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Operational open pit ground support design at Rainy River Mine

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Abstract

Open pit design utilises core-logging and mapped discontinuity data to kinematically determine the optimal geotechnical slope designs. However, with the demand for steepening of open pit slopes to optimise strip ratio, some shallower discontinuities may create unfavourable kinematic conditions that require additional risk mitigation to support steeper slope angles.

This paper presents a case study from Rainy River Mine in Northern Ontario, where kinematic controls on wedge and planar stability failure mechanisms were assessed, and stabilising rockbolt patterns were designed.

A practical approach is presented for collecting high-quality slope scan data using drone photogrammetry and light detection and ranging (LiDAR) techniques, generating detailed representations of potential slope risks. Utilising RocScience's RocSlope3 numerical modelling code (software), accurate 3D models of the slope profiles were developed, incorporating discrete discontinuities, orientations, and persistence model inputs. The Factor of Safety resulting from RocSlope3 models are compared to simplified slope profiles modelling techniques in RocScience SWedge and RocPlane. Fit-for-purpose stabilising rockbolting patterns are prepared to meet design acceptance criteria.

This case study emphasises the importance of integrating widely available scanning techniques to develop representative 3D models, which are critical to develop effective stabilisation solutions of complex sliding failure geometries.

Keywords: *open pit, geotechnical, ground support, bolting, kinematics*

1 Introduction

The demand for steeper open pit slopes in mining operations has necessitated the development of advanced slope stability analysis and support design methodologies. A case study at the New Gold Rainy River Mine, located in Northwestern Ontario, is discussed to highlight the challenging kinematic conditions that led to the need for detailed characterisation of slope failure mechanisms and the implementation of stabilising support systems.

This paper focuses on the implementation of an operational open pit ground support design process at the Rainy River Mine. In addition, 2 case studies applying the process are provided in Section 3, as shown in Figure 1:

1. discrete block, joint-on-foliation wedge sliding failure mechanism
2. bench-scale fault-on-joint wedge failure mechanism.

Using high-resolution slope scanning techniques; photogrammetry and light detection and ranging (LiDAR) techniques, to identify discontinuities and measure bench compliance, geotechnical characterisation is completed

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to support the numerical modelling geometric inputs. The result is a fit-for-purpose methodology to reinforce (ground support tendon/bolt pattern) and retain (mesh/screen) time-dependent kinematic instabilities. The case studies presented are 2 of only a handful required at the site, as most of the wedge hazards are removed by scaling and employing blasting techniques to reduce the occurrence of wedge formation.

Figure 1 Plan view of assessment locations

2 Methodology

The open pit slope support design process follows a similar methodology across the 3 locations assessed, however, with varying levels of detail in each step. The process is not dissimilar to the standard open pit geotechnical design process as outlined by Read & Stacey (2009), in Figure 2. However, a much narrower and simplified approach is required during active operations to manage exposed discontinuities that result in unfavourable kinematics. For an operating mine, it is expected that geotechnical design parameters are largely understood and require only minor adjustments based on the observations and knowledge of the site geotechnical team and/or design consultants. This simplified approach is intended to be carried out on an accelerated timeline to support operational production requirements and before access to the benches is lost, to minimise time exposure risk and cost of implementation.

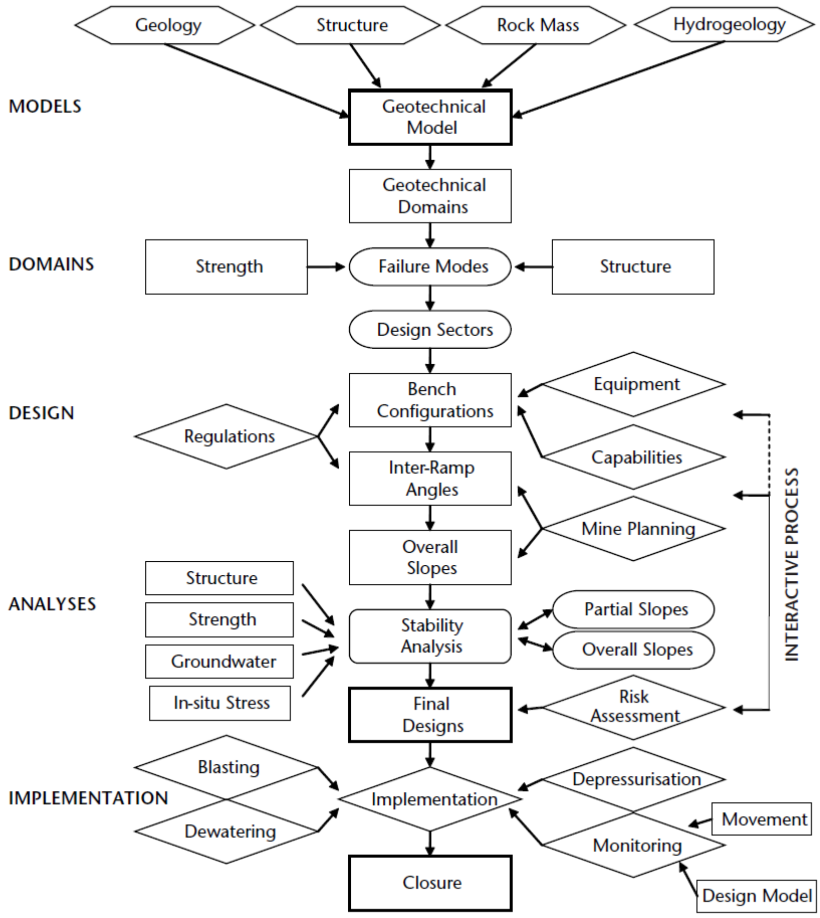


Figure 2 Geotechnical slope design process (Read & Stacey 2009)

The simplified methodology followed is presented in Figure 3. The description of each method stage and case study examples is shown below.

