2008 Reconnaissance-level landform grading field investigation at the Faro Minesite

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EXECUTIVE SUMMARY

A reconnaissance level field investigation and aerial photo gully mapping program was undertaken in September 2008 to provide additional data and observations to guide environmental-assessment level landform design for the Faro Minesite. These findings will be used by the planning and design team in conjunction with similar reports by the vegetation and cover teams.

A gully map was prepared using aerial photo interpretation of stereopairs. Armed with the map, Gord McKenna, and Matthias Jacob (both of BGC) and Maritz Rykaart (of SRK) visited the site on September 9 to 11, 2008 to make observations and measurements regarding the geotechnical and erosional stability of the various dump plateaus, dump slopes, and other slopes in the mine area. Additional, several natural sites around the Faro townsite and on the highway from Whitehorse were made. Findings are captured in a series of summary tables and photographs in this report.

Here are the major findings and the implications for landform design at the Faro Minesite:

- A review of the weather data since 1978 for the Faro Airport suggests that the region has experienced five storms since 1991 that dropped 22 to 44mm of rain (the values at the mine site 15km away and 500m higher are likely larger). These storms likely ranged from 1 in 10 to 1 in 100 year return period events, indicating that the present sites have seen some significant rainfall-runoff events, and that the dump gullying seen presently is not unexpected.

- Existing bare fine-grained slopes at the mine sites are rapidly eroding through rill and gully erosion. The short growing season, and the erodability of bare slopes in the region means that special attention is needed in regrading and revegetating the dump slopes to minimize gully erosion of the cover soils. There is little natural invasion, and the plants are presently doing little to reduce erosion of mine and dump slopes. Dumps will need to be resloped to have intermediate slopes of 3H:1V or flatter, with cross-slope berms to limit flow path lengths, and revegetated with aggressive agronomic grasses and legumes to control erosion. One to two metre high watershed berms are required at the crest of all slopes to minimize erosion due to water exiting benches, plateaus, ramps, and roads.

- A multidisciplinary team should map the various terrain units at the site and determine the regrading / revegetation planning basis for each unit for each area of the mine.

- There is some slumping of 2H:1V and steeper slopes. Final grades shall be designed to be geotechnically stable.

- Coarse grained angle of repose slopes are performing well, and a case to leave these slopes at their angle of repose can likely be made. Vegetation performance of these slopes will be minimal, probably even in the long term.

- Fine grained angle of repose dump slopes are subject to slip-off failures and surface water erosion and require mitigation.

- Slope erosion can be reduced by minimizing the number of rills that coalesce into gullies. At other mines, this has been achieved through corrugation of slopes with dozers during regrading – creating a series of very shallow parallel protorills in a downslope direction.

- Larger scale corrugated slopes are seen in the region (and documented in this report) and may provide an analogue for enhancing relief and diversity of some dump slopes.

- Some slopes have a boulder talus draping the base that captures eroded sediments efficiently to the degree that allows some natural revegetation. It is proposed to include these aprons or boulder checkdams at the base of some slopes. Other toes should be offset from creeks and infrastructure to reduce the impact of sediment deposition.

- Bench and plateau performance is generally good and offer areas to use native vegetation to meet more land use objectives. Use of microtopography on berms and plateaus (as well as slopes) is strongly discouraged as it promotes ponding water and percolation. Instead mesotopographic mounds (in the 10 to 20m wide range) are suggested as a method to enhance positive drainage from all flat areas of the dumps towards lined engineered watercourses.

- Vegetation growth may be too slow to rely upon from vegetated waterways. Rock armoured swales using traditional engineering design methods are recommended.

- Long-term monitoring and maintenance will be an integral component of the design, both for water management at the site, as well as for maintaining good performance of covers and slopes. The site should be designed to facilitate the needed infrastructure and access.

Next steps include an interdisciplinary approach to setting design criteria that align with the closure goals and stakeholder expectations. Zoning the site as suggested in the report will provide a good basis upon which to start the site wide landform designs. Further investigation and especially an empirical, large-scale resloping/ reclamation trial will be required as part of the ongoing design process.

This report provides enough information to create an EA level design (at least from a landform design basis), when combined with the results of the cover report and revegetation report. An initial design for the site and large scale trials are recommended.

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LIMITATIONS OF REPORT

This report was prepared by BGC and SRK for the Faro Mine Closure Office. The material in it reflects the judgment of the authors in light of the information available at the time of report preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be based on it are the responsibility of such Third Parties. BGC and SRK accept no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

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1.0 INTRODUCTION AND BACKGROUND

Landform grading of the Faro and Vangorda/Grum Mine waste dumps is planned as part of closure activities. Following up on a previous recommendation[1], a joint SRK-BGC reconnaissance level investigation was carried out in to provide more definitive design data with regard to the final design of slopes and drainage from the waste dumps, i.e. drainage path lengths, slope angles, catchment areas, etc, and provide a geomorphic basis for landform grading design for the Faro waste rock dumps.

The program involved mapping of gullies on the mine site and nearby areas from aerial photographs, a field visit to the mine site by Gord McKenna, Maritz Rykaart, and Matthias Jakob from September 9 to 11, 2008, analysis of the data, and preparation of this report.

This report provides recommended design parameters for closure planning and conceptual landform design, and a recommendation for a path for continuous improvement of these design parameters.

There are three situations covered by this report:

- Waste rock dump slopes at angle of repose
- Landform graded waste rock dump slopes with till covers
- Landform graded plateaus and terraces

All of the closure options for the Faro and Vangorda/Grum Mine areas include the re-sloping of the waste dumps. In June 2008, SRK issued a draft report presenting a number of example engineered landforms for the waste dumps within the Faro Mine Complex (SRK Report "Faro Mine Complex Mine Area Cover Optimization and Landform Engineering, 2007/08 Task 26 – draft, June 2008). This report presented a number of re-grading options for select zones within the waste dumps and assessed hydrology with a view to producing guidelines for new landform watersheds and slope face configurations. The hydrological tools developed in SRK's report were based on desktop studies and did not involve fieldwork. Field verification of data was recommended in the report.

[1] SRK Report "Faro Mine Complex Mine Area Cover Optimization and Landform Engineering, 2007/08 Task 26 – draft, June 2008

The lead authors of the report are Gord McKenna and Maritz Rykaart. They were joined by Matthias Jakob for the field work and in formulating the conclusions of the report. Courtney Jermyn provided the aerial photo analysis and Ken Sam did the mapping. Climate analysis was done by Jordana Fair and Ashley Perkins. Cam Scott provided project oversight.

1.1 Closure goals

From the Faro website (November 2008), Closure Objectives for the Faro Mine Complex are:

- Protect human health and safety.
- Protect and, to the extent practicable, restore the environment including land, air, water, fish and wildlife.
- Return the mine site to an acceptable state of use that reflects pre-mining land use where practicable.
- Maximize local and Yukon socio-economic benefits.
- Manage long-term site risk in a cost-effective manner

The design strategies in this report are in general agreement with these closure goals.

1.2 Climate

Appendix A contains climate data related to the Faro Airport (15km south of the mine) and the Faro Mine site.

The Yukon has a sub-arctic continental climate with long cold winters and short warm summers. Frost free days range from 21 to 93 days, varying substantially from year to year. There are long hours of sunshine in the summer (the land of the midnight sun) which promote vegetation growth that partially compensate for the cool summer temperatures. Low rainfall in most areas means the Yukon is semi-arid.

According to the 1971-2000 Canadian Climate Norms for the Faro townsite:

- Temperature
    - o Average annual temperature is -2.2°C (average daily temperature is below zero October through March)
    - o Daily average temperature January -21.5°C
    - o Daily average temperature July +15°C
    - o Maximum recorded temperature 33.9°C (Aug 4, 1994)
    - o Minimum recorded temperature -51°C (Jan 12, 1980)
    - o Frost is common in all months, but only June, July, and August typically have one day or less of frost.
- Precipitation
    - o Annual rainfall 214mm. Average annual snowfall 112mm. Average annual precipitation 316mm.
    - o From May to September, 10 to 15 days per month with measurable precipitation is common.
    - o Extreme daily rainfall 29.4mm (May 28, 1993)
    - o Extreme snow depth 64cm (March 27m 1983)
    - o Typical winter snow depth 10 to 30cm
- Wind
    - o Maximum hourly wind speed 50km/h (May 4 1988)

A five-year composite record (1994 to 2000) of hourly meteorological data was prepared for the development of the preliminary Anvil Range Mining Complex waste rock dumps water balance. Annual precipitation values ranged from 171mm in 1997/98 to 345mm in 1994/95. Using regional trends, monthly and annual precipitation data were adjusted for elevation, yielding an annual value of 442mm.

Significantly differing cumulative amounts of evapo-transpiration are simulated for the six hydrologic response units define at Faro with 70mm from the north facing slope, which has the least available energy for the process, to 190mm from the bubble dumps which has both significant amounts of energy and available soil moisture[2].

The maximum 24-hour probable maximum precipitation (PMP) event for a single grid cell (about 4 sq. km) in the Faro Mine vicinity was calculated to be 165mm[3]

A review of the weather data since 1978 for the Faro Airport suggests that the region has experienced five significant storms since 1991 that dropped 22 to 44mm of rain (the values at the mine site 15km away and 500m higher are likely larger). These storms likely ranged from 1 in 10 to 1 in 100 year return period 24 hour events, indicating that the present sites have seen some significant precipitation events, and that the gullying seen presently on unreclaimed dumps is not unexpected. Details are presented in Appendix A.

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[2] 2004, JR Janowicz, NR Hedstrom, RJ Granger, INVESTIGATION OF ANVIL RANGE MINING CORPORATION (FARO) WASTE DUMP WATER BALANCES Preliminary Water Balance, Report prepared for SRK Consulting Inc. on behalf of Deloitte & Touche Inc. Interim Receiver of Anvil Range Mining Corporation, June 2004

[3] 2005, George H. Taylor and Cadee Hale, An Analysis of Probable Maximum Precipitation for the Faro Mine Site, Yukon Territory, Report prepared for Faro Mine Closure Planning Office Whitehorse, Yukon Territory, October 2005

2.0 SCOPE / METHODS

Office work prior to the field visit included examination of black and white stereo aerial photographs (1:10,000 scale) of the mine site and adjacent areas to locate and classify gully features and map several small natural watersheds. This mapping information was transferred from the aerial photos to a GIS database and maps using orthophotos with topographic contours were created. A table of gully parameters was created.

During the field visit, numerous sites on each of the waste dumps were visited, observations made and photographs taken. Measurements of gully parameters, and other erosion observations were made. Additionally, visits to several natural areas (notably near Faro townsite and Carmacks) were also made during transit. The weather during the trip was generally cool and cloudy with some light rain, but did not hamper access or field work.

Back in the office, the data gathered from the field visit were collated and analyzed. Observations have been supplemented with those made by McKenna in 2007 (see BGC, 2007) and those of SRK. A literature review of critical slope lengths for gullying was performed.

An initial draft report was presented at a Faro interdisciplinary working meeting on November 21, 2008.

3.0 RESULTS

This section provides the results of the aerial photo analysis, the observations at the mine sites and of natural slopes in the region, and results of a literature review on critical overland flow path lengths. The tables in this report provide a summary of the information learned.

3.1 Aerial photo analysis

The aerial photograph analysis of gullies and rill fields is presented in Drawings 1 through 4 and in Appendix B. A total of 511 gullies were mapped, 371 (73%) of which were caused by flow from flat areas (plateaus, benches, ramps, and roads) over unvegetated slopes.

It was initially hoped that this exercise would provide a graphical basis for determination of the maximum overland flow path distance before gully initiation on slopes of various steepness. Examination of natural areas provided little insight as these areas are densely vegetated (in ways that will likely take the Faro minesite many centuries to mimic), and gully initiation is not always apparent on the aerial photos.

It was also hoped that the analysis would shed insight into vegetated versus rock armour of natural streams relative to watershed side and slope gradient. It was found that almost all of the streams are either set in bedrock or are heavily armoured with large boulders, and further, vegetation growth (and soil development) is too slow in the region to rely upon for erosion protection in engineered watercourses.

The analysis, however, provided a basis upon which to focus field activities and to document the present erosional performance of the minesite.

Figure 3-1 presents a graph of the results of the analysis that shows the relationship between critical overland flow distance for gully initiation versus slope angle for bare slopes at Faro.

3.2 Observations at the minesite

Table 3-1 provides a summary of the observations made at the minesite during the field visit and the implications for landform design. Select photos from the trip, referenced in the table, are presented in the Photojournal (Appendix C).

A list of slope angle equivalents in presented in Table 3-2 (for reference). Table 3-3 presents a list of material parameters for mine dump materials.

3.3 Observations of natural slopes

Several sites between Whitehorse and the minesite were visited and observations recorded. These include natural analogue slopes near Carmacks and Twin Lakes as well as sites near the Faro Townsite and natural areas around the mine. Observations are presented in Table 3-4.

The implications of these results are summarized in Section 4 below.

3.4 Guidance from the literature

Several experimental studies have been conducted around the world to better understand geomorphic thresholds on gully development by overland flow. Some studies look at the characteristics of contributing catchment areas and others focus on predicting the location of gully initiation. Previous studies have examined the relationship between critical slope and length (Govers, 1991; Savat and de Ploey, 1982; Rauws, 1989) or more commonly between critical slope and area (Desmet et al, 1999; Cheng et al, 2006; Moody and Kinner, 2005; Vandaele et al. 1996; Vandekerckhove et al, 1998; McKenna, 2002) to develop their models.

