TECHNICAL MEMORANDUM

DATE 9 December 2016 **REFERENCE No.** 1410944-011-TM-Rev0-2016

TO Ms. Carrie Gillis
Faro Mine Remediation Project

FROM Ryan Preston, Malcolm Shang and Al Chance **EMAIL** Ryan_Preston@golder.com; Malcolm_Shang@golder.com; Al_Chance@golder.com

FARO MINE REMEDIATION PROJECT - SEPTEMBER 2016 SITE VISIT

1.0 INTRODUCTION

As per work plan # 001 standing offer agreement AAM-13008-GOLD, Mr. Ryan Preston and Mr. Malcolm Shang of Golder Associates (Golder), completed a site visit to the Faro Mine Remediation Project between 7 and 9 September 2016. The purpose of the site visit was to:

- establish a photogrammetry pit slope stability monitoring network and to train Parsons Canada Ltd. (Parsons) staff on the operation of the network.
- visually assess the overburden crest regression along the east wall of the Faro Pit.
- visually assess the potential flow paths from the FCO sump to the Faro Pit.

This memorandum summarizes the activities completed during the site visit.

1.1 Pit Slope Stability Monitoring Background

Golder initially investigated potential pit slope monitoring options in 2014 (Golder memo 1410944-004-TM-Rev0-7000). The goal of the new monitoring options was to provide information on overall slope stability as well as pit crest regression without the need for site staff to access the pit crests or install additional survey monuments on the pit slopes. It was desirable to have a system that site staff with no survey background could operate and train new staff on.

The memorandum recommended a combination of the existing survey pins and photographic comparison for the Faro pit. Until 2015, the existing survey pins, which are currently installed along the pit crest, were professionally surveyed by YES Group, a local surveying company on an annual basis, with the goal of monitoring overall pit wall stability. Photographic comparison was intended to be used to monitor overall pit slope stability by capturing high resolution photos. The rate of regression along the critical area of the east wall of the Faro Pit would also be monitored after placing objects such as a marked telephone pole along the crest area for reference.

The memorandum recommended the same photographic comparison for overall stability and crest regression monitoring in the Grum Pit.

Golder's 2015 site visit report (1410944-007-Rev0-2015) recommended the installation of photogrammetry monitoring networks in both the Faro and Grum pits, with continued professional survey of monitoring survey pins along the east wall of the Faro Pit. Stability of the Vangorda Pit has been largely monitored through visual inspection by Golder and Parsons personnel, particularly the west wall where instability has been observed in the past. For all three pits, a need has been identified for a formal and prescriptive pit slope monitoring plan. The photogrammetry monitoring networks were intended to monitor pit crest regression both through monthly visual comparison of photos between April and October, and twice yearly generation of 3D models after the June and October data collection.

1.2 Faro Pit Crest Regression Background

Seepage daylighting at the overburden/bedrock contact at the North Instability zone of the Faro pit wall is contributing to acceleration of overburden regression (erosion) towards the access road and Faro Creek Diversion Channel (FCDC). In response to overburden regression it was decided that, until the FCDC can be realigned or permanently upgraded, it would be prudent to implement some mitigation measures in the interim to potentially decrease the seepage between the diversion channel and the pit wall, thereby reducing the risk losing the channel and road in this area. Loss of the FCDC would also result in increased water treatment from the Faro Pit. The purpose of the site visit for this task was to visually assess the seepage and the regression area.

1.3 FCO Erosion Flow Path Assessment Background

The objective of this task is to assess the flow paths from the FCO sump to the Faro Pit for potential erosion in case of FCO overflows that may be generated during extreme rainfall events and/or in case of all or portion of the flow in the diversion channel being directed to the FCO sump. The purpose of the site visit for this task was to visually assess the potential overflow paths from the FCO sump to support assessment of erosion potential along the flow path.

2.0 PHOTOGRAMMETRY NETWORK

2.1 Design of the Photogrammetry Network

The Agisoft Photoscan Professional software package, which uses Structure from Motion (SfM) photogrammetry methods, was chosen for generating 3D geometry from photographs. The SfM approach was selected as the data collection requirements are the most flexible and therefore most easily taught and repeated when compared to traditional stereopair photogrammetry. The SfM approach works best when objects are photographed from more than two viewpoints, with reliability generally increasing with additional photo locations. Five photo locations were chosen for each pit, as a compromise between the model quality and the effort required to collect and process the data. The general concept for each pit was to choose five locations to collect photos of the entire area of interest as well as adjacent stable reference areas. The locations were roughly evenly spaced such that the distance between the furthest stations was approximately 1/2 the distance to the monitored slope and the distance between each station was approximately 1/8 the distance to the monitored slope. At this spacing the monitoring points covered approximately the same lateral width as the unstable areas on the facing slopes.

2.1.1 Camera Equipment

After determining the approximate working distance for each pit, a camera and lens combination was selected which would produce photos with a resolution of approximately 2 to 3 cm/pixel, i.e. each pixel of the photos covers 2 to 3 cm of the pit wall. A Canon 5D Mark III with a 200 mm and an 85 mm lens was determined to be sufficient for all three pits.

The distance from the camera to the pit slope varies between each photograph due to rotation of the camera across the slope face and variability of tripod locations. However, model accuracy can be calculated using the average distance, resolution and camera separation. Based on the range of camera separations between approximately 1/8 to 1/2 of distance to the slope face, an average ratio of 1/5 was used for accuracy calculations. Photogrammetry bundle adjustments for all three pits returned re-projection errors between 0.332 and 0.359 pixels. It is expected that future models can maintain an average accuracy of 0.35 pixels which is used to estimate local model accuracy. Absolute model accuracy is dependent on the accuracy of the tripod survey and is not important to slope stability monitoring, which is largely concerned with relative change. Table 1 summarizes the average working distance, photograph resolution and estimated accuracy parallel and normal to the slope faces.

Table 1: Average resolution and estimated 3D model accuracy

Pit	Average Working Distance (m)	Average Photograph Resolution (cm/pixel)	Estimated Accuracy Parallel to Slope Face (cm)	Estimated Accuracy Normal to Slope Face (cm)
Faro	825	2.67	0.93	4.67
Grum	594	1.90	0.67	3.33
Vangorda	414	3.39	1.19	5.93

This resolution and accuracy is considered acceptable to measure crest regression and/or displacements in each of the pits, but is not as accurate as a conventional prism monitoring system. A spherical virtual reality tripod head was selected so that the camera could be panned and tilted consistently and easily. Tripod heads such as the one used can be calibrated so that the camera rotates around the object centre and all photos are captured from the exact same location. This serves to increase the accuracy of 3D models because they rely on the surveyed camera location as an input. Provided the same camera is used each time, tripod heads such as the one provided only require one time calibration. The provided tripod head was calibrated during the site staff training.

Heavy duty aluminum survey tripods were selected for their robust design and relatively low cost. Fifteen tripods were procured from YES so that they could be semi-permanently installed at the selected monitoring stations in each pit and improve repeatability between surveys by allowing photos to be collected from as close to the exact same viewpoint each time.

2.2 Installation of the Photogrammetry Network

Approximate tripod locations were selected from reviewing mine plans prior to arrival on site. They were then adjusted based on sight lines, ease of access and compatibility with other site activities such as snow removal during the site visit. On 7 September an initial set of data were captured from the fifteen monitoring locations over the three pits, and 3D photogrammetry models were generated to confirm the viability of the selected locations. Over 8 and 9 September and the tripods were permanently installed by Parsons staff in collaboration with Golder.

Based on recommendations from Parsons staff conducting tripod installation, four of the five tripods along the Vangorda Pit crest were relocated from the crest to the slope behind the flume. The tripods were relocated because snow is plowed from the road, into the Vangorda Pit, which would have resulted in the loss of the four tripods after the first winter. In the Faro Pit, the previously installed prism monitoring station was found to be favourably located and was therefore used instead of a tripod.

To semi-permanently install the tripods, small holes were dug for each leg and backfilled with concrete (Figure 1). It is expected that the tripods will shift slightly as a result of freeze-thaw cycles and snow loading, but this can be corrected for during processing in the photogrammetry software.

The installed tripods were surveyed by Underhill Geomatics on 9 September 2016 and their locations are presented in Table 1. Figures 2 to 4 show the locations of the tripods.

Table 2: Surveyed Tripod Locations (UTM Nad83 (CSRS) Zone 8

Tripod Name	Northing (m)	Easting (m)	Elevation of top of tripod (m)
Faro 1 (Total station monument)	6914831.179	584166.853	1183.603
Faro 2	6914735.710	584193.976	1183.445
Faro 3	6914647.062	584235.613	1173.309
Faro 4	6914597.548	584320.457	1185.352
Faro 5	6914545.517	584416.871	1191.992
Grum 1	6905086.902	592044.405	1247.742
Grum 2	6905004.298	592050.135	1255.406
Grum 3	6904928.524	592066.524	1261.873
Grum 4	6904849.061	592130.057	1269.261
Grum 5	6904791.985	592157.252	1276.097
Vangorda 1*	6903819	593854	1181
Vangorda 2*	6903830	593908	1183
Vangorda 3	6903761.628	593944.575	1168.728
Vangorda 4	6903749.644	593971.503	1170.598
Vangorda 5	6903667.397	593993.146	1157.263

*Approximate co-ordinates based on handheld GPS to be updated after spring survey

2.3 Training Parsons Staff

On 9 September, Tracey Parkin, David Legault and Frank Pilecki of Parsons were trained on operation of the photogrammetry network. Each of them received instruction on operating the camera, tripod head and tripods, and participated in data collection at the Faro and Grum pits (Figure 5). Due to heavy rain, data were not collected for the Vangorda pit at the time of the site visit, but the location of the tripods and the area of interest for data collection were reviewed both by Parsons staff during tripod installation and from the pit crest road with Parsons staff during photogrammetry training. Following the September site visit, the locations of two of the Vangorda tripods were determined by Parsons management to be unsafe, due to access concerns and their proximity to steep slopes. Golder collaborated with Parsons to provide replacement tripods and suitable locations. During data collection and a classroom session, the goal and logistics of operating the photogrammetry network were discussed.

The PowerPoint presentation provided to Parsons at that time is included as part of the Photogrammetry Network Manual (Attachment 1). The 3D photogrammetry models generated from the data collected by Parsons are presented in Figures 6 to 8.

2.4 Updated Monitoring Schedule

Given the favorable ongoing slope stability performance of the pit walls, in 2015 it was agreed that Golder would carry out pit slope inspections every two years, rather than on an annual basis. This schedule is contingent on the slope continuing to remain stable and not exhibiting a rapid increase in crest regression. It was agreed that the survey pins behind the east wall of the Faro Pit would continue to be read on annual basis by YES.

We also understand that in late 2015, a slope inclinometer was installed behind the crest of the east wall of the Faro Pit. It is Golder's understanding that BGC are receiving and interpreting data from the Faro Pit inclinometers on a regular basis.

In view of the above considerations, given that the photogrammetry monitoring system is now operational, and in the interest of reducing costs, it is recommended that the survey pins be read by YES every second year in conjunction with Golder's pit slope inspection site visit.

Based on discussions with Karen Furlong of the Yukon Government, it is Golder's understanding that additional survey pins will not be installed in the Grum Pit, the existing reference pins and monitoring points will no longer be surveyed, and that the 3D photogrammetry models will be used for overall slope stability and crest regression monitoring. It should be noted that the displacement detection threshold of the 3D models is approximately an order of magnitude higher (less accurate) than survey points.

3.0 FARO PIT CREST REGRESSION AND FCO SUMP EROSION FLOW PATH

The Faro Pit crest regression area was assessed on 7 September 2016 during an overall site tour with Ms. Carrie Gillis and independently by Golder following the site tour. The area was assessed in further detail during an unmanned aerial vehicle (UAV) survey on 8 September 2016. The UAV survey also covered the area of the FCO sump and its associated downstream areas. During the afternoon of 8 September, Mr. Shang met with Ms. Gillis and Mr. Eric Domingue to discuss preliminary potential Faro Pit crest regression mitigation options and the path forward. These findings together with a remedial options review are discussed in a separate technical memorandum (Golder 2016a). A presentation summarizing the findings from the site visit and potential solutions relating to the Faro Pit crest regression is included in Attachment 2.

The FCO sump and potential overflow paths were visually assessed from the ground on 9 September 2016. The potential flow paths were walked, and material types and size distributions were noted. Photographs of the FCO sump potential overflow paths is included in Attachment 3. These findings together with a remedial options review are discussed in a separate report (Golder 2016b).

4.0 VANGORDA PIT SINKHOLE

Golder conducted a site tour with Ms. Gillis and Mr. Domingue on the morning of 9 September 2016 which included discussion of a sinkhole which was recently identified on the Vangorda Pit crest. The sink hole has re-developed in area of previous instability that was re-sloped in the fall of 2015. The instability and the sink hole is developing due to surface runoff from a ditch located approximately50 meters behind the pit wall. Golder's interpretation of the sinkhole and recommendations for remediation were summarized in a 21 September 2016 email (Faro Mine: Vangorda sinkhole) which is provided in Attachment 4.

5.0 CLOSURE

The reader is referred to the Study Limitations, which follows the text and forms an integral part of this memorandum

We trust that this memorandum adequately summarizes the work conducted during Golder's September 2016 site visit at the Faro Mine Remediation Project. Please do not hesitate to contact us if you have any questions or comments.

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Attachments: Study Limitations
Figures 1 to 5
Attachment 1: Photogrammetry Monitoring Network Training
Attachment 2: Faro Overburden Crest Regression Site Visit Findings & Potential Solutions
Attachment 3: FCOSump Flow Path Assessment Site Visit Pictures
Attachment 4: Faro Mine Vangorda Sinkhole

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REFERENCES

Golder Associates Ltd (Golder). 2016a. Faro Mine Remediation Project Overburden Regression Mitigation. Submitted to Faro Mine Remediation Project, Whitehorse, YT, Canada. Golder Doc. No. 1410944-014-TM-RevB-2016. 7 October 2016.

Golder 2016b. Faro Mine Remediation Project FCO Sump Erosion Flow Path Assessment. Submitted to Faro Mine Remediation Project, Whitehorse, YT, Canada. Golder Doc. No. 1410944-015-TM-RevB-2016. October 11, 2016.