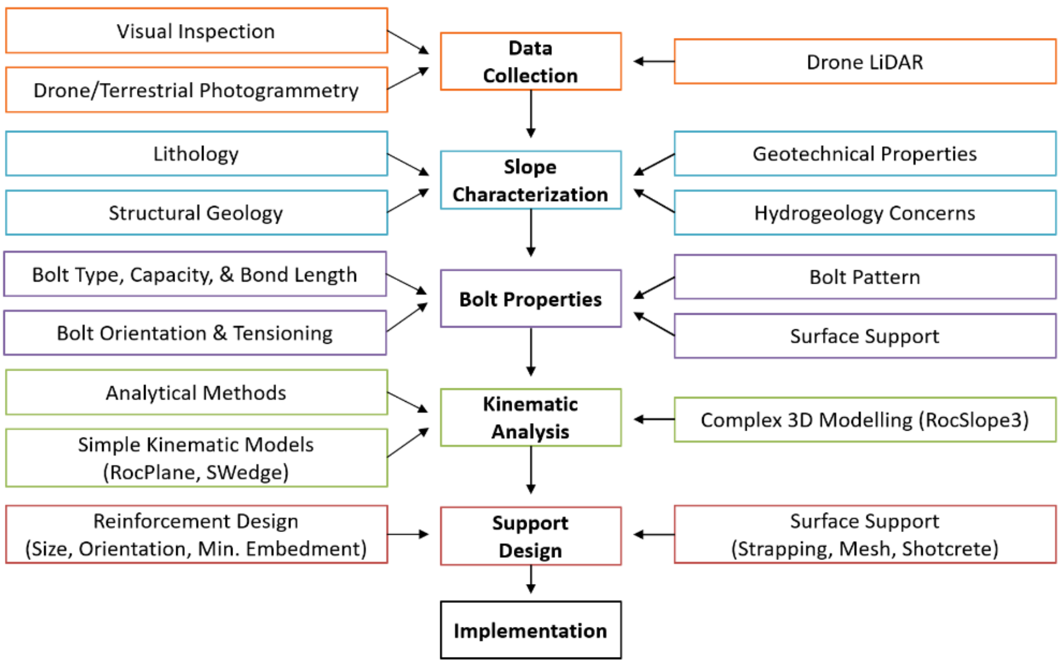


Figure 3 Operational open pit ground support design process (adapted after Read & Stacey 2009)

2.1 Data collection

The data collection process should be an ongoing occurrence during operations, and not only when a new hazard is identified. To understand the local bench-scale variability not captured by the geotechnical domain model, high-resolution data collection techniques are recommended, in combination with site observation and measurements from the geotechnical team.

It is preferred to have both detailed meshes and texture that can be loaded into a 3D visualisation and mapping software (Leapfrog Geo, HiveMap) to identify likely failure mechanisms and scale. These meshes and textures can be collected using drone photogrammetry and/or LiDAR, depending on the capability of the mine’s survey equipment. It is important that meshes represent true 3D surfaces, opposed to 2.5D, to properly capture overhanging geometries (2.5D surfaces will represent overhangs as a vertical face). Similarly, textures or imagery should be wrapped to the surfaces opposed to draping vertically to the surface. These methods will produce the most accurate representation of the slope geometry as shown in the example in Figure 4.

Figure 4 Example of high-resolution three-dimensional mesh and texture showing the Rainy River Mine north wall

While survey data may be collected from terrestrial setups, these often produce blind zones in data based on the equipment’s line of sight.

Another useful source of data can be obtained from the mine’s existing ground control monitoring systems, including radar, prism, hydrogeology, and interferometric synthetic aperture radar data. Depending on the scale of the project area and dataset, early warning deformations may be identified and can provide valuable insight into the failure mechanism (i.e. rotation, sliding, toppling).

2.2 Slope characterisation

Detailed slope characterisation is carried out to understand the variability of the small-scale problem area compared to the geotechnical domain model. Characterising the local geology, structural patterns, faulting, and hydrogeological conditions will provide reasonable supporting evidence to adjust design assumptions to suit the project area. A crucial component of the slope characterisation methodology is the identification and classification of the potential ground control hazard. The mine operating geotechnical team, who are experienced in the local ground conditions, slope monitoring, and history of slope performance, are key mine personnel to identify the hazard and determine a potential failure mode. Key considerations to slope characterisation are discussed in the following subsections.

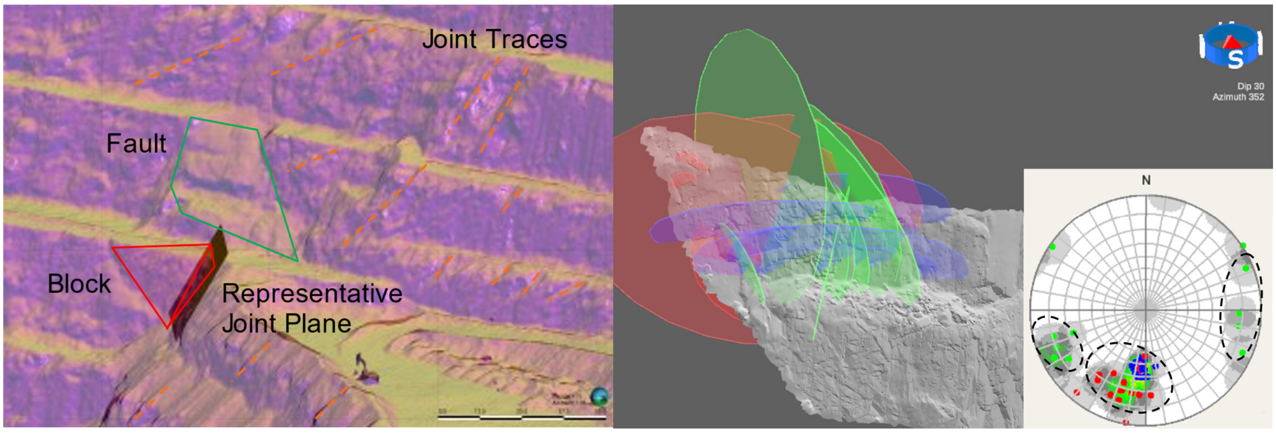
2.2.1 Lithology

As-built slopes should be compared against the site lithology model to understand if any local changes in geology may be impacting the slope performance. This includes small-scale later intrusions (i.e. dykes, veins) that may not have been captured in the model but are observed during mining at the bench-scale. This should be completed by site personnel that can inspect the site and provide photographic markups/sketches that can be transferred to digital scans. Any high-strength contrast lithology contacts or changes in rock mass conditions should be considered when defining the anticipated failure mechanisms.

2.2.2 Structural geology

Structural geology is the primary stability driver when carrying out the kinematic analysis. Similar to the lithology, local changes in the joint patterns, rock fabric, and major structures (i.e. faults) are to be characterised. The level of detail required in the structural geology characterisation should be tailored to the complexity of the potential failure mode. For example, a massive intact wedge formed by 2 intersecting continuous joints may be characterised by digital mapping of the joint orientation to define the block geometry. However, a highly jointed rock mass with a high-continuity foliation/fabric and faulted ground would require characterisation of each of the controlling features including the range of fabric orientation and persistence, definition of principal joint sets, and character of the fault and how it changes along its length.