Concurring conclusions found that gully initiation is complex. Vegetation, morphology, material, geographic location, landuse and climate were found to be important factors that influence gully initiation. Work conducted by Vandaele et al (1996) was of significant interest as they compared results conducted around the world to see how gully initiation differs.

Finding supportive literature to help us better understand and support the Faro study was difficult. There is a lack of information available on gully initiations using slope gradient/critical length relationships and located in comparable environments as Faro. (Much of the mine reclamation literature is focussed on the Revised Universal Soil Loss Equation, which is not applicable to gully erosion (McKenna, 2002). To supplement the Faro study we used data obtained from Vandaele et al. (1996) study and their assumption that drainage area increases linearly with distance from the divide (critical length). Therefore the critical length can be substituted for drainage area (Vandaele et al 1996).

By using the equation:

$$S_{cr}=aA^{-b}$$

where S_{cr} is the critical slope, *a* and *b* are empirical coefficients, and A is the upslope drainage area (ha), and assuming the rill or gully drainage width is 3 or 30m (typical widths of catchment areas for gully fields), we were able to determine the critical lengths of all studies included in Vandaele et al. (1996). This metastudy focuses on the trigger point for gully initiation, looking for universal relationships between catchment area (or the surrogate: slope length) and slope gradient (or slope angle). While the study mainly focuses on managed lands (mostly agricultural, some forestry lands), and for largely unvegetated slopes, it provides an opportunity to compare the unvegetated slopes at the Faro Mine Complex.

The critical lengths from the Faro aerial photo analysis (see Appendix B and Maps 1 through 4) were plotted with the Vandaele data in Figure 3-1. A variety of lowerbound lines could be fit to the Faro data (following the procedures of Vandaele); given an apparent universality of the b parameter (which corresponds to the slope of the line), the waste rock data was fit with a b=0.4 line, as was the glacial till cover data.

While the results in Figure 3-1 are not that compelling, the following observations can be draw:

- Measured critical flow lengths at the Faro site are typically between 10 to 100m for all slopes.
- The critical flow length (planview distance to gully initiation) is highly variable for the Faro Mine Complex dumps, and there is only a modest negative correlation between critical length and slope angle.
- The erodability of the waste rock and the glacial till cover is similar, but the method of analysis indicates a substantially longer critical slope length for the till versus the waste rock for the same slope angle. This result may be due to the scatter in the data.
- The bare waste rock slopes (and those covered with glacial till cover) are less erodible than most of the bare soils in the Vandaele metastudy, but similar to several of these datasets if extrapolated they are for steeper slopes.

The Faro dump slopes need to be protected with a good vegetated cover to create conditions where the critical flow lengths are in a practical range for reclamation. (An alternative is to riprap armour the slopes (as was done for uranium mine tailings dumps on the Colorado Plateau in the 1970s) but this approach would meet few of the goals for the Faro Mine Complex and is not recommended.)

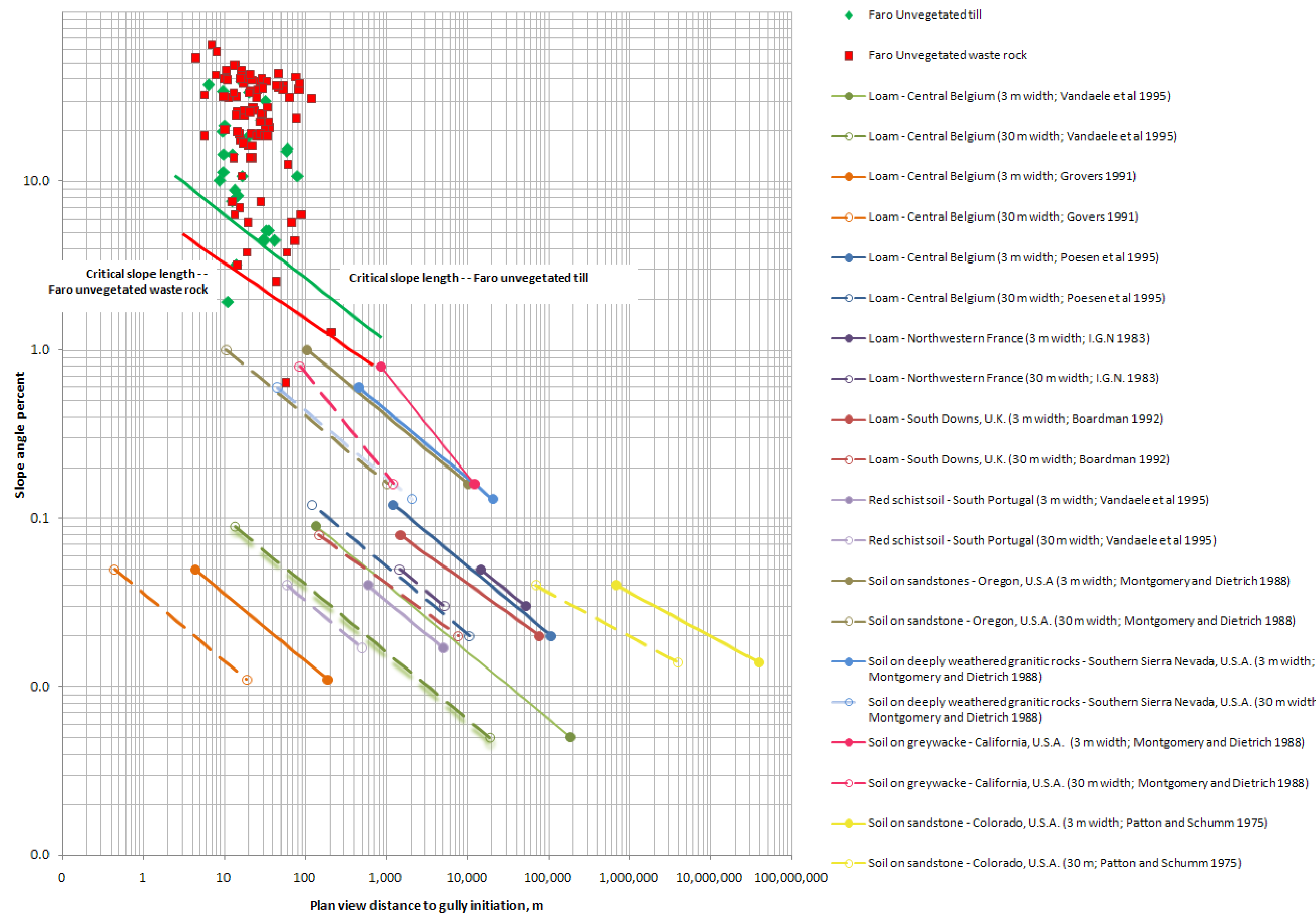

Figure 3-1 Critical slope lengths (modified from Vandaele et al. 1996)

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Table 3-1 Field observations and implications

Slope	Observation	Discussion	Landform design implication
General observations	In almost all cases for waste rock dump slopes and plateaus, **vegetation is sparse** and dominated by willows and mosses. The vegetation is generally not contributing to slope erosion protection, with the exception of a very few areas with grasses. Surprisingly, existing vegetation does not seem to prefer gullies over ridges.	At most mine sites, one would expect greater ingress of vegetation over the past 10 to 20 years. The near lack of ingress in most areas is indicative of the fact that the waste rock makes a poor growth media for most species, the tills (both in the Overburden Dump) and used as cover material is difficult for plants to start to grow, the climate is harsh and there is a slow rate of vegetation growth in this high latitude, high elevation mine site.	Cannot rely on natural invasion for erosion control of bare ground in human timeframes (20 to 50 years). Achieving good ground cover with starter vegetation species is crucial. Reslope angles should be chosen to minimize runoff erosion while initial vegetation takes root (see below).
	Finer grained slopes generally support more vegetation than coarser grained slopes	As would be expected.	Coarse grained slope unlikely to support dense vegetation due to lack of moisture / nutrients (unless capped).
	F**iner grained waste rock slopes show more erosion** than coarser grained slopes	Due to a combination that the coarser-grained slopes have nearly 100% deep percolation (hence little to no runoff), plus the coarser grains are less erodible than the fine grained material.	All other things equal, unvegetated finer grained slopes will erode more than coarser grained slopes. Placement of finer grained tills on slopes as covers will increase runoff.
	Erosion is noted where there is overland flow from plateaus or benches above slopes **"overtopping"**. 371 of the 511 (73%) gullies mapped in the aerial photo analysis were caused by flows from flat areas going over the crests of slopes.	Due to water concentrating on plateaus and running off. Common at most mine sites, but especially prevalent at Faro.	Need to construct watershed berms immediately adjacent to breaks in slopes in all cases, including top plateaus, benches, roads, and ramps.
	Vegetation performance on areas that have been cleared / disturbed is generally much better than waste rock dump slopes or covered waste rock dump slopes. Perhaps this relates to organics in the undisturbed areas.	Worthwhile to compare soils and vegetation performance on these cleared areas to that over the resloped till slopes.	Vegetation is very slow to establish on the waste rock dumps.
	There are small **erosion deposition fans** at the toes of slopes.	Deposition is the second half of the erosion equation. Most of the sediments are being deposited right at the toes of the slopes, as would be expected. Some of the fine grained sediment is being carried further onto plateaus and roads.	Need to allow for some maintenance and allow for accumulation of fans at toes in slopes. Consider having coarse berms at toe to catch erosional debris. Perhaps even some catch berms. Avoid placing critical infrastructures (pipelines, roads, creeks) within this zone – allow an offset.
	Coarse waste rock toe berms (most of which have formed due to segregation of waste rock during dumping from height) have a large capacity to capture eroding sediments.	Rock slopes more than 10 to 15m high tend to show segregation – the finer materials remain at the head of the slope, the angular boulders collect at the toe of the slope, providing some buttressing, but also providing large voids. Finer grained erosional material tends to run into and over these rock talus aprons, limiting transport, and creating conditions that may be conducive to vegetation growth.	Repose slopes will not self armour. Coarse waste rock aprons at toes of slopes may be useful for catching sediment. These have formed naturally by segregation of waste rock. There is an opportunity to create similar aprons or berms offset from the toes of slopes to perform the same function.
	The Faro Creek Rockdrain performance continues to be good. Allows passage of water from Faro Creek beneath the main haul road.	Transmits and attenuates flow, but a barrier to fish movement.	Look for opportunities to use similar structures elsewhere on site.

Slope	Observation	Discussion	Landform design implication
Waste rock, coarse grained, angle of repose slopes	**These coarse grained angle of repose slopes are generally geotechnically stable,** with little to no erosion due to overland flow. There is no evidence of slip off failures in these decade old slopes that are at their angle of repose of 35 to 36 degrees.	Coarse angle of repose slopes generally are permeable enough to accept most precipitation without runoff, and the coarse grained materials are not prone to erosion under previous rainstorms. Most of the coarse grained rock appears to be durable, but a study of the durability would be required to confirm field observations. Regrading of some angle-of-repose slopes would cause additional damage to surrounding natural areas. As discussed below, finer grained slopes are showing some slipoff failures.	Angle of repose slopes may be candidates to be left at repose in some areas, subject to study of long-term stability, the impact of high infiltration rates on chemical loading, and on end land use objectives.
	There is **some erosion** of these slopes where uncontrolled water is allowed to go over the crest		Use of watershed berms is required.
	There is **some (albeit typically very limited) vegetation** on some slopes		Where there are pockets of fine-grained material, natural invasion over time will provide minor vegetation to these slopes.
	There is **no evidence of slip-off style failures** on these slopes . Angle of repose 35 to 36 degrees. No evidence of slip off in coarse areas	Slip off failures occur on finer slopes at repose	
	Boulder roll out from steep slopes (especially angle of repose slopes) presents a quantifiable risk to land users and especially maintenance personnel. Boulders do not tend to remain on steep slopes – they cannot be relied upon to armour repose slopes	Should map the distribution of boulders, and identify hazard zones (restricted access).	If not already, the staff should be alerted to the risks posed by boulder rollout, especially with respect to locating equipment and parking trucks. Consideration for controlling access during rainy weather and spring melt may be useful. The roads down into the mine pits are particularly susceptible. There may be some minor land use impact, especially regarding permanent structures (including mine pumphouses, substations, water treatment facilities, etc.) at the toes of angle of repose slopes. Procedures in OM&S manual about reading instruments and parking on roads.
Waste rock, fine grained, angle of repose slopes	There is **greater vegetation cover** on finer grained angle of repose slopes than coarse grained ones, but is still sparse.	While there may be more moisture holding capacity, these slopes tend to have very little vegetation.	One might attempt to speed revegetation of these slopes through seeding or planting, but it may not provide much effect.
	Some surface water erosion on these slopes.	Some gullying in finer grained areas.	See notes above relative to toe catch berms.
	Boulder roll out from steep slopes (especially angle of repose slopes) presents a quantifiable risk to land users and especially maintenance personnel. Boulders do not tend to remain on steep slopes – they cannot be relied upon to armour repose slopes	See notes above	See notes above
	Several of these slopes are **showing slipoff failures**, up to several metres thick parallel to the slope angle.	These are likely due to saturation of the upper slopes during snowmelts or heavy rains. These slipoff landslides pose considerable risks to people working at the base of slopes, especially if the slipoff materials become mobile. The instability of these slopes may be due to weathering of particular rock types within the waste rock.	These slopes should be identified and targeted for resloping or buttressing. It a few instances, it may be desirable to simply control access to the base of the slopes during periods of snowmelt or heavy rains.
	Regrading may benefit from **alternatives to pushing down slopes**	Alternatives include flattening the slope by unloading the head of the slope and/or placement of wrap-around toe berms (or even leaving the slope at repose)	Need to evaluate every slope individually.

