLAY	Stiff

TBT ENGINEERING
CONSULTING GROUP

DMT 2

Reference No.: **15-125**
Project: **Hwy 502 Slip Failure**
Client: **MTO**

Ground Surface Elevation: 411.500 m
Water Table Depth: 0 m
Depth of DMT: 6 m

INPUT PARAMETERS

A	DMT A reading	bars
B	DMT B reading	bars
γ	Bulk Unit Weight	kN/m³
Po	Effective overb. press.	kPa
U	Pore pressure	kPa
Id	Material Index	
Kd	Horizontal Stress Index	
Ed	Dilatometer Modulus	MPa
	Depth and Elevation	m

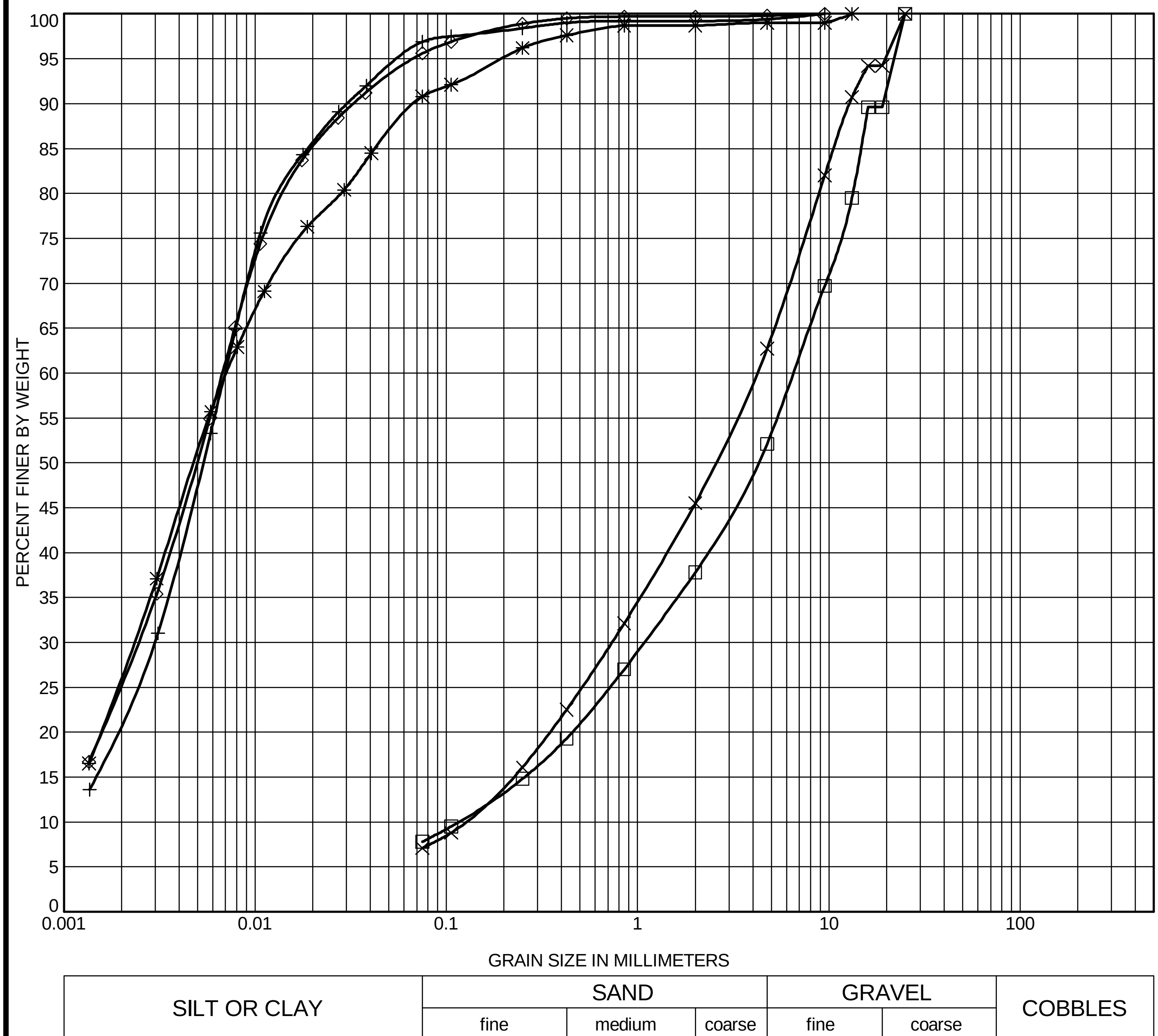
INTERPRETED GEOTECHNICAL PARAMETERS

γ	Bulk Unit Weight of Soil	kN/m³
M	Constrained (oedometer) modulus	MPa
Ko	Coefficient of earth pressure insitu	
OCR	Overconsolidation ratio Pc/Po	
Pc	Preconsolidation pressure	kPa
q	Pc-Po	kPa
Cu	Undrained cohesion (cohesive)	kPa
Phi	Friction angle (cohesionless)	°
	Soil Description	

DEPTH	Elev.	A	B	A'	B'	γ	Po	U	Kd	Ed	M	Ko	OCR	Pc	q	Cu	Phi	Soil Description	
m	m	bars	bars	bars	bars	kN/m³	kPa	kPa		MPa	MPa			kPa	kPa	kPa	degrees		
0.6	410.9	0.6	1.25	0.45	0.45	16.0	2	6	22.7	0.0	0.0	2.99	44.37	76	75	8		CLAY	Very Soft
0.8	410.7	0.45	1.2	0.30	0.40	16.0	3	8	7.3	0.4	0.8	1.51	7.56	22	19	3		Silty CLAY	Very Soft
1.0	410.5	0.65	1.5	0.49	0.70	16.0	4	10	9.3	0.7	1.8	1.76	11.06	46	42	6		Silty CLAY	Very Soft
1.2	410.3	1.3	3.45	1.08	2.65	16.0	5	12	17.6	5.4	16.5						32	Sandy SILT	Loose
1.4	410.1	1.8	4.1	1.57	3.30	16.0	7	14	21.4	6.0	19.3						31	Sandy SILT	Loose
1.6	409.9	2.4	4.5	2.18	3.70	17.0	8	16	24.9	5.3	17.7	3.14	51.06	415	406	42		Clayey SILT	Firm
1.8	409.7	3.4	7.15	3.10	6.35	18.0	10	18	29.9	11.3	39.8						31	SILT	Loose
2.0	409.5	3.5	6.35	3.24	5.55	17.0	11	20	27.2	8.0	27.5	3.30	58.59	656	645	64		Clayey SILT	Stiff
2.2	409.3	2.45	7.9	2.06	7.10	18.0	13	22	14.4	17.4	49.6						35	Silty SAND	Compact
2.4	409.1	2.65	8.05	2.26	7.25	18.0	14	24	14.0	17.3	48.6						34	Silty SAND	Compact
2.6	408.9	3.15	10.20	2.71	8.90	19.0	16	25	15.0	21.4	61.8						34	Silty SAND	Compact
2.8	408.7	3.60	8.10	3.26	7.30	18.0	18	27	16.6	14.0	41.7						31	Sandy SILT	Loose
3.0	408.5	5.00	8.45	4.71	7.65	18.0	20	29	22.5	10.2	33.3	2.97	43.72	857	837	89		Clayey SILT	Stiff
3.2	408.3	5.00	7.60	4.75	6.80	18.0	21	31	20.9	7.1	22.7	2.85	38.88	826	805	88		Silty CLAY	Stiff
3.4	408.1	4.75	7.15	4.51	6.35	18.0	23	33	18.3	6.4	19.5	2.64	31.52	721	698	80		Silty CLAY	Stiff
3.6	407.9	4.90	7.45	4.66	6.65	18.0	25	35	17.5	6.9	20.9	2.58	29.60	726	701	81		Silty CLAY	Stiff
3.8	407.7	5.00	7.80	4.74	7.00	18.0	26	37	16.7	7.8	23.3	2.50	27.42	717	691	82		Silty CLAY	Stiff
4.0	407.5	4.95	7.45	4.71	6.65	18.0	28	39	15.5	6.7	19.6	2.40	24.45	680	652	79		Silty CLAY	Stiff
4.2	407.3	4.80	7.10	4.57	6.30	18.0	29	41	14.1	6.0	16.9	2.27	21.08	621	591	75		Silty CLAY	Stiff
4.4	407.1	4.75	6.90	4.53	6.10	17.0	31	43	13.3	5.4	15.1	2.18	19.12	590	559	72		Silty CLAY	Stiff
4.6	406.9	3.45	8.50	3.08	7.70	18.0	33	45	8.1	16.0	28.6						30	Sandy SILT	Compact
4.8	406.7	4.30	6.35	4.08	5.55	17.0	34	47	10.6	5.1	13.0	1.91	13.54	460	426	60		Silty CLAY	Stiff
5.0	406.5	4.00	6.30	3.77	5.50	17.0	35	49	9.3	6.0	14.5	1.75	10.92	387	351	53		Silty CLAY	Stiff
5.2	406.3	3.85	6.60	3.60	5.80	17.0	37	51	8.4	7.6	13.8	1.64	9.34	344	307	49		Clayey SILT	Firm
5.4	406.1	4.55	6.40	4.34	5.60	17.0	38	53	10.0	4.4	10.9	1.83	12.23	468	430	63		CLAY	Stiff
5.6	405.9	3.75	5.30	3.56	4.50	17.0	40	55	7.6	3.3	7.2	1.54	7.97	317	277	46		CLAY	Firm
5.8	405.7	4.10	7.45	3.82	6.65	18.0	41	57	7.8	9.8	17.1	1.58	8.44	349	308	50		Clayey SILT	Stiff
6.0	405.5	4.15	8.05	3.84	7.25	18.0	43	59	7.6	11.8	20.2						28	SILT	Loose

APPENDIX B

Laboratory Test Data



Remarks:

Test Hole		Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□	**1**	**2.30**	**25**	**6.484**	**1.078**	**0.115**	**47.9**	**44.3**	**7.8**	
✳	**1**	**5.90**	**13.2**	**0.007**	**0.002**		**1.0**	**8.2**	**90.8**	
+	**1**	**7.40**	**9.5**	**0.007**	**0.003**		**0.6**	**2.5**	**96.9**	
×	**2**	**1.00**	**25**	**4.147**	**0.73**	**0.122**	**37.3**	**55.6**	**7.1**	
◇	**2**	**8.90**	**9.5**	**0.007**	**0.002**		**0.2**	**4.2**	**95.6**	

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Thunder Bay, ON
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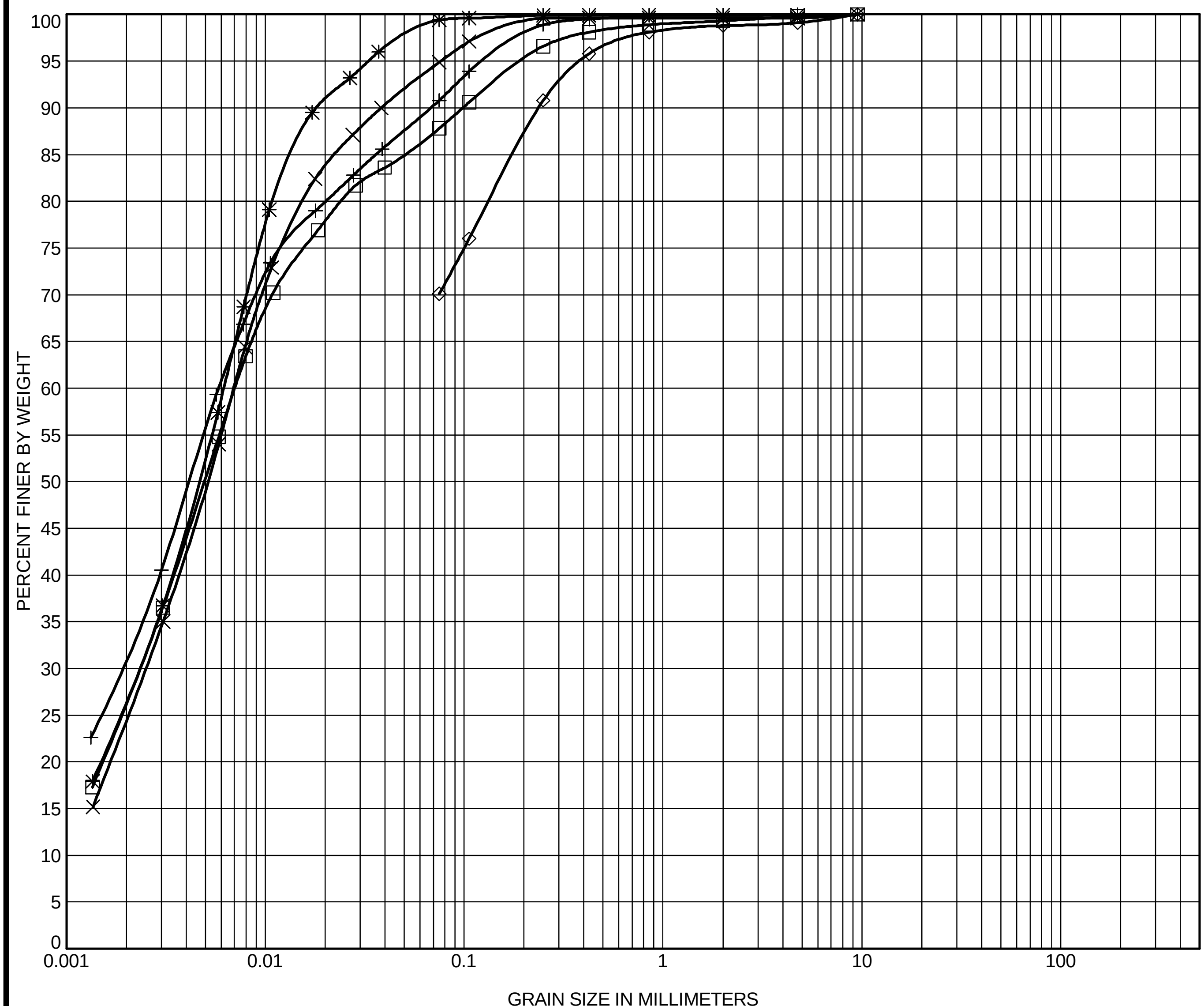
FX: (807) 624-5161
Email: tbte@tbte.ca
Web: www.tbte.ca