The majority of the structural modelling can be completed digitally using high-resolution scans (Figure 5). The data must be field verified prior to beginning the kinematic analysis.



(a) (b)

Figure 5 Example of (a) drone photogrammetry in Leapfrog Geo and (b) discontinuity mapping in HiveMap digital mapping software

2.2.3 Geotechnical properties

The process in this paper assumes that the geotechnical properties by geotechnical domain have been previously defined. The design properties are used as an analogue for the reasonable range of values for the analysis. Back-analyses from actual rockfall events further refines the strength ranges that can be categorised into:

- Discontinuity properties: orientation, joint condition (infill, roughness), spacing, and persistence
- Fault properties: thickness, infill/gouge strength, waviness
- Field intact rock strength: not a direct software input but should be checked for any local weakening.

At Rainy River, the local geotechnical properties or observations are compared against domain-design friction and cohesion estimates. Geotechnical parameter sensitivity assessments are completed in the kinematic analyses software to determine a reasonable worst-case scenario (i.e. if the assigned parameters are incorrect – does the block become unstable?).

Other considerations needed to properly evaluate the reinforcement and surface support elements include blockiness (block size) or foliation intensity. For example, the blockiness of the rock mass may determine the support type – mesh may be required in areas of smaller block sizes to protect against slope unravelling and rockfall risks. Whereas a larger massive block size would be better supported with rockbolt and face plates.

2.2.4 Hydrogeology

The groundwater responses to excavation recorded in the vibrating wire piezometer network (Reis et al. 2024) and a visual assessment of the local drawdown/seepage should be completed to identify pore pressure influence on the evaluated structural controls. Assumptions that bench-scale kinematics are completed on a dry slope in hard rock environments should be verified. A sensitivity analysis can be carried out to consider transient or snowmelt (freshet) pore pressure increases that may represent the most sensitive seasonal periods.

2.3 Support properties

Selecting the appropriate bolt depends on many factors, some of which are not always in the control of the design engineer. For example, procurement, or timing to procure, different reinforcement options that may not always be practical, and the pattern may need to be adjusted to reflect the available ground support materials (i.e. bolt types/lengths). There are other reinforcement aspects that are non-negotiable, for example the length to provide adequate embedment beyond the failure plane. The following are reinforcement design aspects that should be evaluated throughout the process.

2.3.1 Bolt type

The bolt type should be selected based on the expected failure mechanism. For open pit slope applications, a fully encapsulated bolt, such as resin rebar or cable bolts, should be used to protect against corrosion. The grout type and water-cement ratio need to also be considered for these bolt types. However, selecting the appropriate bolt type is not the focus of the study. The designer should reference supplier specifications to determine the appropriate bolt for the application to ensure the tensile and shear capacity is greater than the demands of the failure mode block. Discussions with ground support contractors is needed to verify the element suitability in the given operational context.

Bearing/face plates should be sufficiently large to distribute the load to the rock face. Specialised face plates may also be required depending on the surface support being installed. Strapping and screen installed in a bolt pattern can also be chosen to create a support system instead of singular bolts or screens.

2.3.2 Bolt capacity

The capacity of the bolt is dependent on the type (above), manufacturer, diameter, etc. The bolt capacity will be required to determine if the total capacity of the installed bolts will support the failed block. A 1.5 Factor of Safety (FoS) has been used at Rainy River to the bolt's specified ultimate tensile strength to determine the 'working bolt capacity' which is used for design purposes (Equation 1).

$$Working\ Bolt\ Capacity = \frac{Ultimate\ Tensile\ Strength}{Factor\ of\ safety} = \frac{Ultimate\ Tensile\ Strength}{1.5} \tag{1}$$

Note that applying a FoS to the bolt capacity does not negate the requirement to apply a FoS to the kinematic analysis. The working bolt capacity FoS is independent of the kinematic analysis and these do not compound.

In addition to the working bolt capacity, the load-displacement characteristics of the support element are critical for design. When supporting identified wedges in the pit, the typical approach is to use fully grouted rebar and cable bolts (as demonstrated in the case study examples). These may also be installed as active or tensioned elements before or after grouting, aiming to keep identified wedges in place and limit movement where minimal deformation is acceptable.

In situations where deformation is anticipated, de-bonded and passive support elements are incorporated into the ground support design. Furthermore, the design of the support system should consider both the tensile and shear characteristics of the support elements. For example, if a more rigid support system is required, longer rebars are often used; whereas cable bolts are preferred when some deformation is expected.

Displacement thresholds for monitoring equipment (prisms, radar, etc.) are assigned to accommodate the expected block movement for the selected bolt.

2.3.3 Minimum bond length

The minimum bond length is the length of the bolt extending beyond the failure surface. Typically, a 1–2 m minimum bond length is sufficient to provide higher strength than the bolt (i.e. the bolt would yield prior to the grout). The minimum bond length should be determined for each hole diameter, grout strength, and rock unit. Willie & Mah (2004) present Equation 2, below, to calculate minimum bond length.

$$Minimum\ Bond\ Length = \frac{Design\ Tension\ Force}{\pi \times hole\ diameter \times {}^{UCS}/_{30}} \tag{2}$$

2.3.4 Bolt orientation

The strength of the bolt is greater in pure tension than if there is any shear component acting on the bolt, which is dependent on the orientation of the sliding plane(s). Wyllie & Mah (2004) provide calculations to determine the optimal bolt installation orientation. An example of the optimal bolt orientation for a simple wedge geometry is shown in Figure 6.

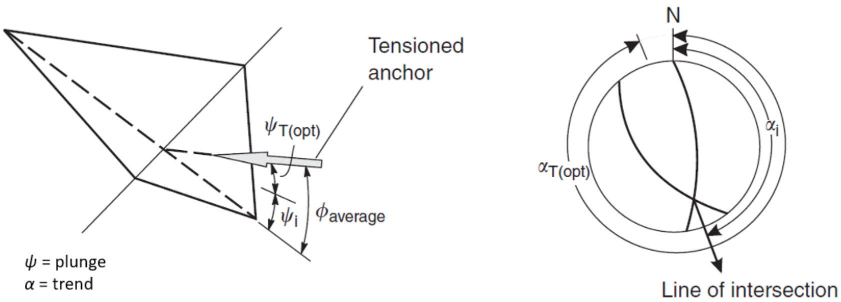


Figure 6 Example of optimal bolt orientation for simple wedge geometry (Wyllie & Mah 2004)

2.3.5 Bolt tension

Certain bolt types allow for pre-tensioning of the bolt to apply active pressure to the face and adding clamping stress across the sliding surface. The FoS of a sliding block can be calculated for active (pre-tensioned) and passive (post-tension) installations.