STUDY LIMITATIONS

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ATTACHMENT 1
Photogrammetry Monitoring Network Training Presentation

Faro Mine Remediation Project

Photogrammetry Monitoring Network Training

Golder Associates

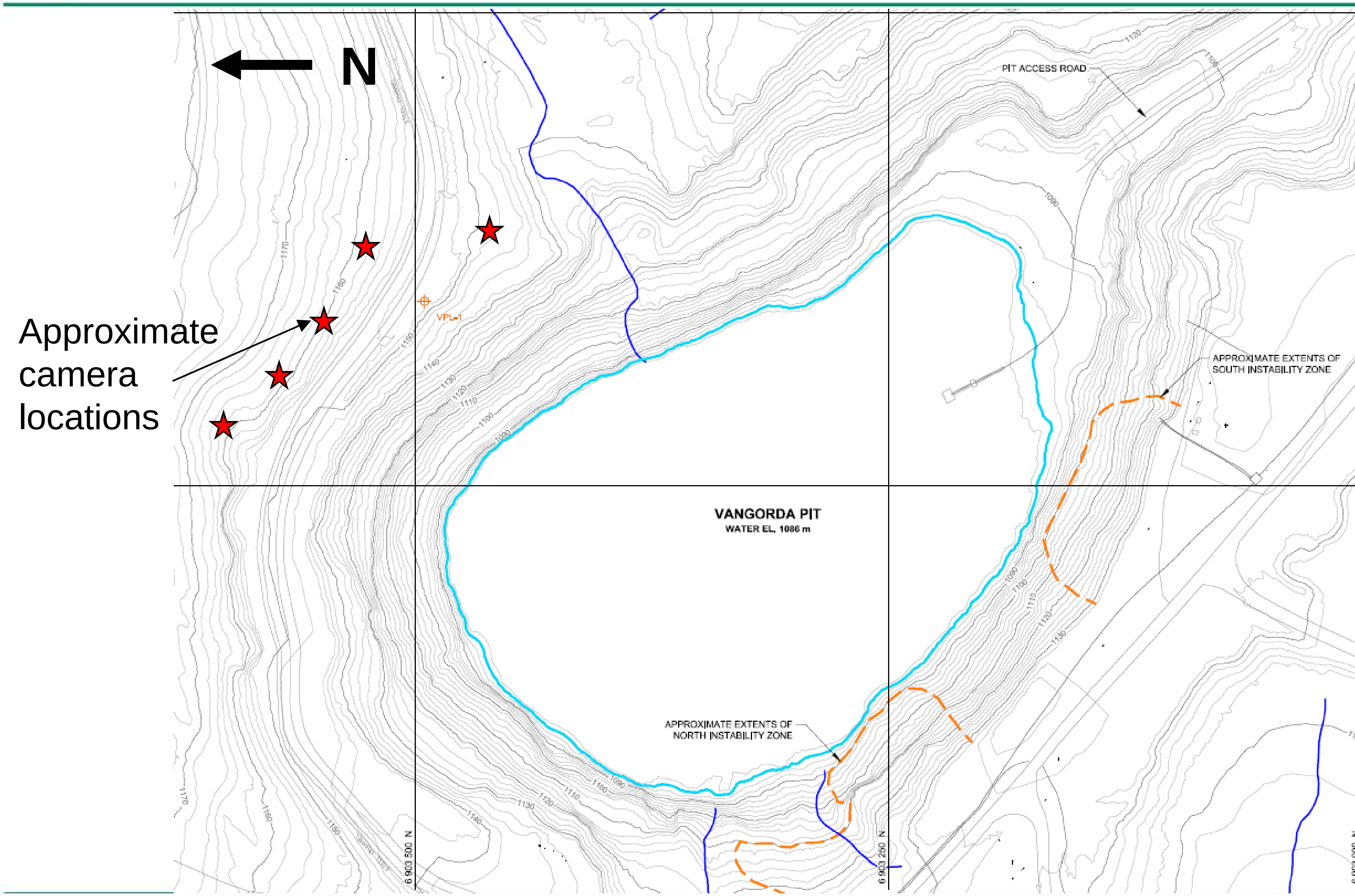
Outline

- Background
  - Purpose of monitoring
  - Areas to monitor
  - How we'll monitor – Photo comparison
  - How we'll monitor – Photogrammetry Models
- Equipment briefing
  - Tripod
  - Tripod head
  - Camera
  - Changing lenses
- Data collection

Purpose of Monitoring

- When working in or around the pits we need to be concerned about slope stability. Failures can result in landslide induced waves which can affect personnel on the other side of the pit
- Monitoring plan isn't final but the general idea is that on a regular basis as well as prior to conducting specific tasks, the identified areas of instability will be monitored

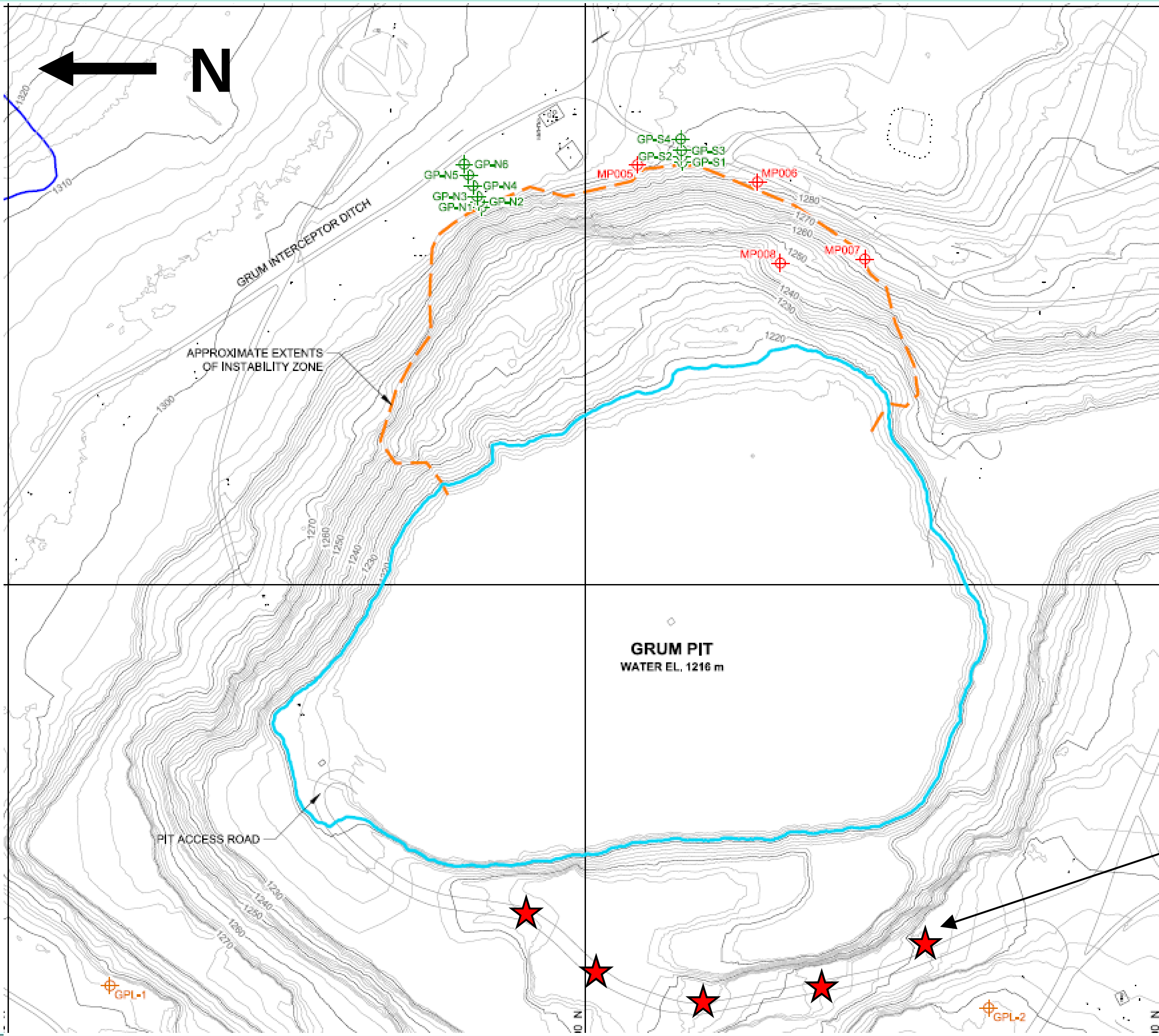
Areas of interest – Vangorda Pit



Golder Associates

Areas of interest – Vangorda Pit

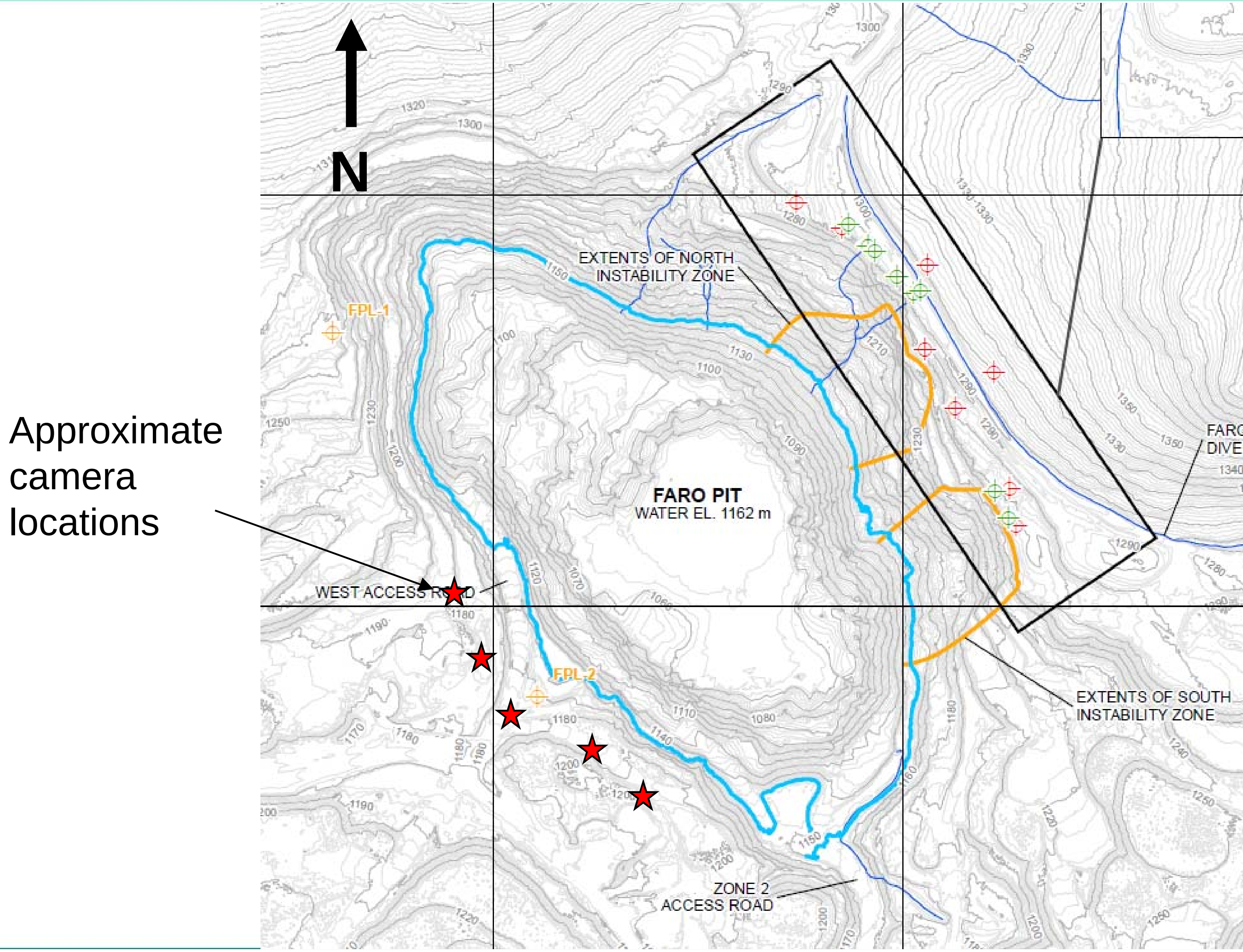
Areas of interest – Grum Pit



Approximate camera locations

Areas of interest – Grum Pit

Areas of Interest - Faro Pit



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Areas of Interest - Faro Pit