Slope	Observation	Discussion	Landform design implication
Waste rock dump plateaus and benches	**Dump plateaus are generally performing well geotechnically** with little obvious differential settlement / subsidence, little to no erosion, but most sites have little natural invasion of vegetation.	These areas will be more physically stable than the slopes and thus provide good areas to achieve some of the land use and closure objectives such as the use of native species and greater reliance of natural succession (consideration of the cover performance not withstanding).	Target dump plateaus and slopes for native revegetation and meso and microtopography (Note: Microtopography not to be used for covers where deep percolation is to be minimized).
	Most of the surface water on the dumps either **infiltrates as deep percolation or evaporates. Runoff** is generally confined to small areas, but importantly immediately adjacent to slopes where it causes incision of the crests and gullying of the slopes. This typically occurs even without much ponding adjacent to the crest, but is made much more intense by ponds that develop next to the crest.	Areas with runoff on the dump surfaces tend to deposit fines into shallow pools. Mapping of these pools after snowmelt and of the fines on the dumps is a useful precursor to the design of the covers and landform grading of the plateaus, especially if used in conjunction with detailed LIDAR topography.	The design should attempt to avoid areas that pond water by providing positive drainage to lined engineered watercourses.
	Ponding on plateaus leads to increased amounts of percolation of water into the dumps, affecting the chemical loading rates. Ponds are generally in the form of shallow pools, often 5 to 20m across, in shallow depressions left over from dump placement or caused by berms. Ponding can also be caused by "roughing" microtopography experiments (as on the Grum Dump).	Should work to avoid closed depressions.	Design the plateau and bench drainage to avoid ponding of water onto slopes. Every drop of runoff water should have a clear path to meet up with engineered watercourses. Engineered watercourses should be lined with low permeability material and have positive drainage to reduce percolation into the dumps. Avoid microtopography on dump areas (to avoid ponding, infiltration, and outburst runoff). Instead focus on mesotopography (10 to 20m wide mounds) that promotes runoff.
	The waste rock dumps already contain large amounts of **topographic diversity** in plan and profile.	Designs should look to take advantage of this natural diversity not just to reduce regrading efforts, but to preserve or enhance topographic diversity for aesthetic and biodiversity considerations.	Work with the existing topography.
	Bubble dumps / free dumps on dump plateaus	The existing freedump piles on many dump plateaus is enhancing percolation of water into the dumps.	It may be worthwhile to target these areas as one of the first regrading activities to reduce percolation into the dumps.
	One of the lower benches on the Grum Waste rock pile is growing well.	This wide bench plateau is a useful location to show how vegetation will evolve on the waste rock pile plateaus.	Monitor this site closely, and determine whether this is a good stakeholder stop.
	Potential show slope above Faro Creek. GPS Point 704, near gully 527 Potential show slope, excellent performance, 27 degrees and steeper, some erosion. Dozer cut (analogue), lots of variety, moss, big gully by pit, pingo like feature at base of slope. Where slope is steeper (30 to 32 degree threshold) there is massive erosion. This is a significant site	Worthwhile to study this area in more detail as part of permit-level designs.	

Slope	Observation	Discussion	Landform design implication
Waste rock, regraded, till covered (Includes till covered slopes on Vangorda Dump and the nominally all till Overburden Dump)	GPS 711. East end Vangorda dump below the test plots The dump was resloped and capped several years ago, but there is little vegetation on most of it, and the slopes are extensively rilled and gullied.	Major difference in rill erosion, volume of water, steepness of slope, coalescing rills. Some grasses in bands immediately after break in slope. Rills get worse just below break in slope. Rather close to ditch, but to reslope would interfere with site boundary	
	Bare till rills and gullies with nearly zero overland flow path length at a threshold slope of 17 to 20 degrees. Minor erosion at 17 degrees (30%, 3.3H:1V) but major erosion at 20 degrees (36%, 2.7H:1V). This pattern was seen at numerous locations at the minesite, perhaps most clearly at the north slope of the Overburden dump.	One of the key observations from the visit. Rills start to form at the heads of slopes, and coalesce into gullies within a few metres of slope length.	Consider 3H:1V as the maximum regraded slope angle for dumps. While heavily revegetated slopes will likely behave well at this slope angle, keeping to this angle (and flatter) will help to reduce the effects of inevitable rilling and gullying and offer the chance at self-armouring with vegetation or rock.
	The glacial till cap, when dry, becomes **very hard**	Seems like a poor media for plants to invade, and even if seeds get into the cracks, one wonders if the physical nature of the material is hard on the plants.	Very little natural invasion. Looks like aggressive agronomics are needed on the slopes to provide good growth and erosion protection. It would seem that the planting has to occur immediately after regrading and tilling, before the till dries out. Suggests that a final tilling and planting is needed in the spring of each year. Need to work closely with revegetation and soils experts to make these slopes grow and perform as intended. Revegetation strategy and plots need to be worked out as a high priority.
	Wet till makes for **slippery roads** and poor trafficability	The till is very moisture sensitive – small amounts of rainfall turn the till from a hard material into an extremely slippery material.	Avoid driving on tipped out benches capped with till. Geotechnical properties of the till should be reviewed to better understand its performance.
	Initiation of small slump in resloped dump	There is the headscarp of a slump in the lowest bench of the resloped capped Vangorda dump. The cause of this slump needs to be investigated and the slope needs to be repaired. The slump may be due to foundation conditions, water table conditions, and something rated to the waste rock or till cover.	Understand the cause of the slump to see if it is due to local conditions (more likely) or whether the slope is generally too steep (less likely)
	Gully depth in low k cover should not exceed cover thickness	Seems obvious, but has major implications and forms perhaps one of the most major design criteria.	Need to design critical covers not to gully and be prepared to fix gullies as they develop.
	Set up for seepage collection drain buried, allows surface water to shed to natural environment (Sketch p 84 notebook). Diverse forest here at 1130masl (ELEVATION CONTROLS?), pine, alder, willow, black spruce, quite a lot of pine	Real problems with overcompaction or other digenesis of placed till. Needs to be formally ploughed and planted right away Designs may be elevation sensitive (different designs for high areas vs low areas of site)	
	Fans developing at toes of slopes	Some erosion, even in well reclaimed systems, is inevitable. Need to design to keep erosion from plugging creeks or tainting waters.	Need to leave area between toe of slope and any toe creek or natural area to collect sediment. Avoid building right out to site boundary or adjacent to critical infrastructure. Need to work out a method for determining practical working offsets.

Slope	Observation	Discussion	Landform design implication
Waste rock, regraded, till covered *(continued)*	**Microtopographic roughening on slope causing erosion**	Slope roughening with microtopography causes coalescing of runoff and considerable gully erosion	Avoid microtopographic roughening of slopes in favour of favour sheetflow. Explore use of corrugated downslope swales to minimize coalescence of rills.
	There is a very small area of the resloped Grum Dump that has **aggressive agronomic grasses.** This is the only area of the site seen for which vegetation is helping to limit erosion.	Shows that agronomics can be used at this site to help stabilize slopes, but the small area also indicates that the agronomics do not spread easily on the dry till covers.	Plan for agronomic grasses and legumes as the first cover on critical slopes.
	Moss seems to be either a factor or an indicator of low erosion.	More likely an indicator	
Resloped glaciofluvial slopes	West side borrow pit performance is good, though vegetation is sparse. Little erosion.		Consideration of using glaciofluvial materials to armour slopes or as cover material should be given.
	Unvegetated, uncompacted glaciofluvial cover at the Vangorda waste rock dump trial has been significantly eroded.		Loose, unvegetated glaciofluvial material does not pose any significant erosion protection
Glacial till pit slopes	Slopes at angle of repose (32 degrees) heavily gullied. Where slumping occurs, slope **angles slump to about 20 degrees**. (36%, 2.7H:1V). Backscarps of slumps are at about 36 degrees. Major slumping around the pits is evident.	There are numerous failing till slopes around the mine pits, erosion makes the slumps worse. Indicates the need for proper design of waste rock dumps.	Need to decide whether these are pit slopes (and hence can be left unreclaimed) or whether they need to be resloped. May be an opportunity to round the edges of the pits, but little opportunity for regrading most of these slopes. 2H:1V slopes (26 degree, 50%) are unstable, need to cut flatter for geotechnical and erosion al stability
	GPS 712 above Vangorda pit – area performing poorly.. Resloped till slope. Slope regraded to a bowl, concentrating water in a small area – fan deposition as filled in a small checkdam, and water is going over the dam causing further erosion. **Slope are concave down**, promoting downslope erosion. Water flows from uncontrolled from plateau above. Very poor vegetation performance too.		
	2H:1V slope above pit, landsliding, minor 0.3 to 0.6m high hummock causing gullying, some revegetation. Six inch rocks roll down slope.		
	Vegetation still only has <10% cover even after many years. Very slow natural invasion. Cryoturbation of soils evident.		
	Slump at Vangorda till dam, 28 degrees, rills, wide bench, GPS NAD 27 UTM 0593184N, 6902556 E 1127masl		

Slope	Observation	Discussion	Landform design implication
Roads and ramps	**GPS 707, near Gully 390** Long slope across way, no gullies. Shallow slip off where top oversteepened Ramp down into pit with steep walls	The existing roads into the Faro pit will likely be used for permanent access and as well as channels for overland flow from the dumps.	Most of these slopes need to be flattened for closure by a combination of regrading or bringing the road / channel elevation higher.
	GPS 708 Driving down ramp Very shallow ramp, 2 to 3 degrees, flow slides, gravelly clayey silt washing down, energetically splashing over waste rock 38 to 40 degree planar backscarp release surfaces, oversteepened, bad actor waste rock. Next slide down ramp, ramp at 4%. 38 to 40 degree backslope, fan lobe toes at 35 degrees.. Conical source areas, boulder rollout onto ramp, small $2m^3$ lobe at toe.		
	Gaps in the berms along the main haul road cause gullying of slope	Simply more evidence that the water running from plateaus needs to be controlled	
Tailings area	**Tailings area not visited during this investigation.**		Landform grading of the tailings surface should include a shallow surface water drainage system to minimize ponding and some shallow mesotopographic mounds to promote runoff and diversity.
Bedrock pit walls	**Slumping** of benches and general physical weathering of pit walls evident.		Need to figure out strategy for transition of dump and pit areas. May be implications for safety.
Infrastructure	Roads, pipelines, powerlines, buildings, water treatment	Generally performing well with high degree of maintenance.	See above for details.
Faro Creek Diversion and other diversions	Good performance to date of rock armoured channels.	Not examined in detail.	Good analogues for some of the closure drainage. Relies on suitably designed riprap and periodic maintenance. May be opportunity for adding some channel diversity or enhanced riparian vegetation.
Recent decommissioning of a water reservoir and dam in the Rose Creek Valley.	Good performance to date	Would be beneficial to declare these areas fully reclaimed, but continue monitoring performance to learn for reclamation of other areas.	Worth reviewing design and documenting success prior to design of new reclamation areas.

Table 3-2. Equivalent slope angle measurements

Slope angle α (degrees)	Slope angle α (%)	Slope angle α (xH:1V)
0	0.0	---
1	1.7	57.3
2	3.5	28.6
3	5.2	19.1
4	7.0	14.3
5	8.7	11.4
6	10.5	9.5
7	12.3	8.1
8	14.1	7.1
9	15.8	6.3
10	17.6	5.7
11	19.4	5.1
12	21.3	4.7
13	23.1	4.3
14	24.9	4.0
15	26.8	3.7
16	28.7	3.5
17	30.6	3.3
18	32.5	3.1
19	34.4	2.9
20	36.4	2.7
21	38.4	2.6
22	40.4	2.5
23	42.4	2.4
24	44.5	2.2
25	46.6	2.1

Slope angle α (degrees)	Slope angle α (%)	Slope angle α (xH:1V)
26	48.8	2.1
27	51.0	2.0
28	53.2	1.9
29	55.4	1.8
30	57.7	1.7
31	60.1	1.7
32	62.5	1.6
33	64.9	1.5
34	67.5	1.5
35	70.0	1.4
36	72.7	1.4
37	75.4	1.3
38	78.1	1.3
39	81.0	1.2
40	83.9	1.2
41	86.9	1.2
42	90.0	1.1
43	93.3	1.1
44	96.6	1.0
45	100.0	1.0

Slope angle α (xH:1V)	***Slope angle α (%)***	***Slope angle α (degrees)***
1.0	*100*	*45.0*
2.0	*50*	*26.5*
2.5	*40*	*21.8*
3.0	*33*	*18.5*
4.0	*25*	*14.0*
5.0	*20*	*11.3*