Assignment of active or passive bolt properties are available in the RocScience software (RocScience 2023, 2025a, 2025b). The active bolt model in RocScience does not account for the shear strength increase as a result of the increase in clamping stress on the sliding surface. The benefits of installing bolts orthogonal to the sliding surface is to provide the maximum clamping stress, however, this may reduce the bolt orientation efficiency (Section 2.3.4).

2.3.6 Bolt pattern

The bolt pattern on the slope face should apply a reasonably uniform stress to the sliding plane (Willie & Mah 2004). For larger block sizes the number of bolts required will be calculated in the support design. Ideally the horizontal and vertical spacing should be roughly equal, however the local slope geometry and block geometry may warrant specified bolt placement to reinforce discrete blocks. In smaller block sizes an equal bolting pattern is typically applied with surface/areal support.

2.3.7 Surface support type

Surface support may be required to allow the bolting pattern to act as a support system, where bolts can distribute load to adjacent bolts. Additionally, surface support can be applied to protect against smaller instabilities between installed bolts. Examples of surface support include strapping, mesh/screen, and shotcrete/liners. Similar to the bolt type, the designer must reference surface support literature for more detail in selecting the appropriate types.

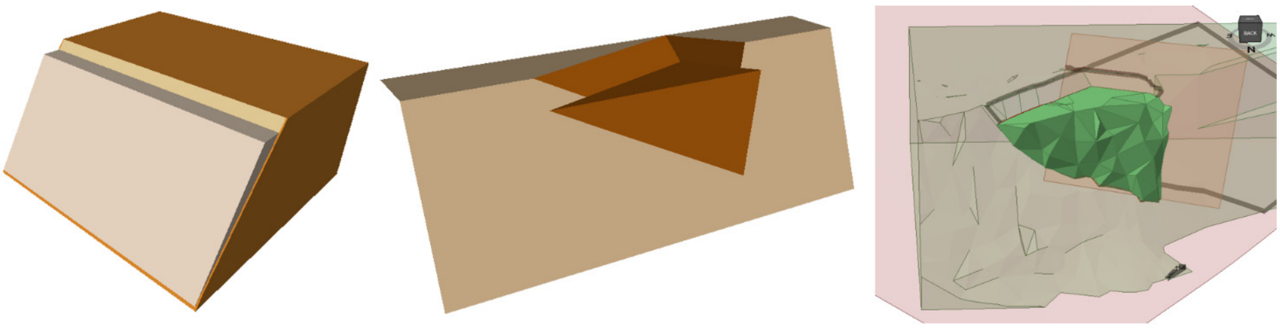
There are other design elements in the rockbolting process that may not be listed here but should be considered. This is meant to be an introduction of some of the key properties that need to be evaluated.

2.4 Kinematic analysis

Kinematic analyses are conducted using RocScience software and in-house scripts to evaluate the stability of the excavated slopes and to determine the scale of the potential unstable mass. Analytical kinematic methods (i.e. spreadsheets) are also used for confirming the modelling software results. Although the resulting FoS or Probability of Failure (PoF) values are relied on for the design of ground support elements, the geometric intersections produced by the software are equally important to compare with the historical bench performance (and geological controls) observed elsewhere in the open pit.

As this paper is focused on the use of RocScience software/codes, it is the ability of these codes to evaluate the anticipated failure mechanism from the slope characterisation process that determines which software code is used. Below are some applied examples using the software.

- RocPlane (Figure 7a): applied to simple planar sliding analyses. RocPlane models the interaction between foliation planes and joint sets, assessing the risk of daylighting and sliding failures.
- SWedge (Figure 7b): applied to simple wedge stability analyses, focusing on the intersection of discontinuities such as foliation planes and joint sets. SWedge provides initial FoS for unsupported blocks and allows for the modelling of bolting patterns to achieve target FoS values.
- RocSlope3 (Figure 7c): applied to increasingly complex, multi-block, kinematic analyses and captures actual face profiles. Capable of incorporating probabilistic discontinuity set properties and assigning synthetic joint sets to the rock mass, while also incorporating discrete discontinuities, orientations, and persistence data. RocSlope3 allows for the refinement of block geometries and the validation of bolting patterns.



(a) (b) (c)

Figure 7 Applied examples of RocScience software. (a) RocPlane; (b) SWedge; (c) RocSlope3

2.4.1 Current conditions

When assessing the current conditions, kinematic analyses are initially carried out without ground support assumptions. The modelling software allows quick sensitivities to be run on the input properties (joint strengths, bolt properties, slope orientation, etc). Where there are no obvious indicators of imminent wedge detachment, a target FoS of 1.0–1.1 is considered appropriate for initial calibration of an intact block. The model input properties can be adjusted, within reason, to achieve the target FoS to represent current slope condition.

It is recommended to keep the kinematic analyses relatively simplistic, and only add additional complexity to the models when justified. For example, SWedge assumes fully persistent, planar discontinuities whereas there may be a degree of rock bridging or surface undulations. The accuracy of the models can be lost when layering the complexity.

2.4.2 Support design

With the kinematic model created, there are a few ways to model an applied bolt force. The most straightforward of these methods is to use the 'Simple Bolt Force'. This option allows you to provide an even force across the face of the block in the direction of the user-defined bolt orientation. The Simple Bolt Force model does not account for the bolt failure mode (tension, shear, or combination) and does not have bolt orientation efficiency applied. The 'Force' input in the bolt properties dialog box needs to be adjusted until the desired FoS or PoF (if using a probabilistic approach) is achieved. To determine the number of bolts required across the block face, the force of the simple bolt is divided by the working bolt capacity (Equation 3).

$$Number\ of\ Bolts = \frac{Simple\ Bolt\ Force}{Working\ Bolt\ Capacity} \tag{3}$$

It is suggested to begin with the 'Simple Bolt Force' bolt property before adding complexity to the model. The bolt complexity can be added by using the 'Use Shear Strength' and 'Use Bolt Orientation Efficiency' options in the bolt properties. Both these can only reduce the bolt capacity. With a thorough understanding of the software calculations, the designer can carry out sensitivity models using these bolt options to understand the impact to the FoS.

