STATE OF COLORADO

Eschberger - DNR, Amy <amy.eschberger@state.co.us>

# TR application 7, for Cross Gold Mine (m1977-410) a Geotechnical Stability Exhibit in accordance with Rule 6.5(3)

**rmittasch@nedmining.com** <rmittasch@nedmining.com> Thu, May 7, 2020 at 1:00 PM
To: "Eschberger - DNR, Amy" <amy.eschberger@state.co.us>

Dear Ms. Eschberger:

As you requested in your correspondence dated April 7, 2020, attached is the Technical Revision Application to the Division. I will be mailing a hard copy to your office.

This Technical Revision is to Geotechnical Stability Exhibit in accordance with Rule 6.5(3), which will show through appropriate geotechnical and stability analyses that off-site areas will be protected based on current conditions at the Idaho Tunnel, with appropriate factors of safety incorporated into

Please feel free to contact our Team or myself if there are any questions regarding this matter.

Yours truly,

Richard Mittasch

Calais Resources Colorado, Inc.

Grand Island Resources, LLC

VP of operations

(516) 582-0833

Rmittasch@nedmining.com

**Idaho Tunnel Slope Stability TM (final)x.pdf**
3678K

**COLORADO DIVISION OF RECLAMATION, MINING AND SAFETY**

1313 Sherman Street, Room 215, Denver, Colorado 80203 ph(303) 866-3567

# REQUEST FOR TECHNICAL REVISION (TR) COVER SHEET

File No.: M- 1977-410 Site Name: Cross Gold Mine

County Boulder TR# _______________ *(DRMS Use only)*

Permittee: Calais Resources Colorado, Inc.

Operator (If Other than Permittee): _______________

Permittee Representative: Richard Mittasch

Please provide a brief description of the proposed revision:

This Technical Revision has been prepared to present geotechnical stability analyses for the slopes adjacent to the Idaho Tunnel Portal in response to a Minerals Program Inspection Report from DRMS dated March 26, 2020 in conjunction with the Cross Mine, DRMS Permit No. M-1977-410.

As defined by the Minerals Rules, a Technical Revision (TR) is: "a change in the permit or application which does not have more than a minor effect upon the approved or proposed Reclamation or Environmental Protection Plan." The Division is charged with determining if the revision as submitted meets this definition. If the Division determines that the proposed revision is beyond the scope of a TR, the Division may require the submittal of a permit amendment to make the required or desired changes to the permit.

The request for a TR is not considered "filed for review" until the appropriate fee is received by the Division (as listed below by permit type). Please submit the appropriate fee with your request to expedite the review process. After the TR is submitted with the appropriate fee, the Division will determine if it is approvable within 30 days. If the Division requires additional information to approve a TR, you will be notified of specific deficiencies that will need to be addressed. If at the end of the 30 day review period there are still outstanding deficiencies, the Division must deny the TR unless the permittee requests additional time, in writing, to provide the required information.

There is no pre-defined format for the submittal of a TR; however, it is up to the permittee to provide sufficient information to the Division to approve the TR request, including updated mining and reclamation plan maps that accurately depict the changes proposed in the requested TR.

Required Fees for Technical Revision by Permit Type - Please mark the correct fee and submit it with your request for a Technical Revision.

| **Permit Type** | **Required TR Fee** | **Submitted** (mark only one) |
|---|---|---|
| 110c, 111, 112 construction materials, and 112 quarries | $216 | ☑ |
| 112 hard rock (not DMO) | $175 | ☐ |
| 110d, 112d(1, 2 or 3) | $1006 | ☐ |

# Cross Mine (M1977-410)
# Technical Revision No. 7

**Submitted by:**

**Calais Resources Colorado, Inc.**

**Prepared for:**

**Colorado Division of Reclamation, Mining and Safety**

**May 7, 2020**

# Technical Memorandum

| | | | |
|---|---|---|---|
| **DATE:** | 7 May, 2020 | **PROJECT:** | Cross Mine |
| **ATTENTION:** | Richard Mittasch | **COMPANY:** | Grand Island Resources, LLC |
| **PREPARED BY:** | Dave Hallman, PE, PG | **REVIEWED BY:** | RM |

**SUBJECT:** Idaho Tunnel Portal – Slope Stability Analysis

## 1.0 INTRODUCTION

This Technical Memorandum has been prepared to present geotechnical stability analyses for the slopes adjacent to the Idaho Tunnel Portal in response to a Minerals Program Inspection Report from DRMS dated March 26, 2020 in conjunction with the Cross Mine, DRMS Permit No. M-1977-410. As indicated in the Inspection Report from DRMS, the Idaho Tunnel (at the Caribou Mine) has collapsed creating potential slope stability issues near the northern permit boundary and the adjacent Caribou Road. This is a concern pursuant to Rule 3.1.5(3) and C.R.S. 34-32-116(7)(h) which require areas outside of the affected land to be protected from slides or damage occurring during the mining operation and reclamation.

The stability evaluation presented was based largely on observation and professional judgement as limited engineering data was available. This work was conducted by Mr. David Hallman, a geological engineer with 37 years of experience and licensed as Colorado Professional Engineer (Civil) 26076, as affirmed by the stamp and signature affixed at the end of this document.

## 1.1 BACKGROUND

### 1.1.1. Location

The Cross Mine site is located approximately 3 miles west of Nederland, Colorado adjacent to the Roosevelt National Forest, at an elevation of 9700 feet above mean sea level (MSL). The general location is parcels of land in Section 9, Township 1 South, Range 73 West of the 6 Principal Meridian, County of Boulder, State of Colorado. This is an existing hard rock mining operation owned by Grand Island Resources Inc. (GIR), although at present, no active mining is being conducted.

### 1.1.2. Portal Rehabilitation

Entrance to the Idaho Tunnel at the mine site was in such a state of neglect and disrepair from long-term gradual deterioration that it was not safe to enter and operate the mine water system per the approved permit. In particular, the timber ground supports at the portal were tilted dangerously askew and the ground slopes adjacent to the portal also exhibited signs of shallow slope failures and sloughing, such as titled trees (Photograph 1).

***Photograph 1 – Idaho Tunnel Portal prior to Rehabilitation***

The timbered tunnel entrance and area around the opening were excavated in November 2019 in order to stabilize the tunnel portal. This effort involved excavating approximately 25 feet into the hillside, installing soil anchors, and applying a layer of shotcrete of variable thickness (Photograph 2). This work was performed by Harrison Western Construction Corporation, a licensed contractor.

The tunnel portal is being enlarged to a nominal 10-ft. x 10-ft. opening in order to replace the existing ground support which is failing and remove the loosened rock surrounding the present opening. The enlarged tunnel opening is supported by steel sets installed at 4-ft center-to-center spacing with full lagging on the back and ribs. The steel sets consist of W6x20 wide-flange I-beams and support posts. The lagging consists of 3-in. x 8-in. Douglas Fir planks. Grouted threadbar spillings were installed at 12-inch spacing above the tunnel opening prior to excavation.