GRAIN SIZE DISTRIBUTION

Project: HIghway 502 Resurfacing

W P: 6310-10-00

DIST: HWY: 502



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ 2	10.50	9.5	0.007	0.002		0.2	12.0	87.8	
✳ 2	12.00	9.5	0.006	0.002		0.1	0.5	99.4	
+ 4	1.50	4.75	0.006	0.002		0.0	9.2	90.8	
× 4	4.60	9.5	0.007	0.002		0.4	4.7	94.9	
◇ 5	2.30	9.5				0.9	29.0	70.1	

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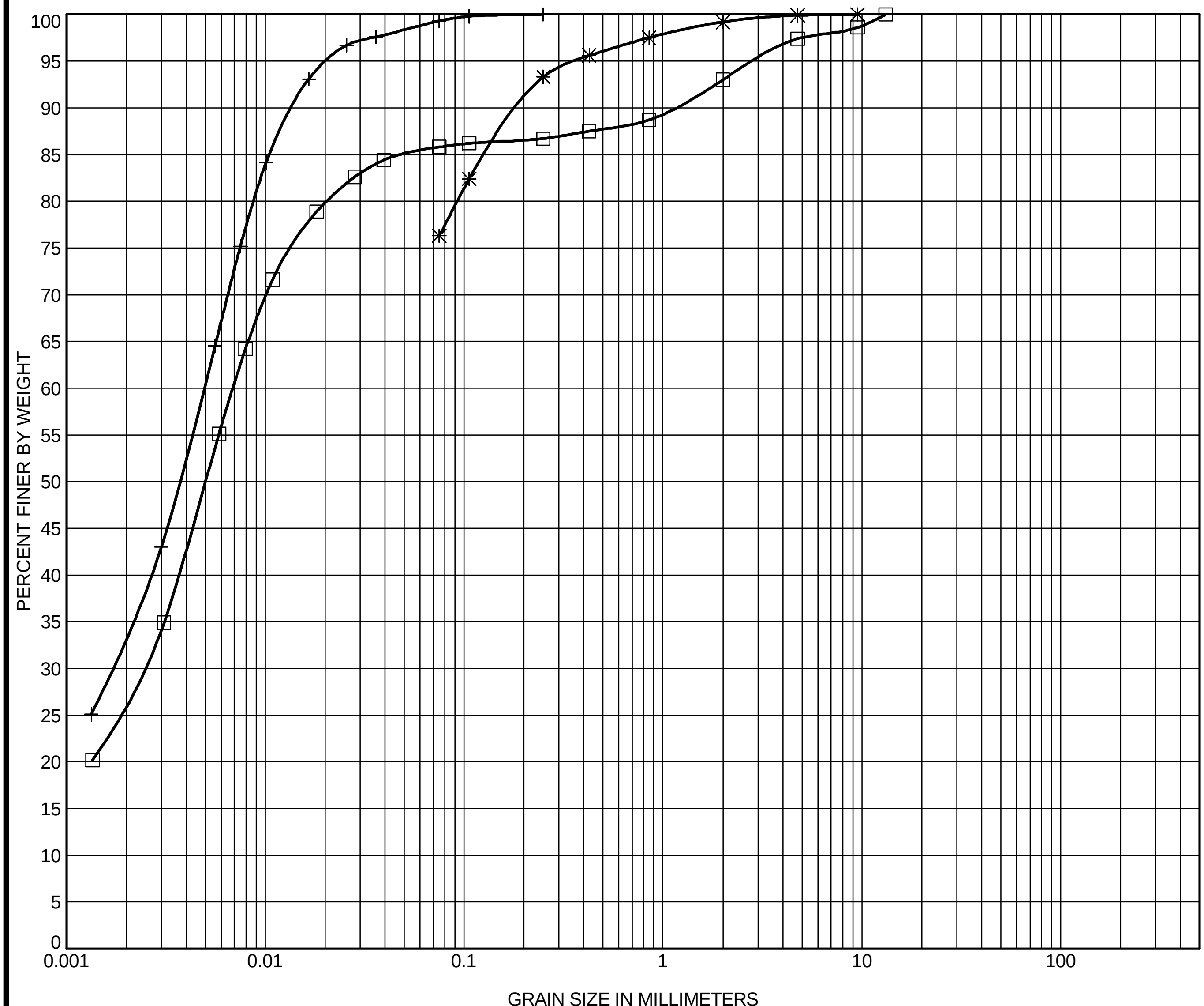
GRAIN SIZE DISTRIBUTION

Project: HIghway 502 Resurfacing

W P: 6310-10-00

DIST: HWY: 502



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ **5**	**3.00**	**13.2**	**0.007**	**0.002**		**2.6**	**11.6**	**85.8**	
✳ **5**	**4.60**	**9.5**				**0.1**	**23.6**	**76.3**	
+ **5**	**5.90**	**0.25**	**0.005**	**0.002**		**0.0**	**0.7**	**99.3**	

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Web: www.tbte.ca

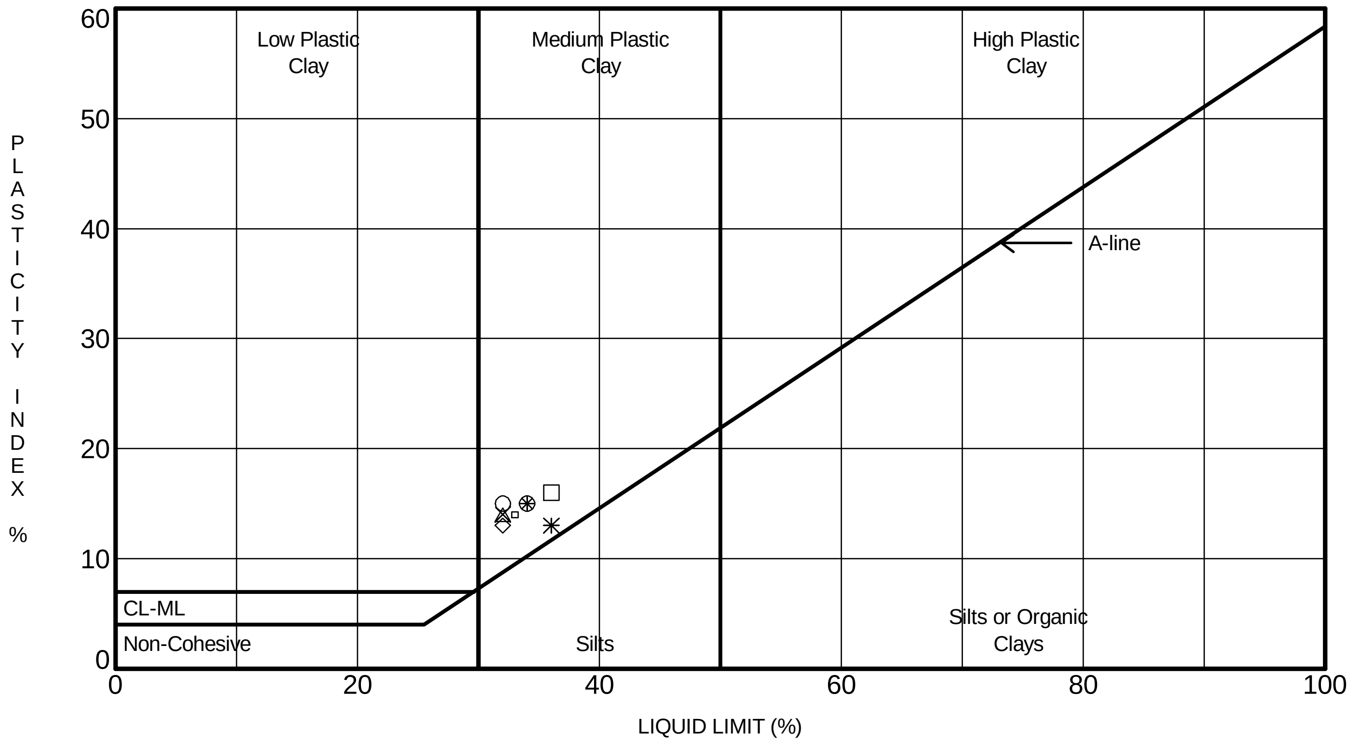
GRAIN SIZE DISTRIBUTION

Project: HIghway 502 Resurfacing

W P: 6310-10-00

DIST: HWY: 502

MTO_GS 15-011 MTO.GPJ ON_MOT.GDT 2/5/16



Remarks:

	Borehole No.	Sample No.	Depth (m)	LL%	PL%	PI%	M/C%	
□	**1**		**5.90**	**36**	**20**	**16**	**23**	
✳	**1**		**7.40**	**36**	**23**	**13**	**36**	
+	**2**		**8.90**	**34**	**19**	**15**	**31**	
×	**2**		**10.50**	**32**	**18**	**14**	**30**	
◇	**2**		**12.00**	**32**	**19**	**13**	**34**	
△	**4**		**1.50**	**32**	**18**	**14**	**19**	
○	**4**		**4.60**	**32**	**17**	**15**	**31**	
▫	**5**		**3.00**	**33**	**19**	**14**	**28**	
⊗	**5**		**5.90**	**34**	**19**	**15**	**34**	

TBT Engineering Ltd.
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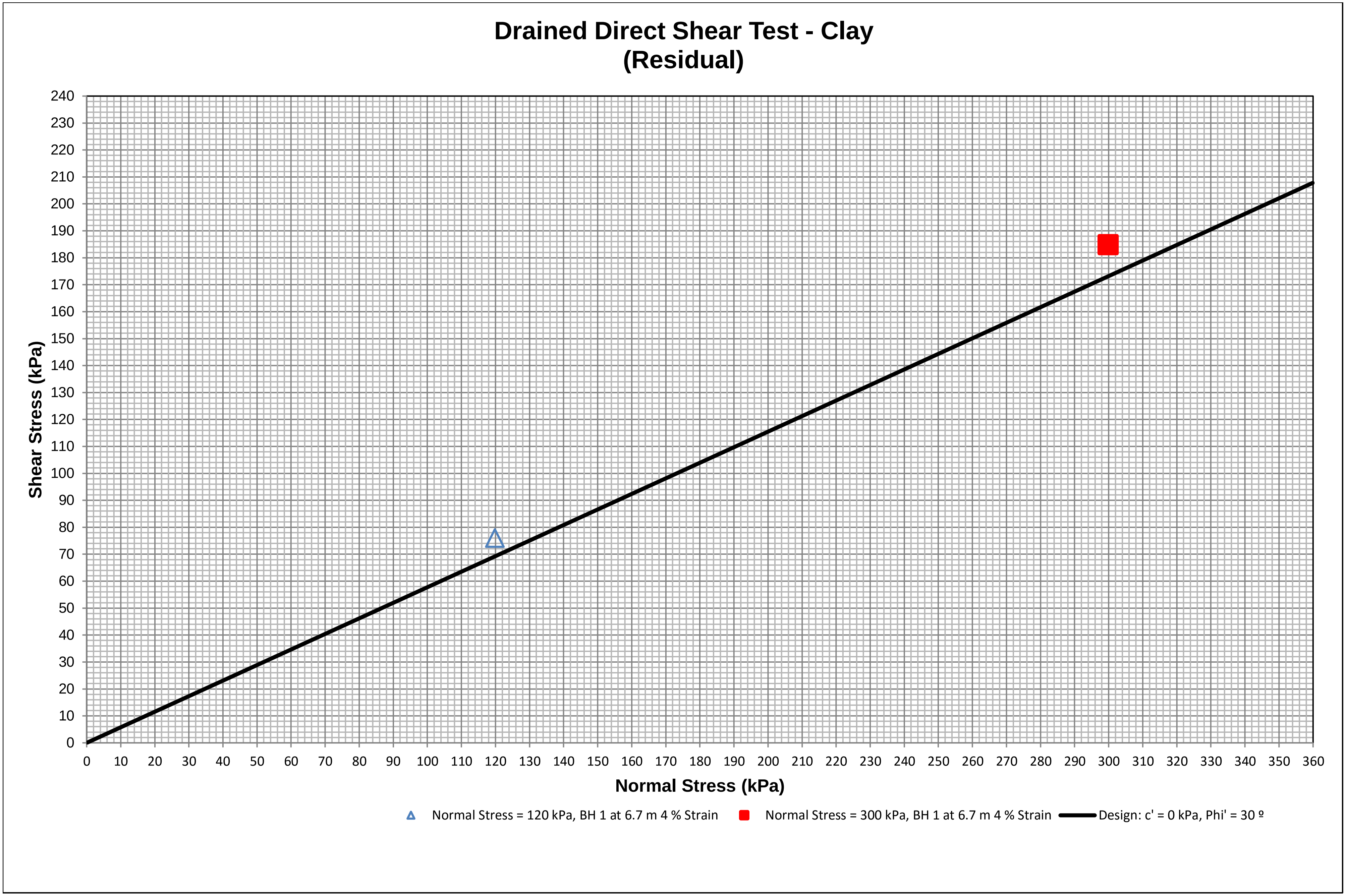
ATTERBERG LIMIT RESULTS