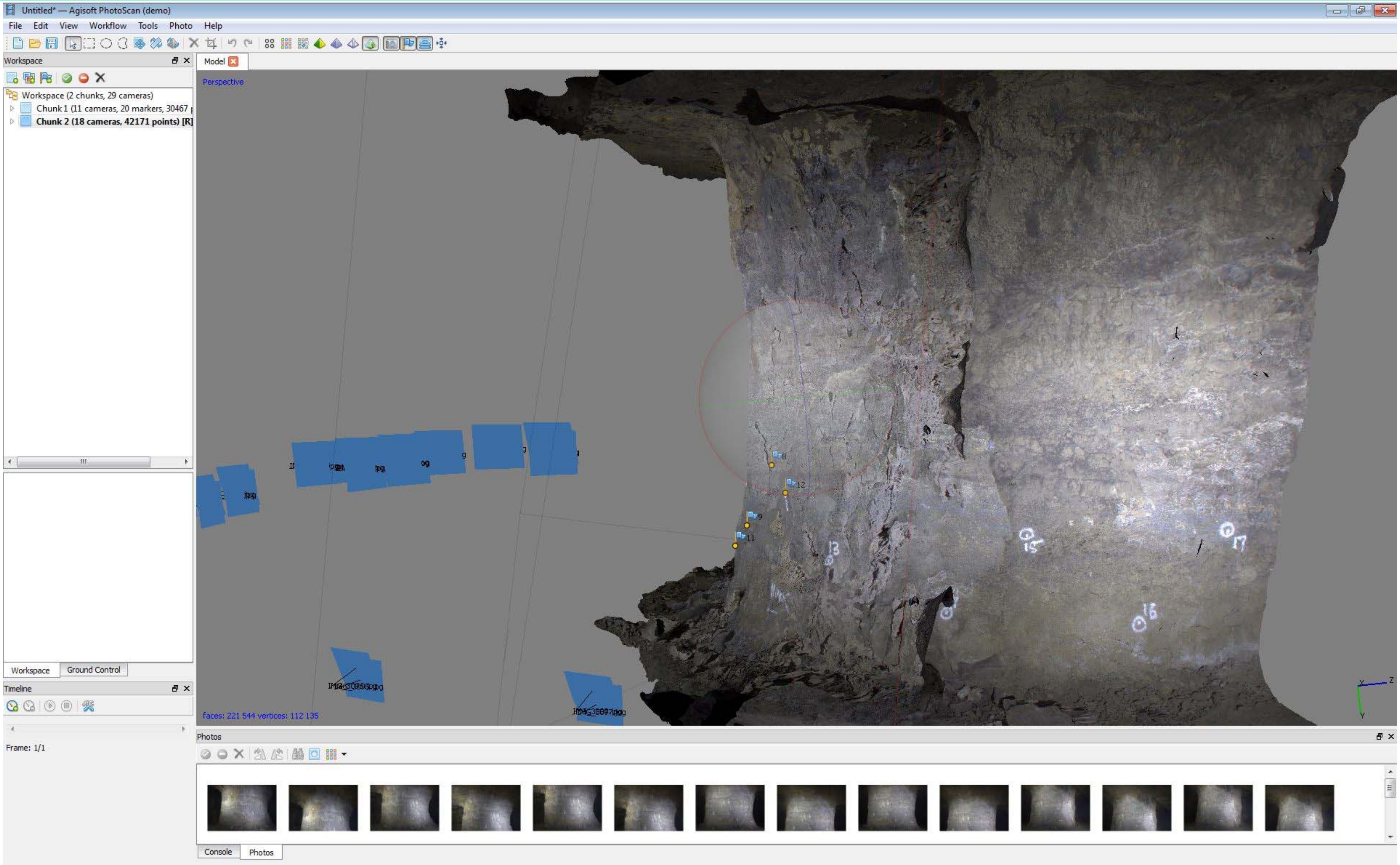
Things to look for

- Cracks opening
- Sluffing material
- Bulging
- New seepage

Example: Pillar Spalling – 1st Observation

Example: Pillar Spalling – 2nd Observation

Example: Pillar Spalling – 1st Observation



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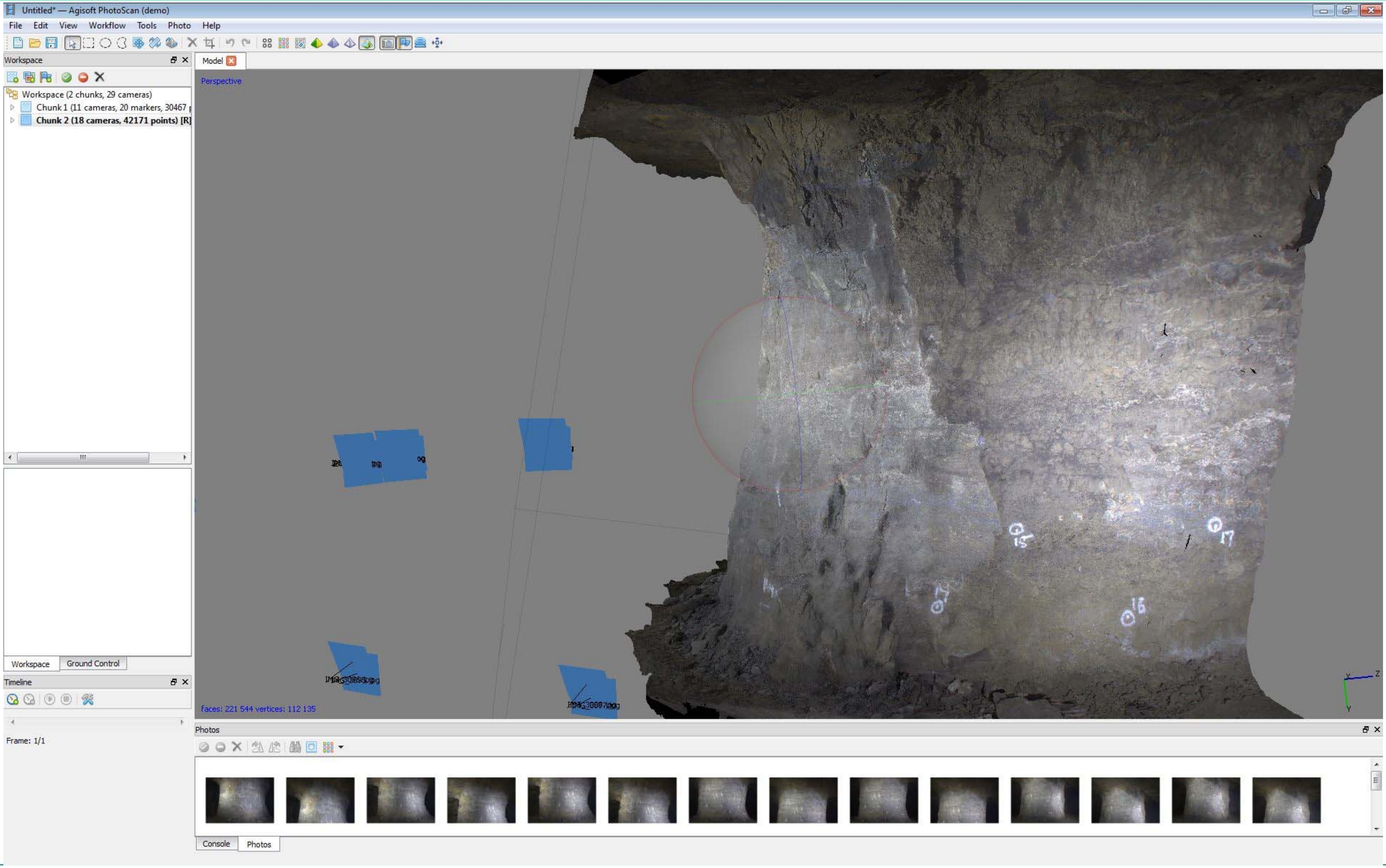
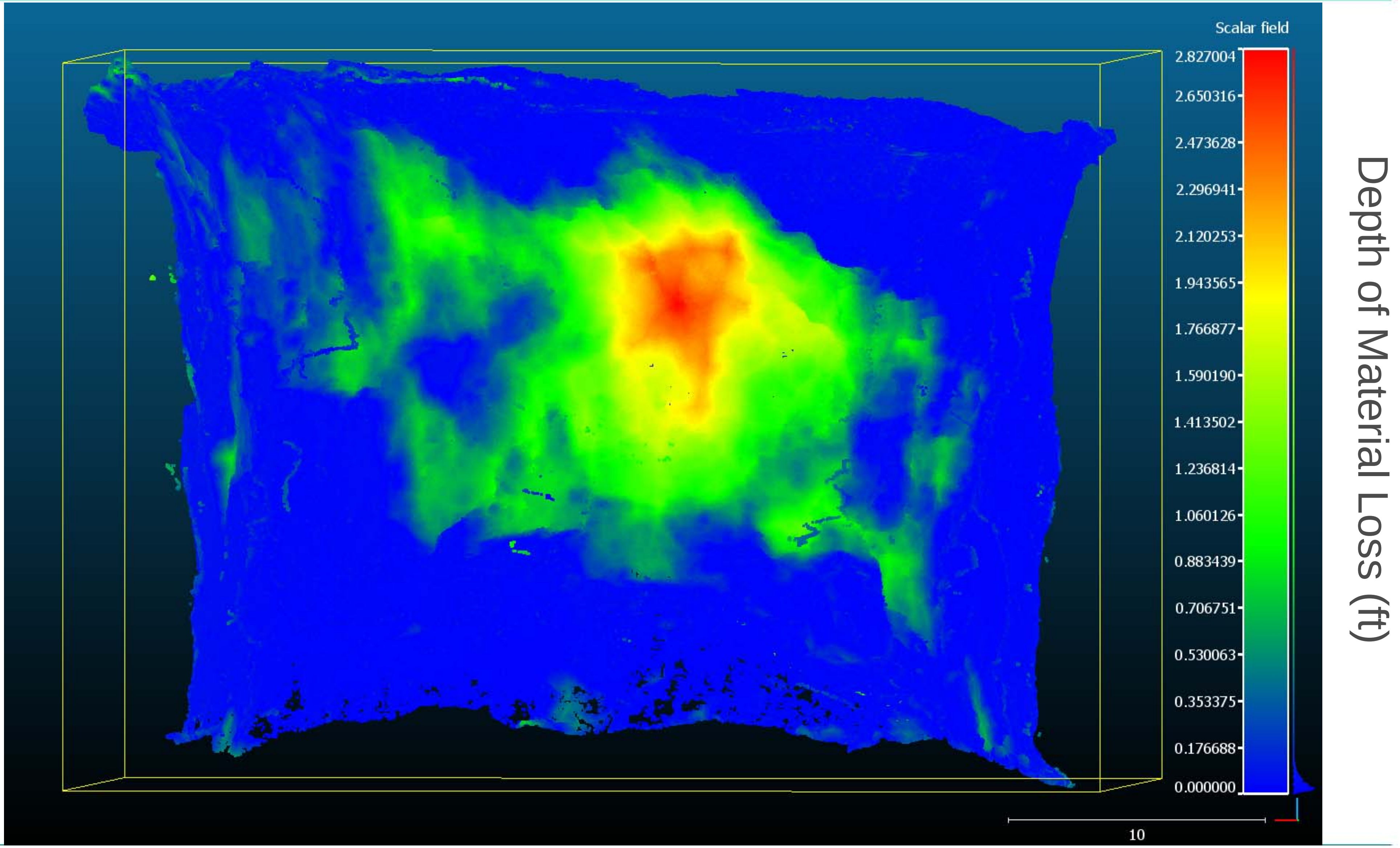
Example: Pillar Spalling – 2nd Observation

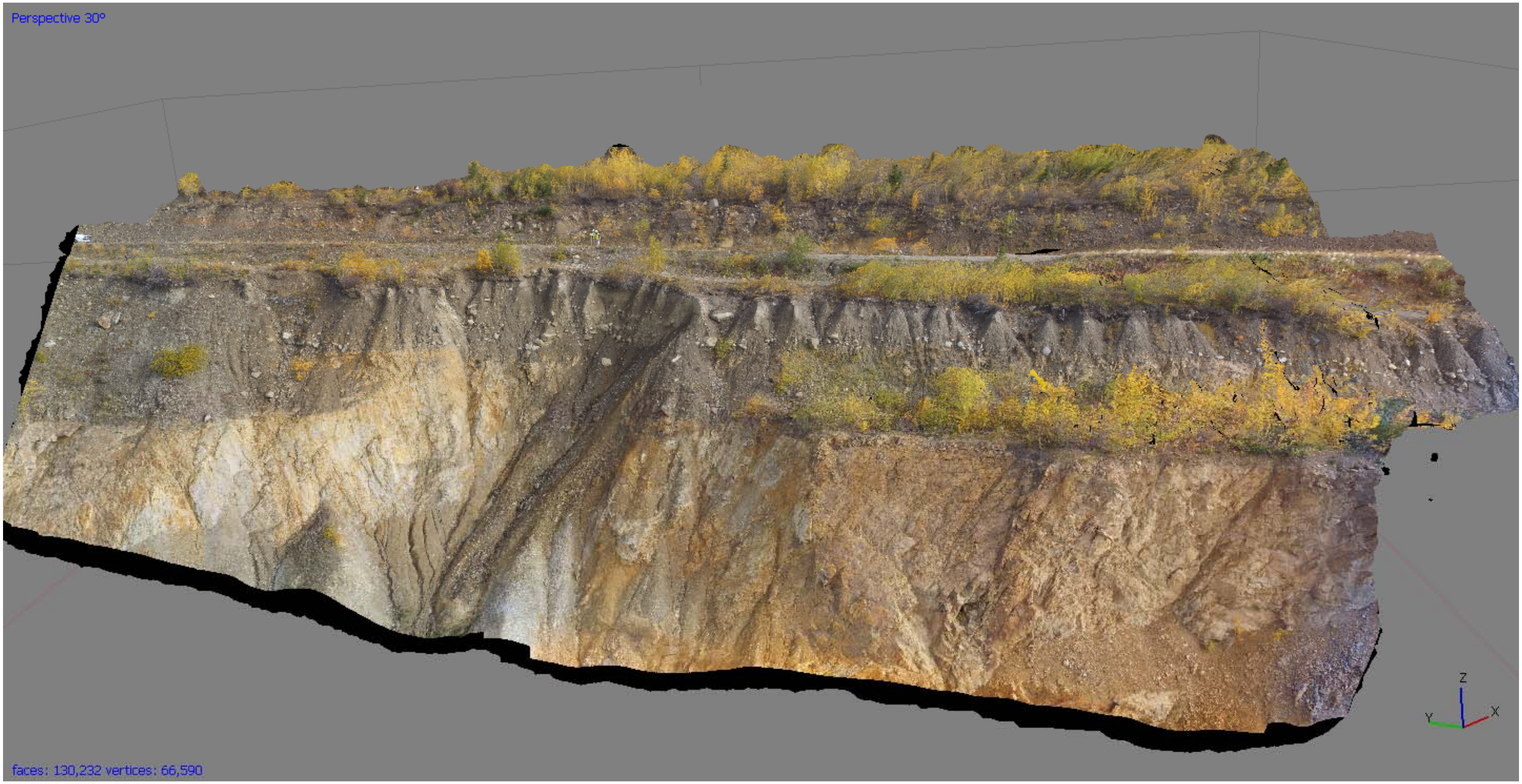


Example: Pillar Spalling – Model Comparison



Seepage

Photogrammetry Comparison – 3D Model



Photogrammetry Comparison – 3D Model

Golder Associates

Equipment – The Tripod

Equipment – The Tripod Head

Equipment Briefing – The Camera

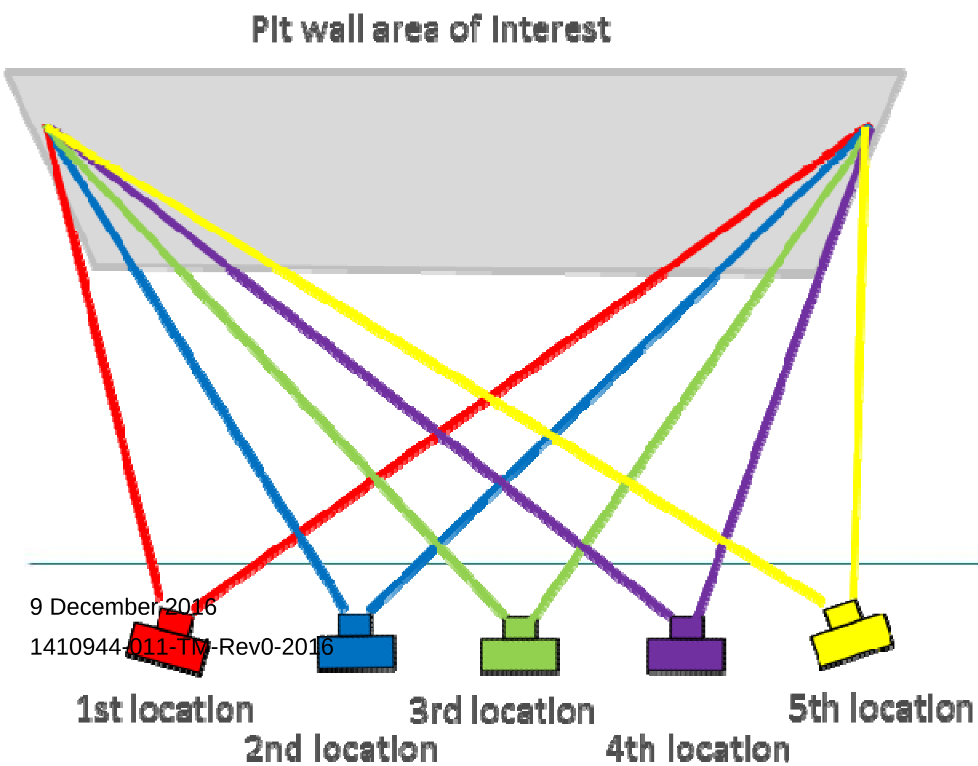
Camera Parts

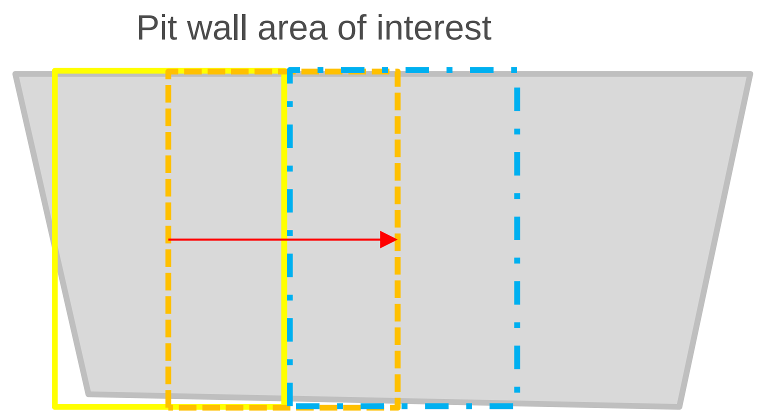
1. Switch from Autofocus (AF) to Manual focus (MF)
2. Leave on Av (Aperture priority)
3. Press half way to focus during AF
4. Adjust Aperture (Leave at 8.0)
5. Shows Aperture value
6. Shows ISO (Leave at auto)
7. Leave on RAW+L
8. Press “INFO” until this screen appears, press Q and use joystick to select value to adjust, adjust with scroll wheel and button
9. Review photos
10. Delete photos
11. Use LCD screen as viewfinder
12. Zoom in and out of reviewed photos

Data Collection

Procedure

1. Camera on Autofocus (AF)
2. Confirm camera settings: RAW+L, 2 second timer, Av, F8.0, ISO 200.
3. Press half way to focus on middle of pit wall
4. Switch from Autofocus (AF) to Manual focus (MF)
5. Take photos, panning over area of interest with ~30% vertical and horizontal overlap between photos
6. Review photos for focus (using zoom button) and exposure
7. Move to next camera station and repeat





50% Overlapping photos and panning path

Changing lenses and hands on camera use

- Break for hands on training

ATTACHMENT 2

Faro Overburden Crest Regression Site Visit Findings & Potential Solutions

Faro Mine Remediation Project

Faro Overburden Crest Regression
Site Visit Findings & Potential Solutions

FOR DISCUSSION ONLY

Golder Associates

Introduction

- Summary of Technical Memorandum:
  - 1410944-014-TM-RevB-2016-Overburden Regression Mitigation

- Problem:
  - Seepage daylighting at the overburden/bedrock contact at the North Instability zone of the Faro pit wall is contributing to acceleration of overburden regression (erosion) towards the access road and Faro Creek Diversion (FCD) channel.
  - Overburden regression thought to be due to freeze-thaw of seepage exiting the overburden-bedrock contact.
  - Background information and Sept 2016 site visit indicate seepage most likely due to groundwater at the overburden-bedrock contact and minor seepage from FCD channel.