Table 3-3 Geotechnical properties of mine materials

Material type	Geotechnical description	Comments and observations
Coarse waste rock dump material	• Waste rock presents normally 40 to 60% fines; • Clasts greater than 10 cm are typically between 20 cm and 50 cm with some boulders of up to 1 metre diameter	• Generally geotechnically and erosionally stable at angle of repose over many decades. Generally supports only very modest vegetation cover. • The calc-silicates in the Faro waste rock dumps were identified as being the most suitable candidate for riprap
Fine waste rock dump material	• In general highly weathered • Specific gravity between 2.85 and 2.88 • Well graded gravel-sand mixture • The smaller than 50mm fraction comprises of 49% gravel, 39%sand and 12% sand • K_{sat} around 5 x 10^{-3} cm/sec; AEV 0.1 kPa	• Subject to slip-off style landslides and erosion, significant natural invasion of native species.
Glaciofluvial sandy gravel	• Poorly graded gravel-sand mixture with abundance of gravel and sand and virtually no fines • Specific Gravity between 2.68 and 2.73 • Significant amount of cobbles and boulders; the fraction smaller that 50mm comprised of 16 to 40% gravel, 60 to 78% sand and 0 to 6% fines • K_{sat} between 4 x 10^{-5} and 1 x 10^{-3} cm/sec; AEV between 0.1 and 3 kPa	
Glacial till	• Till deposits generally consist of unsorted clay, silt, sand, pebbles and cobbles with minor boulders, deposited by or from glacial ice. Till is common as a veneer (Tv, <1m thick) over much of the Faro and Vangorda-Grum areas and grades into blanket deposits (Tb, >1m thick) on more gentle slopes and valley bottoms. • Bulk density: 1.84 t/m^3; Bulking factor:1.2; excavated density:1.53 t/m^3; shrinkage factor:0.9; compacted density:2.04 t/m^3; K_{sat} 2 x10-4 to 6 x10^{-5} cm/sec	• At a general gradation of 2.5H:1V the glacial till cover has physically held up exceptionally well after 10 years; There is no evidence of cracking of the cover, either due to freeze/thaw action or natural wetting and drying. Some minor vegetation spots have started to develop on the cover, mostly within the erosion gullies • There are numerous erosion gullies on the cover; however the largest gullies are less than 200mm deep, with the majority being between 50 and 100mm deep • A test strip regraded to approximately 3H:1V and seeded suggests that vegetation could be successfully established on the till.
Natural Soils	• Local organic deposits are typically less than 1m thick and of variable composition.	• Organic soil deposits for establishing vegetative covers are identified on the surficial geological maps but the volumes tend to be small and typically require significant effort to develop road access.
Natural stream channel armour	• Rounded cobbles and boulders, some coarse woody debris, low-energy overbank areas covered with organic rich sands and silts (often multiple layers of organic horizons, frequent roots).	• Many natural streams on bedrock

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Table 3-4 Observations from natural areas

Location	Observation	Photo	Landform design implication
First stop, slopes 110km north of Whitehorse GPS 701 61.620N 135.87W Elevation 2200ft (670m) NTS 105E12 Near Klusha Creek, Conglomerate Mountain Yukon Highway 2; Klondike Highway 110km north of Whitehorse 150km SW of Faro Minesite ~5km south of South of Twin Lakes campground	Corrugated slopes on a large scale Slopes are steep and roughly linear top to bottom Subtle ridge and swale topography Large mounds on the slopes Some solifluction like rock strips near heads of slopes Aspen vegetation in the swales Some bedrock cored Approx 2 to 4m high ridges, perhaps 20m spacing Concave toe (probably) hidden by trees From topo maps, slopes are 27 to 33 degrees at midslope. West facing		These slopes provide useful analogues to for dozer-sized downslope furrows for Faro waste rock dumps. They provide insight into geometry, soils, vegetation communities and tailored planting, convex toe slopes, and mounds on the slopes. Useful natural analogue for large downslope corrugated slopes. If this technique is used, each site should be visited by a multidisciplinary team for a half day visit.
Slopes near Carmacks UTM Zone 8 NAD 83 0446877, 6884262 Elev. 576m 62.086N 136.017W NTS 115I01 North side of Highway 4 (Robert Campbell Highway), close to the Yukon River. Approx 13km east of Carmacks, 140km west of Faro Minesite	Slope length 80-100m Swale crest to swale crest: 20 to 25 m Swale cross slope: 10 to 15 degrees Swale longitudinal slope: 25 to 27 degrees Swale depth (crest to thalweg): 2.1 to 2.3m Stable dozer cut like slopes, 20m wide, 25 degrees, 2m deep, 15 degree side slopes, base width about 10m South facing Thick, organic rich soils in swales, dense vegetation. Very thin soil cover on ridges.		

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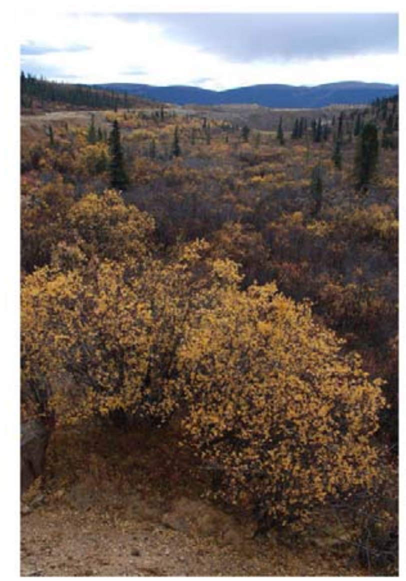
Location	Observation	Photo	Landform design implication
Gullies above Faro townsite GPS 709, 587,072, 6,899,917 Close to gully 562	Show slope analogue, bare upper slopes, good place to bring people out to. Likely very thin soil covers.		This slope provides a useful analogue to for dozer-sized downslope furrows for Faro waste rock dumps. It provides insight into geometry, soils, vegetation communities and tailored planting, convex toe slopes, and mounds on the slopes. Useful natural analogue for large downslope corrugated slopes. If this technique is used, the site should be visited by a multidisciplinary team for a half day visit.
Gullies below Faro townsite (Gully behind townhouse over Pelly River)	28 degree valley wall, trembling aspen forest, glaciofluvial vegetated circular scarp		

Location	Observation	Photo	Landform design implication
Fingers natural area Tourist stop near Faro – 710 GPS	Till over bedrock, not a great tour site, gullies undercut, lookout.		Interesting soils and vegetation patterns, but may not be applicable to mine reclamation.
Headlands of Rose Creek (adjacent to Rose Creek Diversion)	Some creeks are underlain by organic wetland material. Fen like wetland in uplands for Rose Creek has just a few inches of peat developed over the many years. No erosion.	 Visited in 2007	With the very slow growth of vegetation at the mine site, will need to have rock armoured channels. However, the geometry of this channel may be useful for the upper reaches of the plateau channels (headwaters) where there is very little gradient.

Location	Observation	Photo	Landform design implication
Creeks near the mine 62°18'19.09"N 133°17'51.26"W	Creek near 563 Creek, flowing over rocks. Borrow pit, rounded cobbles in silty sand matrix, 5 to 10mm organic layers, willows – sparse but nice 500usgpm In undisturbed areas, moss hummocks, blue berry, two organic layers. Almost all creeks are naturally armoured with boulders or are underlain by bedrock.		Almost all creeks are naturally armoured with boulders or are underlain by bedrock. Plan to armour all channels. Give consideration to building floodplain and tree islands as in these natural creeks.
Natural area at base of two dump swales just southwest of Faro pit GPS 706	There are some areas of natural veg in the mine area – try to preserve these as seed sources		Attempt to preserve natural areas within the mine footprint, starting with mapping them. Use coarse boulders to trap sediments coming from the dump slopes.

4.0 DESIGN ELEMENTS AND STRATEGIES

Table 4-1 and Figure 4-1 provide a summary of design elements and strategies proposed for the Faro Minesite.

Table 4-1 Landform design learnings

Area	Learning	Potential strategy
Operations	• Boulder rollout from angle of repose slopes presents a hazard to workers. The greatest risks are on highly travelled roads during times of rainfall or snowmelt.	• Work with mine staff to develop procedures to safeguard people and equipment.
	• There is a risk of sliding off of outward sloped till covered benches and roads	• Highlight risks at next safety meeting.
	• The existing free-dump piles on slopes are likely enhancing percolation into the dumps, increasing the amount of water treatment needed.	• Consider prioritizing some plateau reclamation activities to reduce short term percolation into the dumps.
Planning	• The dump slopes are going to be difficult to reclaim due to their high erodability and the slow growth of ground cover in the region. • A new strategy of corrugated drainage and agronomic planting on slopes will be needed.	• Close cooperation between the planning, cover, landform grading, and vegetation members is required to finalize the design strategy for the site.
Zoning	• One of the next planning design steps is to zone the site such that every square inch of site is mapped in plan view.	• Zone the existing site such that every square inch of site is mapped. o Terrain units may include: ▪ Previously (and finally) reclaimed areas. ▪ Natural area not to be disturbed (upland, wetland, watercourse) ▪ Natural area that may be disturbed (upland, wetland, watercourse) ▪ Waste rock slopes that may be left at angle of repose ▪ Pitwalls that may be left as is ▪ Slopes to be regraded to 3H:1V or flatter ▪ Plateaus and benches with low reactivity waste rock ▪ Plateaus and benches with medium reactivity water rock ▪ Plateaus and benches with high reactivity waste rock ▪ Infrastructure and diversions (that will remain) ▪ Tailings and tailings dams

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Area	Learning	Potential strategy
Slope performance	• **Every slope is unique and must be evaluated independently.**	• **Characterize the ages of each slope using historical aerial photos and mine records and create a map. Mark the existing performance of the slopes based on detailed aerial photographic analysis and field truthing (next level of detail from this study) to aid permit-level designs and decision making. Some drilling or test pitting of the waste rock dumps and other areas may be required.**
	• **Even after many years, there is very little natural invasion of protection onto the slopes. That which does invade is doing little to nothing to protect the slopes from erosion. The areas with resloped glacial till or till covered resloped waste rock dumps has sparse vegetation and much of the soil is not conducive to germination and growth of groundcover.**	• **A program to revegetate till capped resloped dumps should be instigated that uses aggressive agronomic grasses and legumes to help reduce the erosion on slopes. Techniques for revegetation toward these groundcovers need to be developed as a high priority.**
	• **Fine grained, unvegetated slopes are eroding fairly rapidly, with numerous gullies and rills. Eroded material is accumulating in fans at the base of slopes.** • **There would appear to be a threshold slope angle at which erosion accelerates remarkably. <u>For the glacial till, this angle appears to be between 17 and 20 degrees.</u>**	• **Slopes should be regraded to a maximum steepness of 3H:1V and revegetated as quickly as practical with erosion reducing groundcover vegetation.**
	• Most of the existing slope erosion is caused by water flowing over the crest of plateaus and berms onto unprotected slopes. Almost 75% of the gullies mapped are caused by this mechanism.	• Build a watershed berm at the top of every slope (include the edge of plateaus, ramps, and roads). Watershed berms are 1 to 2m high berms built from fill that stop water from flow over the crest of slopes. Overland flow is directed towards engineered drainage swales. The berms are capped and revegetated.
	• Slumping of till slopes at 2H:1V is common.	• Slumps should be mapped and investigated. Reslope angles need to be flat enough to promote geotechnical stability.
	• Coarse grained waste rock dumps at repose are showing good geotechnical and erosional stability.	• Some areas of coarse grained waste rock dumps should be left at their angle of repose. An investigation into the durability of these slopes will be needed. (See the recent Questa Mine (New Mexico) studies into weathering of angle of repose dump slopes). • Boulder rollout from these slopes remains a hazard that will need to be dealt with through design and institutional controls.
	• Some fine-grained waste rock dump slopes at repose are eroding and exhibiting shallow slip-off failures	• The performance of these slopes should be mapped and investigated. It is unlikely that many of these fine-grained slopes can be left at their angle of repose. • It may be possible to dump coarse rock in a thick enough layer to stabilize these slopes at repose.
	• Angle of repose slopes support little vegetation.	• While attempting to seed or plant finer grained angle of repose slopes, leaving these areas unvegetated and allowing (what will likely be very modest) natural invasion to occur.
	• More severe gully erosion results when rills coalesce on the slope (a hazard with relying upon sheet flow to reduce erosion). If the rills can be kept from coalescing, gully erosion can be minimized.	• Create corrugated (downslope parallel ridge/swale patterned) slopes on resloped till covered dumps at two scales: o Create rills with a dozer with a special attachment. Alternatively, these may be created by ploughing or furrowing with specially adapted farm equipment. The protorills would be 10 to 20cm and 5 to 10cm

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Area	Learning	Potential strategy
Slope performance ***(continued)***		deep wide with similar sized ridges between. o Create larger downslope furrows using a large dozer with similar dimensions to those seen in the natural environment – 2m deep, 20m wide, with 20m wide ridges between and thick organic vegetation in the swales. The limited supply of good soil will restrict the number of these furrows that can be created. o Avoiding roughening slopes using microtopography as this concentrates the flow into gullies and rills that promotes erosions. o Avoid slope shapes that concentrate flows on the slopes. Where this is required, armouring of the slope will be needed.
	• The erosional (and vegetation) performance of glaciofluvial sediments seems to be better that that of placed tills.	• Consider use of glaciofluvial sediments as waste rock caps in regrading, reclamation, and cover trials.
	• Cleared areas have better regrowth than dump slopes	• Investigate the differences to see if there are strategies that could be employed on the waste rock dumps to better mimic these less drastically disturbed areas.
	• Fans of eroded debris form at the toes of slopes • Coarse waste rock at the base of some slopes does a good job of capturing much of this eroded debris	• Create an offset between the final toes of slopes and roads, ditches, creeks, etc to allow material to accumulate. • Add a toe berm of coarse rock to the base of some slopes, perhaps as a catch berm) to trap sediment. • Plan for access for maintenance for removal of eroded material and repair of gullies.
	• Gullying through shallow covers can expose the waste rock beneath	• The slopes need to be designed to minimize erosion in critical areas of covers and the cover thickness must allow for a certain degree of erosion in some areas. Again, maintenance and repair of the covers will be required.
	• The maximum overland flow path distance for unvegetated slopes is extremely variable and generally very short.	• Field tests on revegetated slopes should be conducted to determine the maximum overland flow path distance. With this knowledge, a spacing of lateral berm channels to break up slopes can be designed. • Existing berms should be used where practical. • Lateral berm channels should be designed into the resloping design.