W P: 6310-10-00

District:

Highway: 502


Drained Direct Shear Test - Clay
(Residual)
Shear Stress (kPa)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
360
Normal Stress (kPa)
Normal Stress = 120 kPa, BH 1 at 6.7 m 4 % Strain
Normal Stress = 300 kPa, BH 1 at 6.7 m 4 % Strain
Design: c' = 0 kPa, Phi' = 30 º

APPENDIX C

Borehole Locations, and Soil Strata Drawing

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

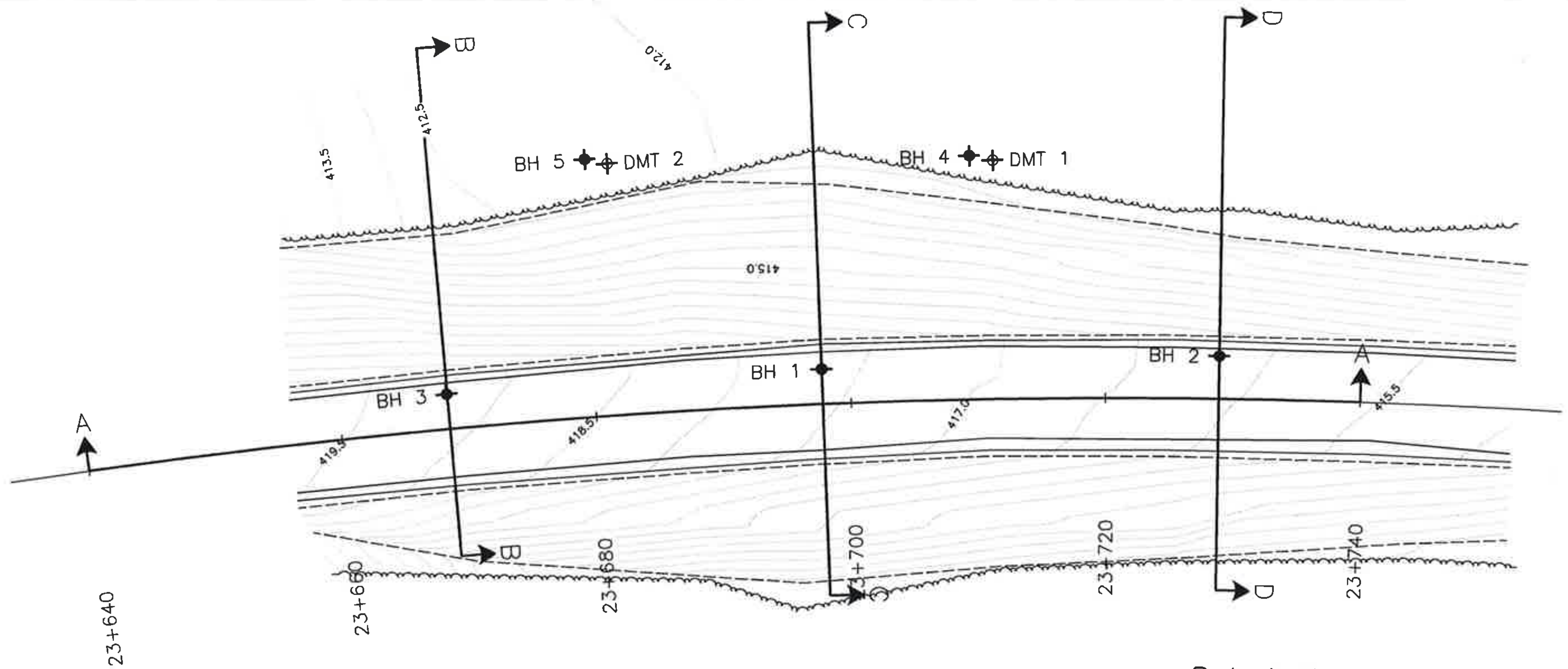
GEOCRES No. 52F-046
CONT No.
GWP No. 6310-10-00

SHEET

HWY 502
EMBANKMENT STABILITY
BOREHOLE LOCATIONS AND SOIL STRATA

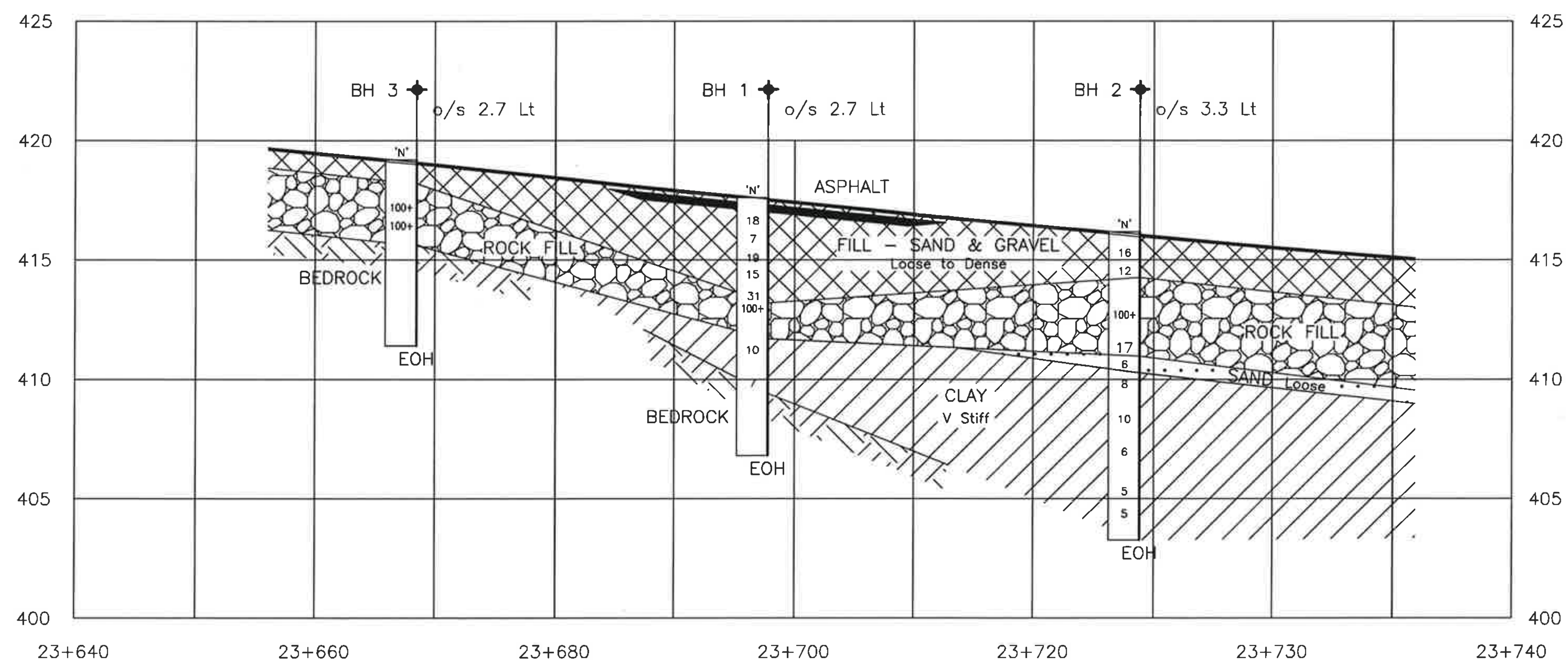
Ontario — Ministry of Transportation, Northwestern Region, Structural Section

TBT ENGINEERING CONSULTING GROUP



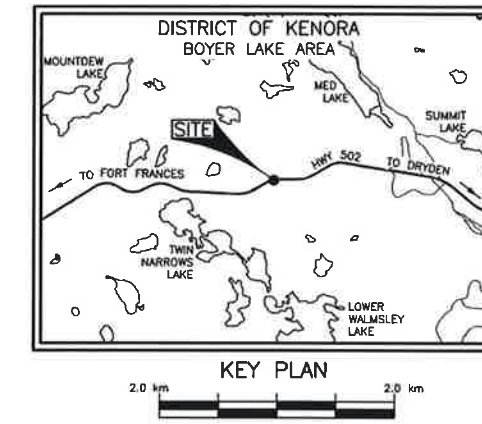
PLAN

SCALE 10 0 10 m



SECTION A – A

SCALE
HOR 10 0 10 m
VERT 5 0 5 m



KEY PLAN

SOIL STRATA SYMBOLS

TOPSOIL/ ORGANICS
SAND
FILL – SAND & GRAVEL
SILT
ROCK FILL
BEDROCK
CLAY

LEGEND

Borehole
Dilatometer Test
'N' Std Pen Test (Blows/0.3m)
Water Level
AR Auger Refusal

No	ELEVATION	CO-ORDINATES (MTM) NORTH	EAST
BH 1	417.6	16 5 478 618	330 242
BH 2	416.2	16 5 478 649	330 236
BH 3	419.2	16 5 478 589	330 249
BH 4	411.5	16 5 478 627	330 224
BH 5	411.9	16 5 478 597	330 229
DMT 1*	412	16 5 478 629	330 224
DMT 2*	412	16 5 478 599	330 229

* LOCATION AND ELEVATION ARE APPROXIMATE.

–NOTE–
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS
02/05/15 TB DRAFT
DESCRIPTION

DESIGN	CHK	CODE XXXXX-XX	LOAD XX-XXX-XXX	DATE 20140513
DRAWN TB	CHK GM	SITE .		DWG 1

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

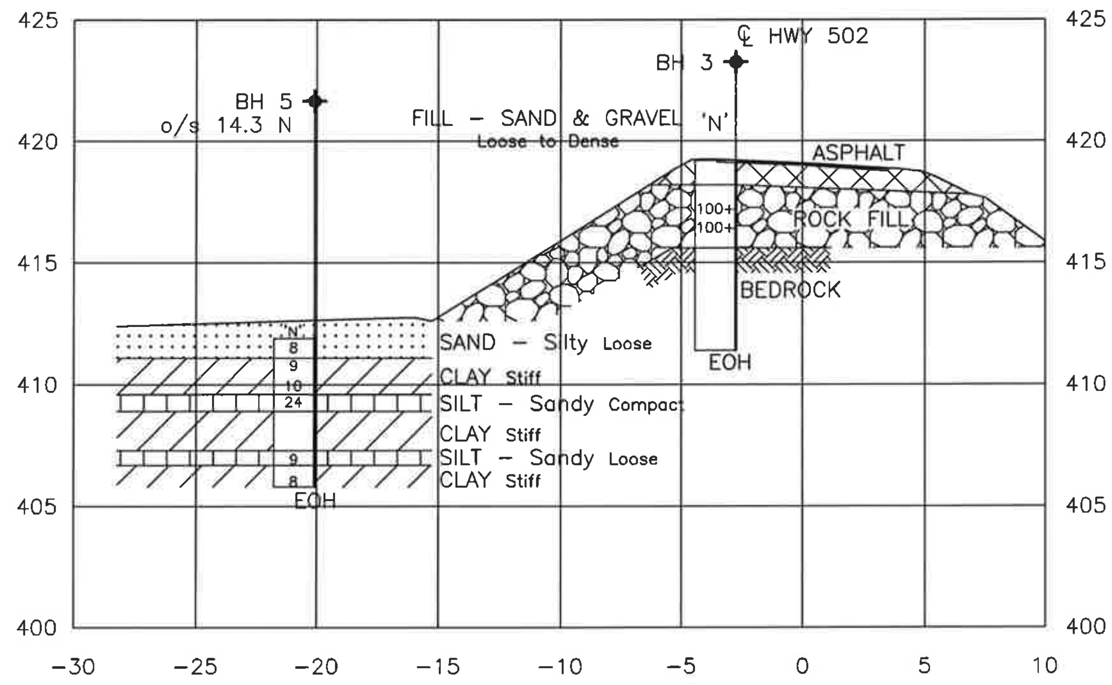
GEOCRES	No.	52F-046
CONT	No.	
GWP	No.	6310-10-00

HWY 502
EMBANKMENT STABILITY
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

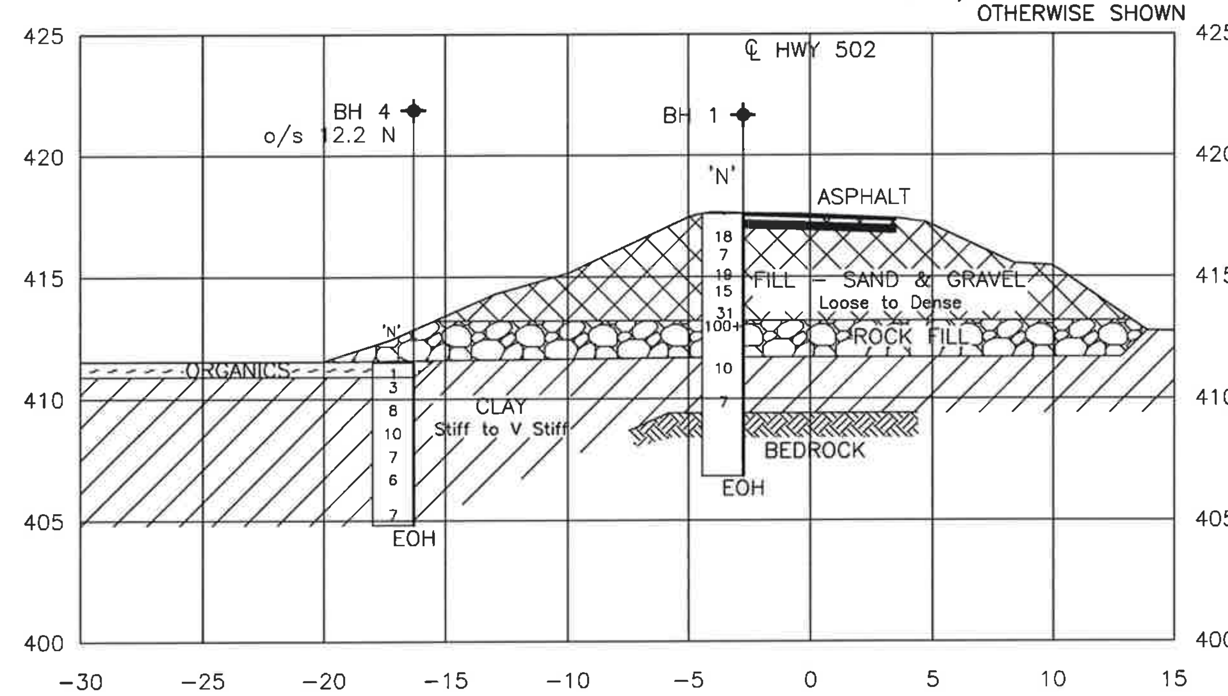
Ontario — Ministry of Transportation, Northwestern Region, Structural Section