- Task objective:
  - Assess the seep and surrounding area, and provide recommendations for mitigation of potential erosion in the short term, until a permanent solution for realignment of the FCD can be implemented.

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Faro Creek Diversion - Background

- Purpose:
  - Divert Faro Creek around Faro Pit, and intercept surface runoff from surrounding catchment.

- Construction:
  - Cut and fill methods - founded in both overburden and rock.
  - ~ 500 m of the FCD is located above the crest of the Faro Pit east wall.

- Performance:
  - Concerns regarding leakage into the Faro Pit and Faro Valley Waste Dump were raised during operation.

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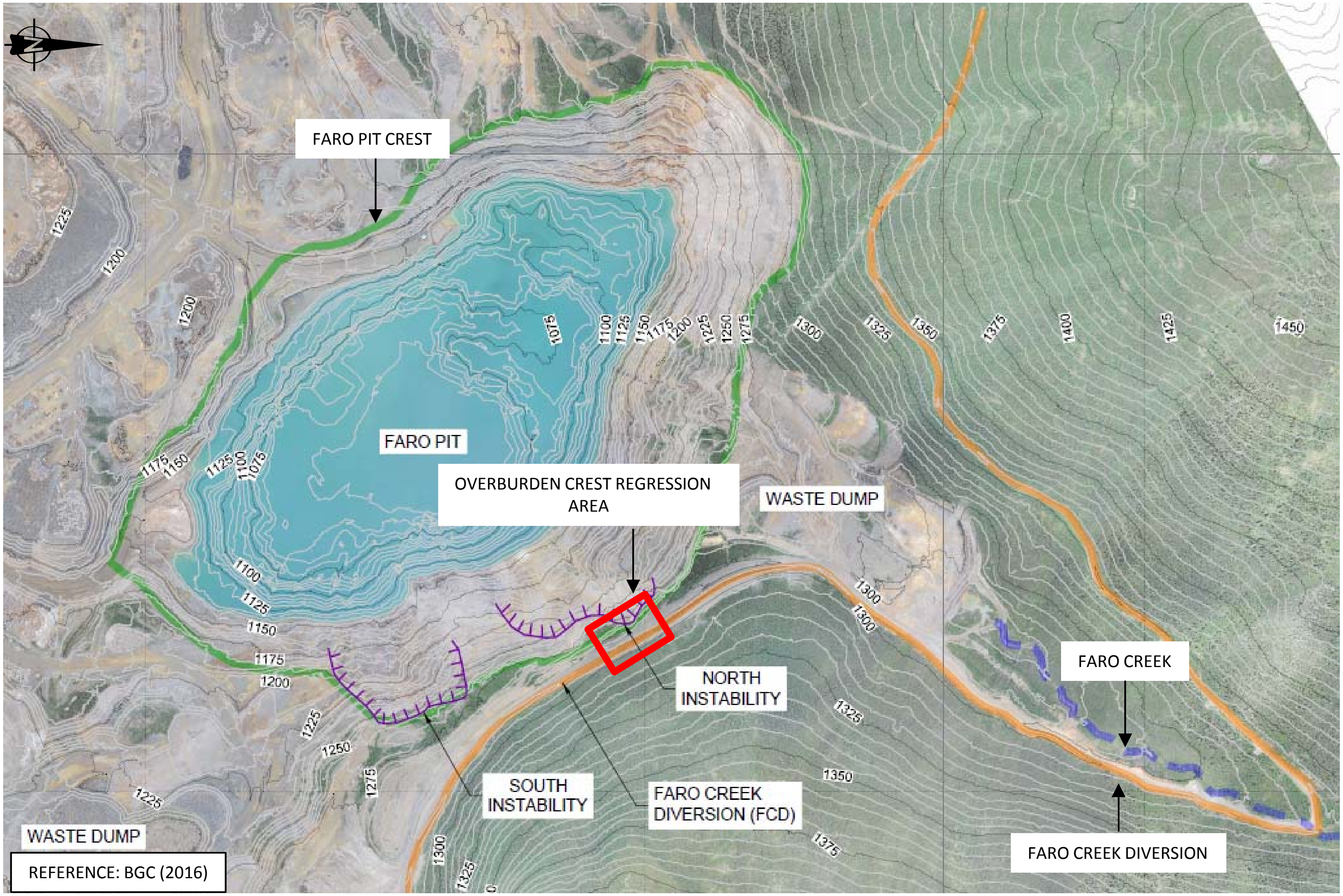
Faro Creek Diversion – Prior Remediation Measures

- During operation
  - Excavation of ditches with the occasional addition of a liner (Piteau 1985)
    - Ineffective where ditches intercepted dykes and faults.
    - Details (location, extent, design) are unknown.
  - Placement of a half culvert flume sections and plastic tarpaulins (SRK 2003)
    - Measures proved ineffective.
    - Details (location, extent, design) are unknown.

- Post-closure
  - 2003 remedial works - based BGC recommendations
    - Channel geometry changed and lined with Bentomat® clay liner and rip-rap (0.1 to 0.3 m).
    - Safety berm constructed.
    - Details (location, extent, design) are unknown – no as-built records.

FOR DISCUSSION ONLY

Overburden Crest Regression Area – Plan



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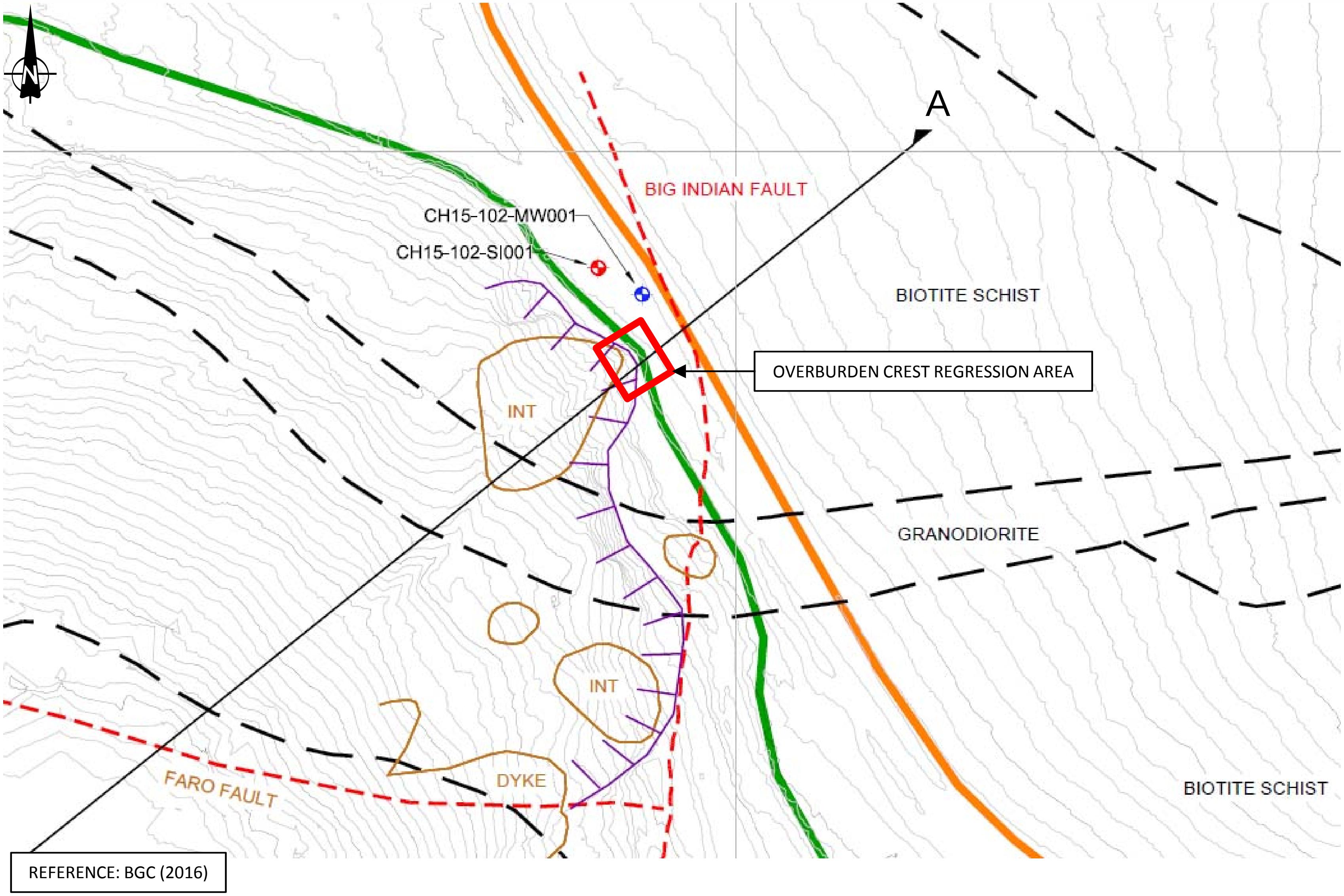
Overburden Crest Regression Area – Plan



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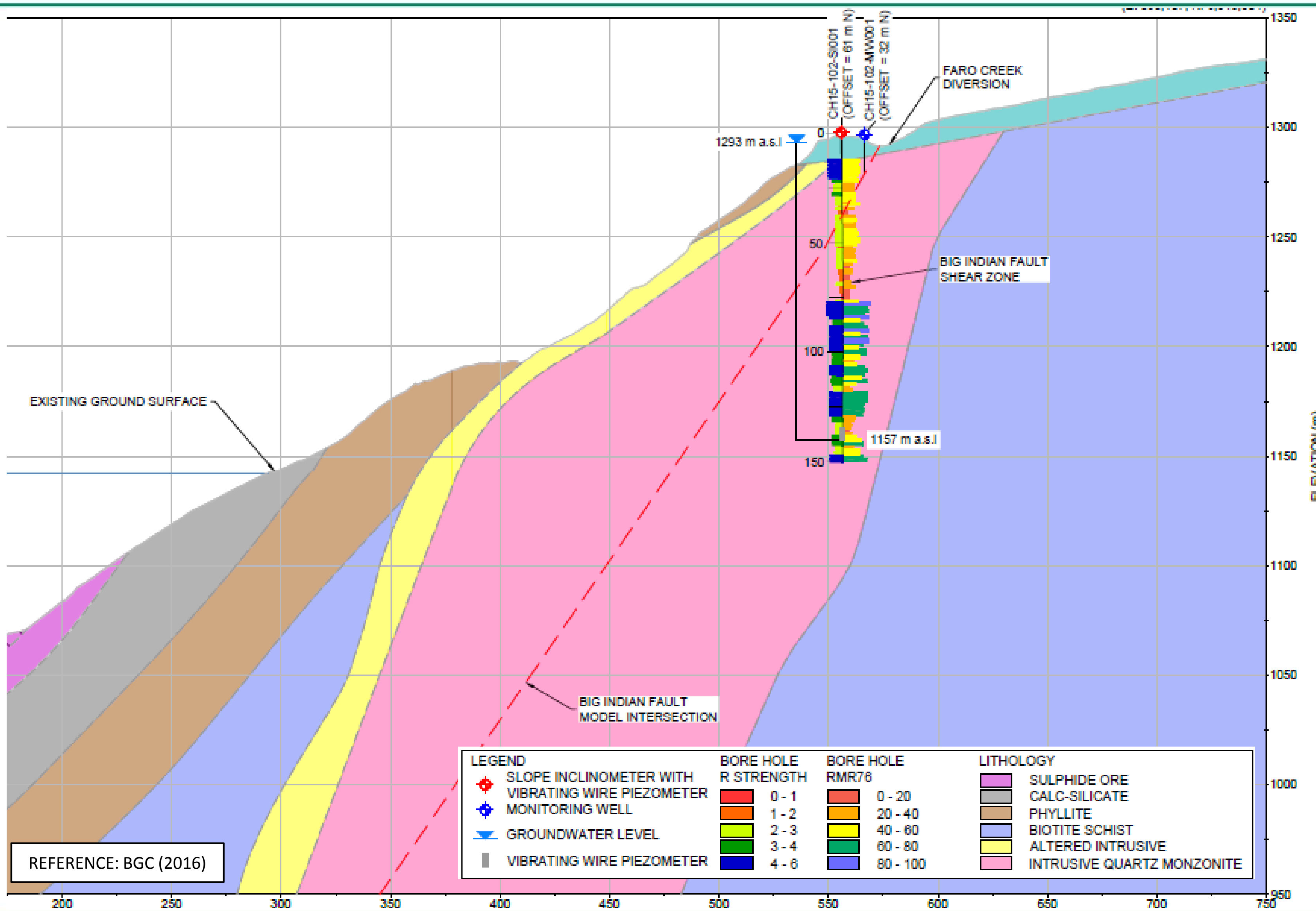
Overburden Crest Regression Area – Section A