In December 2019 a roof collapse occurred a short distance into the tunnel during initial rehabilitation efforts by Harrison Western. The roof failure occurred in an 11-12 ft section of unsupported ground as the tunnel opening was being enlarged through a section of mixed soil and decomposed gneiss. The collapse completely blocked the mine opening, crushed the pipe carrying the flow of mine water, and daylighted in the slope below County Road 128 (Caribou Road), leaving a large remnant void above the tunnel opening which estimated to be approximately 65 cubic yards.

***Photograph 2 – Current Condition of the Idaho Tunnel Portal. The three safety cones and caution tape at the top of the slope mark the edge of Country Road 126 (Caribou Road). The crown hole over the void is visible between the two small trees above the portal.***

### 1.1.3. Collapse Repair

In late February 2020, two additional new steel sets were installed in the area of the tunnel portal beneath the collapse and lined with lagging on the ribs and back. As with the initial two steel sets, these consisted of W6 x20 wide flange steel beams and posts installed on 4-ft center-to-center spacing. Lagging consisted of 3-in. x 8-in. treated Douglas Fir planks. This design and installation were inspected and approved by Mr. David Hallman, a geological engineer with 37 years of experience and registered as Colorado Professional Engineer No. 26076.

The narrow gap between the new ground supports and the existing ground was been closed using pieces of lagging, plywood, polyurethane foam, and caulk to create a tight seal. The remaining void created by the portal collapse will be backfilled with pervious cellular concrete to provide permanent ground support that will stabilize the slope and allow drainage.

The completed cellular concrete backfill will be significantly stronger than the soil which originally comprised the slope while imposing only a fraction of the weight. This will serve to increase stability of the slope below the county road. The flowable nature of the backfill will allow it to completely encapsulate the tunnel lining system in a solid mass to create robust permanent support for the mine entrance. The previous nature of the backfill will allow groundwater to freely drain from the slope in order to ensure long-term stability.

Mix Design Information (per cubic yard):

| | |
|---|---|
| Cement: | 622 lbs |
| Water | 323 lbs |
| Cellular Foam: | 18.7 cf |
| Air Content: | 69% |
| Unit Weight: | 35.0 pcf |
| water/cement ratio: | 0.52 |
| Permeability (ASTM D2434): | 8.7 x $10^{-2}$ cm/sec |

Compressive Strength

| | |
|---|---|
| 7-Day: | 100 psi |
| 28-day: | 214 psi |

Placing the cellular concrete backfill was originally scheduled for April 1, 2020 but was postponed due to the Corona virus and social distancing concerns. At this time, it is not known when the work will resume. Following placement, the cellular concrete backfill will harden rapidly and allow rehabilitation of the tunnel to resume within several days following receipt of the appropriate approvals

This Technical Memorandum presents the results of an engineering evaluation of the geotechnical stability of the overall slopes above and adjacent to the portal slopes, and provides this information to DRMS.

## 1.2 Geology

### 1.2.1. Regional

The Caribou area, which is part of the Front Range Mineral Belt, is underlain by igneous and metamorphic rocks of pre-Cambrian age. These rocks are and, with the exception of locally covered by unconsolidated Quaternary glacial and stream deposits. . is devoid of sedimentary rocks., The pre-Cambrian rocks in the Caribou area and in the adjoining areas to the north and south are intruded by Tertiary igneous rocks which form several small stocks. The three principal rock formations in the Caribou area are the Idaho Springs formation and the Boulder Creek granite of pre-Cambrian age, and the Tertiary monzonite of the Caribou stock. The Caribou stock also contains comprises small bodies of diorite, diabase, gabbro, and ultra-basic rocks. Minor units The Idaho Springs formation consists of include pre-Cambrian amphibolite, mica schist, biotite gneiss, quartz monzonite gneiss and pegmatite.

### 1.2.2. Roadside Geology

The Caribou Road (County Road 126) above the Idaho tunnel is located entirely in mixed soil and rock colluvium and regolith materials. Fresh gneiss of the Idaho Springs formation is present a short distance above the road and to the south of the tunnel portal.

### 1.2.3. Tunnel Geology

Figure 1 depicts a 1954 geologic map[1] of the initial portions of the Idaho Tunnel which was annotated by the previous operator and local miner, Tom Hendricks. As depicted on this map the ground conditions starting at the portal consist of "Alluvial Rock" transitioning to "Decomposed Granite" and then "Weak Hard Rock", none of which are proper terms to describe the geology, although they do provide some indications in that regard.

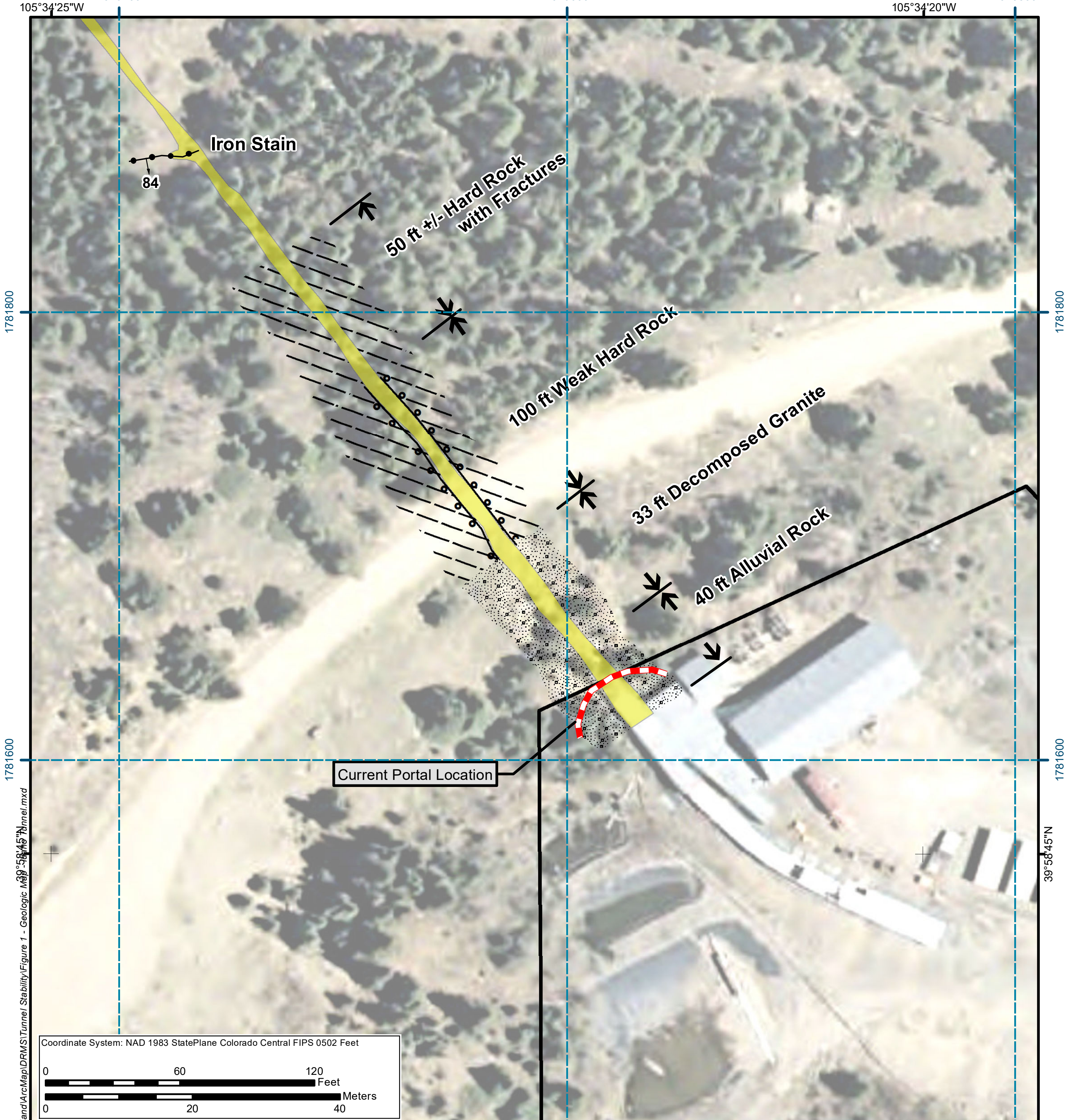
Geology exposed in the initial portal excavation and collapse void includes fractured and weathered blocky gneiss in the left wall or 'rib' when looking into the tunnel (Photograph 3). This material is interpreted as similar to the "Weak Hard Rock" depicted on Figure 1.