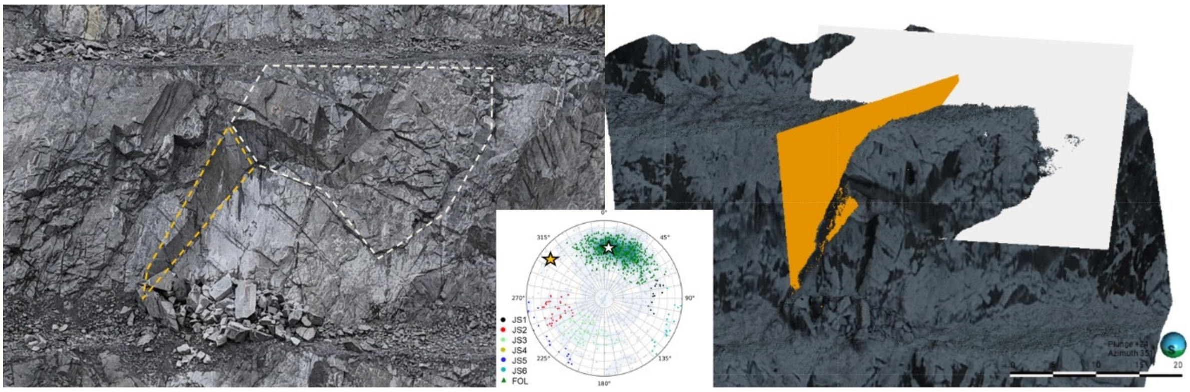
2.5 Implementation

This study does not go into detail on the implementation and construction of the reinforcement design in an open pit environment. The topics related to quality control and quality assurance of bolt installations, safety practices during installation, winter specific activities, orientation of bolts, quality control, and specialised rope access equipment, are a few of many details that can be discussed at length.

3 Case studies: application of the operational open pit ground support design process

3.1 Location 1: discrete block

The Location 1 slope risk consisted of an approximately 400 m^3 irregular block that was undercut by foliation with a cross-cutting release planar feature into the slope. Figure 8a shows that a sliding instability has previously occurred and deposited material on the bench below. The Rainy River geotechnical team collected high-resolution drone LiDAR survey data of the slope to support the structural and slope geometry characterisation. The observed contributing failure planes were mapped to model the expected failure mechanism in 3D geological software (Figure 8b).



(a) (b)

Figure 8 (a) Photo of slope face where potentially unstable block is identified; (b) Mapped features contributing to wedge geometry

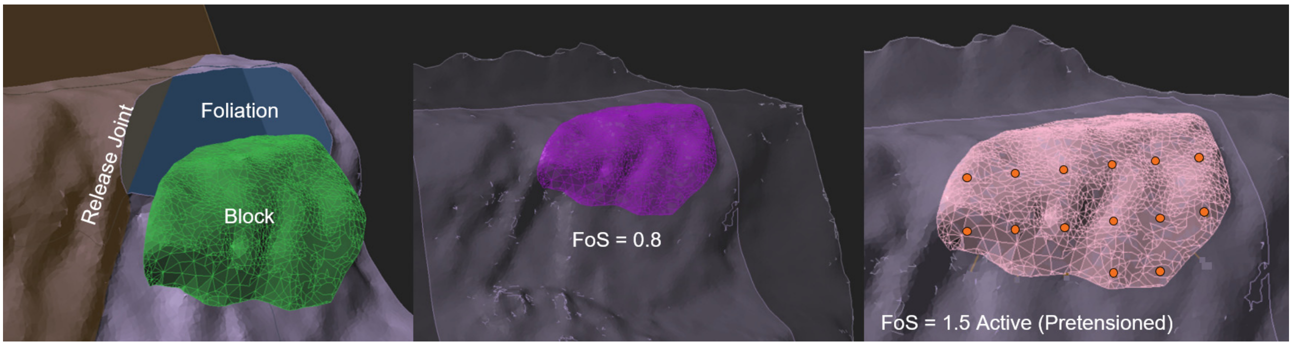
Location 1 is within the footwall of the regional mineralisation shear zone. The footwall is comprised primarily of a felsic metavolcanic unit with intense foliation that parallels the slope orientation dipping at approximately 60° to the south. The foliation is locally variable and undulating and can undercut the intended bench face angle; a primary contributor to the slope risk at Location 1. No major geologic structures are identified in the area.

A random joint orientation (i.e. a joint not associated with a design joint set) was measured as a possible release plane for the block (orange features in Figure 8a and 8b). The release joint and the undercutting foliation planes were measured and generated into representative surfaces for kinematic analysis.

Joint and foliation shear strength properties were assigned based on knowledge gained from other bench-scale rockfall reviews.

No seepage observations were made near Location 1 and because the foliation plane did not extend beyond the upper bench, the slope was assumed to be dry at the wedge scale.

Due to the irregular shape of the remaining slope risk to be stabilised, it was determined that a 3D model using RocScience RocSlope3 would be appropriate (Figure 9a). The unsupported kinematic assessment FoS was 0.8, indicating an unstable slope (Figure 9b). For this scenario, geotechnical parameters were not adjusted to achieve closer to a 1.0–1.1 FoS. This was assumed to be a conservative approach, since the block had not failed, but was agreed as a reasonable approach for this scenario.



(a) (b) (c)

Figure 9 (a) RocSlope3 model showing modelled failure planes; (b) FoS calculated on unsupported block; (c) FoS when applying 14 bolts

The contractor responsible for installing the ground support provided a list of available bolt types for the support design. A #10 all-thread bar was selected for this application which had the ability to add couplers, to extend the bar installation depths to design requirements. The bolting pattern was applied in RocSlope3

(Figure 9c). A FoS of 1.5 was applied to the manufacturer bolt ultimate tensile strength of 565 kN, resulting in a working bolt capacity of 377 kN. Bolts were to be pre-tensioned to apply active pressure to the slope face. Due to the blocky nature of the slope face, surface support comprising chain-link mesh was recommended across the face to protect against rockfall caused by the release of smaller discrete blocks.