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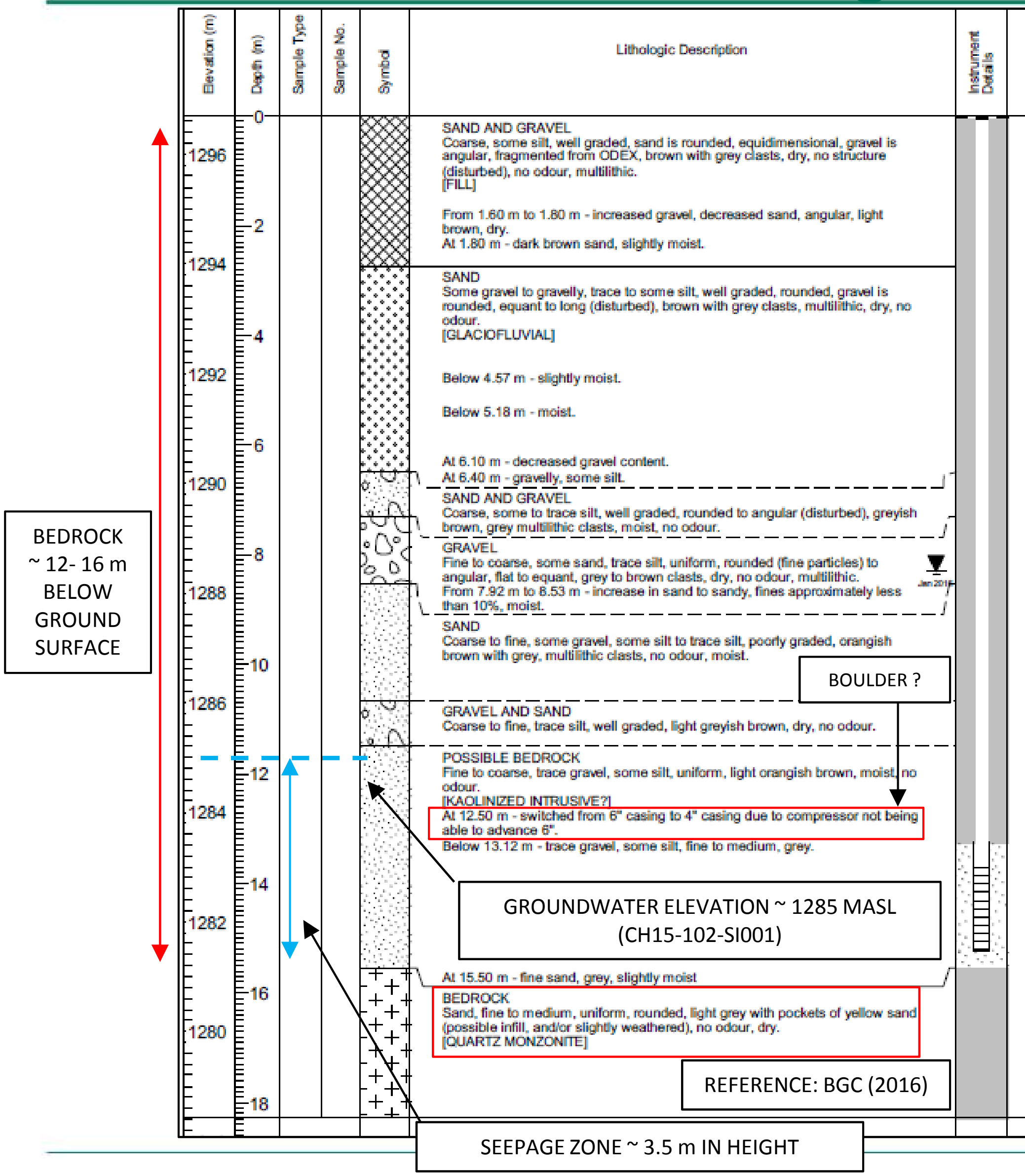
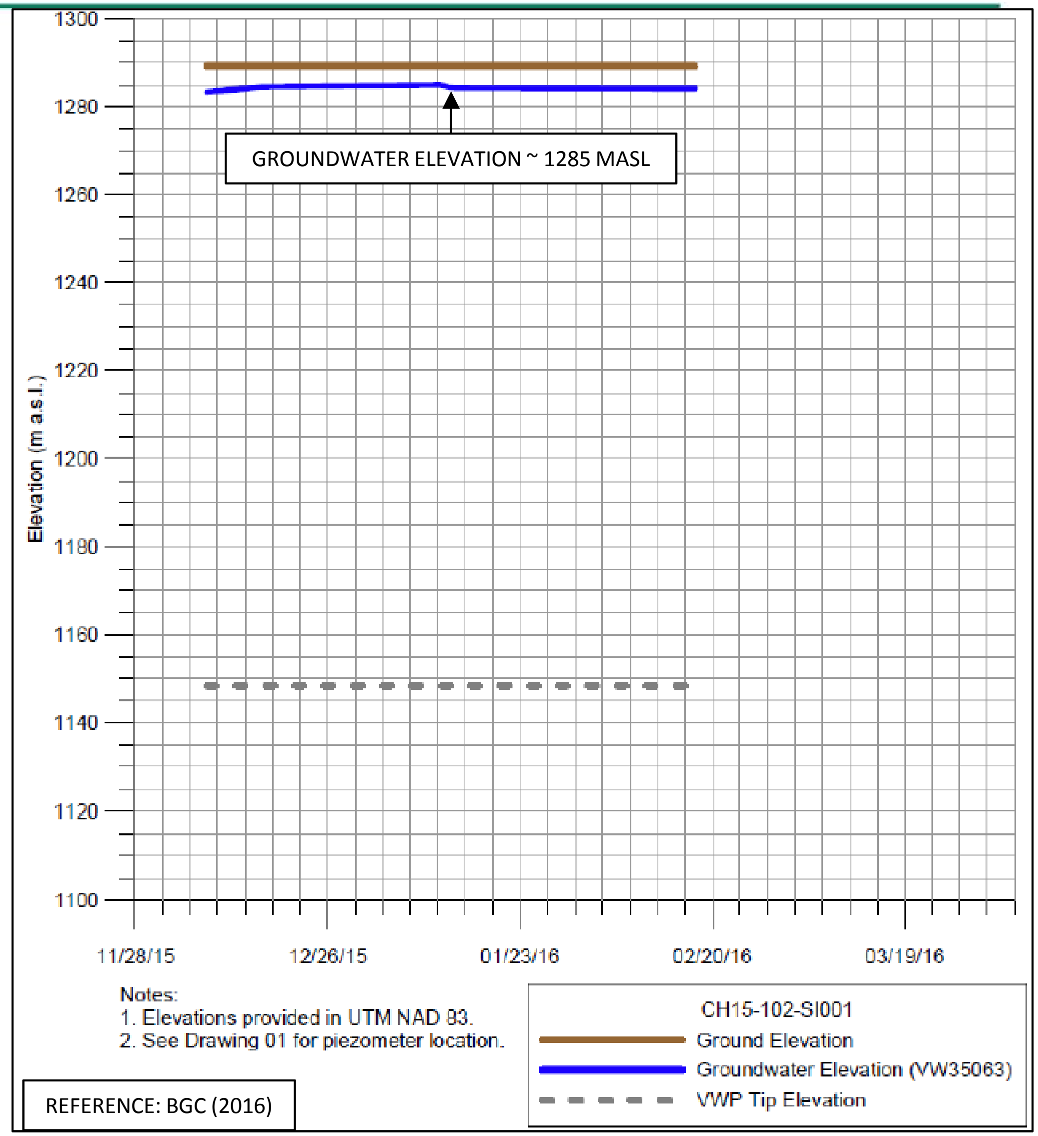
Overburden Crest Regression Area – Drillhole Log #CH15-102-MW001





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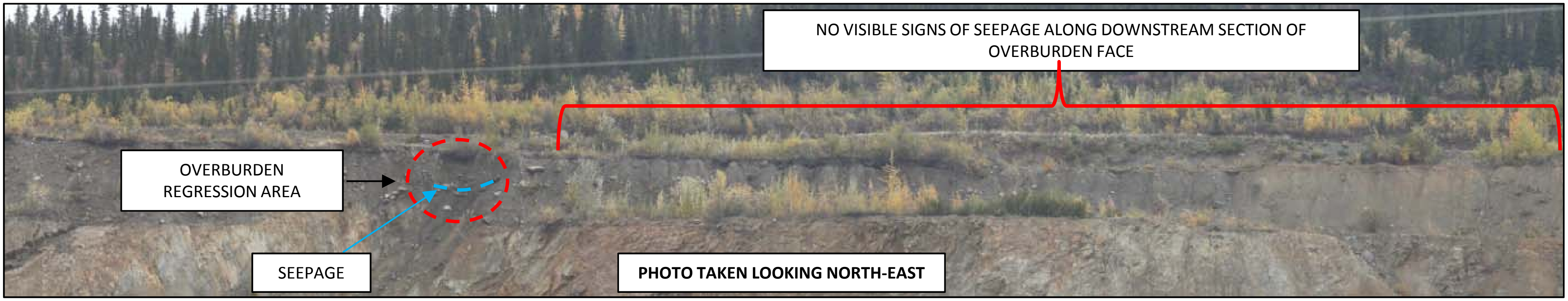
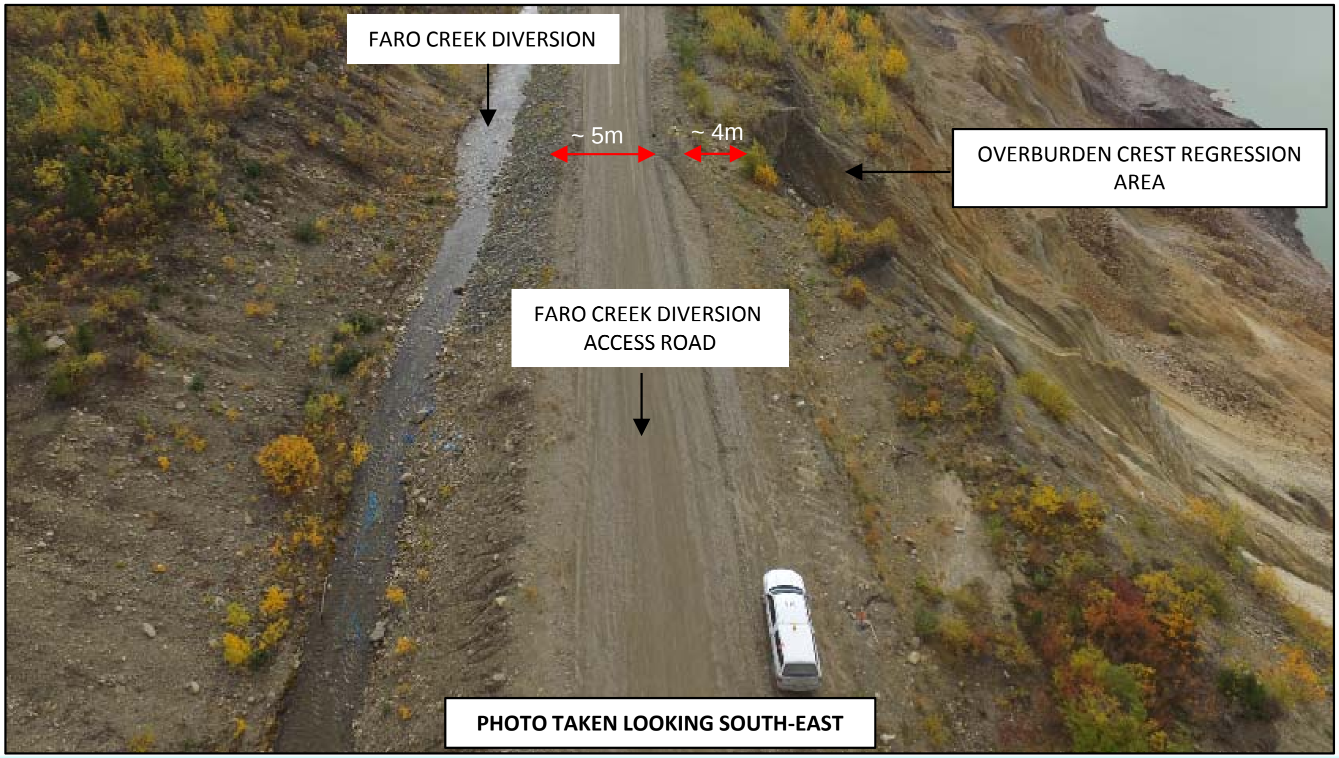
Overburden Crest Regression Area – Site Visit Photographs





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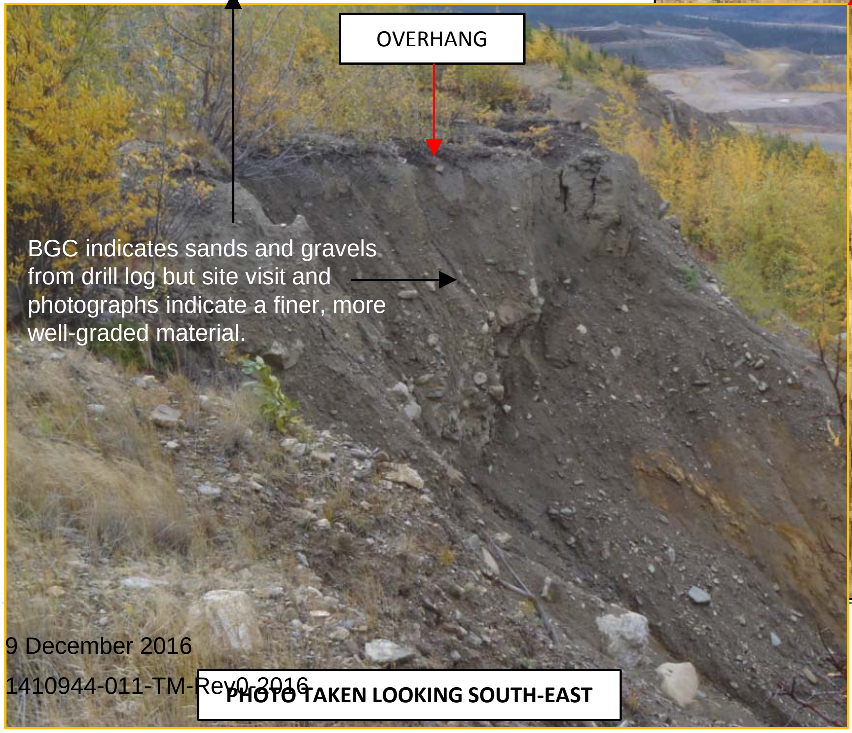
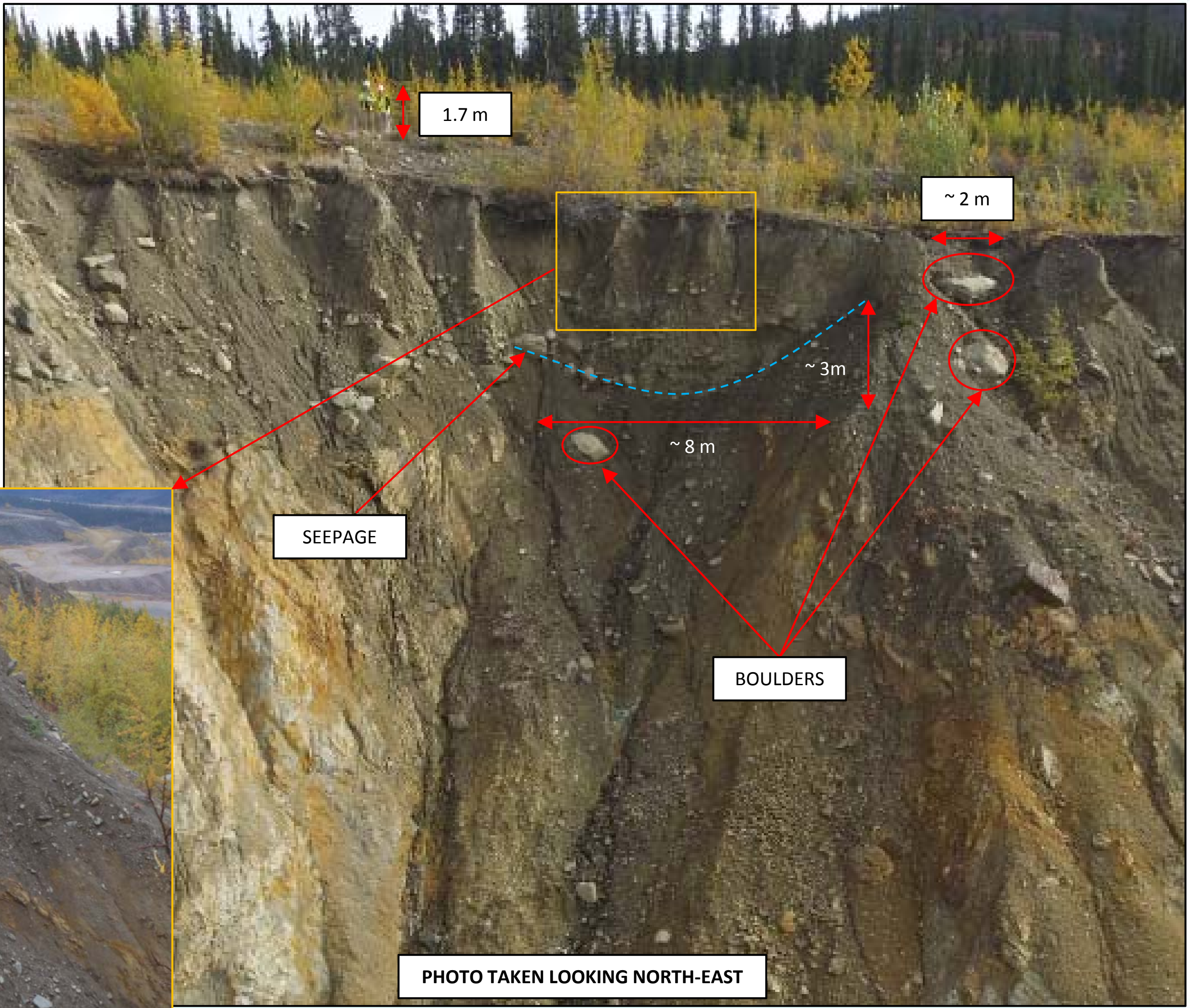
Overburden Crest Regression Area – Site Visit Photographs