***Photograph 3 – Weathered and fractured gneiss in the left rib beneath the portal collapse. Green paint marks at 4-ft intervals mark the approximate location for the next steel sets.***

The right rib of the portal in the area of the collapse occurs in granular decomposed gneiss overlying deeply weathered blocky gneiss (Photograph 4). This material is interpreted as similar to the "Decomposed Granite" depicted on Figure 1.

Regolith and colluvial soils are exposed in the collapse void above the tunnel horizon (Photograph 5), excavation wing walls (Photograph 6), and the Caribou Road cut. This material is interpreted as similar to the "Alluvial Rock" depicted on Figure 1.

[1] Moore, F.B., Cavender, W.S., and Kaiser, E.P., 1954; "Geology and Uranium Deposits of the Caribou Area, Boulder County, Colorado." US Geological Survey Trace Elements Investigations Report 228, March 1954




**Legend**

- SWMP Boundary
- Idaho Tunnel
- Portal Location

**Geology**

- Overburden
- Gneiss and Schist
- Cribbing
- 85 Vein, showing dip; dashed where inferred

N

| | |
|---|---|
| Project | Idaho Tunnel Portal Slope Stability |
| Title | **Geologic Map - Idaho Tunnel** |

GRAND ISLAND RESOURCES

| | | | | |
|---|---|---|---|---|
| Project No. US 0401 | | | File No. | |
| GIS: | JST | 05/06/20 | Scale As Shown | Rev 0 |
| Check: | JST | 05/06/20 | **Figure 1** | |
| Review: | JST | 05/06/20 | | |

Path: C:\Users\jst52\Documents\NMX\GIS\Projects\Nederland\ArcMap\DRMS\Tunnel Stability\Figure 1 - Geologic Map - Idaho Tunnel.mxd

***Photograph 4 – Decomposed gneiss overlying weathered and fractured gneiss in the right rib beneath the portal collapse. Green paint marks the approximate location of the next steel sets at 4-ft intervals.***

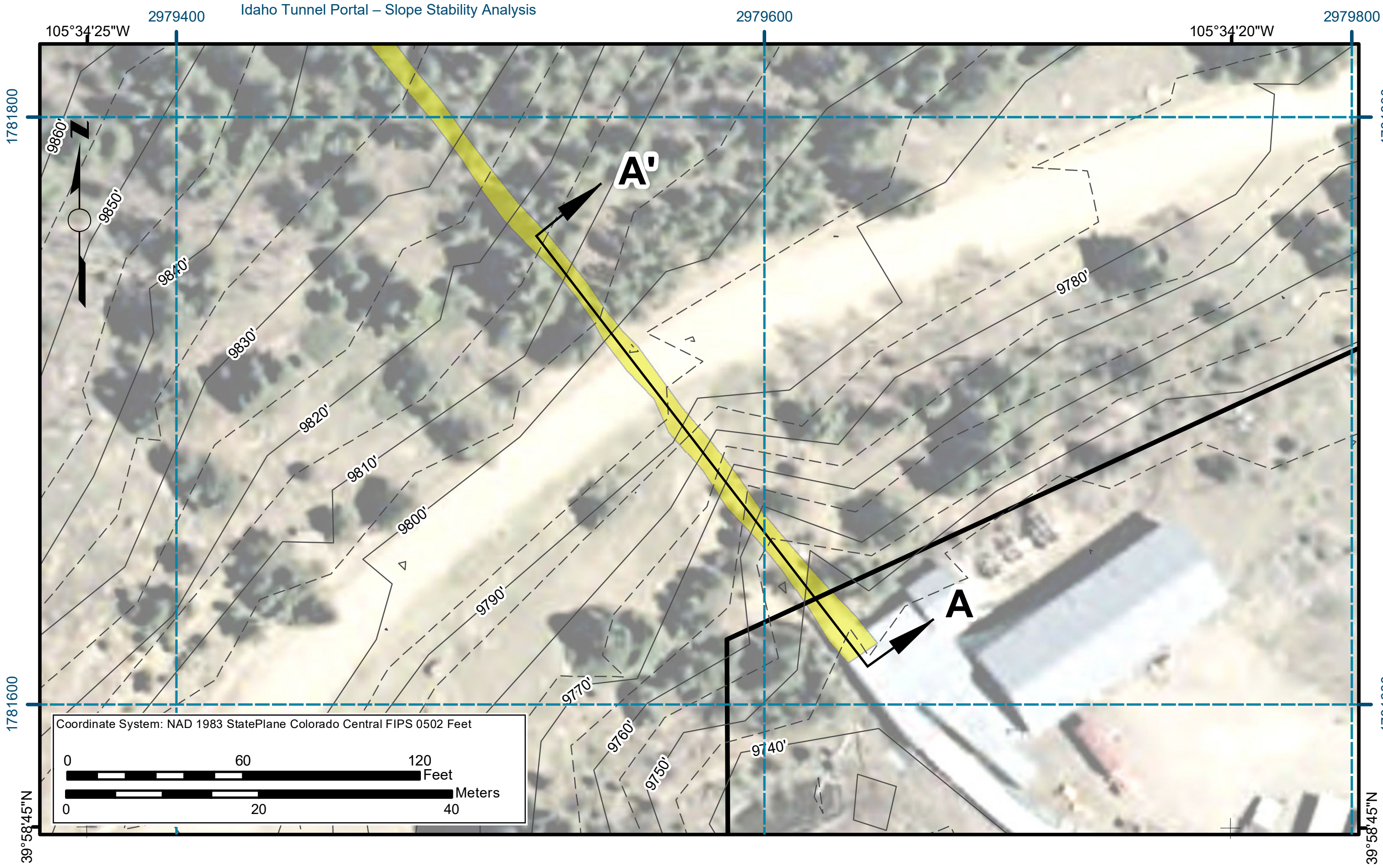
***Photograph 5 – Regolith and colluvium exposed in the walls of the collapse void. The threaded bars are some of the spillings which were installed before enlarging the portal excavation.***