Area	Learning	Potential strategy
Bench and plateau performance	• The geotechnical and erosional performance of berms and plateaus is good. Little differential settlement is observed.	• Target these areas for reclamation with native vegetation.
	• Microtopography promotes standing water (which can lead to increased percolation or to overtopping of benches). • There are areas of ponded water and sediments that indicate ephemeral ponding on dumps. • Freedump areas (areas with individual dump truck loads of waste rock left unbladed) promote percolation. (Some people refer to these areas as bubble dumps).	• As mentioned above, prioritize areas of freedumped waste rock that is promoting percolation into the dumps. • Incorporate the cover design into the topographic design. • Using LIDAR, aerial photos, and ground truthing, map areas of ponded water or sediments that indicate ponding water. • Design the plateaus with positive drainage (with slopes of 1 to 3% where practical) to promote runoff. • Avoid creating microtopography on plateaus in favour of meso- and macro-topography to promote positive drainage to engineered watercourses. • Mesotopography can be achieved using 10 to 20m wide, 1 to 2m high mounds for diversity, runoff, and aesthetics. • Allow for maintenance to fix areas that have settled and are ponding water.
	• The tops of the dumps already have high levels of substrate and topographic diversity	• Work with the existing topography to minimize regrading and keep or enhance topographic diversity. In particular, pay attention to visual aspects of the ridge lines, which already have a high degree of diversity on many dumps.
	• One of the lower Grum Dump benches is showing good performance, especially with respect to revegetation.	• Confirm the good vegetation performance and look to bring stakeholders here as an example of early reclamation success.
Pitslope performance	• Rockslope benches are rapidly deteriorating	• A review of safety and procedures for working in the ponds should be made.
	• Till and glaciofluvial slopes are slumping and eroding and show very poor performance.	• Need to declare whether these are part of the pitslopes (likely) or whether they will be attended to. • Consideration of the transition between these areas and natural or reclaimed areas is needed. Rounding of the upper transitions of these slopes may be worthwhile. • Slope stability should be re-evaluated for these areas, an include any future changes in planned water levels (and potential for rapid drawdown).
Channel performance	• Vegetation grows too slowly to be useful for erosion protection on slopes – rip rap is needed. • Existing natural watercourses are almost all lined with boulders, except at the low gradient headwaters. • Existing rip rap channel performance is good. The steel flume channel has been very high maintenance.	• Design channels with engineered rip rap. • May be able to grass the very low gradient upland channels on the plateaus, then transition into riprap.
	• Rip rap channels promote infiltration / percolation	• Engineered channels on dumps will need to be lined.
	• Natural armoured channels have complex floodplains.	• May be able to include some habitat enhancement features and other diversity into channel designs.

Area	Learning	Potential strategy
Natural slopes and analogues	• Natural slopes in the region are old and well vegetated. Their performance has evolved over millennia to become very good.	• Understanding the performance of natural slopes in the region has been less informative than originally anticipated, due the long time that will be required to establish mature vegetation on the mine slopes.
	• In some areas, the natural slopes are highly corrugated with parallel downslope ridges and swales.	• These areas are documented in this report and worthy of some additional study by an interdisciplinary team.
Tailings areas	• There is wind erosion of the tailings deposits (and likely the dumps as well) that needs to be remediated. • The tailings has shallow areas of ponded water. • Tailings reclamation was not a focus of this investigation.	• A system of shallow surface water swales to minimize ponded water, surrounding mesotopographic mounds to promote runoff and diversity is recommended. • Some maintenance of settlement features will likely be required, as is maintenance of the dams. • All soil slopes and swales should be vegetated with agronomic grasses. There may be an opportunity to use native vegetation on some of the mounds in the tailings area.
Infrastructure	• The mine infrastructure was not a focus of this investigation. • This report did not consider the performance of internal drains, the water filled pits, water treatment and water management, permanent facilities and roads.	• The infrastructure will change considerable with mine reclamation and is an important consideration in design and scheduling.
Monitoring and maintenance	• In addition to the water management work, much of the rest of the site will require long-term monitoring and maintenance.	• Start to identify the needs and plan the transition into the landform design.
Other design elements	• There are opportunities to include other landform design elements from other mines. These have been previously presented by BGC in 2007.	• The list includes the following elements: o Meandering Creek o Coversoil and revegetate bare areas, creeks o Irregular ridge mounds o Swales at toe to drain plateaus o Wetlands at toes o Tailored planting o Swales on slopes o Signage o Sustainable seepage controls o Add additional fill at toe o Mounds on plateaus, benches o Brushpiles / snags o Rockpiles o Coversoil diversity o Access controls o Viewing platforms / photo locations

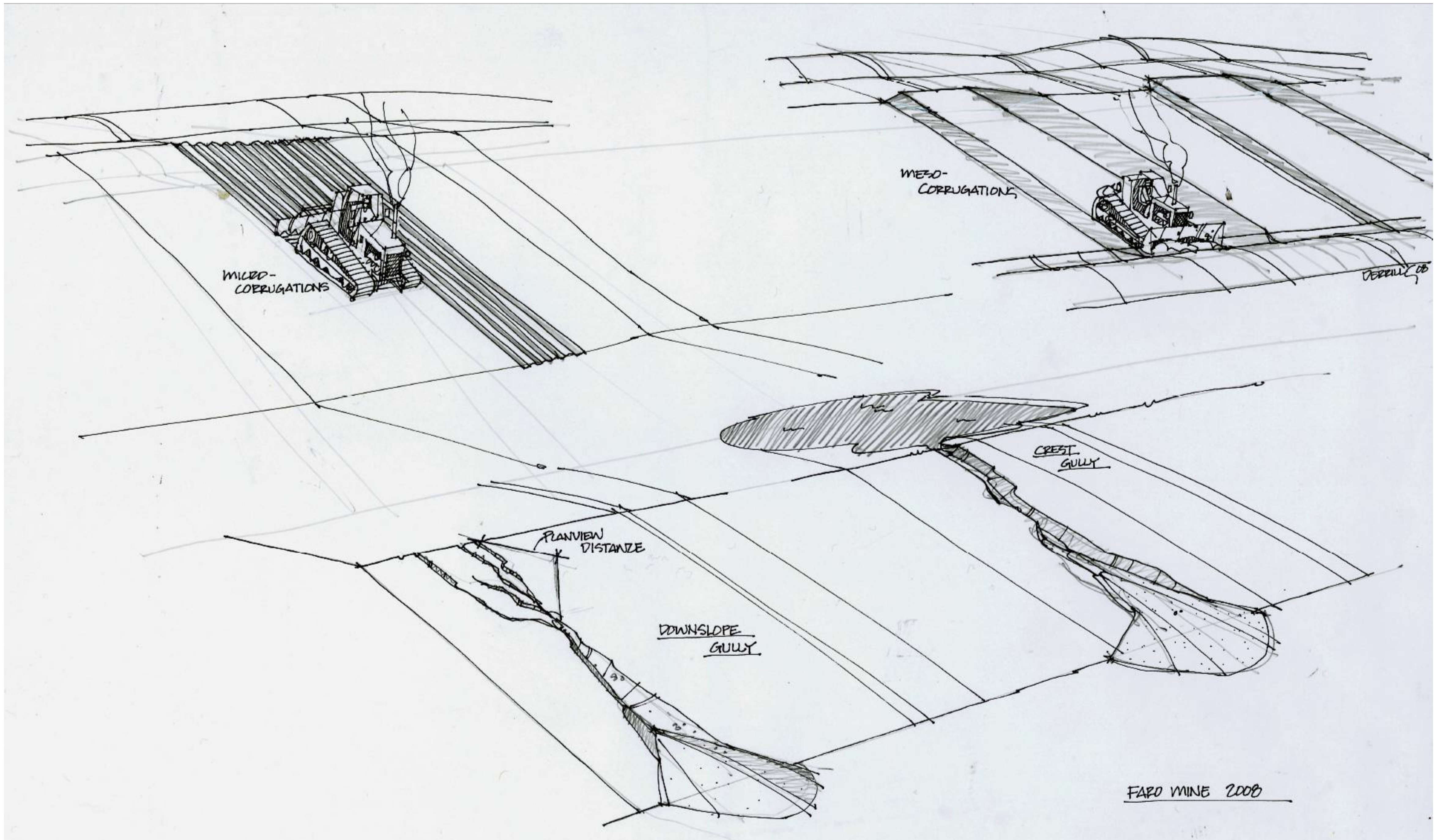


Figure 4-1. Schematic views of microcorrugation, meso corrugation, and gully definitions (downslope gully showing definition of planview distance, and crest gully caused by overtopping of crest by overland flow from plateau, beach, road, or ramp.

5.0 CONCLUSIONS AND RECOMMENDATIONS

- Existing conditions
  - The mine site has seen numerous significant storms since the waste rock dumps were constructed. The climate is harsh at the mine site latitude and elevation and vegetation growth rates are slow.
  - Bare resloped dumps and fine-grained waste rock dumps at repose are actively eroding with rill and gully erosion. Most of the gullies are caused by flow of runoff water from plateaus, berms, roads, and ramps. Many gullies are caused by coalescing of rills on the slopes. In some cases, slopes are slumping, which exacerbates and is exacerbated by gully erosion.
  - Till slopes that are less than 17 degrees (3.3H:1V) have greatly reduced erosion rates and similar slopes are greater than 20 degrees (2.7H:1V) show rapid rill and gully erosion.
  - Angle of repose coarse waste rock slopes are presently generally geotechnically and erosionally stable.
  - Rock and soil slopes above the mined out pits are slumping and eroding.
  - Vegetation on the dumps is sparse and is not contributing to erosional stability of the slopes. Natural invasion is very slow.
  - The performance of the benches and plateaus is generally good, but many areas have very high infiltration rates due to ponding of water.
  - Natural watercourses are generally in bedrock or are naturally armoured with boulders.
- Analyses
  - Plots of planview distance to gullying vs slope angle at the mine indicate the need for a good vegetative cover to limit gully erosion
  - Vegetation growth rates and soil formation rates are too slow to use vegetated channels, rock armoured channels are recommended.
  - The stability of each pitwall should be evaluated.
- Design recommendations
  - Vegetation of the till slopes and covers is extremely poor. Good groundcover and good root systems are needed to stabilize slopes, likely necessitating use of agronomic grasses and legumes on slopes, with seeding/planting to be done in conjunction with placement or tilling of slopes.
  - Final grades shall be designed to be geotechnically stable.
  - Dumps will need to be resloped to have intermediate slopes of 3H:1V or flatter, with cross-slope berms to limit flow path lengths, and revegetated with aggressive agronomic grasses and legumes to control erosion.
  - One to two metre high watershed berms are required at the crest of all slopes to minimize erosion due to water existing benches, plateaus, ramps, and roads – the leading cause of erosion presently.
  - Coarse grained angle of repose waste rock slopes are performing well, and a case to leave these slopes at their angle of repose can likely be made.
  - Regrading of final slopes to create micro-corrugations shall be used to reduce gully erosion. Meso-corrugations can be used for some slopes where suitable reclamation material can be employed in the swales.
  - Boulder talus checkberms and aprons should be used to catch eroded slope materials at the toes of some slopes.
  - Use of microtopography (small mounds, 0.5 to 2m size) on berms and plateaus (as well as slopes) is strongly discouraged as it promotes ponding water and percolation. Instead mesotopographic mounds (in the 10 to 20m wide range) are suggested as a method to enhance positive drainage from all flat areas of the dumps towards lined engineered watercourses.
  - Plateaus and benches should be considered for native vegetation planting.
  - All watercourses should be designed using rip rap armour and civil engineering open channel flow design techniques, incorporating fluvial geomorphology principles where practical. Many channels will required lining to limit percolation into underlying materials.
  - Long-term monitoring and maintenance will be an integral component of the design, both for water management at the site, as well as for maintaining good performance of covers and slopes. The site should be designed to facilitate the needed infrastructure and access.
- Next steps
  - The geotechnical stability of interim and final dump slopes and pit slopes should be evaluated.

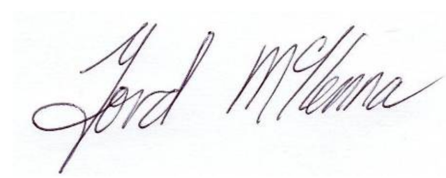
- The site should be zoned into the recommended reclamation units by a multidisciplinary design team to facilitate EA-level site-wide and landform designs. A design basis memorandum should be generated by this same team.
- Large-scale regrading and revegetation plots should be constructed as soon as practical using the technologies and strategies proposed by the multidisciplinary design team. Empirical results from several seasons of performance can be used in fine tuning the design of the rest of the landscape.