TBT ENGINEERING CONSULTING GROUP



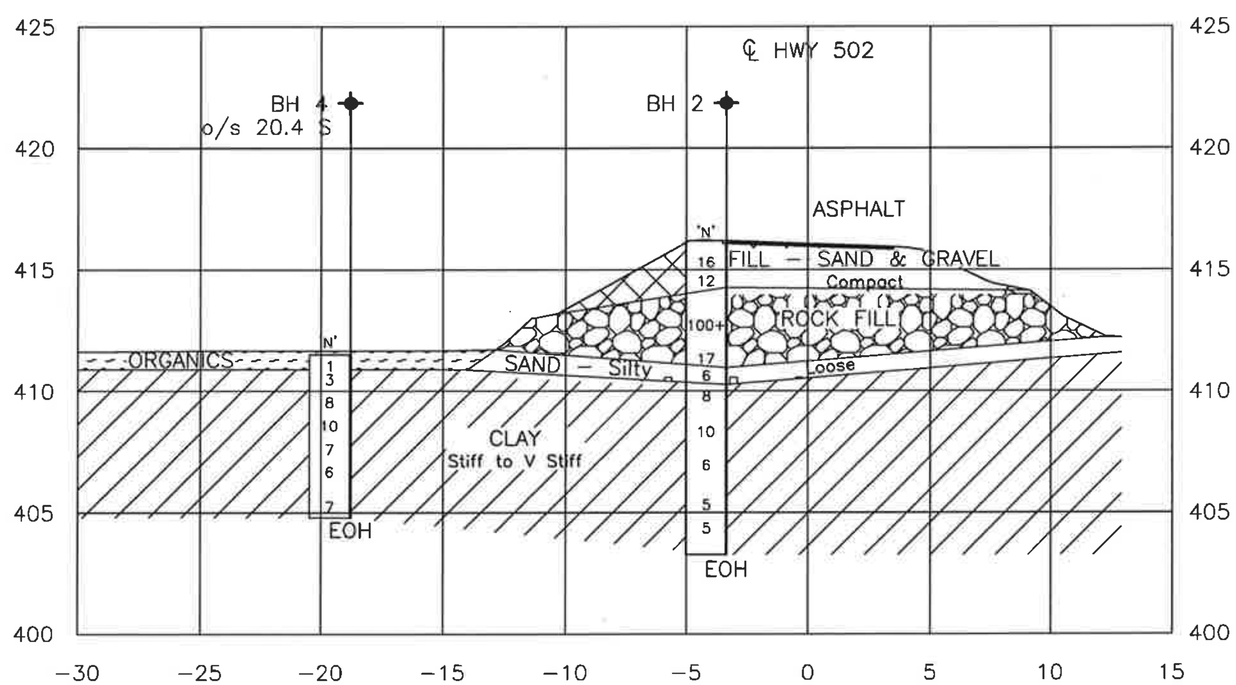
SECTION B - B

SCALE 10 0 10 m



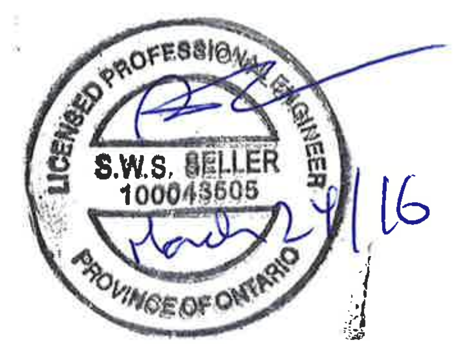
SECTION C - C

SCALE 10 0 10 m



SECTION D - D

SCALE 10 0 10 m



SOIL STRATA SYMBOLS

- TOPSOIL/ ORGANICS
- SAND
- FILL - SAND & GRAVEL
- SILT
- ROCK FILL
- BEDROCK
- CLAY

LEGEND

- Borehole (BH)
- Dilatometer Test (DMT)
- 'N' Std Pen Test (Blows/0.3m)
- Water Level
- AR Auger Refusal

No	ELEVATION	CO-ORDINATES (MTM) NORTH	EAST
BH 1	417.6	16 5 478 618	330 242
BH 2	416.2	16 5 478 649	330 236
BH 3	419.2	16 5 478 589	330 249
BH 4	411.5	16 5 478 627	330 224
BH 5	411.9	16 5 478 597	330 229
DMT 1*	412	16 5 478 629	330 224
DMT 2*	412	16 5 478 599	330 229

* LOCATION AND ELEVATION ARE APPROXIMATE.

-NOTE-
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS

20160224	TB	DRAFT

DESCRIPTION

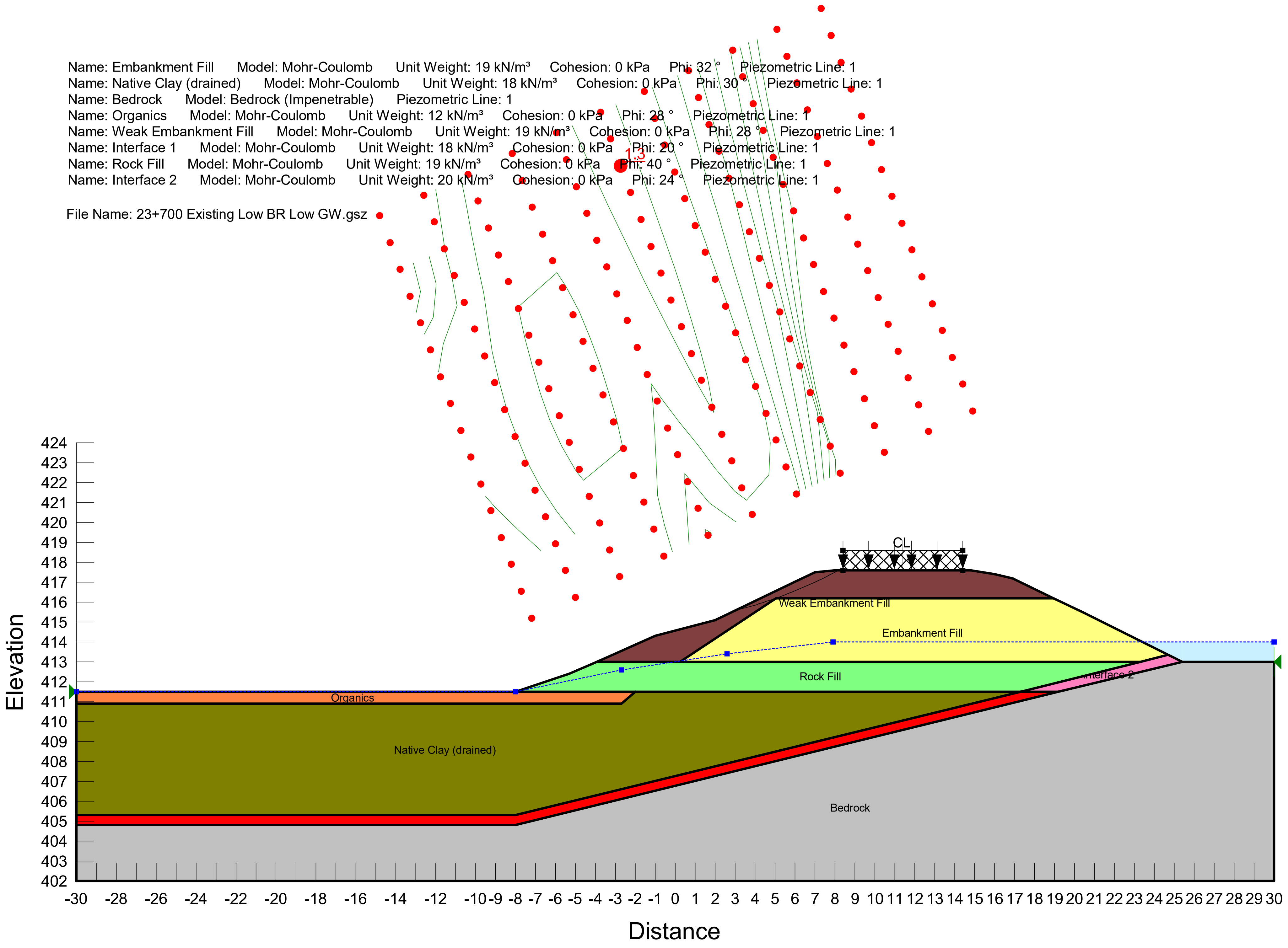
DESIGN | CHK | CODE XXXXX-XX | LOADXX-XXX-XXX | DATE 20160224
DRAWN TB | CHK GM | SITE | DWG 1

TBTE REF No.:15-011

APPENDIX D

Stability Models

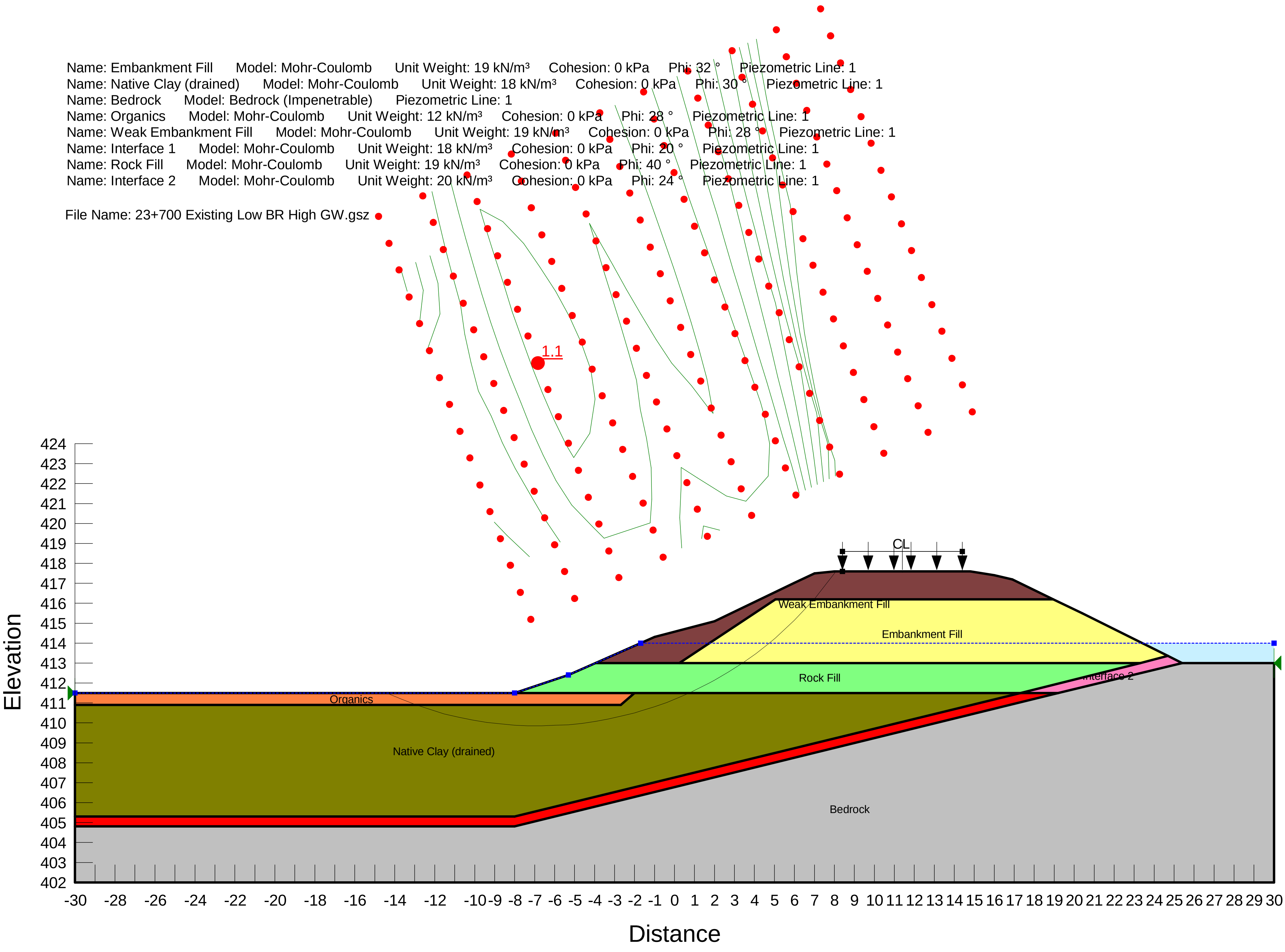
Existing Embankment Configuration



Existing Embankment Configuration

Name: Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °   Piezometric Line: 1
Name: Native Clay (drained)   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 30 °   Piezometric Line: 1
Name: Bedrock   Model: Bedrock (Impenetrable)   Piezometric Line: 1
Name: Organics   Model: Mohr-Coulomb   Unit Weight: 12 kN/m³   Cohesion: 0 kPa   Phi: 28 °   Piezometric Line: 1
Name: Weak Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 28 °   Piezometric Line: 1
Name: Interface 1   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 20 °   Piezometric Line: 1
Name: Rock Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 40 °   Piezometric Line: 1
Name: Interface 2   Model: Mohr-Coulomb   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 24 °   Piezometric Line: 1