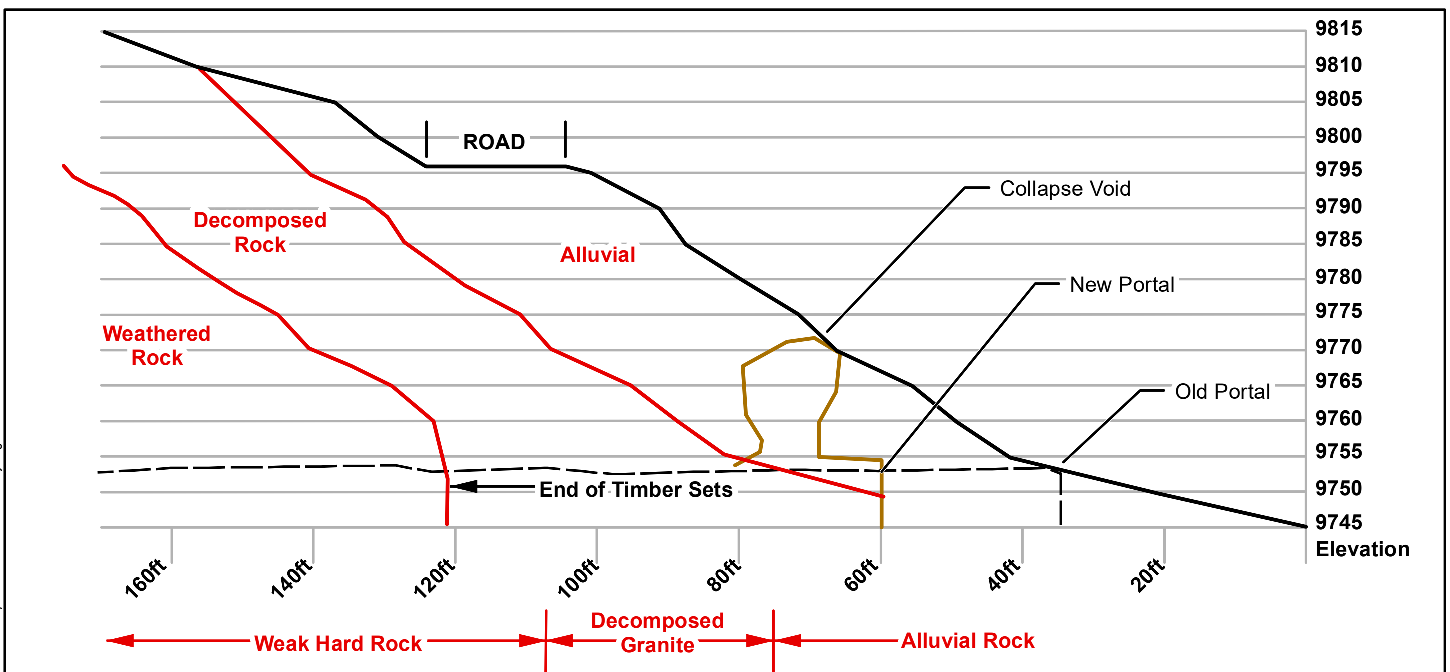
***Photograph 6 – Regolith and colluvium exposed in the right (north) wing wall of the portal excavation.***

GIR has explored the first 200 ft of the Idaho Tunnel in order to investigate the corresponding ground conditions that can be anticipated during the rehabilitation efforts. Starting from the back of the last steel set, the existing ground support consists of timber sets with full lagging on the back and ribs for the next 41 ft, followed by rock bolts and chain link mesh. The timber sets retain loose soil and rock, obscuring the undisturbed ground. Loose blocky material has also fallen onto much of the chain link and pulled it from the roof in places. The ground mass and rubble observed consists of granular fragments of decomposed rock mixed with blocky pieces of rock, transitioning more to angular pieces of highly fractured weathered rock with increasing distance into the tunnel. Other than a change in the type ground support previously employed, there does not seem to be a well-defined point in the tunnel at which a change from “Decomposed Granite” to “Weak Hard Rock” occurs. It appears to be a gradual transition with some of each type of material found within the other.

At approximately 200 ft from the new portal there is a collapse after which, the rock exposed in the sides of the tunnel (ribs) appears to be fresh and less fractured gneiss, the tunnel exhibits a more regular 6 ft x 6 ft opening, and there is no ground support visible. This is interpreted as the “Hard Rock with Fractures” indicated on Figure 1.

Grand Island Resources, LLC
Idaho Tunnel Portal – Slope Stability Analysis




**Legend**

SWMP Boundary
Idaho Tunnel

NOTE:
Contours were generated using open source LiDAR data collected from *https://www.opentopography.org/*.
Golden Field Services processed the data using Global Mapper and provided ground truthing on site using GPS equipment. Golden Field Services then combine the ground truthing and open source data.

Path: C:\Users\jst52\Documents\NMX\GIS\Projects\Nederland\ArcMap\DRMS\Tunnel Stability\Figure 2 - Plan and Profile.mxd

Project
Idaho Tunnel Portal Slope Stability

Title
**Plan and Profile**

GRAND ISLAND RESOURCES

| Project No. US 0401 | | | File No. | |
|---|---|---|---|---|
| GIS: | JST | 05/06/20 | Scale As Shown | Rev 0 |
| Check: | JST | 05/06/20 | **Figure 2** | |
| Review: | JST | 05/06/20 | | |

# 2.0 PROBLEM DESCRIPTION

Figure 2 presents a plan and profile of the Idaho Tunnel based on 10-ft topographic contours of the original ground surface. Superimposed on this figure are the approximate position of the rehabilitated tunnel portal following excavation.

The material encountered during portal excavation and currently exposed in the wing walls consisted of regolith and colluvium, with some decomposed rock encountered at depth. The excavated slopes stood unsupported following excavation and were dry at the time (Photograph 7). The maximum height at the taller left (south) wing wall is 28 ft, sloping at an angle of 70-80 degrees from horizontal. The top of the excavation is approximately 40 ft from County Road 128 (Caribou Road) at the closest point and 20 ft lower in elevation. This creates potential long-term concerns for stability of the road.

***Photograph 7 – Idaho Tunnel Portal following excavation***

The excavated slope above the portal opening and wing walls were reinforced with 10- and 20-ft soil nails, 6-gauge wire mesh, and nominal 6-inches of fiber-reinforced shotcrete. Grouted threadbar spillings were also installed at 12-inch spacing above the portal. These were reportedly 35 ft long, extending into harder ground and grouted. Unfortunately, little as-built documentation is available.