6.0 CLOSURE

BGC and SRK are pleased to provide this report and design recommendations for the Faro Minesite and we appreciate continuing to be involved in this important project.

Please feel free to contact the undersigned anytime with questions or comments.

Yours truly,



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Appendix A. Climate information

Introduction

The present analysis looks at whether the minesite has experienced extreme precipitation events since the dumps were construction to determine whether the depth and intensity of rilling and gullying can be explained. The short answer is that the minesite has experienced five rainstorms that lie between the 25 to 100 year return period events – about what one would expect statistically.

The data used in this appendix is from the Environment Canada Climate Data website. The data is from the Faro A climate station at the airport in Faro, Yukon (Latitude: 62° 12.6' N, Longitude: 133° 22.8' W, Elevation: 716.6masl). The data consists of measurements taken between 1978 and 2006 summarized to a single daily value. Data used includes the mean daily temperature, the total daily snowfall, total daily rainfall, total daily precipitation (the sum of daily snowfall and rainfall), and snow on ground (the depth of snow on the ground at the end of the day). Significant amounts of data were missing from years 1978, 2000, 2002, 2003, 2004, and 2005 and were therefore excluded from many analyses. The dataset is provided on CD with this report.

The Faro mine site is located at an average elevation of 1220masl, 503m higher than the airport where the data was collected. To estimate the rainfall at the minesite, the airport readings are typically multiplied by a factor of 1.40 (based on previous work by SRK).

Temperature and Precipitation

Trends in Precipitation

Figure A-1 shows the total annual precipitation per year at the Faro Airport from 1979 to 2006 (excluding years 2000, 2002, 2003, 2004, and 2005 due to missing data).

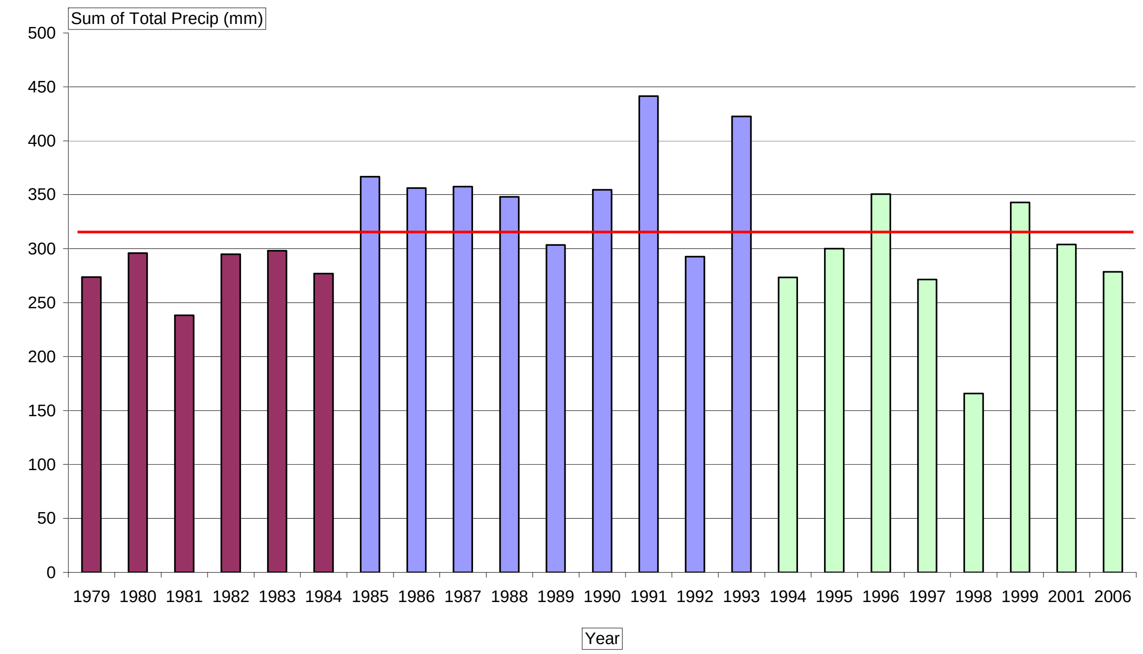

Figure A-1 Total Annual Precipitation (mm) 1979-2006 (Faro Airport)

The red line represents the average annual precipitation of 313mm. The graph shows that the annual precipitation can be separated into three groups. From 1979 to 1984, the total annual precipitation was consistently less than the average. From 1985 to 1993, the total annual precipitation was usually above or well over the average. From 1994 onwards, there is less annual precipitation and annual totals are generally below average.

Trends in Daily Temperatures

Figure A-2 below shows the daily average temperature for a typical year at the Faro Airport (excluding 2000, 2002, 2003, 2004, and 2005 due to lack of complete datasets). 1984 was chosen to represent a typical year based on average because its average annual temperature was closest to the overall average yearly temperature of -2.1 ºC for the years 1978 to 2006.

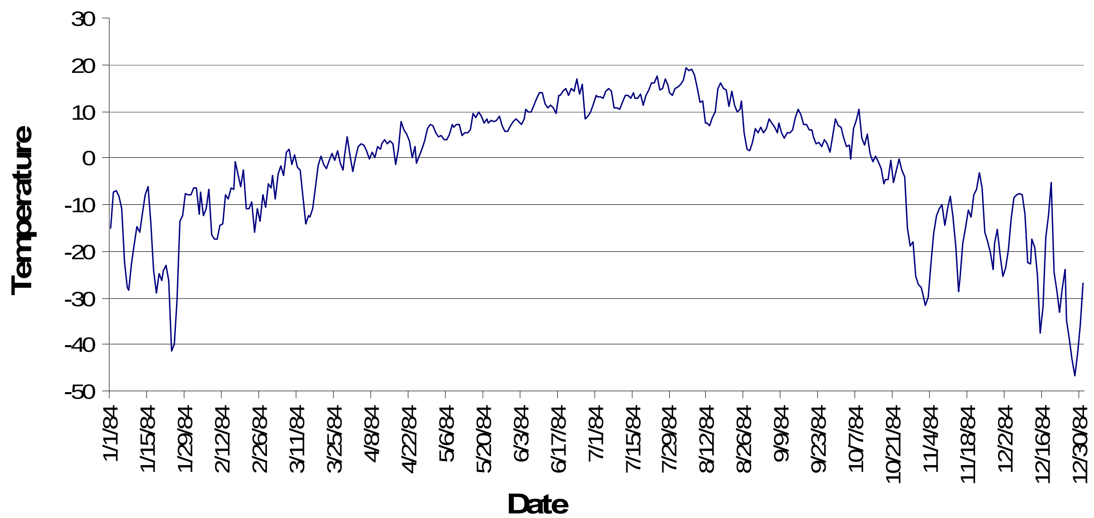

Figure A-2 Daily Average Temperature for a Typical Year (Faro Airport)

Figure A-2 shows that temperatures are not generally above 0 ºC until the beginning of May and remain above 0 ºC until about the end of September. The growing season is very short.

Averages and Extremes

Table A-1 Temperature Averages and Extremes (Faro Airport)

Average annual temperature	-2.1 ºC
Maximum recorded temperature	23.7 ºC on June 24, 2004
Minimum recorded temperature	-48.8 ºC on January 2, 1982
Daily average temp in January	-20.6 ºC
Daily average temp in July	15.0 ºC

Table A-2 Precipitation Averages and Extremes (Faro Airport)

Average annual precipitation	313mm
Average annual rainfall	211mm
Average annual snowfall	112cm
Extreme precipitation event	44.0mm rain July 26-27, 1991 (48 hours)
Extreme daily rainfall	29.4mm on May 28, 1993
Extreme daily snowfall	12.8cm on November 30, 1991
Average depth of snow on ground at the end of winter	28cm

Analysis of Severity of Storms to data

Return Periods

The predicted 24 hour rainfall events are presented in the following table for return periods of 10, 25, 50, and 100 years. Two different distributions were used for comparison, the Gumball Extreme Type I and the Generalized Extreme Value. Excluded from the analysis are the years 1978, 2000, 2002, 2003, 2004, and 2005 due to lack of complete datasets for these years. The largest precipitation events for each year were rainfall events that did not include any snowfall. The second and fourth overall largest storms both occurred in May of 1993 and thus the fourth largest storm were excluded when calculating return periods.

It should be noted that over the 27 years of record, the standard deviation of the maximum 24 hour precipitation event is small. So the 10 to 100 year return period rainfall events are all very similar (see Table A-3).

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Table A-3 Return Periods (Faro Airport)

Return Period (years)	Distribution Type	Prediction (mm)
10	Gumbel Extremal Type I	24.11
	Generalized Extreme Value	23.37
25	Gumbel Extremal Type I	27.91
	Generalized Extreme Value	26.00
50	Gumbel Extremal Type I	30.73
	Generalized Extreme Value	27.72
100	Gumbel Extremal Type I	33.53
	Generalized Extreme Value	29.25

Five Largest Rainstorms to date

Below is a list of the five largest storms that occurred at the Faro airport between the years of 1979 and 2006:

Table A-4 Largest Rainfall Events (Faro Airport)

Rank	Amount of Rain	Time Period	Date	Maximum 24 hour precipitation (mm)	Date
1	44.0	48 hours	July 26-27, 1991	23.8	July 27
2	37.2	48 hours	May 27-28, 1993	29.4	May 28
3	25.2	24 hours	May 16, 2005	25.2	May 16
4	25.1	24 hours	May 17, 1993	25.1	May 17
5	22.6	24 hours	June 5, 1995	22.6	June 5

Comparison of Return Period Predictions and Storms to date

Figure A-3 shows the daily precipitation for 1993. The red bar represents the May 28 rainfall event, the largest 24 hour rainfall event since 1979. According to the Gumbel Extremal Type I distribution, this value is larger than the 25 year return period prediction. However, when compared using the Generalized Extreme Value distribution, it is larger than the 100 year return period prediction. This indicates that the Faro airport has experienced a fairly severe rainstorm during its existence. The second and third largest 24 hour rainstorms, 25.2 and 25.1 mm are both larger than the 10 year return period but smaller than the 25 year return period for both distributions. This indicates that they were not very significant storms.

Faro Mine Closure

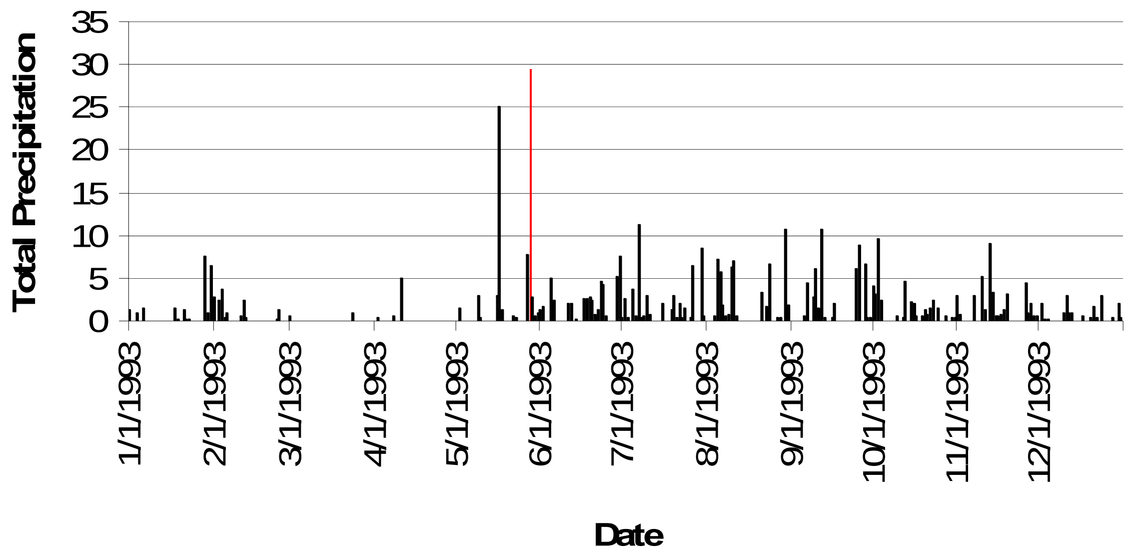

Figure A-3 Total Precipitation (mm) for 1993

Snowfall and Snow Melt

Total Annual Snowfall

The graph below shows the total snowfall for years 1979 to 2006 at the Faro airport station (excluding 200, 2002, 2003, 2004, and 2005).