The following slope support recommendations were provided for Location 1 to achieve a minimum FoS of 1.5:

- Minimum of 14 pre-tensioned #10 all-thread bolts to be installed based on the pattern and bolt lengths indicated in Figure 10; the first row starting 2 m below the crest.
- Bolts to be installed 10° (down) from horizontal at approximate azimuth 345° (perpendicular to the slope aspect), installing as close to perpendicular as possible to the determined failure plane. This allowed for simplified bolt installation and clamping stress to the foliation surface.
- Grout to be mixed according to specifications, between 0.25–0.34 water/cement ratio. Grout tube to be used for bottom-up grouting.
- Surface chain-link mesh to be installed using suitable spike face plates. Spike face plates must be installed horizontally as per manufacturers specifications.
- Mesh spot or pin bolts are to be installed as required to maintain mesh tight to the rock face.
- Support systems are to be installed on a 'top-down' approach.

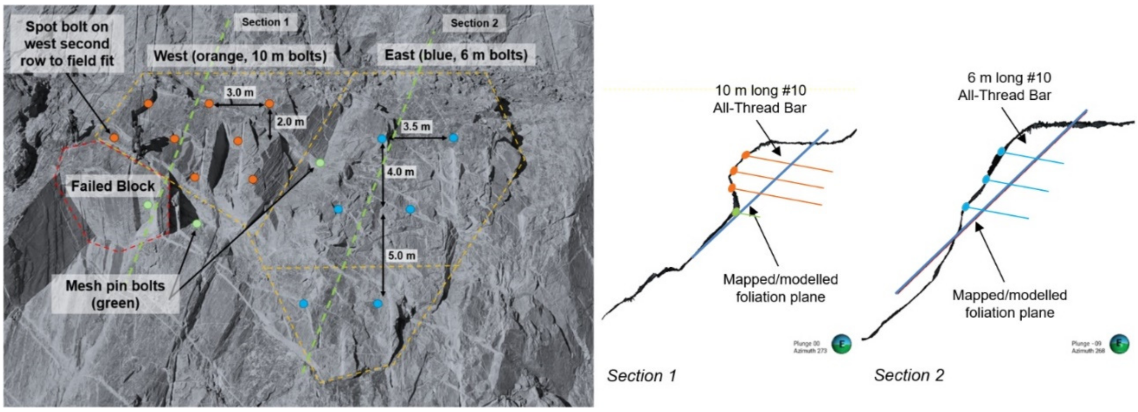
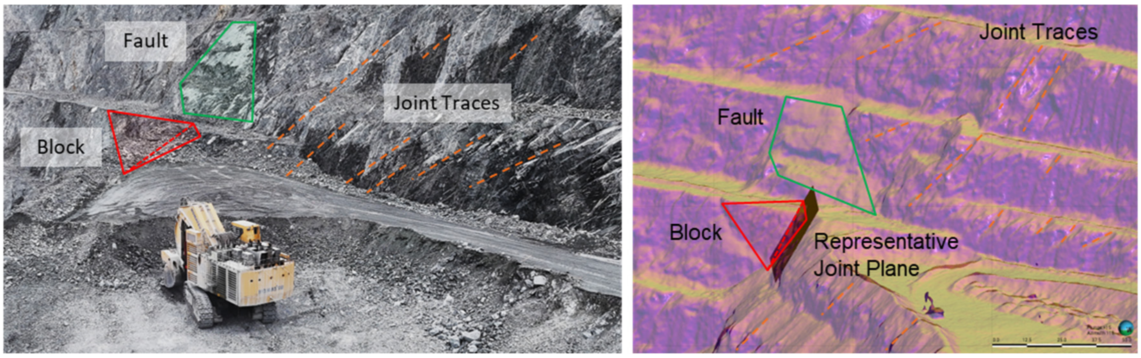


Figure 10 Bolting pattern design to support irregular block shape at Location 1

3.2 Location 2: bench-scale wedge

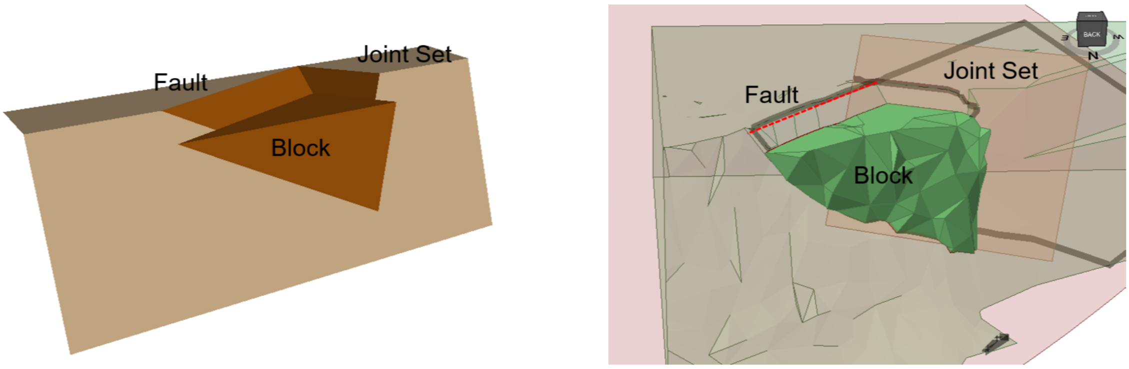
Location 2 slope hazard comprised of an approximately 1,300 m^3 block that was generated by an intersection of a fault and dominant joint set (Figure 11). Excavation of an interim slope toward the final south wall was expected to expose the block identified by the mine's geotechnical team. The design was to support the maximum possible block size prior to mining in front of the block. High-resolution drone photogrammetry scans of the slope were taken to support the local mapping and define the joint set orientations to incorporate into kinematic analyses.



(a) (b)

Figure 11 (a) Photo of slope face where potentially unstable block is identified; (b) Observed features contributing to block geometry

The block shape resembled a typical wedge geometry and allowed kinematic analyses to be completed using both RocScience SWedge and RocSlope3 software (Figure 12).



(a) (b)

Figure 12 Unsupported kinematic stability models using RocScience. (a) SWedge; (b) RocSlope3

The fault orientation was modelled using Leapfrog to capture the 3D representation (Figure 13). The 3D fault mesh is imported directly into RocSlope3. However, a fault orientation of 44/315° (dip/dip direction) was selected for modelling in SWedge due to the software limitation of model only planar features. Visual inspection of the pit face fault exposure and core photos (Figure 14) were completed to validate the applied discontinuity strength properties.