As of May 2, 2020, the sink hole above the collapse has crown slightly in size. Otherwise, there are no obvious signs of slope stability issues with the excavation or adjacent slopes, such as cracking or slumping, despite the occurrence of spring thaw and presence of some ground water. Locations which had been seeping water have stopped (Photograph 2) and the ground exposed in the non-shotcrete covered margins of the excavation has dried considerably.

# 3.0 STABILITY ANALYSIS

## 3.1 Approach

The stability analyses were conducted as two-dimensional limit-equilibrium analysis using commercially available software. Three cases were considered at which the slope was observed to be stable and therefore must exhibit a Factor of Safety (FoS) greater than unity; at the end of excavation, during spring thaw, and with an open void present. For the end of excavation scenario, the slope reinforcement was neglected in the analysis and the slope was assumed to be fully drained. For the spring thaw scenario, the presence of groundwater in the slope was considered in the analysis. The open collapse void and backfilled void were considered separately.

The actual FoS should be higher than the results presented for 2D analyses section due to the concaved slope orientation and 3D edge effects. Studies have shown that these 3D effects can become significant, often increasing the FoS by 10-20 percent, or even more[2]. This effect tends to become more significant as the amount of slope curvature increases, particularly as the ratio of the slope width to slope height drops below 3. In the case of the Idaho Tunnel Portal, the excavation has a relatively narrow open width of approximately 30 ft at the base of the mouth of the excavation relative to a height ranging from 15 to 28 ft. These effects have been considered qualitatively in the results discussion.

## 3.2 Software

The stability analyses were conducted using the RocScience SLIDE2 software, a 2D slope stability program for evaluating the safety factor or probability of failure, of circular and non-circular failure surfaces in soil or rock slopes. Slide2 analyzes the stability of slip surfaces using vertical slice or non-vertical slice limit equilibrium methods like Bishop, Janbu, Spencer, and Sarma, among others. Search methods can be applied to locate the critical slip surface for a given slope. The Bishop method of slices for circular failures surfaces while the Janbu method of slices for satisfying both moment and force equilibrium was adopted for non-circular surfaces.

The Slide2 software also allows the effects of slope reinforcement to be included in the analyses.

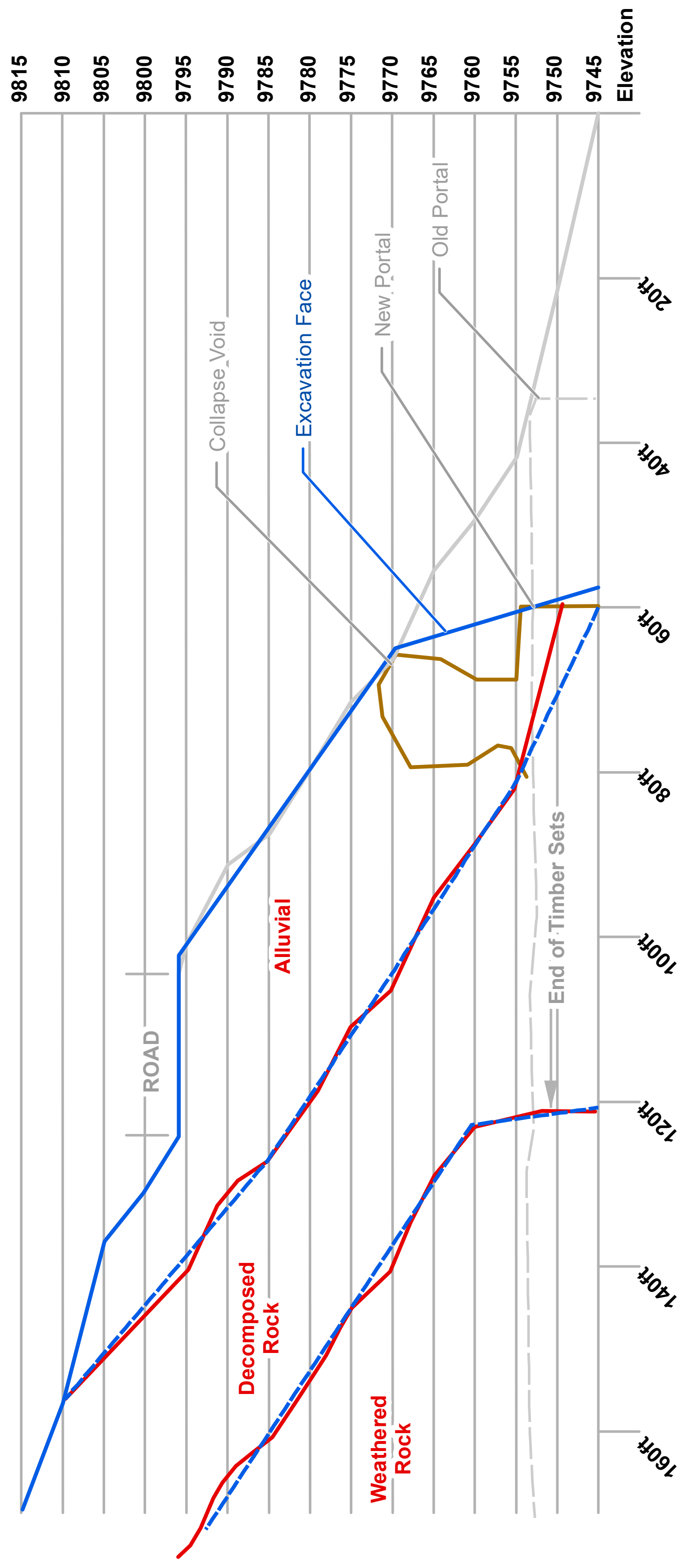
## 3.3 Model Input

### 3.3.1. Slope Geometry

An idealized representative two-dimensional cross-section was considered for analysis. This section consisted of the profile along the axis of the tunnel included on Figure 2, at the maximum cut slope on the left (south) side of the portal excavation. The idealized slope consisted of a 28-ft high excavation at an angle of 75-degrees then natural ground sloping at approximately 40 ft to the edge of the 20-ft wide County Road. Figure 3 presents the idealized slope stability cross-section superimposed on the tunnel profile section.

Included on this figure is the assumed material distributions as described in the following section.