Depth (m)	Material
0 – 2.7	SAND AND GRAVEL
2.7 – 6.5	SAND
6.5 – 7.3	SAND AND GRAVEL
7.3 – 8.5	GRAVEL
8.5 – 10.6	SAND
10.6 – 11.6	SAND AND GRAVEL
11.6 – 15.5	POSSIBLE BEDROCK
> 15.5	BEDROCK

BGC (2016)





FOR DISCUSSION ONLY

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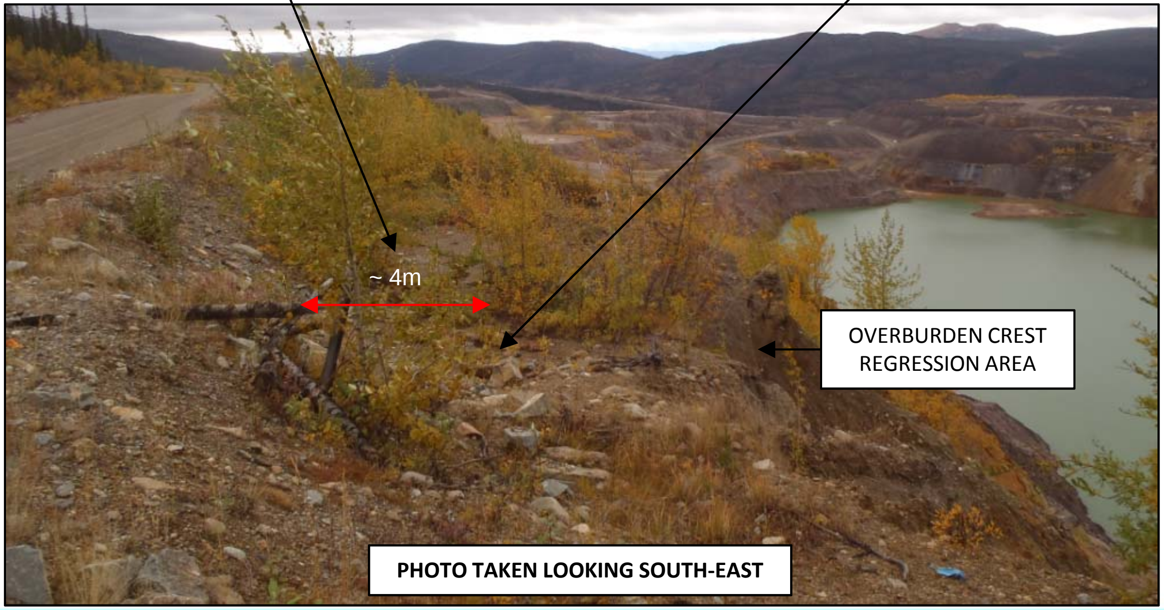
Overburden Crest Regression Area – Site Visit Photographs

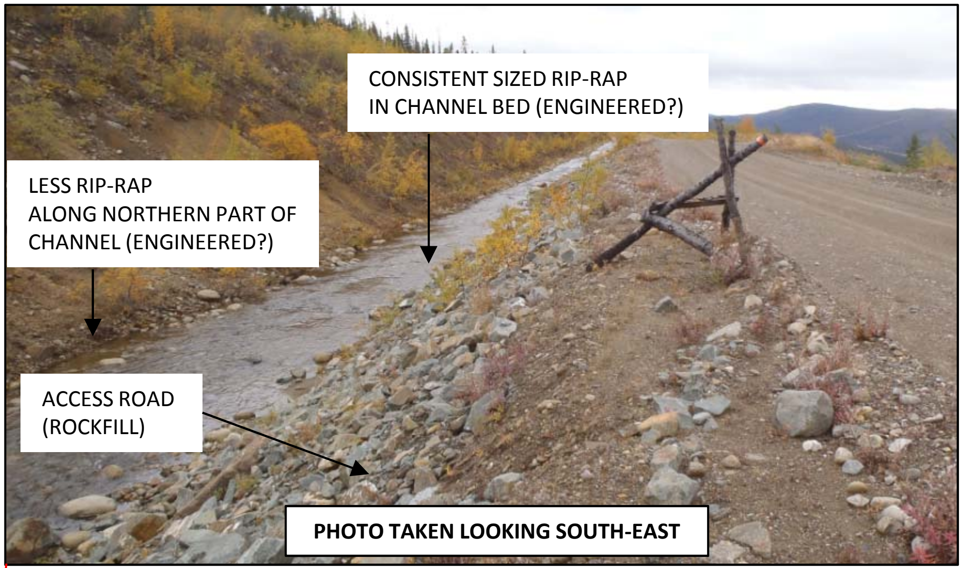
NO VISIBLE SIGNS OF INSTABILITY ON SURFACE OF NARROWEST SECTION BETWEEN PIT AND FCD – NO CRACKS

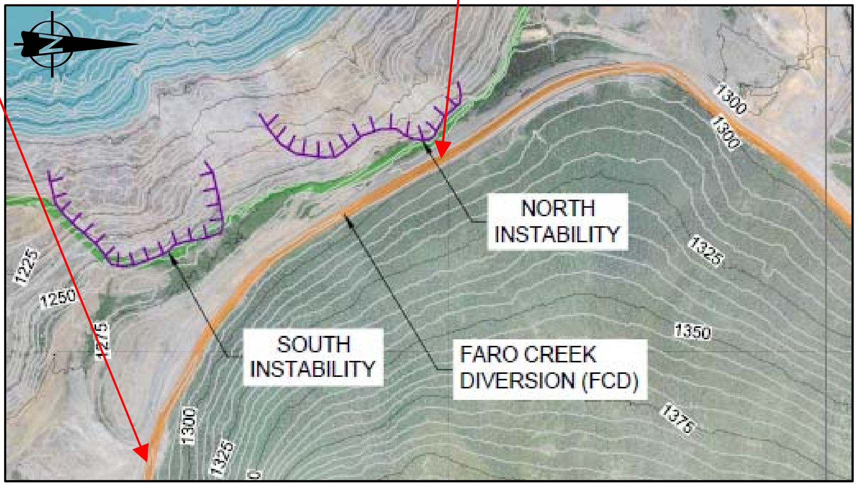


FOR DISCUSSION ONLY

Golder Associates

Faro Diversion Channel – Site Visit Photographs





FOR DISCUSSION ONLY

Overburden Crest Regression – Solutions

- Solutions:
  1. Do nothing / minor re-sloping
  2. Cut-off / divert seepage
  3. Allow seepage to occur while retaining soil particles

- Options considered:
  - Do nothing / minor re-sloping (base case)
    - Estimated crest regression ~ 33 cm per year.
    - Factors that could lead to a larger loss of material than last 10 years:
      - overhang area susceptible to slip failure with continued erosion undermining this area.
      - a substantially wetter year/years.
    - Suggested that re-slope the overburden to angle of repose using crest-chaining method. Method involves large and heavy metals chains draped over crest and dragged by dozer to destabilize loose material along crest. Would reduce likelihood of slip failure due to continued erosion of overhang section.
    - Option may be preferable for the short term if risk is acceptable.

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Overburden Crest Regression – Solutions

- Cut-off / divert seepage
  - FCD with impermeable liner and bedrock tie-in – not preferable due to space constraints and bedrock depth (12-16 m).
  - Grouting – not preferable due to possible low permeability of till based on visual assessment. Visual assessment is inconsistent with BGC (2016) log (see slide 10). BGC (2016) indicates more sands and gravels.
    - Grouting may be possible if fines content is low. Further soil sample testing would be required to assess the feasibility of this option.
  - Jet-grouting – not preferable due to presence of boulders.
  - Cement-Soil-Mixer – not preferable due to presence of boulders.
  - Trench cutter cut-off wall – not preferable due to cost (approx. $1-2 million to mobilize) and limited number of machines in North America.
  - Secant pile wall – possible but more suitable as a more permanent option. Machines are more common than trench cutters.
- Allow seepage to occur while retaining soil particles
  - Shotcrete / mesh / drain system – not preferable because possible expansion-contraction cracking, and drain may freeze and block during in winter which may lead to a build up of water and destabilization of shotcrete cover.
  - Inclined drain holes through bedrock into overburden – not preferable since previous experience had limited effectiveness.
  - Geofabric / geotextile / mesh system – possible but durability considerations.

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Overburden Crest Regression – Solutions Progressed to Conceptual Level

- Do nothing / minor re-sloping (base case).
- Geofabric / geotextile / mesh system.
- Secant pile wall.

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Overburden Crest Regression – Do Nothing / Minor Re-sloping Option

- Pros:
  - Cost.
  - Estimated crest regression ~ 33 cm per year.

- Cons:
  - There is a risk of a larger loss of material than what has occurred in the last 10 years due to a substantially wetter year/s.

- Considerations:
  - It may be worthwhile to re-slope the overburden to angle of repose using crest-chaining method. Method involves large and heavy metals chains draped over crest and dragged by dozer to destabilize loose material along crest. Would reduce likelihood of slip failure due to continued erosion undermining this area.

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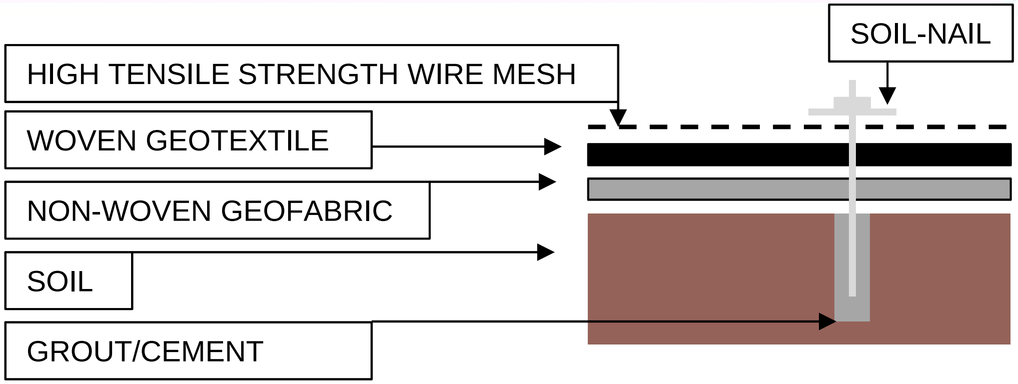
Overburden Crest Regression – Geofabric / Geotextile / Mesh System Option

- Concept:
  - Allow seepage to occur while retaining soil particles.
  - Layered system of:
    - Non-woven geofabric to allow seepage and retain soil particles.
    - Woven geotextile as UV protection for the geofabric.
    - High tensile strength wire mesh and soil-nails to hold the system in place.
  - Soil-nails:
    - Installed manually using hammer drills.
    - Are hollow and threaded. Grout/cement is injected into soil-nail which exits the drill bit and flows back along the nail to form an anchor.
  - Manual installation.



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Overburden Crest Regression – Geofabric / Geotextile / Mesh System Option

- Pros:
  - Cost.
- Cons:
  - Seepage will continue – may continue to erode rocks below.
  - Expansion/contraction (-40 °C to 20 °C) of geotextile material could lead to tears at anchor points.
  - Manually installed soil-nails maximum depth estimated to be 2-3 m.
  - Manually installed soil-nails within the seepage zone (which may be ~3 m in height and 8 m wide) may not extend past the active freeze-thaw zone (typically ~ 2 m) – this poses a risk of soil-nail pull out in this area.
  - UV degradation of geotextile over time - although some products can last > 50 years.
- Considerations:
  - Prior to installation, overburden re-sloped to angle of repose using crest-chaining method. Method involves large and heavy metals chains draped over crest and dragged by dozer to destabilize loose material along crest.
  - Health and safety risks associated with install but risks can be managed with experienced contractor. Similar systems installed for rock instability in highway/road construction.
  - Additional studies required to confirm the feasibility of this option are:
    - geotechnical investigation to determine the material properties of the overburden material.
    - feasibility level design, work methodology and cost estimate.

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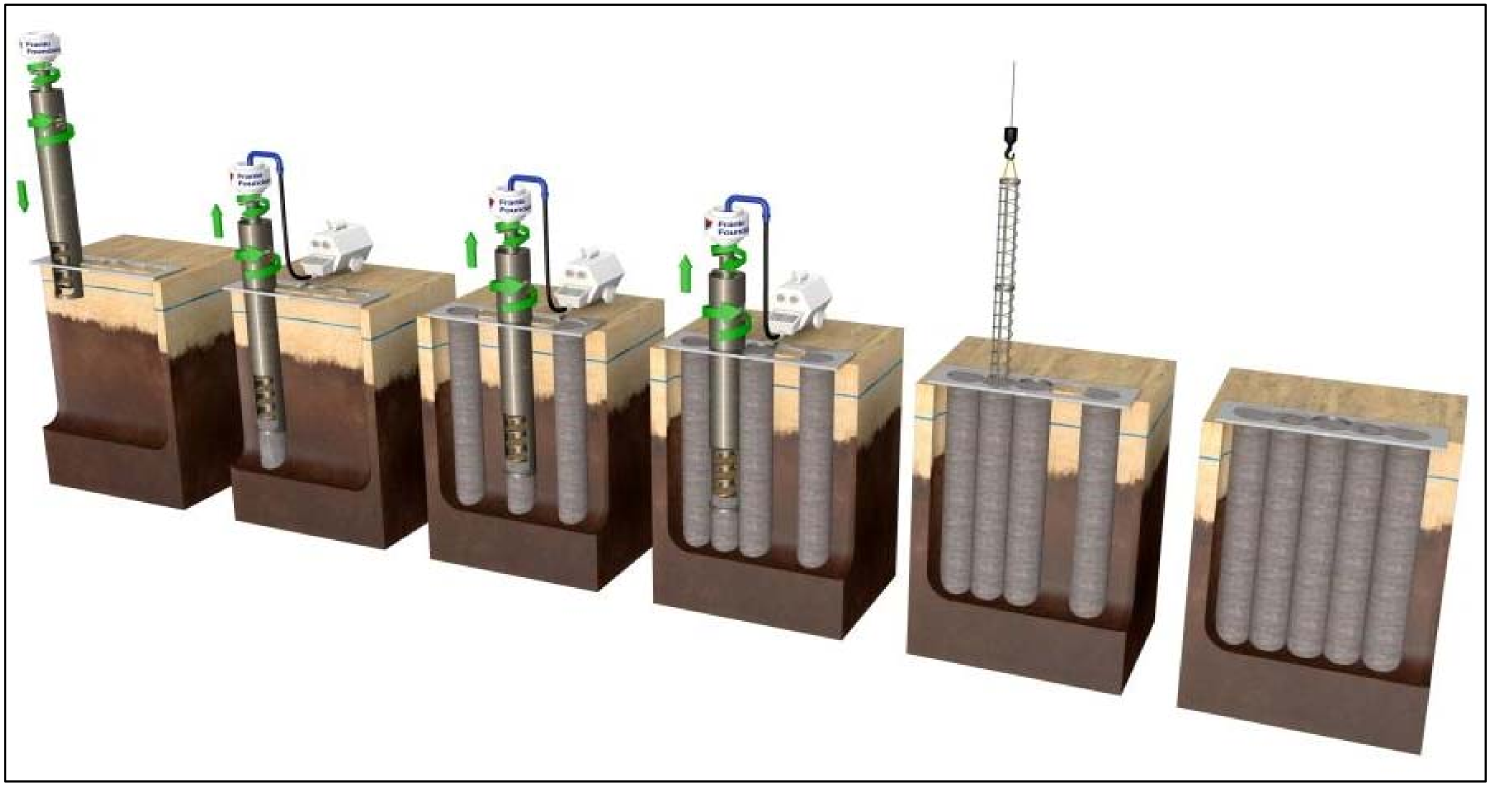
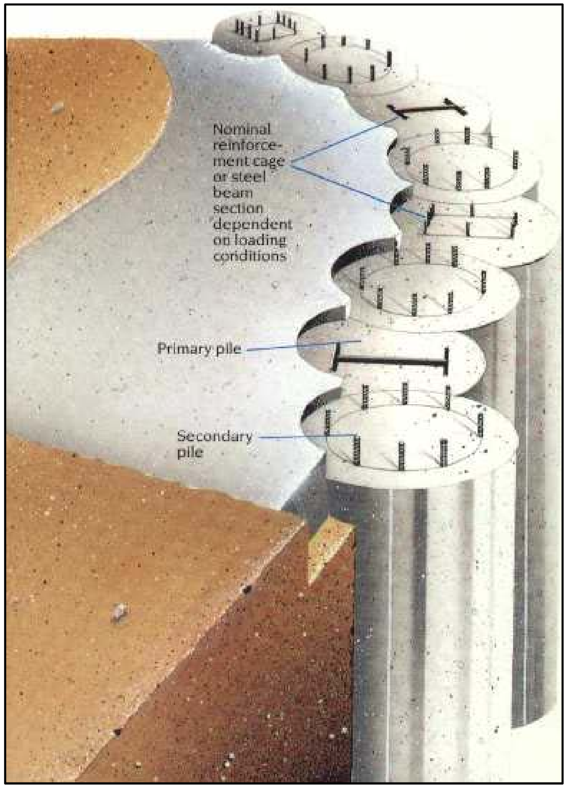
Overburden Crest Regression – Secant Pile Wall Option