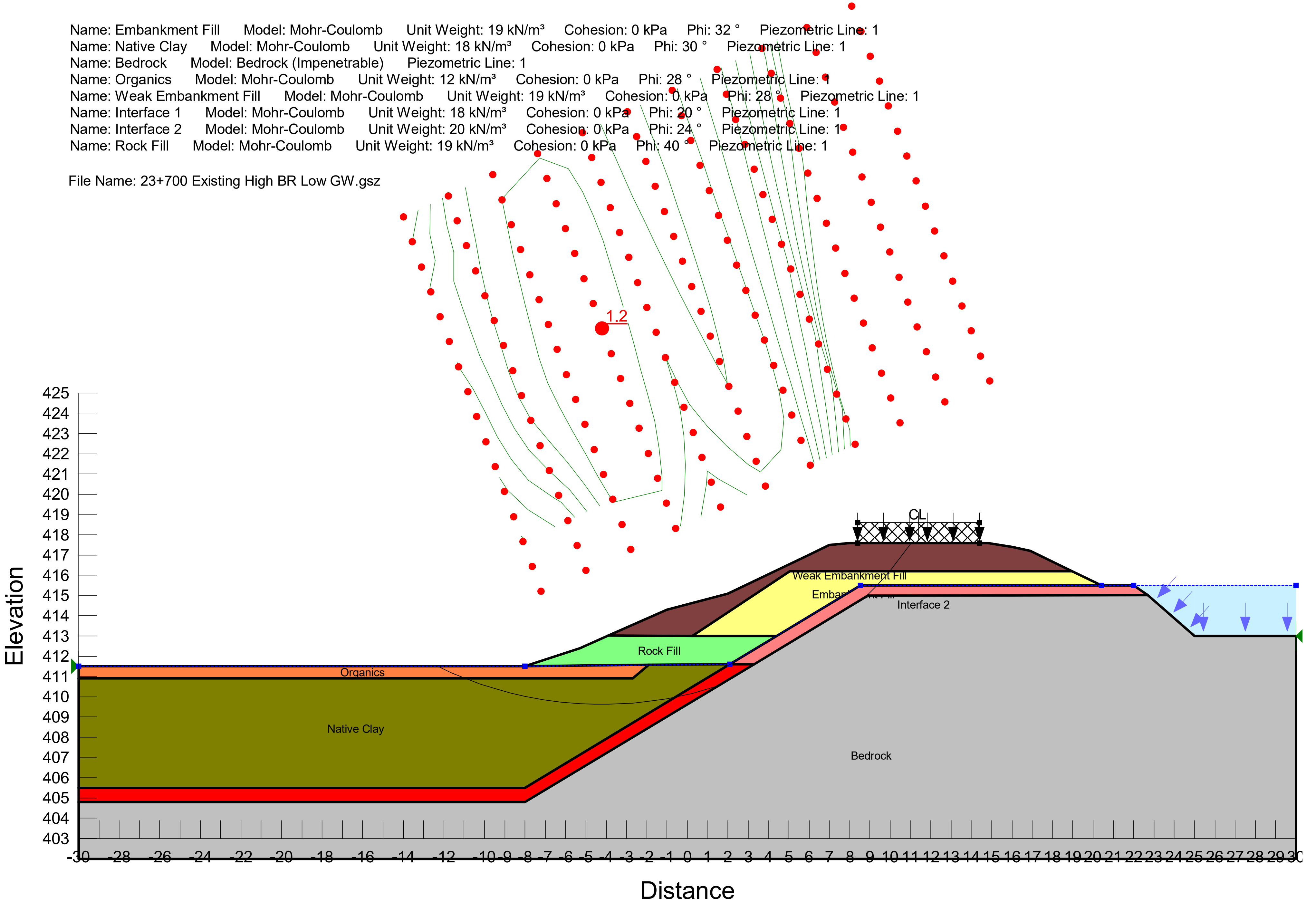
File Name: 23+700 Existing Low BR High GW.gsz



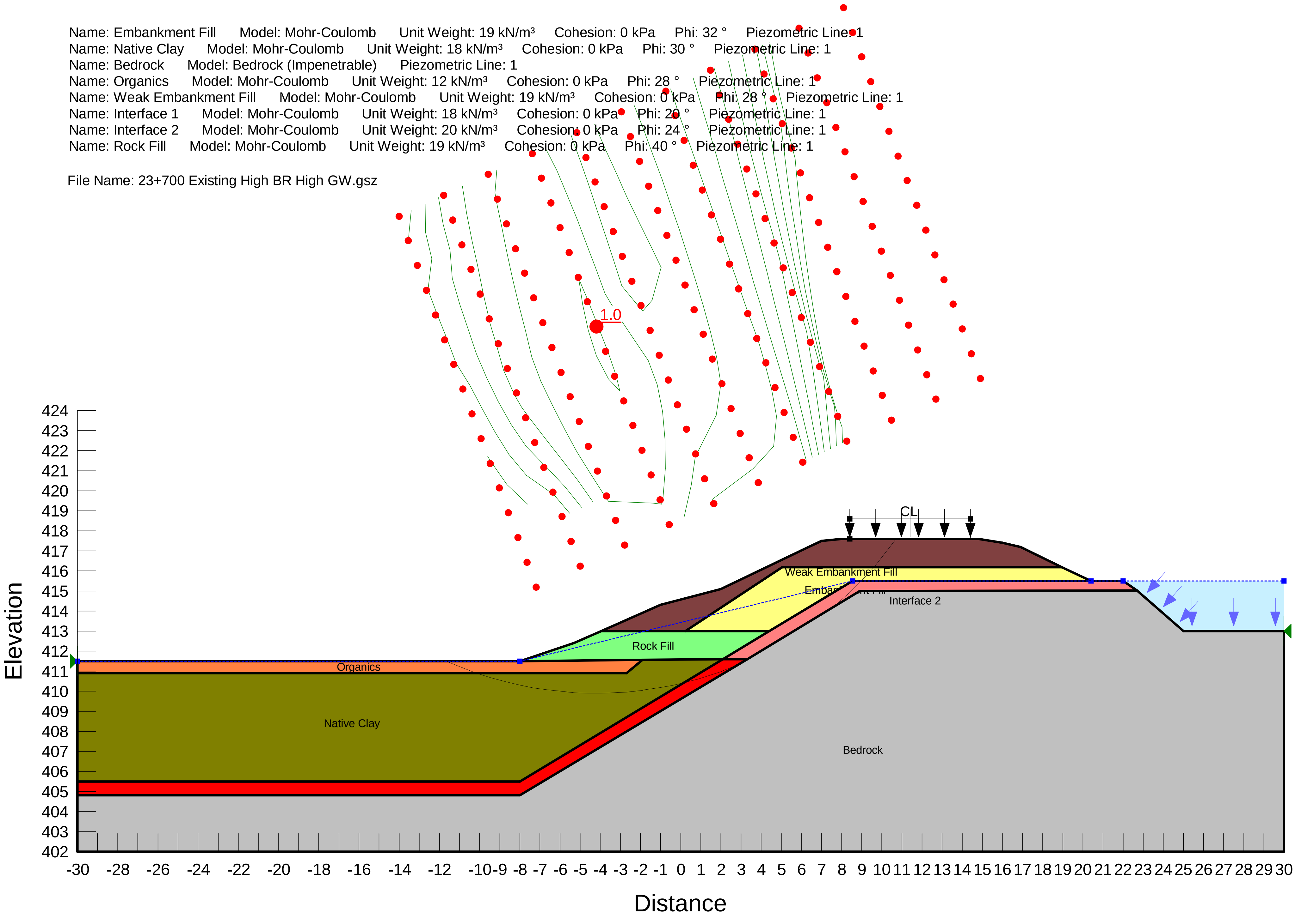
Exisitng Embankment Configuration

Name: Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °   Piezometric Line: 1
Name: Native Clay   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 30 °   Piezometric Line: 1
Name: Bedrock   Model: Bedrock (Impenetrable)   Piezometric Line: 1
Name: Organics   Model: Mohr-Coulomb   Unit Weight: 12 kN/m³   Cohesion: 0 kPa   Phi: 28 °   Piezometric Line: 1
Name: Weak Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 28 °   Piezometric Line: 1
Name: Interface 1   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 20 °   Piezometric Line: 1
Name: Interface 2   Model: Mohr-Coulomb   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 24 °   Piezometric Line: 1
Name: Rock Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 40 °   Piezometric Line: 1

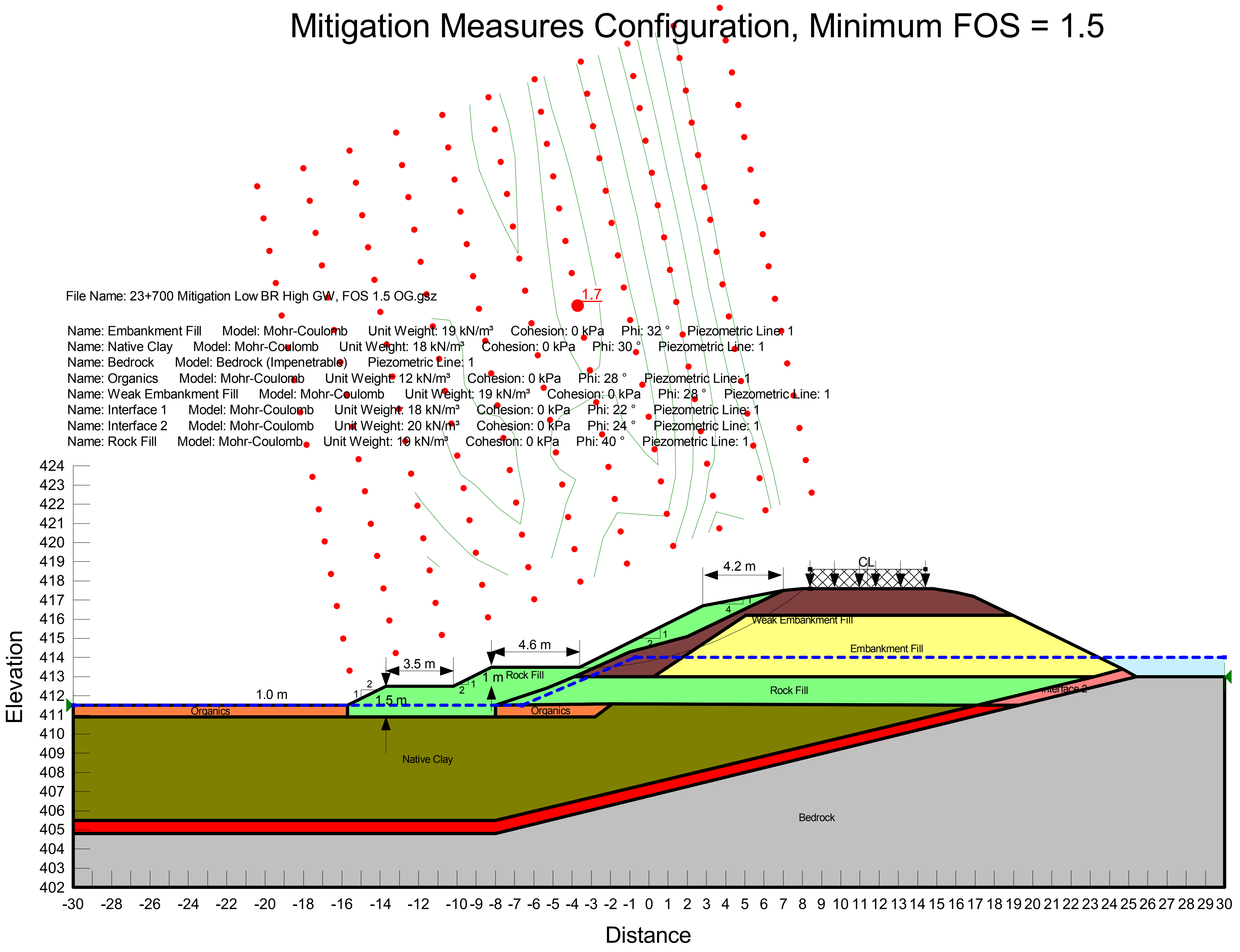
File Name: 23+700 Existing High BR Low GW.gsz