[2] Zhang, Y., Chen, G., Zheng, L., Li, Y., and Zhuang, X,. 2013; "Effects of geometries on three-dimensional slope stability." Canadian Geotechnical Journal. Vol. 50, No. 3, pp. 233 – 249.




| Project | |
|---|---|
| Idaho Tunnel Portal Slope Stability | |

Title

**Idealized Slope Stability Analysis Section**

| Project No. US 0401 | | | File No. | |
|---|---|---|---|---|
| GIS: | JST | 05/06/20 | Scale As Shown | Rev 0 |
| Check: | JST | 05/06/20 | **Figure 3** | |
| Review: | JST | 05/06/20 | | |

GRAND ISLAND RESOURCES

Path: C:\Users\jst52\Documents\NMX\GIS\Projects\Nederland\ArcMap\DRMS\Tunnel Stability\Figure 3 - Stabilized Slope.mxd

### 3.3.2. Material Distribution

An "Alluvial Rock" soil unit was assumed to comprise the first 40 ft of the original tunnel as depicted on Figure 2. Based on the rock materials exposed at the base of the portal excavation (Figure 7) and currently exposed in the tunnel ribs (Photographs 3 and 4), this is a conservative assumption as at least some portions of this interval will include decomposed or weathered rock.

For the stability analysis, the "Decomposed Granite" unit was assumed to comprise the next 33 ft at the tunnel horizon. The transition from "Decomposed Granite" to "Weak Hard Rock" was modeled to coincide with the change in the type of ground support used in the tunnel. This is slightly further into the slope than the geology depicted on Figure 1 and therefore, more conservative.

This layered profile was then carried up the height of the slope for the stability analysis section as depicted on Figure 3. In reality, these layers are likely thickest at the toe of the slope down at the portal level and taper in thickness moving higher up the slope and this assumption will also be conservative.

### 3.3.3. Material Properties

The analyses incorporated shear strength parameters for the soil material, decomposed rock and weak weathered rock mass separately. Since the slope height is not great, the shear stresses will be low. For the low range of stresses present, equivalent linear Mohr-Coulomb shear strength parameters were assumed.

During excavation the regolith and colluvium "Alluvial Rock" unit was observed to stand near-vertical for up to 28 ft without ground support. From an engineering perspective this material consists of poorly-graded sandy gravel with cobbles, silt and clay (GP). For the purposes of the stability analysis this material was assigned a friction angle of 38 degrees and 500 psf cohesion with a moist unit weight of 125 pcf. Areas which contain a higher proportion of coarse rock fragments will exhibit higher shear strength, and the overall average strength is likely higher, however, if failure were to occur it will tend to pass through the weaker materials which offer less resistance.

From an engineering perspective the "Decomposed Granite" unit consists of rock which has been weathered and decomposed in situ, but has not been disturbed and retains the original rock fabric. This material represents a weak rock mass for which the Hoek-Brown criterion[3] was used to estimate the average rock mass strength across this material based on a large body of empirical data. Assumed rock mass parameters for Decomposed Rock:

Intact Rock UCS = 1000 -2000 ksf (7,000 – 14,000 psi)
GSI = 15 (Disintegrated with highly weathered surfaces with soft clay coatings or infilling)
mi = 25
D = 0

[3] E.Hoek and E.T.Brown, 2018; "The Hoek–Brown Failure Criterion and GSI – 2018 Edition." Journal of Rock Mechanics and Geotechnical Engineering, Volume 11, Issue 3, June 2019, Pages 445-463

The "Weak Hard Rock" unit represents highly fractured rock with some weathering and is quite variable. In some areas the material is quite weathered and grades into fully decomposed rock, while in other areas it more closely resembles fractured hard rock with little weathering present. Assumed rock mass parameters for Weak Hard Rock:

Intact Rock UCS = 1000 -2000 ksf (7,000 – 14,000 psi)
GSI = 45 (Blocky/Disturbed/Seamy with rough, slightly weathered, iron stained surfaces -or- Very Blocky with smooth, moderately weathered and altered surfaces)
mi = 25
D = 0

### 3.3.4. Ground Support Elements

Due to their relatively short length and irregular pattern of placement, the soil anchors were neglected in the analyses. The shotcrete will have little overall effect on global stability of the slope and was also neglected in the analyses for conservatism. The primary purpose of the shotcrete is to control shallow surface sloughing and raveling.

### 3.3.5. Idaho Tunnel

Due to the ground support elements that will be employed and its small size relative to the scale of the slope, the tunnel opening was not included in the stability section. Spillings installed above the top of the tunnel opening will become integrated with the cellular concrete void fill to help stabilize the opening and face of the excavation below the County Road. Its is anticipated that additional spillings and possibly forepolling will be required when tunnel rehabilitation resumes. These measures as well as the timely installation of steel sets or shotcrete and mesh as ground support for the tunnel will be employed to prevent additional collapse beneath the road.

### 3.3.6. Groundwater Conditions

The slope was initially modeled as drained, without groundwater to calibrate the model to conditions which existed as the excavation was completed.

Subsequently, a parametric study was conducted to evaluate the sensitivity to water levels to reflect conditions which may exist during spring thaw. This was conducted by progressively raising a perched water table within the Alluvial Rock unit in 5 ft increments to evaluate the effect this had on the Factor of Safety.

### 3.3.7. Collapse Void

The open collapse void was neglected in the base case analyses since it is not present everywhere within the slope. However, its inclusion is useful for back analysis to provide constraint on the shear strength of the material comprising the slope.

The 200 psi cellular concrete void fill is much stronger than the soil and rock colluvium material it replaces. Additional runs were made to assess the amount of beneficial effect this mass of stronger material has on stability of the slope in the sections where it will be present.

# 4.0 ANALYSIS RESULTS

Analysis of the slope under drained conditions indicates a minimum Factor of Safety (FoS) failure surface of 1.36 for a non-circular failure of the excavation slope. The minimum FoS for a failure surface which intersects the County Road was only slightly higher at 1.37. Figure 4 presents a summary of these stability analysis results and includes the critical failure surface as well as a summary plot of all trial failure surfaces color-coded by FoS. These analyses demonstrate that the lower FoS failure surfaces pass entirely through the colluvium and regolith soil materials due to the slope geometry. The position of the weak hard rock and decomposed rock beneath the slope has little to no effect on the overall stability.