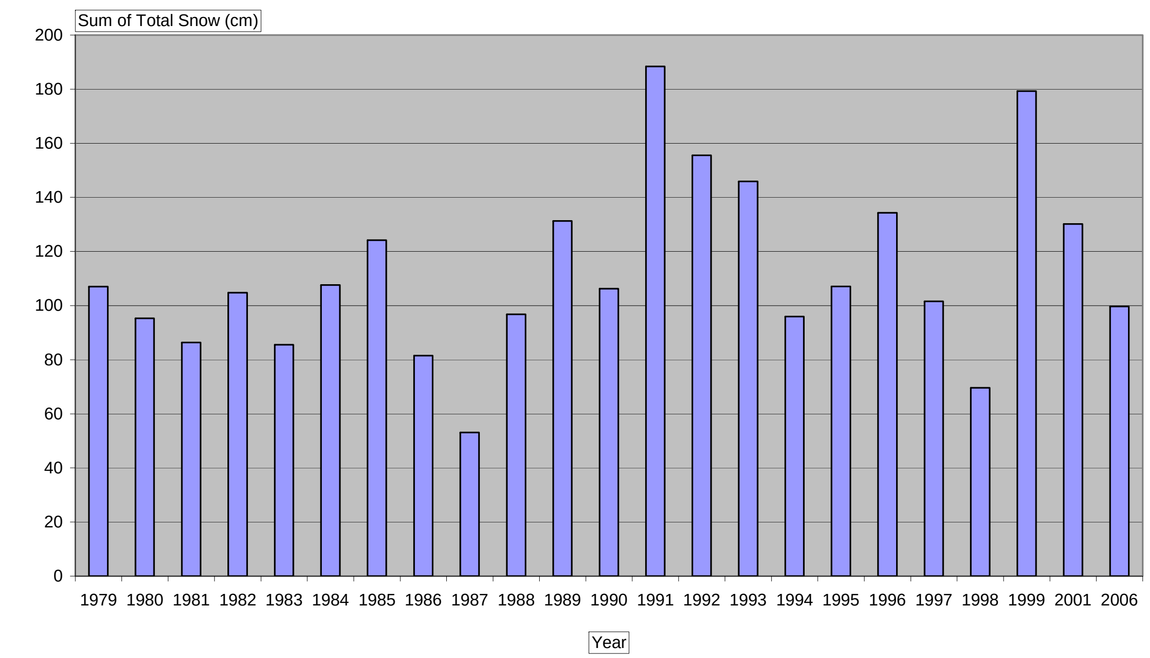

Figure A-4 Total Annual Snowfall

The average annual snowfall is 112cm. Figure A-5 shows the depth of snow on the ground at the end of winter from years 1981 to 2006 (excluding 2003) from the Faro airport climate station. The end of winter is taken as March 21st of each year, as this is an average date for when snow stops accumulating and begins melting. This graph can give an indication of how much melt water there was each spring.

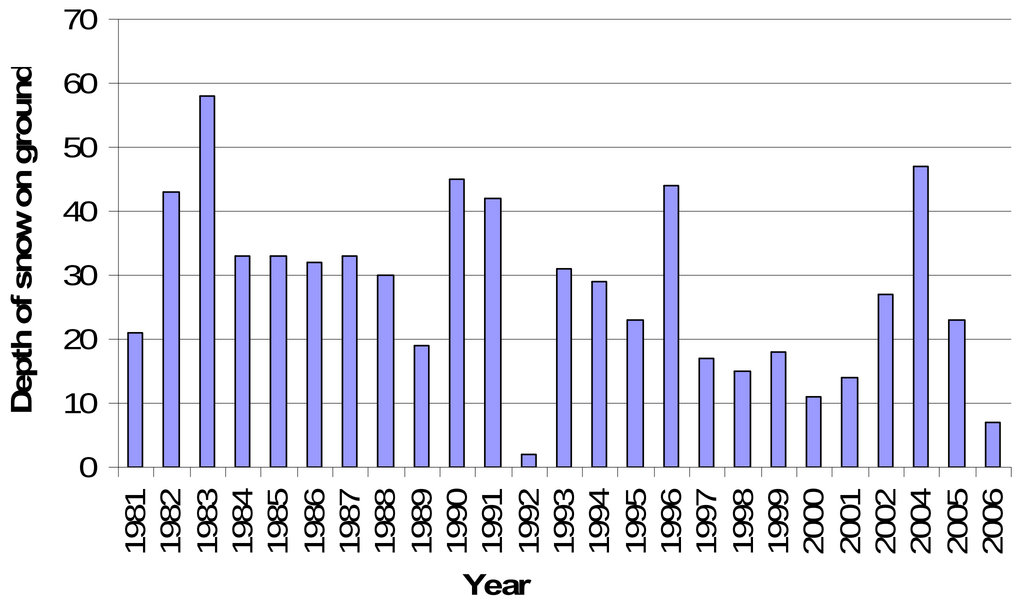

Figure A-5 Depth of Snow on Ground (cm) at the end of Winter

The average amount of snow on the ground at the end of winter is 28cm. 1993, the snowfall amount was above average (146cm) and the amount of snow on the ground at the end of winter was 31.0cm, which is also above the average of 27.9cm. It can therefore be concluded that in 1993, the year of the largest rainfall event, there was also a significant amount of snowmelt.

Conclusions

Based on data from the Faro Airport, the Faro minesite has experienced five significant rainstorms including a May 28, 1993 rainstorm that had a 25 to 100 year return period and likely occurred as a rain-on-snow event. The gullies presently observed on the mine dump slopes are a result of these events, and perhaps some smaller events too. So the degree and intensity of gullying on the unreclaimed mine slopes can be qualitatively explained by the occurrence of storms that would be typically expected in the region since mining began. The gullies are neither an abnormal response to a site untested by storms nor the product of an unexpectedly large storm.

Appendix B. Aerial photo analysis

Table B-1 Gully database from aerial photograph analysis

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
1	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench. Area might have been changed by trucks
3	Waste rock dump	Downslope	Waste rock	Moderate	7	16	Top of secondary bench, downslope; disturbed
4	Waste rock dump	Downslope	Waste rock	Moderate	19	22	Disturbed area
5	Waste rock dump	Downslope	Waste rock	Moderate	16	20	Top of secondary bench, downslope; disturbed
6	Waste rock dump	Downslope	Waste rock	Moderate	14	13	Top of secondary bench, downslope; disturbed
7	Waste rock dump	Downslope	Waste rock	Shallow	32	11	Disturbed area
8	Waste rock dump	Downslope	Waste rock	Shallow	25	15	Top of secondary bench, downslope; disturbed
9	Waste rock dump	Downslope	Waste rock	Shallow	26	20	Top of secondary bench, downslope; disturbed
10	Waste rock dump	Downslope	Waste rock	Shallow	25	18	Disturbed area
11	Waste rock dump	Crest	Waste rock	Moderate		0	Disturbed area
12	Waste rock dump	Downslope	Waste rock	Moderate	26	24	Disturbed area
13	Waste rock dump	Downslope	Waste rock	Moderate	14	21	Initiation zone is within trees.
14	Waste rock dump	Downslope	Waste rock	Shallow	17	16	Draining from the road
15	Waste rock dump	Downslope	Waste rock	Moderate	43	11	Draining from the road
16	Waste rock dump	Crest	Waste rock	Moderate		0	
17	Waste rock dump	Downslope	Waste rock	Deep	44	46	Hard to identify from air photo scale, possible gully
19	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
20	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench; area might be disturbed by machines

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
21	Waste rock dump	Downslope	Waste rock	Moderate	19	15	Disturbed area
22	Waste rock dump	Crest	Waste rock	Moderate		0	Top of secondary bench, downslope; disturbed
23	Till cover?	Crest	Till	Moderate		0	Channel banks, start of water source areas hard to located
24	Waste rock dump	Crest	Waste rock	Shallow		0	
25	Waste rock dump	Crest	Waste rock	Moderate		0	
26	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
27	Waste rock dump	Crest	Waste rock	Moderate		0	
28	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
29	Waste rock dump	Crest	Waste rock	Shallow		0	
30	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
31	Waste rock dump	Downslope	Waste rock	Shallow		0	Where slope starts to steepen off the bench
32	Waste rock dump	Downslope	Waste rock	Shallow		0	Where slope starts to steepen off the bench
33	Till cover?	Crest	Till?	Deep		0	Off the road
34	Waste rock dump	Crest	Waste rock	Deep	4	73	Possible spill over edge of bench, possible flowed from ponding, interesting area
35	Waste rock dump	Crest	Waste rock	Shallow	8	28	Top of bench deviated from other channel deviated from other channel
36	Waste rock dump	Crest	Waste rock	Moderate	4	58	Top of bench
37	Waste rock dump	Crest	Waste rock	Shallow	4	19	Top of bench deviation from main flow source
38	Waste rock dump	Crest	Waste rock	Deep	3	43	Caused by ponding? Gully starts on flat area of the bench. Near small bench, from ponding?
39	Till cover?	Crest	Till?	Moderate		0	Off ramp, water flows down ramp or from the slope above. Machine generated?
40	Waste rock dump	Crest	Waste rock	Shallow		0	Machine generated? Side of road

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
41	Waste rock dump	Crest	Waste rock	Deep		0	Side of road location difficult to find on Google
42	Waste rock dump	Crest	Waste rock	Shallow		0	Location difficult to find on Google side of the road
43	Waste rock dump	Crest	Waste rock	Shallow		0	Side of the road side of the road
44	Waste rock dump	Crest	Waste rock	Shallow	0	44	Side of the road side of the road
44	Waste rock dump	Crest	Waste rock	Shallow	0	44	Side of the road where slope starts to steepen off the bench
45	Waste rock dump	Downslope	Waste rock	Shallow		0	Where slope starts to steepen off the bench, side of the road
46	Road	Crest	Road fill/waste rock?	Moderate		0	Side of the road side of road
47	Road	Crest	Road fill/waste rock?	Shallow		0	Side of road initiates as three separate routes that combine into one.
48	Waste rock dump	Crest	Waste rock	Shallow		0	Initiates as three separate routes that combine into one. Base of bench in a debris fan; possibly derived from bench above.
49	Waste rock dump	Downslope	Waste rock	Moderate	3	14	Base of bench in a debris fan; possibly derived from bench above. Water from channel feature on bench slope
50	Till cover?	Crest	Till	Shallow		0	Small , beside road machine generated?
51	Waste rock dump	Crest	Waste rock	Moderate		0	Machine generated? Multiple small gullies on road
52	Till cover?	Crest	Till?	Moderate		0	Multiple small gullies on road top of bench
53	Waste rock dump	Crest	Waste rock?	Moderate		0	Top of bench
54	Waste rock dump	Downslope	Waste rock	Shallow	19	25	Top of bench
55	Waste rock dump	Downslope	Waste rock	Shallow	21	36	Top of bench
57	Natural	Crest	Glacial fluvial?	Moderate		0	Natural gully locations
58	Waste rock dump	Downslope	Waste rock?	Moderate	39	34	Top of bench
59	Waste rock dump	Downslope	Waste rock	Deep	41	10	Middle of slope top of bench
60	Waste rock dump	Crest	Waste rock	Moderate	34	21	Top of where slope becomes steepened. Crest
61	Road	Crest	Road fill	Shallow		0	

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
62	Road	Crest	Road fill	Shallow		0	
63	Road	Crest	Road fill	Shallow		0	
64	Road	Crest	Road fill	Shallow		0	
65	Road	Crest	Road fill	Moderate		0	
66	Road	Crest	Road fill	Shallow		0	
67	Road	Crest	Road fill	Shallow		0	
68	Waste rock dump	Crest	Waste rock	Shallow		0	Pit slope
69	Waste rock dump	Crest	Waste rock	Shallow		0	Pit slope
70	Waste rock dump	Crest	Waste rock	Shallow		0	Pit slope
71	Waste rock dump	Crest	Waste rock	Shallow		0	Pit slope
72	Waste rock dump	Crest	Waste rock	Shallow		0	Pit slope
73	Waste rock dump	Crest	Waste rock	Moderate		0	Pit slopes road bank
74	Road	Crest	Road fill	Moderate		0	
75	Waste rock dump	Crest	Waste rock	Moderate		0	
76	Waste rock dump	Downslope	Waste rock	Shallow	43	8	
77	Waste rock dump	Downslope	Waste rock	Shallow	39	27	
80	Waste rock dump	Crest	Waste rock	Shallow		0	
82	Waste rock dump	Crest	Waste rock	Shallow		0	
83	Waste rock dump	Crest	Waste rock	Shallow		0	
84	Waste rock dump	Crest	Waste rock	Shallow		0	Beside road
85	Waste rock dump	Crest	Waste rock	Moderate		0	Beside road