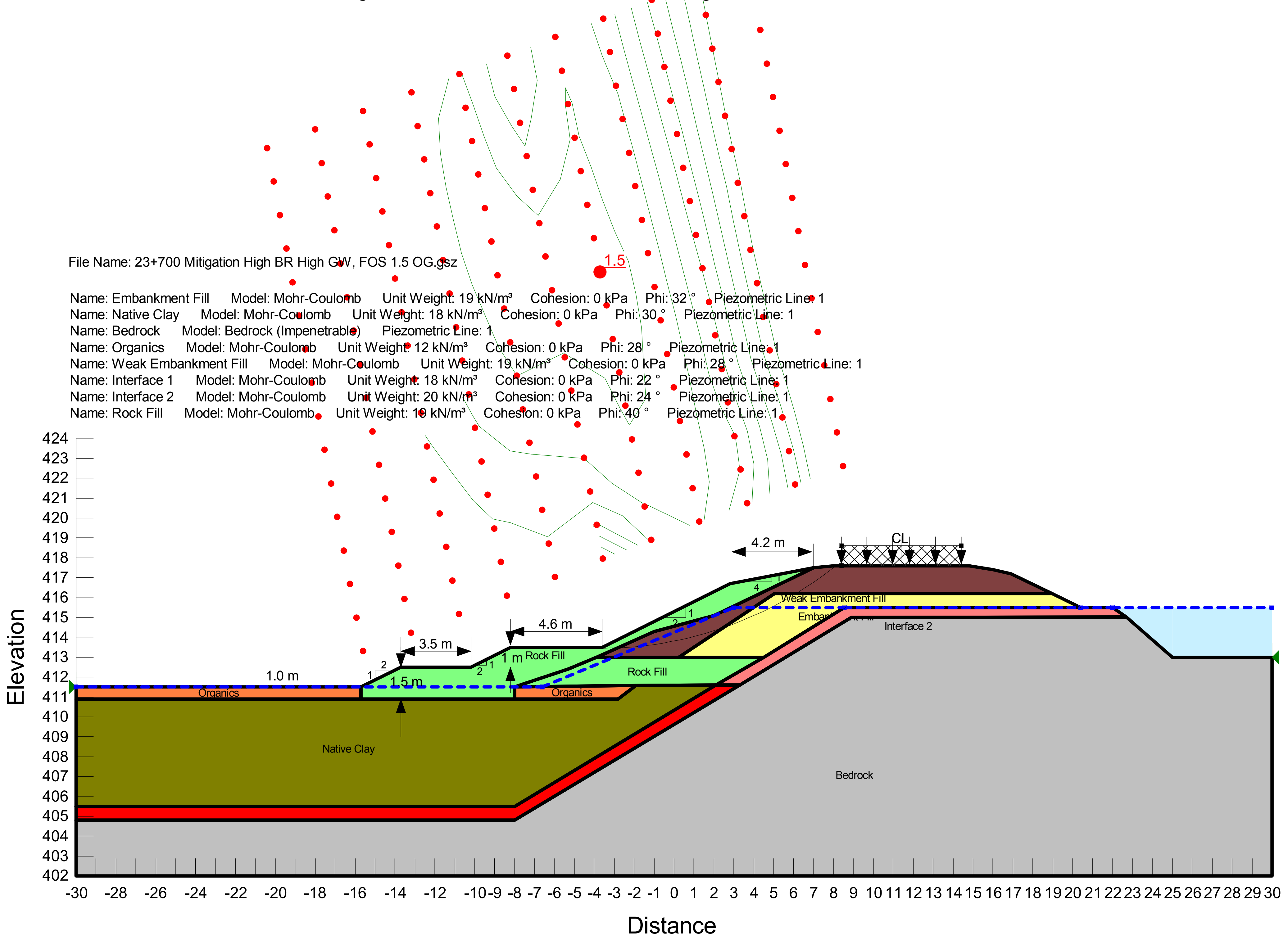
Exisitng Embankment Configuration



Mitigation Measures Configuration, Minimum FOS = 1.5



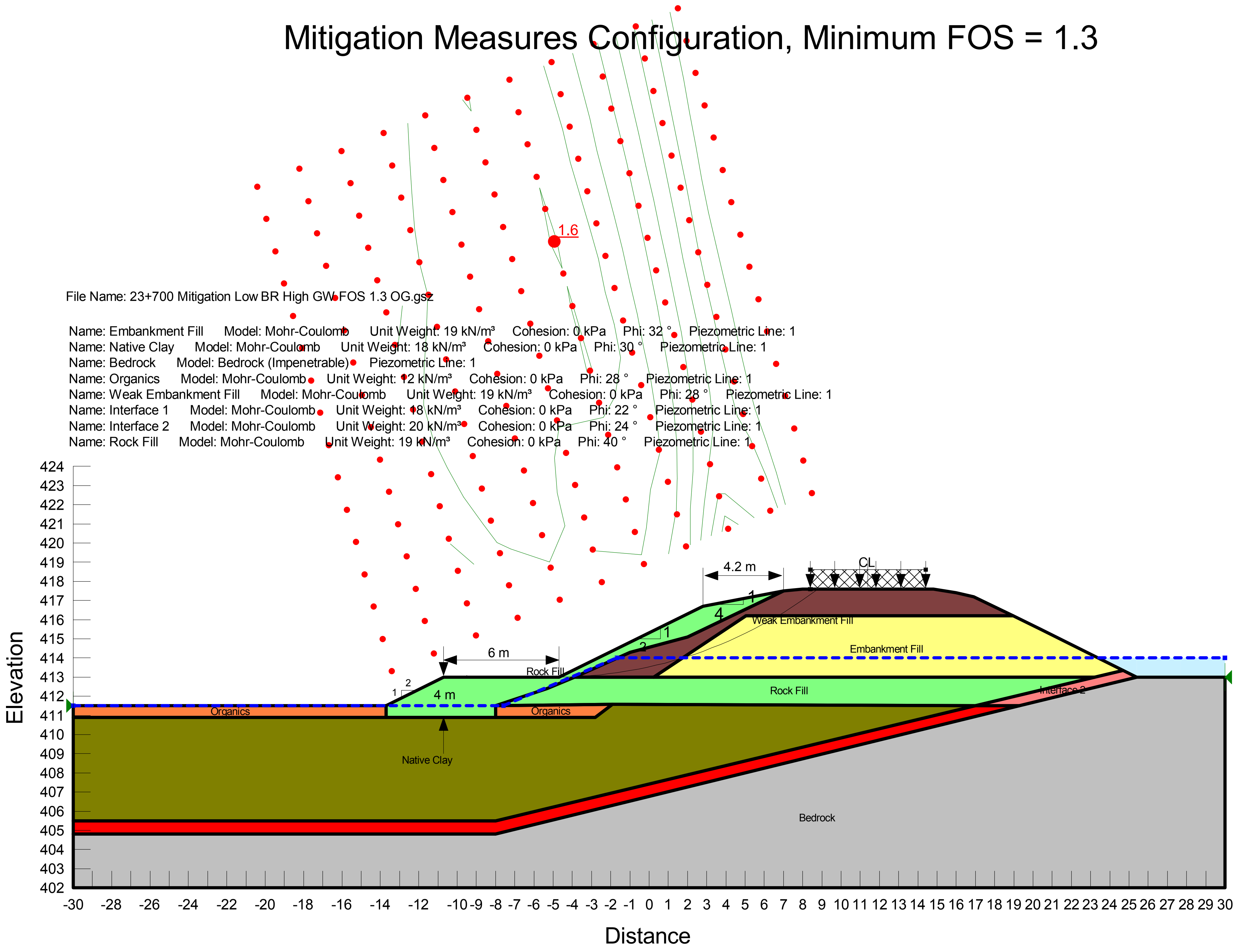
Mitigation Measures Configuration, Minimum FOS = 1.5



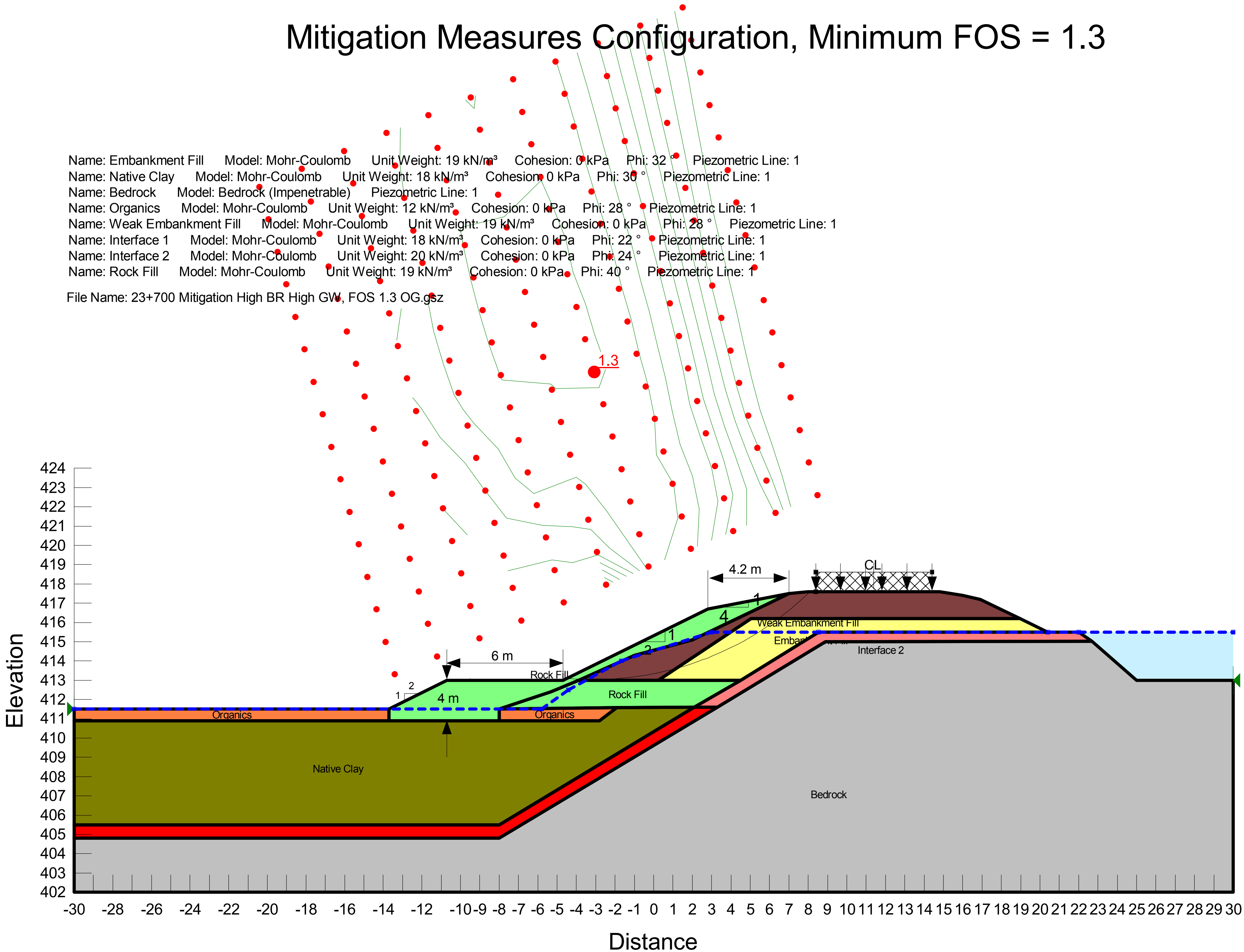
Mitigation Measures Configuration, Minimum FOS = 1.3

File Name: 23+700 Mitigation Low BR High GW FOS 1.3 OG.gsz

Name: Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °   Piezometric Line: 1
Name: Native Clay   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 30 °   Piezometric Line: 1
Name: Bedrock   Model: Bedrock (Impenetrable)   Piezometric Line: 1
Name: Organics   Model: Mohr-Coulomb   Unit Weight: 12 kN/m³   Cohesion: 0 kPa   Phi: 28 °   Piezometric Line: 1
Name: Weak Embankment Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 28 °   Piezometric Line: 1
Name: Interface 1   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 1
Name: Interface 2   Model: Mohr-Coulomb   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 24 °   Piezometric Line: 1
Name: Rock Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 40 °   Piezometric Line: 1



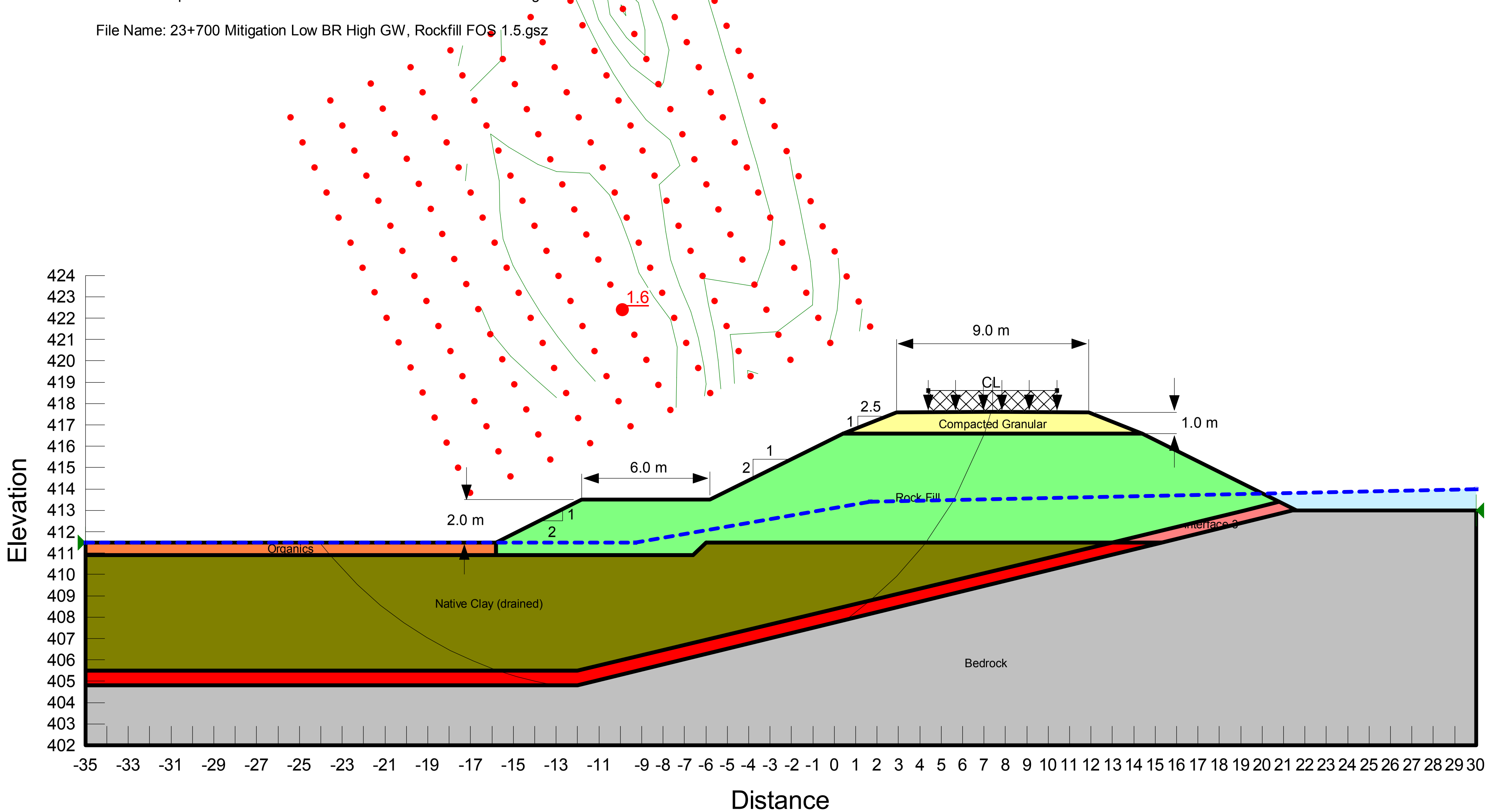
Mitigation Measures Configuration, Minimum FOS = 1.3