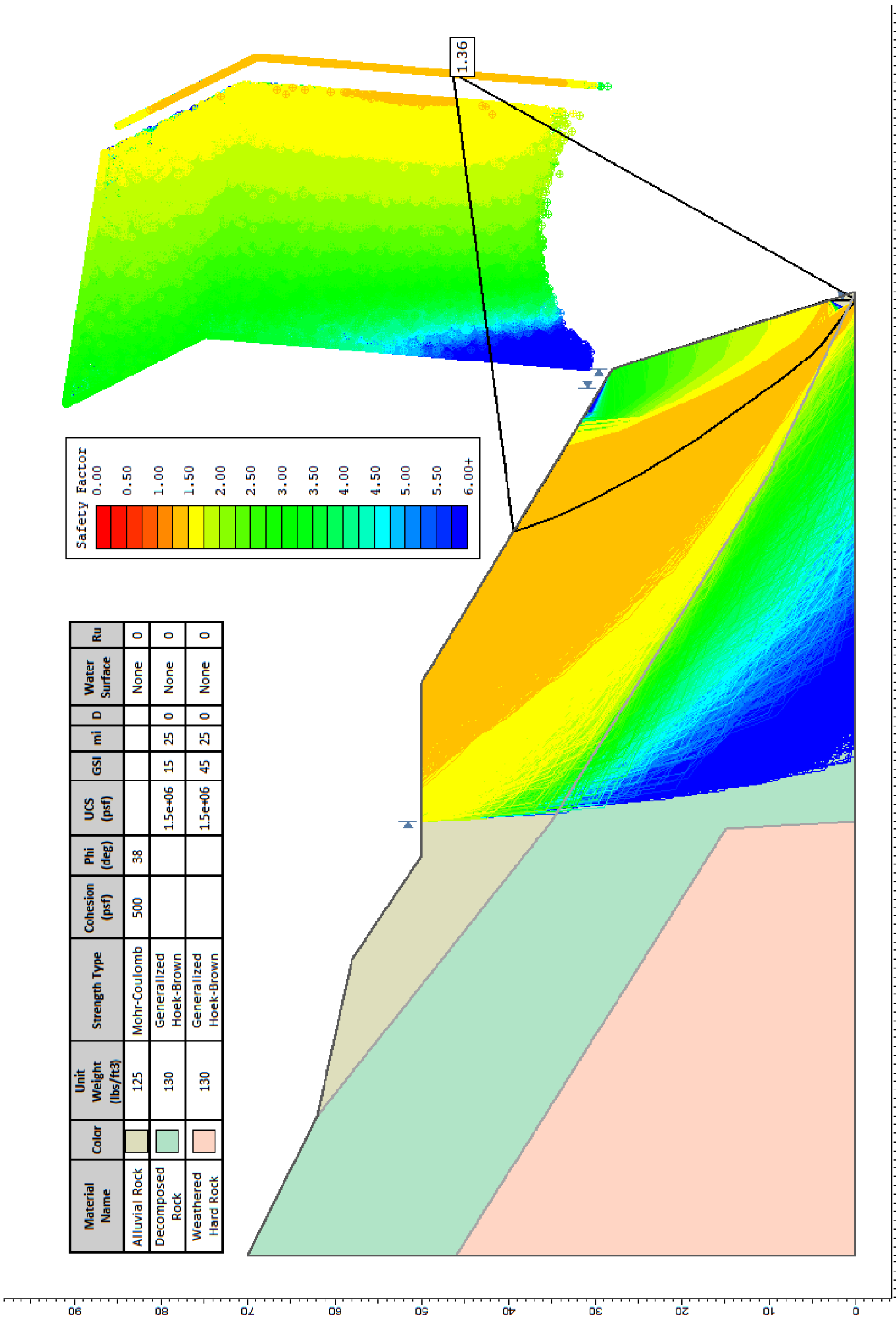
During spring thaw, several areas of seepage were observed coming through the shotcrete facing (Photograph 2). This seepage indicates that portions of the slope may become saturated during seasonally high water levels. The seepage is not present everywhere and does not discharge uniformly from the slope which suggests isolated areas of seepage flow rather than complete saturation. Table 1 presents a summary of perched water depth with the Alluvial Rock unit versus FoS. As indicated in this table, a perched water depth of 15 ft, or about half the thickness of the material, results in a FoS of 1.0. Figure 5 depicts the stability section with the assumed perched water table and critical failure surface from this analysis.

Including the open collapse void in the stability section reduces the minimum FoS to 0.74 for a non-circular and 0.90 for a circular failure surface respectively, indicating a condition of instability. Since the slope was observed to be stable despite the presence of the tunnel and open void, these results serve to demonstrate that the shear strength adopted for the regolith and colluvial soils is conservatively low. These results are presented in the summary included in Table 1.

Including the 200 psi cellular concrete void fill within the stability section increases the FoS considerably. The minimum FoS for all trial failure surfaces passing through the cellular void fill is above 4.0.

***Table 1 – Stability Analysis Summary***

| Model Case | Water Depth (ft) | Minimum FoS | |
|---|---|---|---|
| | | Janbu, non-circular | Bishop, circular |
| Fully Drained | 0 | 1.36 | 1.46 |
| Perched Water | 5 | 1.32 | 1.46 |
| Perched Water | 10 | 1.12 | 1.40 |
| Perched Water | 15 | 1.00 | 1.24 |
| Open Void | 0 | 0.74 | 0.90 |
| Cellular Concrete | 0 | > 4.0 | > 4.0 |




| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | UCS (psf) | GSI | mi | D | Water Surface | Ru |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alluvial Rock | | 125 | Mohr-Coulomb | 500 | 38 | | | | | None | 0 |
| Decomposed Rock | | 130 | Generalized Hoek-Brown | | | 1.5e+06 | 15 | 25 | 0 | None | 0 |
| Weathered Hard Rock | | 130 | Generalized Hoek-Brown | | | 1.5e+06 | 45 | 25 | 0 | None | 0 |

Path: C:\Users\jst52\Documents\NMX\GIS\Projects\Nederland\ArcMap\DRMS\Tunnel Stability\Figure 4 - Stability Analysis Summary.mxd

Project

Idaho Tunnel Portal Slope Stability

Title

**Stability Analysis Summary**
**Base Case, Drained, Non-Circular**

GRAND ISLAND RESOURCES

| | | | | |
|---|---|---|---|---|
| Project No. US 0401 | | | File No. | |
| GIS: | JST | 05/06/20 | Scale As Shown | Rev 0 |
| Check: | JST | 05/06/20 | **Figure 4** | |
| Review: | JST | 05/06/20 | | |

# 5.0 CONCLUSIONS

For geotechnical stability of the Country Road a required minimum FoS is not defined by the current Boulder County Multimodal Transportation Standards[4]. The Colorado Department of Transportation (CDOT) Geotechnical Design Manual[5] requires a minimum FoS of 1.1 during construction and 1.3 under long term static loading conditions for embankment and cut slopes except where failure or significant deformation will affect bridges or critical facilities. Design for seismic loading conditions is not required by CDOT for non-critical slopes.

The results of the analyses and discussion presented herein are sufficient to demonstrate that the slope meets the CDOT stability criteria for the construction case in its current condition. With a calculated minimum FoS of 1.36 for the slope under drained conditions, the 2D analyses also demonstrate that the slope will meet the CDOT criteria for long-term static loading conditions provided that adequate drainage can be maintained.

The presence of seepage during spring thaw indicates that some saturation of the slope may occur during seasonally high water levels. This can have a significant deleterious effect on stability of the slope. Parametric analyses suggest that should the surficial colluvium and regolith soil materials become saturated over approximately half their thickness then instability could occur. However, seepage from the slope does not appear uniformly which suggests isolated areas of seepage flow through discrete pathways typical in mountainous terrain, rather than complete saturation. The shotcrete facing should be provided with weep holes to prevent the buildup of water pressure in the slope behind the shotcrete.

The Idaho Tunnel also serves as a drain to some extent to limit water pressures in the slope. The collapse void will be mitigated by backfilling it with pervious cellular concrete which will increase this effect. Stability of the slope could be further enhanced with horizontal drains if necessary.