- Intersecting concrete piles to create a continuous wall.
- Commonly used as cut-off wall to stop seepage and as a retaining wall.
- Explanatory video





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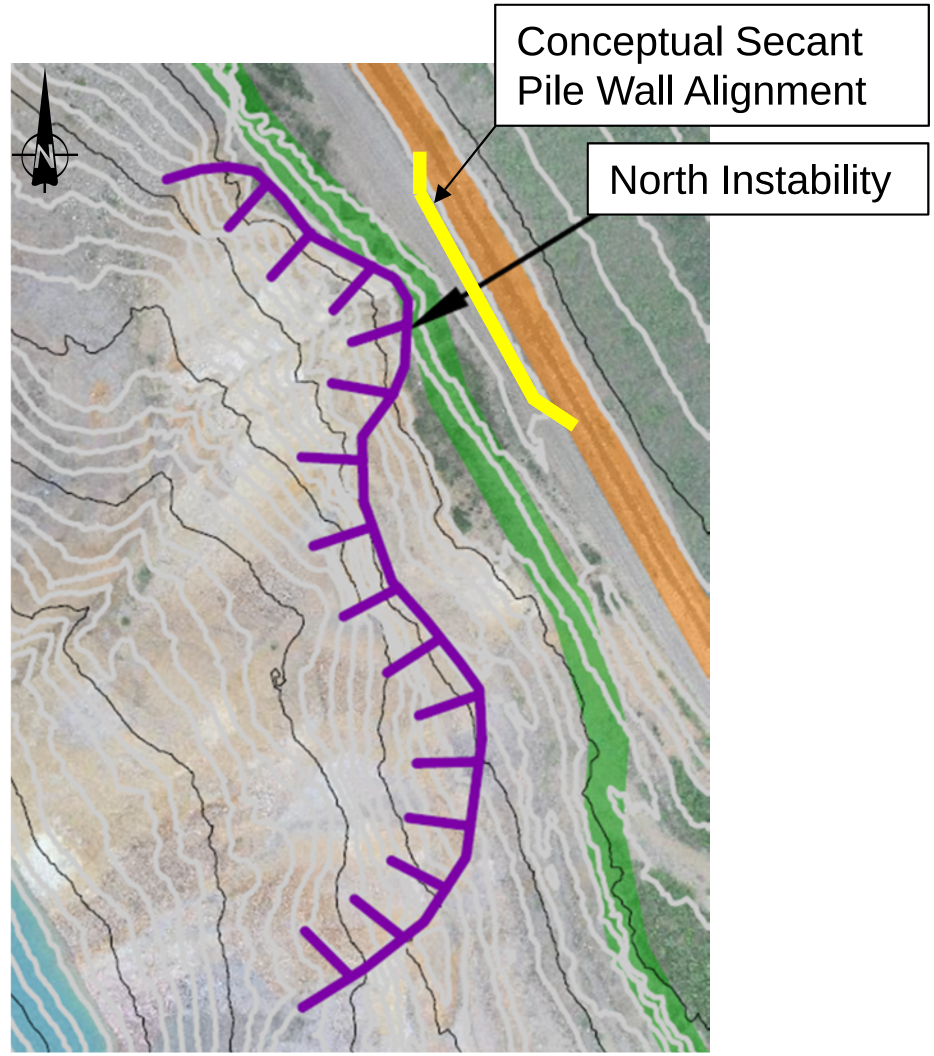
Overburden Crest Regression – Secant Pile Wall Option

- Concept:
  - Cut-off seepage and divert back into FCD channel.
  - No signs of seepage downstream of regression area - no reason to suspect diverting back into channel will result in seepage in overburden downstream.
- Pros:
  - Known technology.
  - Can install through boulders.
  - Can act as retaining wall if overburden in area continues to erode as long as rock in which it is founded is stable.
- Cons:
  - Specialized equipment.
  - Cost.



FOR DISCUSSION ONLY

Overburden Crest Regression – Secant Pile Wall Option

- Sufficient space:
  - During the screening assessment, a concern was raised as to whether there would be sufficient working space for a secant pile wall to be installed.
  - Golder discussed this with a secant pile specialist, and the specialist indicated that there would be sufficient space as long as:
    - the secant pile wall can be installed along the edge of the access road closest to the FCD channel; and
    - two-way traffic is not required in the area during construction.

- Effect of Additional Load on Slope Stability:
  - High level slope stability assessment. The results of the analysis indicate that:
    - the slope stability is sensitive to the machine load and the shear strength properties of the overburden.
    - the slope stability is not sensitive to the liquefaction of an isolated saturated zone (3.5 m above bedrock) beneath the machine load.
    - an acceptable Factor of Safety of 1.5 can be achieved if the overburden has an effective strength friction angle of 35° and a cohesion of at least 26 kPa.
    - Refer to technical memorandum for assumptions and result figures.

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Overburden Crest Regression – Secant Pile Wall Option

- Considerations:
  - May be suitable as a more permanent mitigation measure.
  - Additional studies required to confirm the feasibility of this option are:
    - geotechnical investigation to determine the material properties of the overburden material and depth to bedrock.
    - feasibility level design, work methodology and cost estimate.

Overburden Crest Regression Area – Comparison of Solution Options

Options	Longevity Estimate	Cost Estimate	Pros	Cons
Do nothing / Minor re-sloping [Base Case]	~ 10 years	CAD $ 45,000	• Cost – cheapest option	• There is a risk of a larger loss of material than what has occurred in the last 10 years possibility of wetter year/s.
Geofabric / geotextile / wire mesh system	~ 15 years (consists of ~ 5 year life of Geofabric / geotextile / mesh system and ~ 10 year of base case natural erosion)	CAD $ 770,000	• Cost – likely cheaper than channel realignment and secant pile wall.	• Continued seepage and erosion of rocks below. • Potential tearing at anchor points. • Anchors may not extend past the freeze-thaw zone in seepage area (which could be ~ 3 m high x 8 m wide).
Secant pile wall	> 30 years	CAD $ 3,405,000	• Known technology. • May also act as retaining wall if founded in stable bedrock.	• Specialized equipment. • Cost.
Channel realignment	> 30 years	Done by others (out of Golder scope).		

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Overburden Crest Regression – Conclusions

- The Do Nothing / Minor Re-sloping Option:
  - May be the most preferable interim mitigation measure if the existing rate of regression and risk of possible faster regression, due to a possible wetter year/s, is acceptable.
  - The majority of the cost for this option is associated with the cost of the chains. There may be a potential cost saving if suitable chains are available on site or can be sourced locally.
- The Geofabric / Geotextile / Mesh Option:
  - May be a suitable interim mitigation measure if a design life of approximately 15 years is required.
  - It is expected this mitigation measure will degrade over time due to seasonal changes in temperature (- 40 °C to 20 °C), the active freeze-thaw zone (which may loosen soil nails) and UV radiation exposure.
- The Secant Pile Wall Option:
  - May be suitable as a permanent mitigation measure if the bedrock on which it is founded is stable. Possible since BGC (2016) indicated that further regression of the North Instability Zone is likely limited by relatively fresh and massive quartz monzonite unit encountered behind the crest.
  - The majority of the cost is associated with the cost of the concrete and steel reinforcement. There may be a potential cost saving if these materials can be supplied or sourced locally.
- Additional studies:
  - Geotechnical investigations will be required for the geofabric / geotextile / mesh system and secant pile wall options to determine the material properties of the overburden. The secant pile wall option will also require the confirmation of bedrock depth along its alignment.

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Overburden Crest Regression – Recommendations

- The three conceptual mitigation options, described in this document, are compared to the proposed FCD channel realignment. If desired, Golder is available to provide a cost estimate for the FCD channel realignment, or assist with options comparison.

- Geotechnical investigations are carried out prior to the feasibility design of either the geofabric / geotextile / mesh system or secant pile wall option.

- Feasibility level and detailed designs are carried out prior to the implementation of either the geofabric / geotextile / mesh system or secant pile wall option.

FOR DISCUSSION ONLY

Overburden Crest Regression – References

- BGC Engineering Inc. 1993. *Faro Mine Complex Faro Open Pit Stability Assessment*. Prepared for CH2M Hill Canada Ltd. Project No. 1085007. Submitted March 2016.

- Golder Associates Ltd. 2016. *Faro Mine Complex 2015 Pit Slope Stability Review*. Project No. 1410944-2015. Submitted February 2016.

- Klohn Crippen Berger. 2016. *Faro Mine Complex 2015 Annual Geotechnical Review*. Prepared for Yukon Government. Document reference: M09770A05.730. Submitted March 2016.

FOR DISCUSSION ONLY

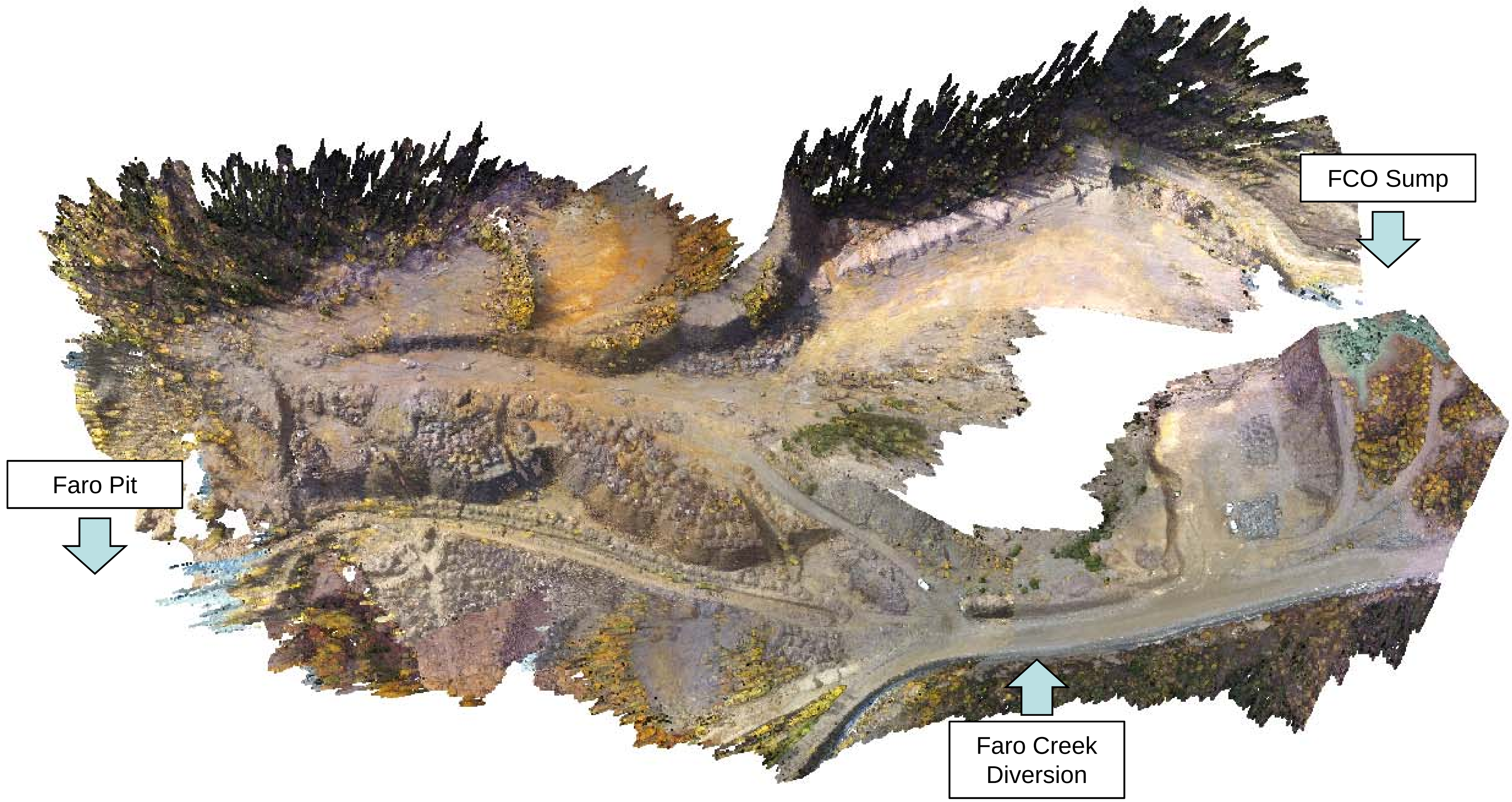
ATTACHMENT 3
FCO Sump Flow Path Assessment Site Visit Pictures