Reconstruction Configuration, Minimum FOS = 1.5

Name: Native Clay (drained) Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Interface 3 Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1

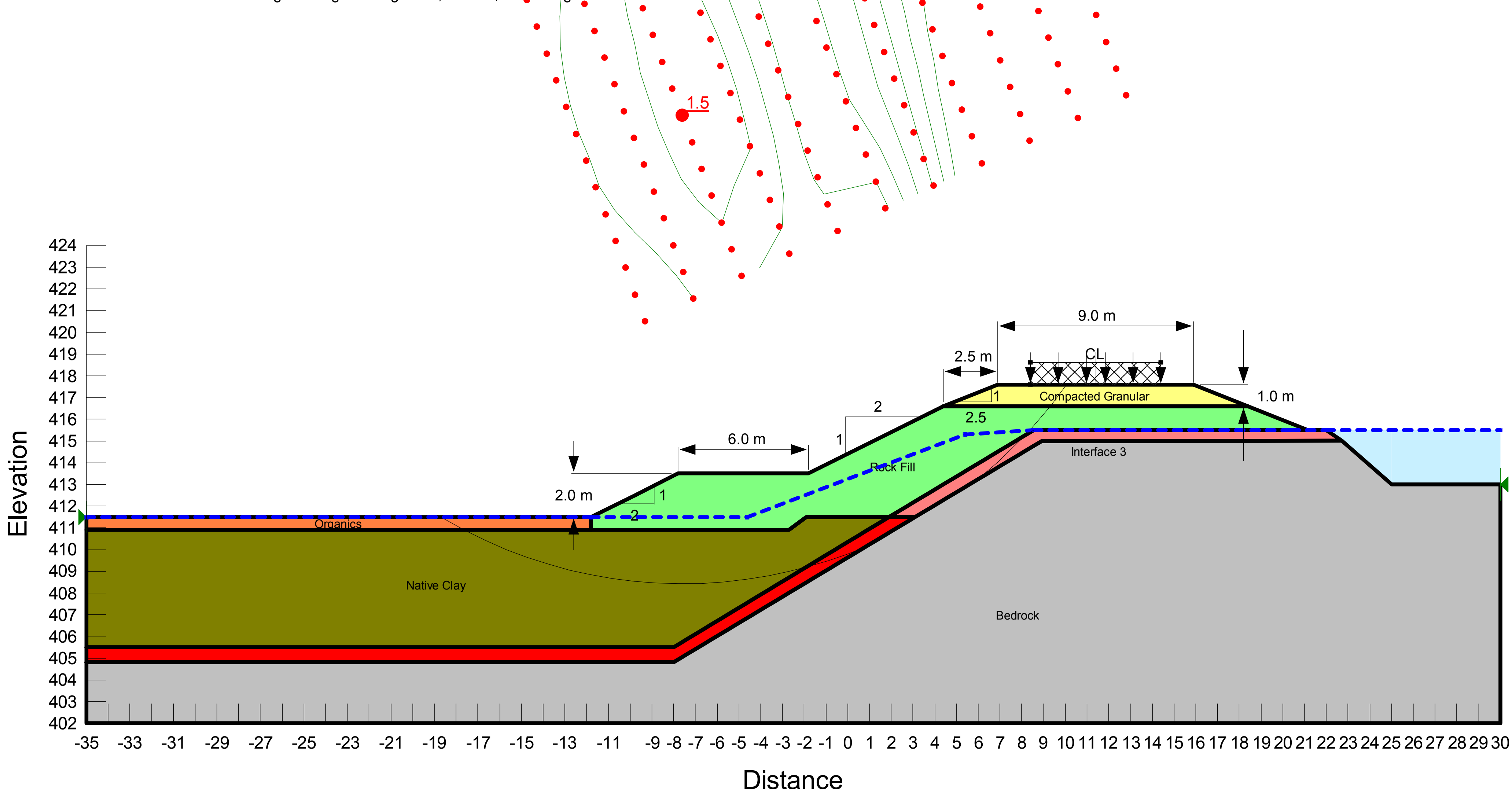
File Name: 23+700 Mitigation Low BR High GW, Rockfill FOS 1.5.gsz



Reconstruction Configuration, Minimum FOS = 1.5

Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1
Name: Native Clay Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Interface 3 Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1

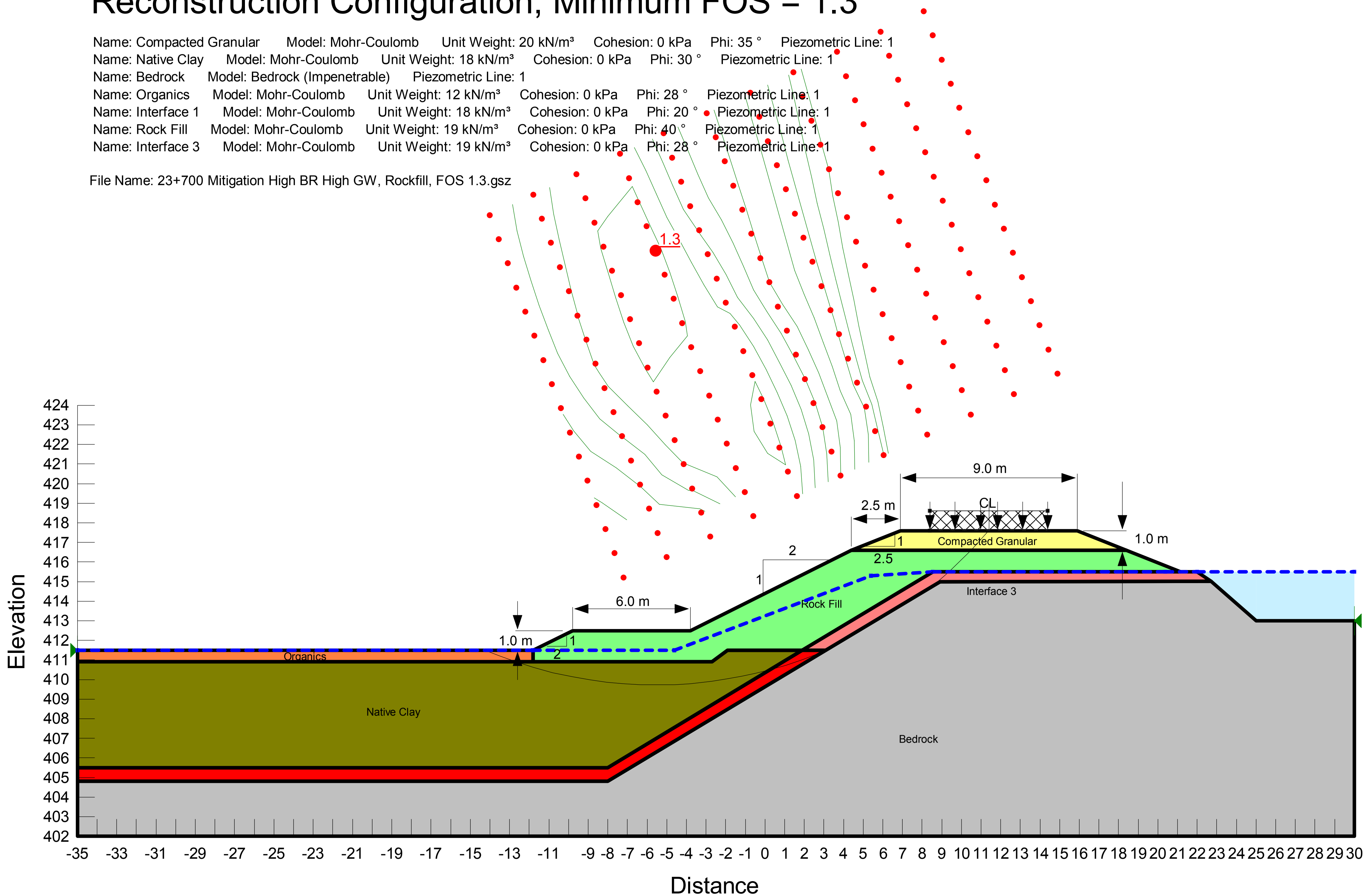
File Name: 23+700 Mitigation High BR High GW, Rockfill, FOS 1.5.gsz



Reconstruction Configuration, Minimum FOS = 1.3

Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1
Name: Native Clay Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Interface 3 Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1

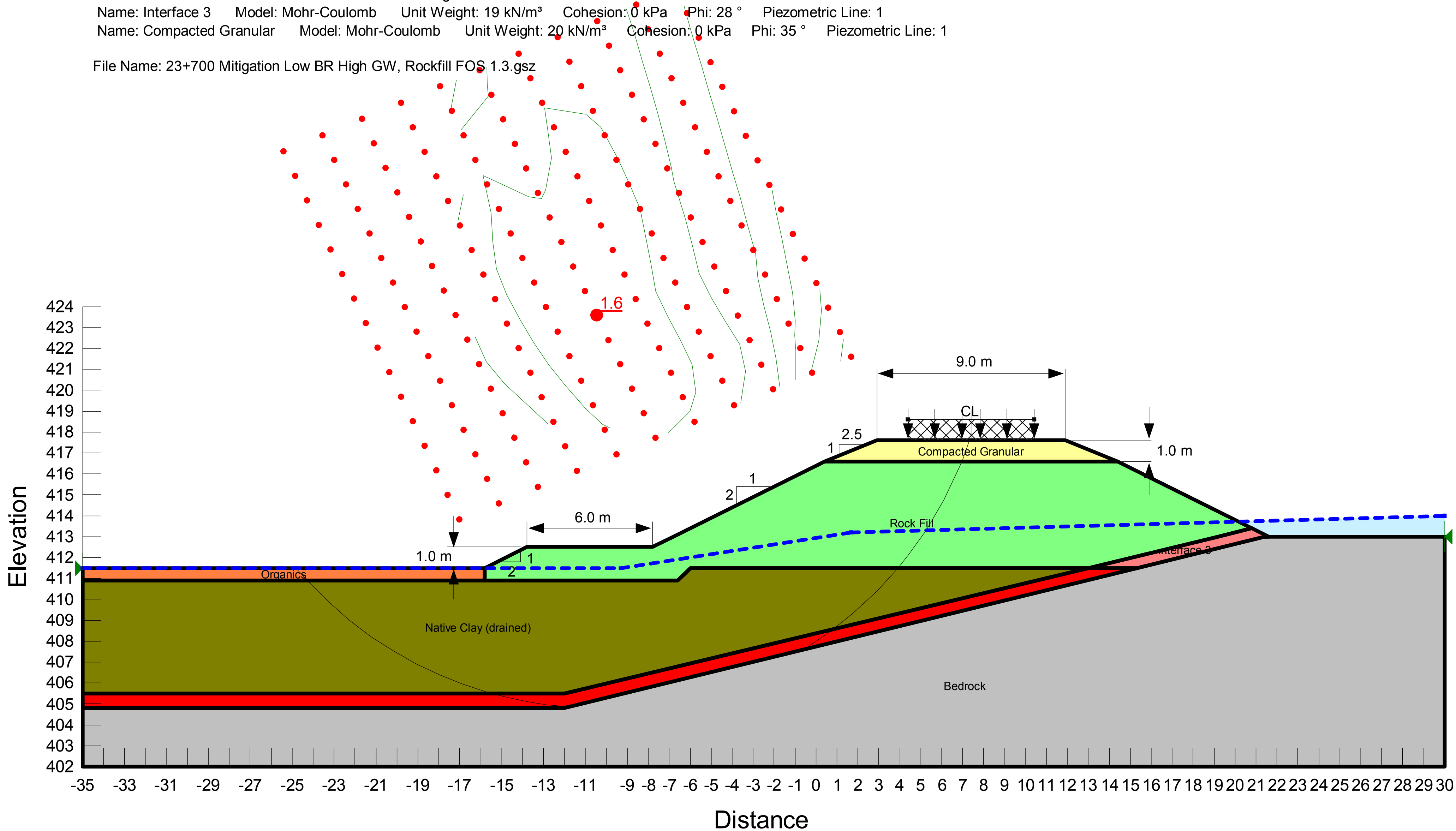
File Name: 23+700 Mitigation High BR High GW, Rockfill, FOS 1.3.gsz