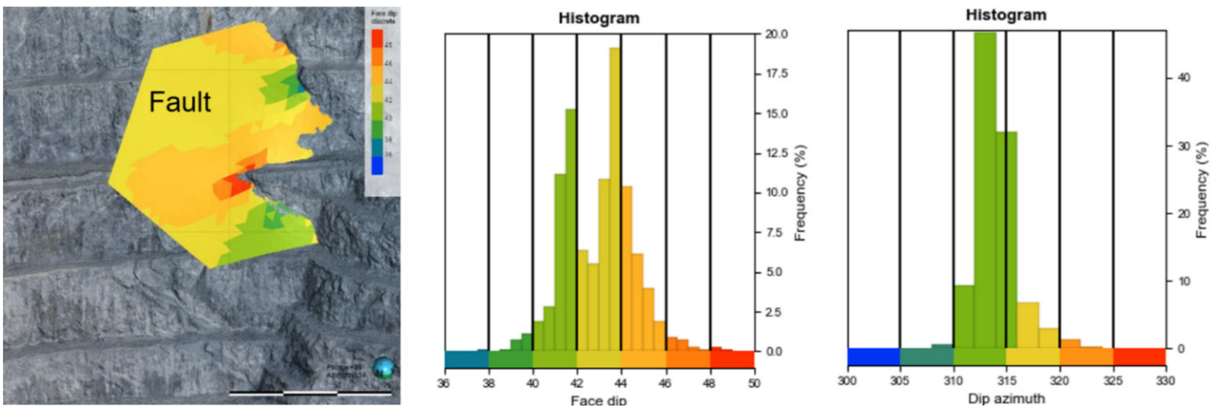


Figure 13 3D fault model based on surface mapping

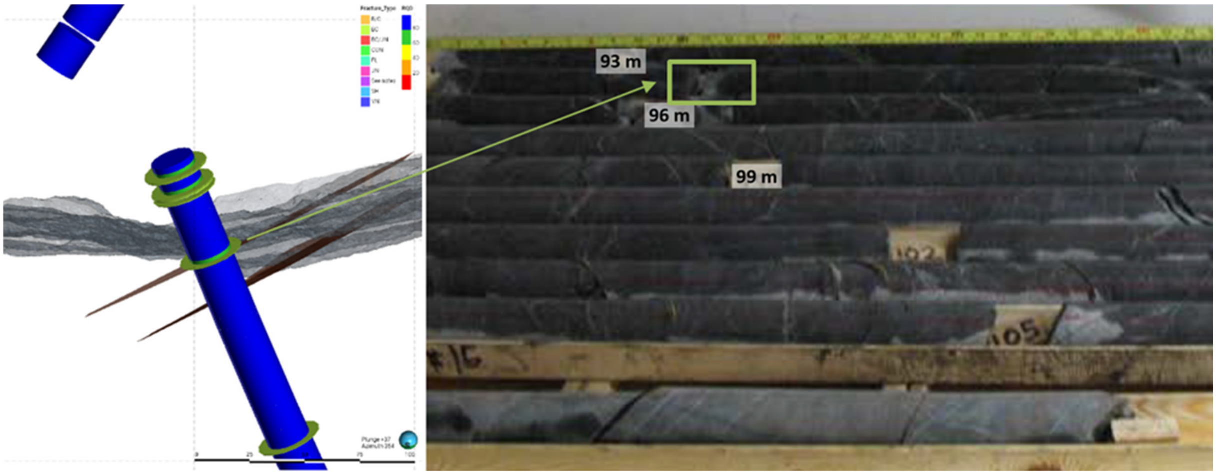
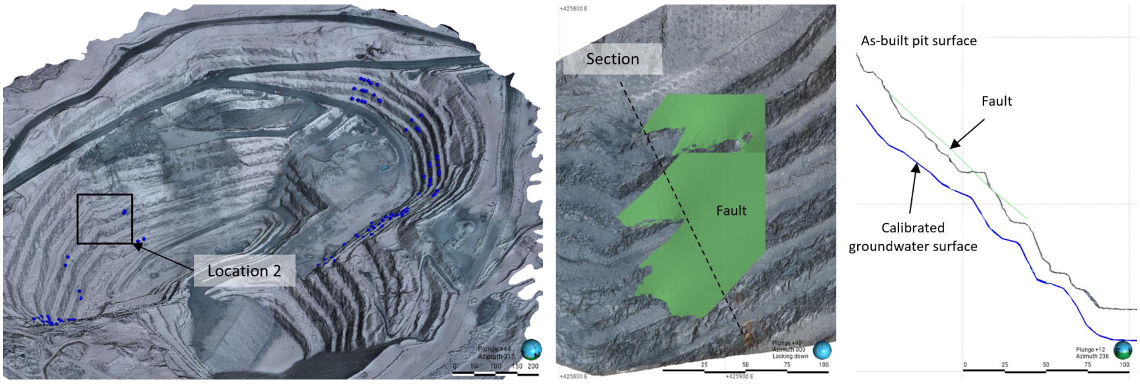


Figure 14 3D fault model based on surface mapping

A calibrated groundwater model was generated as part of the south wall slope performance review and was based on monitoring of deep nested vibrating wire piezometers and pit face seepage observations (Figure 15a). The calibrated groundwater model was compared to the block geometry. The water surface was predicted to be behind the block shape and, as a result, the slope was assumed to be dry at the wedge scale.



(a) (b)

Figure 15 (a) Seepage mapping of as-built pit; (b) Calibrated groundwater model at Location 2

The unsupported kinematic assessment FoS was 0.7 for both the SWedge and RocSlope3 models (Figure 16). For this scenario, geotechnical parameters were not adjusted to achieve closer to a 1.0–1.1 FoS for two primary reasons:

1. The orientation, persistence, and location of the modelled joint set was a worst-case scenario (i.e. fully persistent across the wedge, oriented in unfavourable wedge geometry within the joint set window, and located to generate the maximum wedge volume).
2. The wedge is currently stabilised by the unmined material in front of the wedge. The unsupported block is possible to fail when the material is blasted un-buttressing the block.