Faro Mine Remediation Project

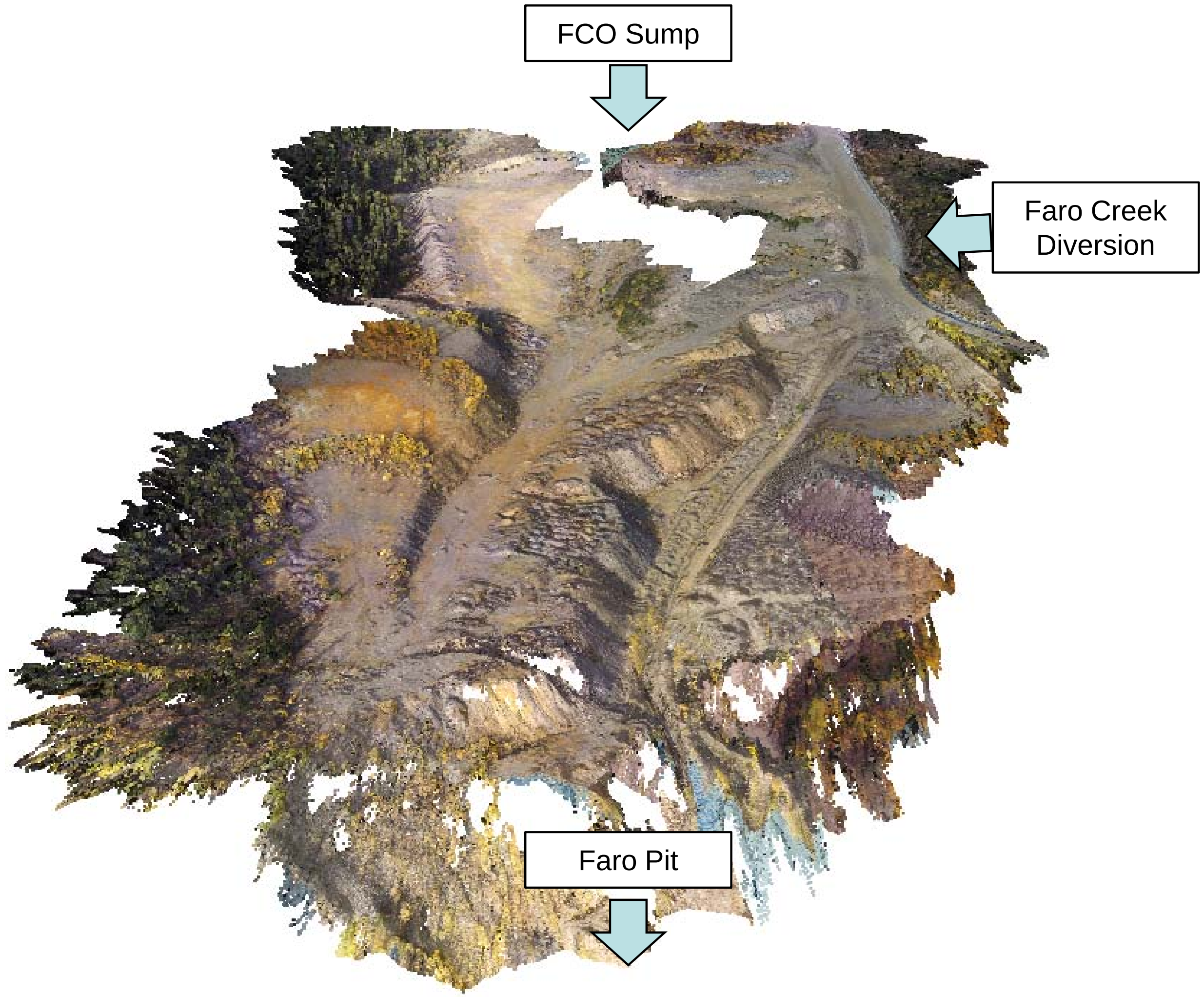
FCO Sump Flow Path Assessment Site Visit Pictures

Golder Associates

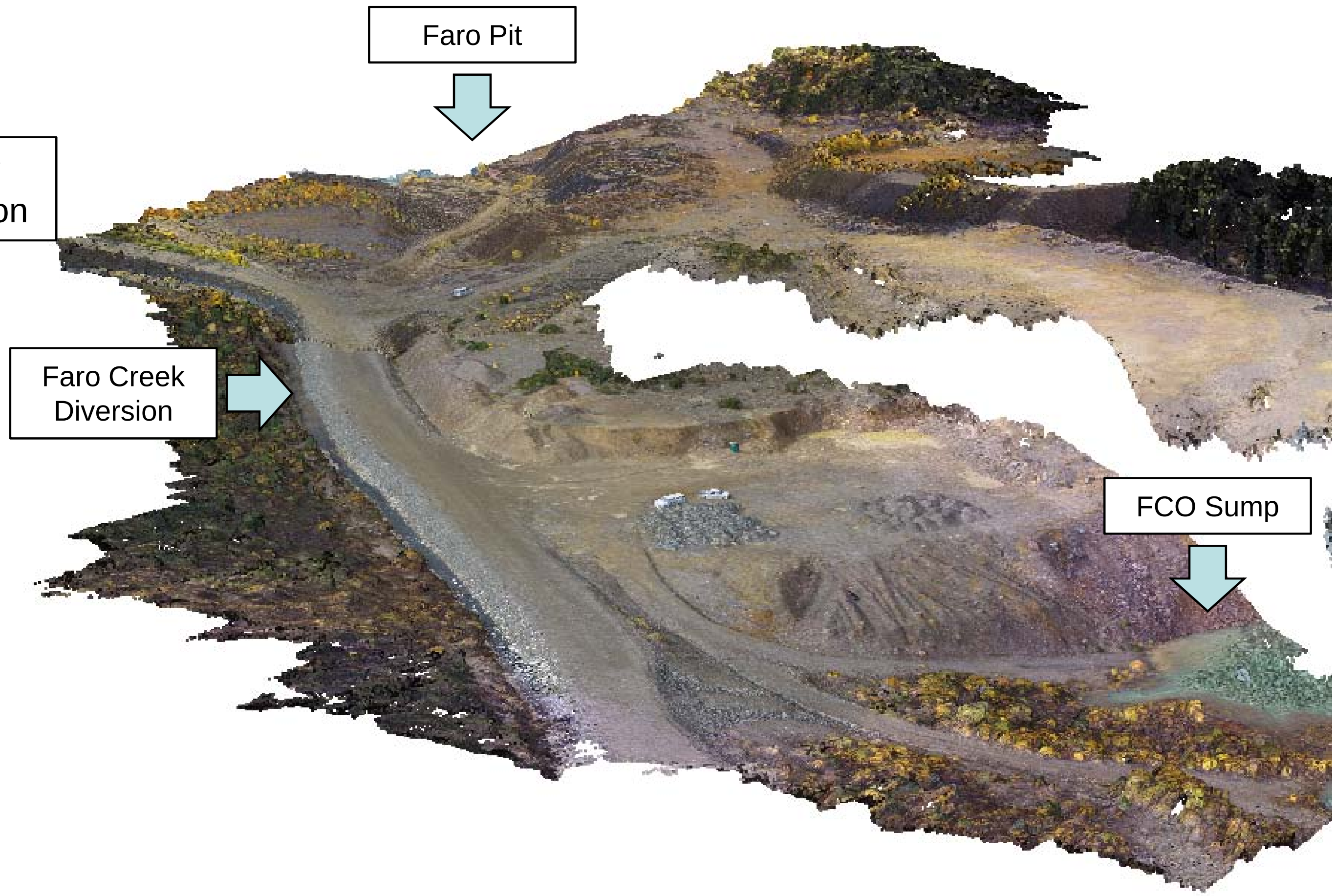
FCO Sump Erosion Flow Path – Plan View



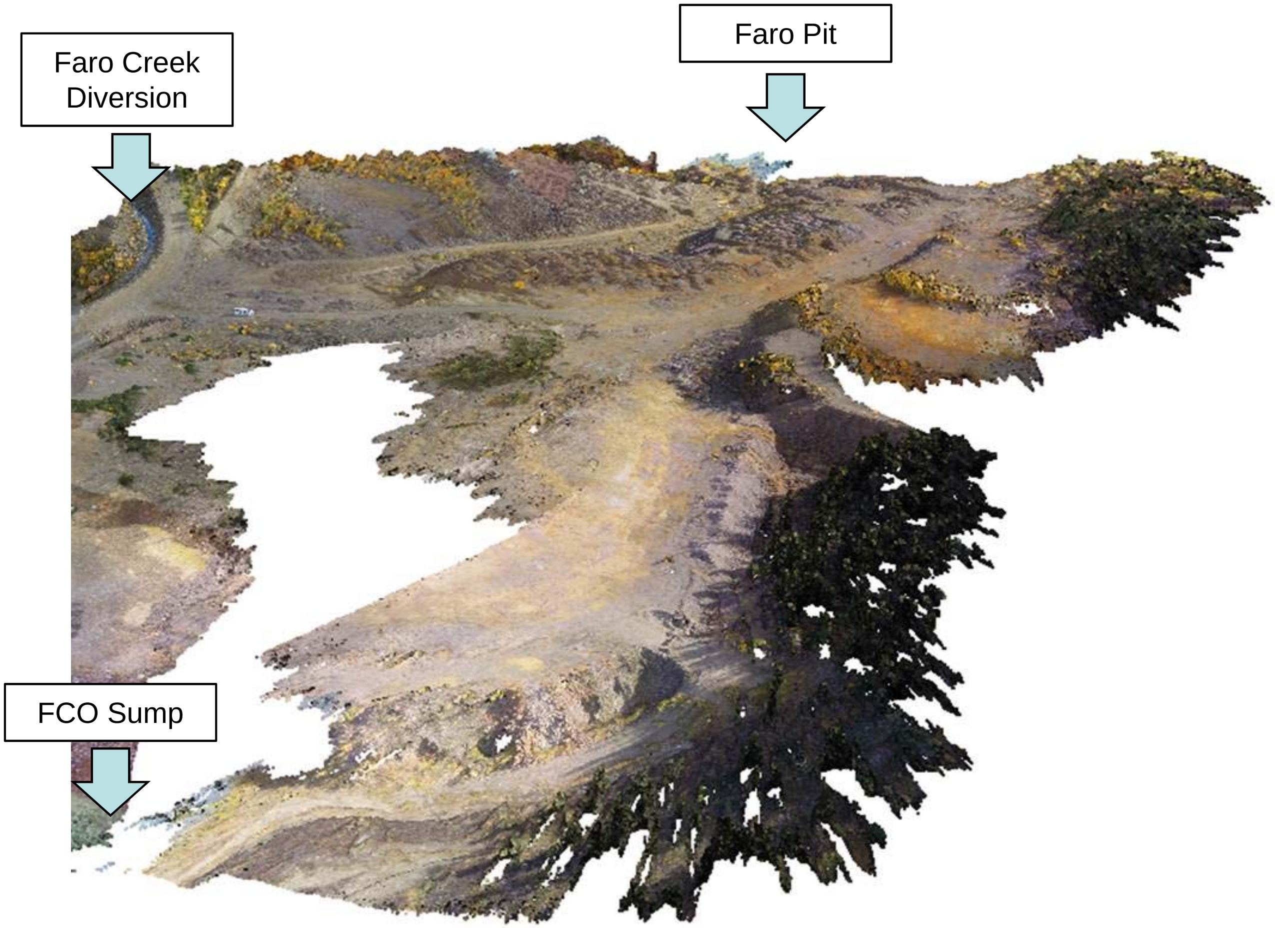
FCO Sump Erosion Flow Path – View from Faro Pit



FCO Sump Erosion Flow Path – View of FCO Sump Eastern Flow Path



FCO Sump Erosion Flow Path – View of FCO Sump Western Flow Path



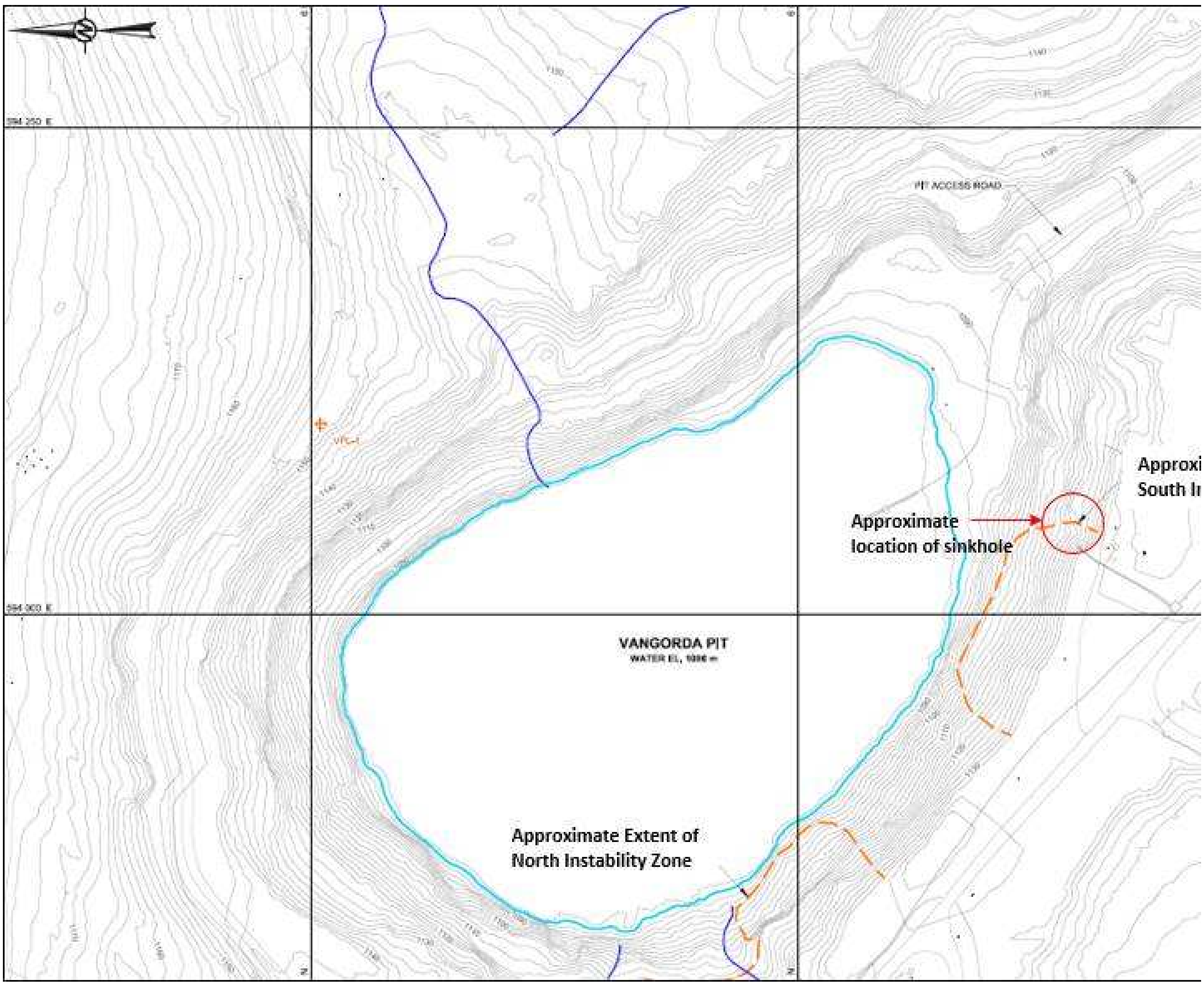
ATTACHMENT 4
Faro Mine Vangorda Sinkhole

Shang, Malcolm

From: Shang, Malcolm
Sent: Wednesday, September 21, 2016 9:19 AM
To: 'Carrie.Gillis@gov.yk.ca'
Cc: Carter, Hugh; Chance, Al; Preston, Ryan
Subject: Faro Mine: Vangorda sinkhole

Hi Carrie,

We've discussed the sinkhole that has formed in the overburden on the southern crest of the Vangorda pit (see images below).



It is our understanding that the sinkhole was first seen a week before the 2015 Golder site visit, and that it was recommended, as part of the 2015 site inspection report, that the crest be sloped back in this area. Subsequently the area was sloped back in 2016 by the site staff, however, the sinkhole reappeared on the 7/8 September 2016.

Based on the information available, it appears that water may be seeping and running off from the ditch (in which the pipeline sits) upstream of the sinkhole area. Seepage from this area may be causing the sinkhole, and runoff from this area is likely causing the erosion gully adjacent to the sinkhole. The water may be coming from rainfall or breaks in the pipeline - either by accident or maintenance.

It is suggested that:

- the sources of ponded water upstream of the sinkhole area are identified and diverted away from this area to prevent ponding - which may be the source of the seepage seen.
- the pipeline is inspected for leaks/breaks and these be repaired.
- the drainage in the area and ditched is remediated such that the surface run-off is diverted away from the pit crest and not channeled into the erosion gully adjacent to the sinkhole.

In the interim, it is suggested that:

- this area be inspected visually before entering the pit.
- the site staff work in pairs - with one person as a spotter.

If you have any questions please feel free to contact us.

Kind regards,

Malcolm Shang (BSc Eng (Civil/Environmental) GDE (Mining)) | Geotechnical Specialist | **Golder Associates Ltd.**
Suite 200 - 2920 Virtual Way, Vancouver, BC, V5M 0C4 ◄ We Have Moved!
T: +1 (604) 296 4200 | **D:** +1 (604) 296 4324 | **F:** +1 (604) 298 5253 | **E:** Malcolm_Shang@golder.com | **www.golder.com**

Work Safe, Home Safe