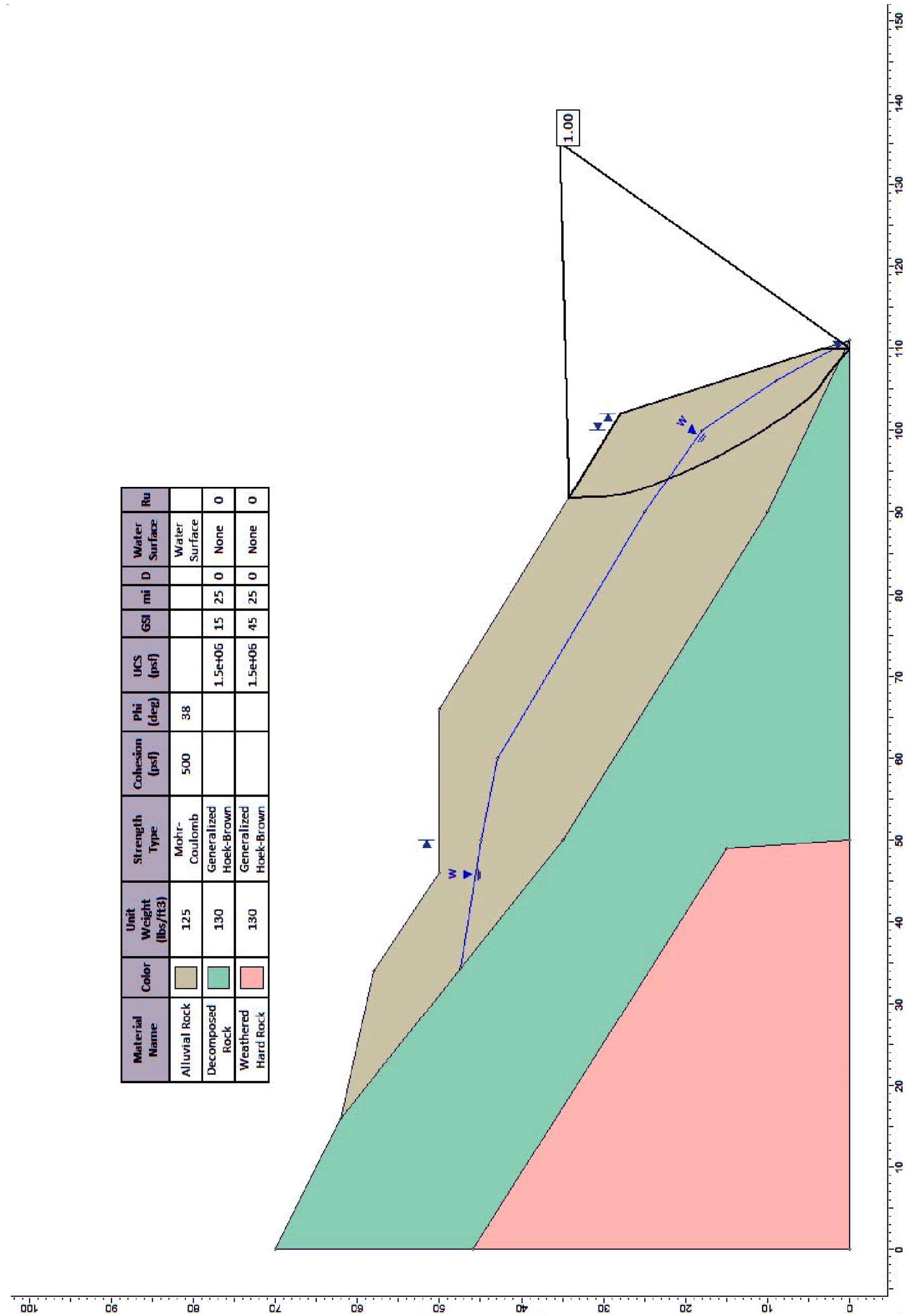
The cellular concrete void fill is much stronger than the colluvial material it replaces and increases the FoS significantly when included in the analyses by imparting a buttressing effect. There are areas of the excavated slope on either side of the portal which would have none of this material in section. However, the actual FoS on these sections should be higher than 2D analyses results due to 3D effects related to the concaved slope orientation and adjacent areas which are buttressed by the cellular concrete void fill.

Spillings installed through the cellular void fill and similar ground control elements installed when rehabilitation of the tunnel resumes will serve to underpin the portion of the slope directly above the Idaho Tunnel and below the County Road. Permanent tunnel lining ground support installed as the tunnel is rehabilitated will ensure that stability of the tunnel itself does not impact the road.

The slope stability evaluation presented was based largely on observation and professional judgement as limited engineering data was available. Data deficiencies at this time include:

- As-built configuration of the portal excavation
- Accurate topographic data for the slope and road
- Subsurface geology beneath the slope

[4] https://assets.bouldercounty.org/wp-content/uploads/2017/02/multi-modal-standards.pdf
[5] https://www.codot.gov/business/designsupport/materials-and-geotechnical/programs/geotech/docs/cdot-gdm




| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | UCS (psf) | GSI | mi | D | Water Surface | Ru |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alluvial Rock | | 125 | Mohr-Coulomb | 500 | 38 | | | | | Water Surface | |
| Decomposed Rock | | 130 | Generalized Hoek-Brown | | | 1.5e+06 | 15 | 25 | 0 | None | 0 |
| Weathered Hard Rock | | 130 | Generalized Hoek-Brown | | | 1.5e+06 | 45 | 25 | 0 | None | 0 |

Project

Idaho Tunnel Portal Slope Stability

Title

**Stability Analysis Summary**
**Spring Thaw, Undrained, Non-Circular**

GRAND ISLAND RESOURCES

| Project No. | US 0401 | | File No. | |
|---|---|---|---|---|
| GIS: | JST | 05/06/20 | Scale As Shown | Rev 0 |
| Check: | JST | 05/06/20 | **Figure 5** | |
| Review: | JST | 05/06/20 | | |

Path: C:\Users\jst52\Documents\NMX\GIS\Projects\Nederland\ArcMap\DRMS\Tunnel Stability\Figure 5 - Stability Analysis Summary.mxd

- Groundwater conditions
- Laboratory testing data to determine the geomechanical properties of the materials comprising the slope
- Shotcrete thickness distribution
- Soil anchor installation details and pullout capacity

This study should be updated and reassessed once additional data such as the as-built slope geometry becomes available. In other cases, the cost and effort required to refine the analyses may be more than the value provided. For example, the cost to accurately characterize the highly variable geologic conditions within the slope may be higher than the cost implications of adopting conservative assumptions, such as those provided herein. Similarly, the cost to accurately characterize and monitor the potential ground water variations would likely be higher than the cost to install horizontal drains to ensure drainage.

Stability analysis of the Idaho Tunnel portal slopes was conducted by Mr. David S. Hallman, licensed as Colorado Professional Engineer (Civil) 26076, as affirmed by the stamp and signature affixed below.