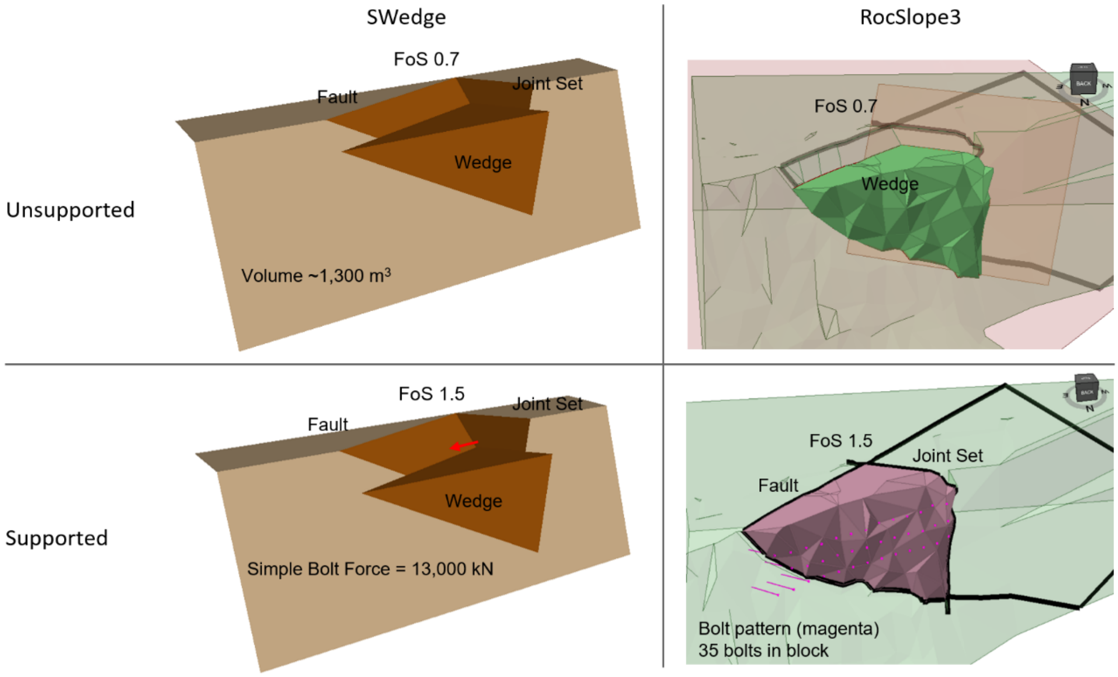


Figure 16 Unsupported and supported models using SWedge and RocSlope3 software

A #10 all-thread bar was again selected for application at Location 2, resulting in a working bolt capacity of 377 kN. Bolts were to be pre-tensioned to apply active pressure to the slope face. Surface support comprised of 0-gauge mesh strapping was installed horizontally between bolts to tie reinforcement into the ground support system.

A FoS of 1.5 is achieved in SWedge using an applied 'Simple Bolt Force' of 13,000 kN, which required 35 bolts to be installed. The RocSlope3 model also required 35 bolts to achieve a 1.5 FoS (Figure 16). The agreement between the 2 software codes suggests that the 3D interpretation of the fault does not have a material impact on the stability.

The following slope support recommendations were provided for Location 2 to achieve a minimum FoS of 1.5:

- Minimum of 34 pre-tensioned #10 all-thread bolts to be installed on a staggered 3 m by 3 m pattern and bolt lengths indicated in Figure 17; the first row starting 2 m below the crest.
- Bolts to be installed 10° (down) from horizontal at approximate azimuth 155° (perpendicular to the slope aspect), installing as close to perpendicular as possible to the determined failure plane. This allowed for simplified bolt installation and clamping stress to the foliation surface.
- Grout to be mixed according to specifications, between 0.25–0.34 water/cement ratio. Grout tube to be used for bottom-up grouting.
- Surface 0-gauge mesh strapping to be installed horizontally between bolts with minimum 3 square overlap between strap segments.
- Support systems are to be installed on a 'top-down' approach.

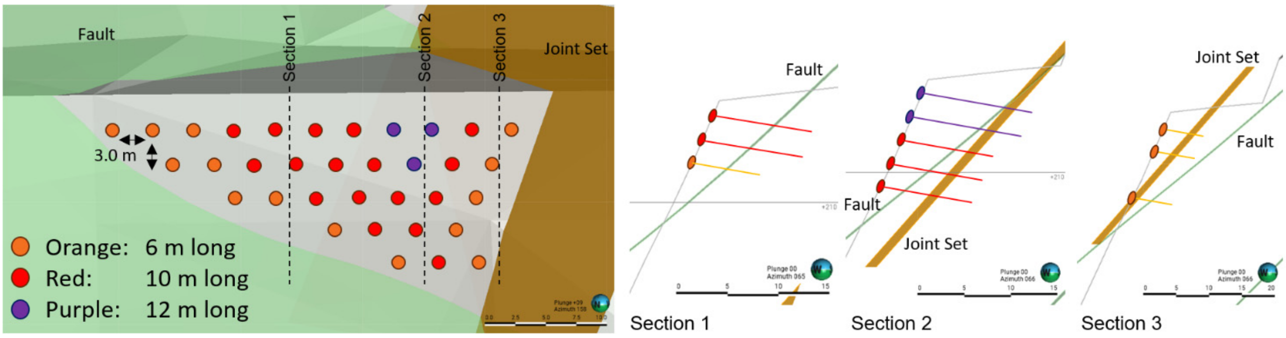


Figure 17 Bolting pattern design to support fault-on-wedge geometry at Location 2

4 Conclusion

As part of the operational open pit ground support design at Rainy River Mine, a systematic workflow has been established by SRK and the New Gold geotechnical team to assign hazard and associated risk ratings to identified slope instabilities. This approach includes a performance review of implemented slope support systems to address any concerns arising from unexpected slope behaviour. Pre-defined methods for collecting and processing geologic structural and geotechnical characterisation data are clearly outlined, along with recommended numerical modelling techniques tailored to represent the local geologic complexity and anticipated failure mechanisms.

This study demonstrates the importance of integrating advanced scanning technologies and 3D numerical modelling tools for slope stability analysis and ground support design in open pit mining. The case study at Rainy River Mine highlights several key findings.

1. Drone photogrammetry and LiDAR scanning provided high-quality data for slope characterisation, enabling the identification of critical discontinuities and the development of accurate 3D models.
2. RocScience software tools (SWedge, RocPlane, and RocSlope3) were instrumental in assessing slope stability and designing fit-for-purpose ground support systems. RocSlope3, in particular, allowed for the refinement of block geometries and bolting patterns.
3. Rockbolting patterns were designed to achieve target FoS. Pre-tensioned bolts and surface ground support types were critical for stabilising fractured rock masses and limiting smaller block failures.

These findings underscore the need for detailed slope characterisation and site-specific ground support strategies to address the challenges under challenging kinematic conditions. The methodologies and results presented in this paper provide a framework for future slope stability studies in similar mining environments.

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