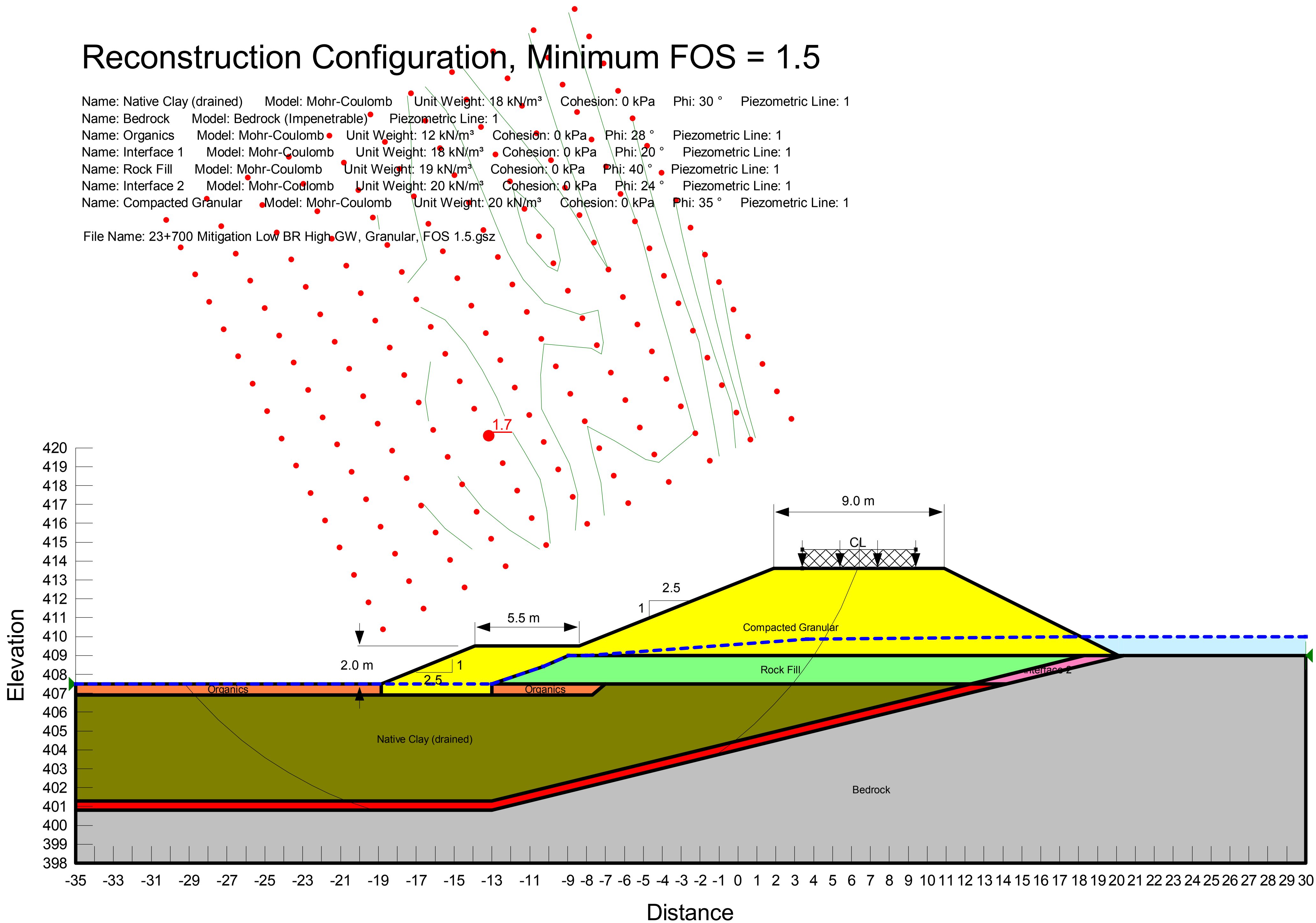


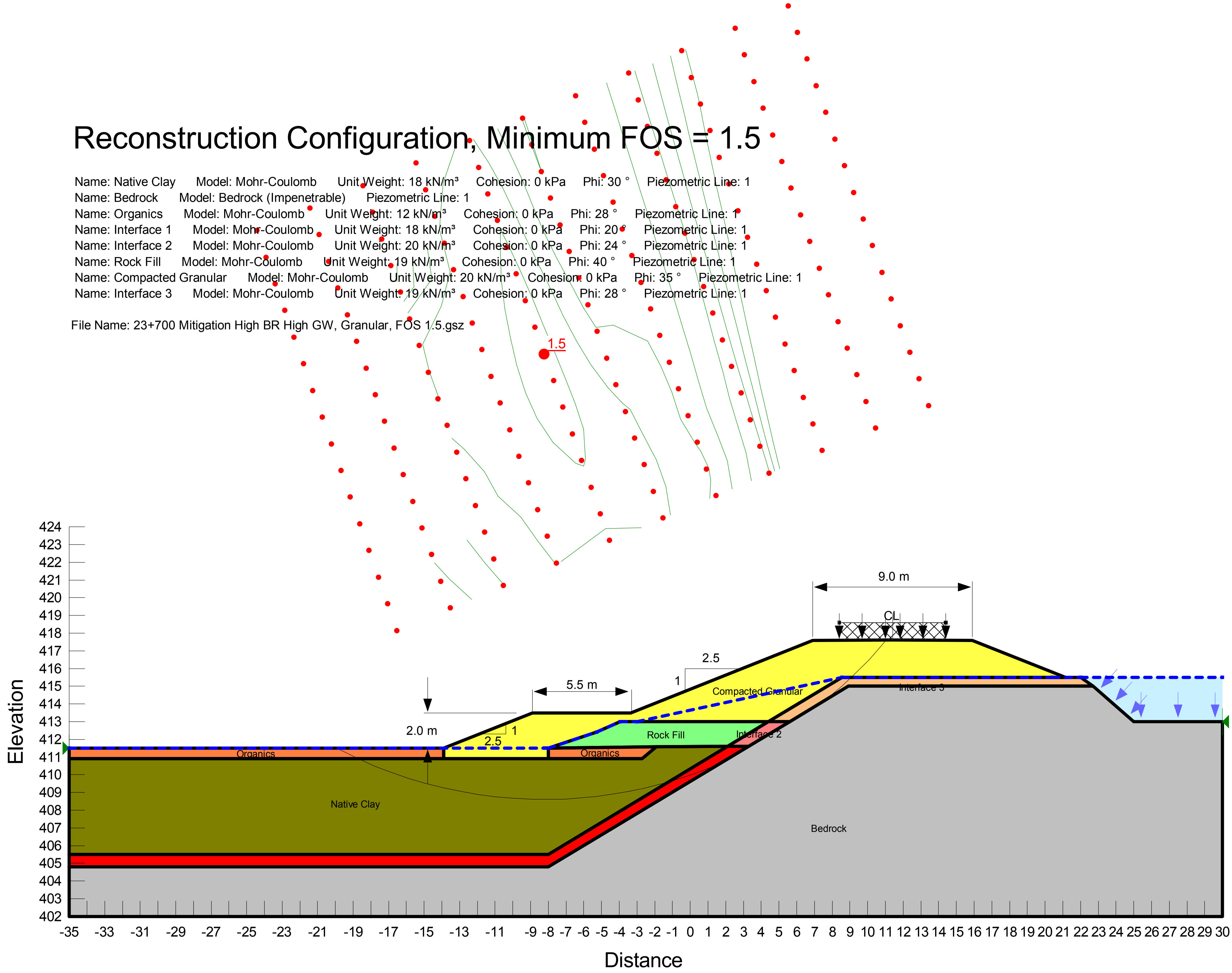
Reconstruction Configuration, Minimum FOS = 1.3

Name: Native Clay (drained) Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Interface 3 Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1

File Name: 23+700 Mitigation Low BR High GW, Rockfill FOS 1.3.gsz




Reconstruction Configuration, Minimum FOS = 1.5
Name: Native Clay (drained) Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Interface 2 Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 24 ° Piezometric Line: 1
Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1
File Name: 23+700 Mitigation Low BR High GW, Granular, FOS 1.5.gsz
1.7
9.0 m
CL
2.5
1
5.5 m
2.0 m
1
2.5
Compacted Granular
Rock Fill
Organics
Organics
Native Clay (drained)
Bedrock
Elevation
Distance


Reconstruction Configuration, Minimum FOS = 1.5
Name: Native Clay Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Interface 2 Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 24 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1
Name: Interface 3 Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
File Name: 23+700 Mitigation High BR High GW, Granular, FOS 1.5.gsz
1.5
9.0 m
CL
2.5
1
5.5 m
2.0 m
2.5
1
Compacted Granular
Interface 3
Rock Fill
Interface 2
Organics
Organics
Native Clay
Bedrock
Elevation
424
423
422
421
420
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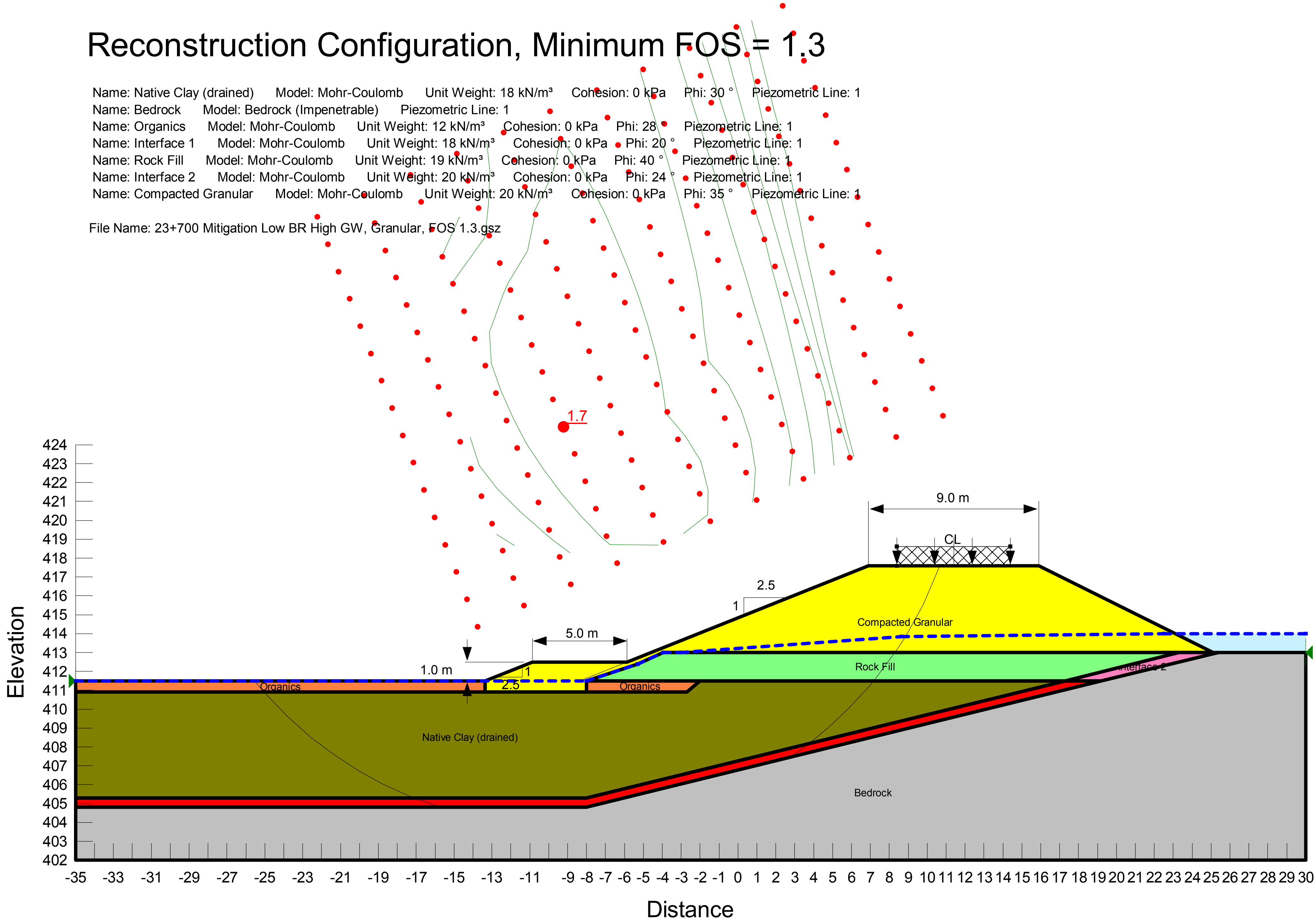
-35 -33 -31 -29 -27 -25 -23 -21 -19 -17 -15 -13 -11 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Distance

Reconstruction Configuration, Minimum FOS = 1.3

Name: Native Clay (drained) Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Interface 2 Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 24 ° Piezometric Line: 1
Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1

File Name: 23+700 Mitigation Low BR High GW, Granular, FOS 1.3.gsz



Reconstruction Configuration, Minimum FOS = 1.3

Name: Native Clay Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Organics Model: Mohr-Coulomb Unit Weight: 12 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1
Name: Interface 1 Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 20 ° Piezometric Line: 1
Name: Interface 2 Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 24 ° Piezometric Line: 1
Name: Rock Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 40 ° Piezometric Line: 1
Name: Compacted Granular Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 ° Piezometric Line: 1
Name: Interface 3 Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Piezometric Line: 1

File Name: 23+700 Mitigation High BR High GW, Granular, FOS 1.3.gsz