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
86	Waste rock dump	Crest	Waste rock?	Shallow		0	Beside road
87	Waste rock dump	Crest	Waste rock?	Moderate		0	Beside road
88	Waste rock dump	Crest	Waste rock?	Moderate		0	Beside road
89	Waste rock dump	Crest	Waste rock?	Shallow		0	Beside road
90	Waste rock dump	Crest	Waste rock?	Shallow		0	Beside road
91	Waste rock dump	Crest	Waste rock?	Shallow		0	Well developed gully, water source originates from the waste rock tear above it, which formed a gully then the water flowed over the gently sloping top of the waste rock tear then as it flowed over the edge formed second gully;
92	Waste rock dump	Crest	Waste rock?	Deep	14	22	Well developed gully, water source originates from the waste rock tear above it, which formed a gully then the water flowed over the gently sloping top of the waste rock tear then as it flowed over the edge formed second gully;
93	Waste rock dump	Downslope	Waste rock?	Moderate		0	
94	Waste rock dump	Downslope	Waste rock?	Moderate		0	Water source is from #98
95	Waste rock dump	Crest	Waste rock?	Moderate		0	Water sources is from #98 water sources is from #98
96	Waste rock dump	Crest	Waste rock?	Moderate		0	Water sources is from #98 water sources is from #98
97	Waste rock dump	Crest	Waste rock?	Moderate		0	Water sources is from #98 water source is from #100
98	Waste rock dump	Downslope	Waste rock?	Moderate		0	Water source is from #100 water source is from line 212
99	Waste rock dump	Downslope	Waste rock?	Moderate		0	Water source is from line 212
100	Waste rock dump	Crest	Waste rock?	Moderate		0	
101	Waste rock dump	Crest	Waste rock?	Shallow	27	22	Top of bench
102	Waste rock dump	Crest	Waste rock?	Shallow	35	26	Top of bench
103	Waste rock dump	Crest	Waste rock?	Moderate	32	14	Top of bench
104	Till cover?	Downslope	Till	Shallow	11	10	Bottom of steep bench slope, slope becomes more gentle. Top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
105	Till cover?	Downslope	Till	Shallow	20	10	Bottom of steep bench slope, slope becomes more gentle. Top of bench
106	Waste rock dump	Crest	Waste rock?	Deep		0	See id# 92 small
107	Waste rock dump	Crest	Waste rock?	Moderate		0	Small
108	Waste rock dump	Crest	Waste rock?	Moderate		0	Small narrow small forming gullies top of bench
109	Till cover?	Crest	Till	Shallow		0	Narrow small forming gullies top of bench
110	Till cover?	Crest	Till	Shallow		0	Narrow small forming gullies top of bench
111	Till cover?	Crest	Till	Shallow		0	Narrow small forming gullies top of bench
112	Till cover?	Crest	Till	Shallow		0	Narrow small forming gullies top of bench
113	Till cover?	Crest	Till	Shallow		0	Narrow small forming gullies top of
114	Till cover?	Crest	Till	Shallow		0	Top of bench narrow small forming gullies.
115	Till cover?	Downslope	Till	Moderate	10	9	Narrow small forming gullies.
116	Till cover?	Crest	Till	Moderate		0	Narrow small forming gullies.
117	Till cover?	Crest	Till	Moderate		0	Narrow small forming gullies. Short
118	Till cover?	Crest	Till	Shallow		0	Short narrow, short
119	Till cover?	Crest	Till	Shallow		0	Narrow, short side of the road
120	Waste rock dump	Crest	Waste rock?	Shallow		0	Narrow, short side of the road
121	Waste rock dump	Crest	Waste rock?	Shallow		0	Narrow, short side of the road
122	Waste rock dump	Crest	Waste rock?	Shallow		0	Narrow, short , side of the road water source is from line 215 or bench
123	Waste rock dump	Crest	Waste rock?	Moderate		0	Water source is from line 215 or bench short , water source 215
124	Waste rock dump	Downslope	Waste rock?	Moderate		0	Short , water source 215
125	Waste rock dump	Downslope	Waste rock?	Moderate		0	Short , water source 215 travels down into 124 and 125
126	Waste rock dump	Downslope	Waste rock?	Moderate	17	17	Travels down into 124 and 125 top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
127	Waste rock dump	Downslope	Waste rock?	Moderate	24	76	Pit wall, top of bench
128	Pit wall	Crest	Rock	Moderate		0	Next to small pit bench
129	Pit wall	Crest	Rock	Shallow		0	Located at the edge of a small bench in pit located at the edge of a small bench in pit
130	Pit wall	Crest	Rock	Moderate		0	Located at the edge of a small bench in pit bank of pit
131	Waste rock dump	Downslope	Waste rock?	Moderate	19	34	Bank of pit
132	Waste rock dump	Crest	Waste rock?	Shallow		0	Gully is continued from bench above
133	Waste rock dump	Crest	Waste rock?	Shallow		0	Gully is continued from bench above..
134	Waste rock dump	Crest	Waste rock?	Shallow		0	Gully is continued from bench above.
135	Waste rock dump	Crest	Waste rock?	Shallow		0	Gully is continued from bench above. Middle of bench
136	Waste rock dump	Downslope	Waste rock?	Shallow	43	21	Middle of bench side of the road
137	Waste rock dump	Downslope	Waste rock?	Shallow	36	30	Middle of bench side of the road
138	Waste rock dump	Downslope	Waste rock?	Deep		0	
139	Waste rock dump	Downslope	Waste rock?	Deep		0	
140	Waste rock dump	Downslope	Waste rock?	Moderate		0	
141	Waste rock dump	Downslope	Waste rock?	Shallow		0	Top of bench
142	Till cover?	Crest	Till	Shallow		0	Top of bench
143	Till cover?	Crest	Till	Shallow		0	Top of bench
144	Till cover?	Crest	Till	Shallow		0	Top of bench
145	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench
146	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench, short
147	Waste rock dump	Crest	Waste rock	Deep		0	Short , top of bench middle of small slope

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
148	Waste rock dump	Downslope	Waste rock	Shallow	20	14	Middle of small slope top of bench
149	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
150	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
151	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench caused by ponding over flow.
152	Waste rock dump	Crest	Waste rock	Deep		0	Caused by ponding over flow. Machine made? On a little ledge
153	Waste rock dump	Downslope	Waste rock	Deep	25	29	Machine made? On a little ledge top of bench
154	Waste rock dump	Downslope	Waste rock	Deep	25	28	Machine made? On a little ledge top of bench
155	Waste rock dump	Downslope	Waste rock	Deep	23	35	Machine made? On a little ledge top of bench
156	Waste rock dump	Downslope	Waste rock	Deep	20	31	Machine made? On a little ledge top of bench
157	Waste rock dump	Downslope	Waste rock	Deep	19	28	Machine made? On a little ledge top of bench
158	Waste rock dump	Downslope	Waste rock	Deep	23	28	Machine made? On a little ledge top of bench
159	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
160	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
161	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench where slope starts to steepen off the bench
162	Waste rock dump	Downslope	Waste rock	Shallow	32	10	Where slope starts to steepen off the bench
163	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
164	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
165	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
166	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
167	Waste rock	Crest	Waste rock	Moderate		0	Top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
	dump						
168	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench not the best representative point for gully graph; represents watershed graph better, water flows down ramp
169	Waste rock dump	Crest	Waste rock	Moderate	1	208	Not the best representative point for gully graph; represents watershed graph better, water flows down ramp not the best representative point for gully graph; represents watershed graph better.
170	Waste rock dump	Crest	Waste rock	Deep		0	Cuts back into bench, believe to have initiated at the cliff of the bench, similar to the other gullies in the area. Short , top of bench
171	Waste rock dump	Crest	Waste rock	Shallow		0	Short , top of bench
172	Waste rock dump	Crest	Waste rock	Shallow		0	Short , top of bench beside the road unsure if this was machine generated, 2 parts
173	Waste rock dump	Crest	Waste rock	Shallow		0	Beside the road unsure if this was machine generated, 2 parts short
174	Waste rock dump	Downslope	Waste rock?	Moderate	38	84	Short top of bench
175	Till cover?	Crest	Till	Shallow		0	Top of bench
176	Till cover?	Crest	Till	Shallow		0	Top of bench
177	Till cover?	Crest	Till	Shallow		0	Top of bench
178	Till cover?	Crest	Till	Shallow	38	6	Top of bench
179	Till cover?	Crest	Till	Shallow		0	Top of bench
180	Till cover?	Crest	Till	Shallow		0	Top of bench
181	Till cover?	Crest	Till	Shallow		0	Top of bench
182	Till cover?	Crest	Till	Shallow		0	Top of bench
183	Waste rock dump	Downslope	Waste rock/rock?	Moderate	32	25	From small bench
184	Waste rock dump	Downslope	Waste rock/rock?	Moderate	40	22	
185	Waste rock dump	Downslope	Waste rock/rock?	Moderate	64	7	
186	Till cover?	Crest	Till	Shallow		0	Top of bench
187	Till cover?	Crest	Till	Shallow		0	Top of bench
188	Till cover?	Crest	Till	Shallow		0	Top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
189	Till cover?	Crest	Till	Shallow		0	Top of bench
190	Till cover?	Crest	Till	Shallow		0	Top of bench
191	Till cover?	Crest	Till	Moderate		0	Top of bench
192	Till cover?	Crest	Till	Shallow		0	Top of bench
193	Till cover?	Crest	Till	Moderate		0	Top of bench
194	Till cover?	Crest	Till	Shallow		0	Top of bench
195	Till cover?	Crest	Till	Moderate		0	Top of bench
196	Till cover?	Crest	Till	Shallow		0	
197	Till cover?	Downslope	Till	Moderate	30	32	
198	Till cover?	Downslope	Till	Shallow	23	28	
199	Till cover?	Downslope	Till	Moderate	19	20	
200	Till cover?	Downslope	Till	Moderate	34	10	
201	Till cover?	Crest	Till	Moderate	21	10	Combined with 200. Combined with 200.
202	Waste rock dump	Crest	Waste rock	Moderate		0	Narrow gully
203	Waste rock dump	Crest	Waste rock	Moderate		0	Narrow gully. Water source unknown, top of little ledge on pit cliffs
204	Waste rock dump	Crest	Waste rock?	Deep		0	Water source unknown, top of little ledge on pit cliffs water source unknown.
205	Waste rock dump	Crest	Waste rock?	Moderate		0	Water source unknown. Top of bench
206	Till cover?	Crest	Till	Deep		0	Top of bench beside road
207	Waste rock dump	Crest	Waste rock?	Shallow		0	Beside road
208	Waste rock dump	Crest	Waste rock?	Shallow		0	Beside road top of small bench.
209	Waste rock dump	Crest	Waste rock	Moderate		0	Top of small bench, combines together
210	Till cover?	Crest	Till	Shallow		0	Combines together combines together
211	Till cover?	Crest	Till	Shallow		0	Combines together combines together

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
212	Till cover?	Crest	Till	Shallow		0	Combines together top of bench
213	Waste rock dump	Crest	Waste rock?	Moderate		0	Top of bench
214	Waste rock dump	Crest	Waste rock?	Deep		0	Top of bench
215	Waste rock dump	Crest	Waste rock?	Deep		0	Top of bench
216	Waste rock dump	Crest	Waste rock?	Deep		0	Top of bench
217	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
218	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench, road bank
219	Waste rock dump	Crest	Waste rock	Shallow		0	Road bank slope of pit
220	Waste rock dump	Crest	Waste rock	Moderate		0	Slope of pit slope of pit, initially a debris flow, will probably progress into a gully.
221	Waste rock dump	Crest	Waste rock	Deep		0	Slope of pit, initially a debris flow, will probably progress into a gully. Short
222	Waste rock dump	Crest	Waste rock	Shallow		0	Short
223	Waste rock dump	Crest	Waste rock	Shallow		0	
224	Waste rock dump	Crest	Waste rock	Shallow		0	Short length
225	Waste rock dump	Crest	Waste rock	Moderate		0	Short very small
226	Waste rock dump	Crest	Waste rock	Moderate		0	Very small
227	Waste rock dump	Crest	Waste rock	Moderate		0	Very small
228	Waste rock dump	Crest	Waste rock	Moderate		0	Very small, road bank
229	Till cover?	Crest	Till?	Moderate		0	Road bank road bank
230	Waste rock dump	Crest	Waste rock	Moderate		0	Road bank narrow long gully
231	Waste rock dump	Crest	Waste rock	Shallow		0	Long narrow gully

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
232	Waste rock dump	Crest	Waste rock	Shallow		0	Long narrow gully
233	Waste rock dump	Crest	Waste rock	Shallow		0	Narrow long gully narrow long gully, questionable feature (is the slope retrogressing?)
234	Waste rock dump	Crest	Waste rock	Shallow		0	Narrow long gully, questionable feature (is the slope retrogressing?) Narrow long gully, machine made?
235	Waste rock dump	Crest	Waste rock	Shallow		0	Narrow long gully, machine made?
236	Waste rock dump	Crest	Waste rock	Shallow		0	Narrow long gully, machine made?
237	Waste rock dump	Crest	Waste rock	Shallow		0	Narrow long gully, machine made?
238	Waste rock dump	Downslope	Waste rock/rock?	Moderate		0	
239	Waste rock dump	Downslope	Waste rock/rock?	Moderate	59	8	Top of bench
240	Waste rock dump	Crest	Waste rock/rock?	Moderate	42	18	Top of bench off small bench
241	Waste rock dump	Downslope	Waste rock/rock?	Moderate	0	5	
242	Waste rock dump	Crest	Waste rock/rock?	Moderate	13	61	Combines with 506
243	Waste rock dump	Downslope	Waste rock/rock?	Moderate	31	117	Combines with 506
244	Till cover?	Downslope	Till	Moderate	0	10	Flows downslope and into a creek
245	Waste rock dump	Crest	Waste rock	Moderate		0	Flows downslope and into a creek just below of small vegetated bench
246	Waste rock dump	Downslope	Waste rock	Moderate	54	4	Just below of small vegetated bench top of small vegetated bench
247	Waste rock dump	Downslope	Waste rock	Shallow	16	22	Top of bench
248	Till cover?	Crest	Till?	Deep		0	Side of the road side of the road
249	Till cover?	Crest	Till?	Deep		0	Side of the road flows into tailings, gully continues in tailings
250	Till cover?	Crest	Till?	Deep		0	Flows into tailings, gully continues in tailings combines with 252, initiates at base of the slope under the road.
251	Till cover?	Crest	Till?	Deep		0	Combines with 252, initiates at base of the slope under the road. Combines with 251; initiates at the edge of the road.

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
252	Till cover?	Crest	Till?	Deep		0	Combines with 251; initiates at the edge of the road.
253	Waste rock dump	Downslope	Waste rock	Shallow	19	31	Top of bench
254	Till cover?	Crest	Till?	Deep		0	Combines with 253, 255, and 256 in the tailings. Initiates on the road combines with 253, 254, and 256 in the tailings. Initiates on the road
255	Till cover?	Crest	Till?	Deep		0	Combines with 253, 254, and 256 in the tailings. Initiates on the road combines with 253, 254, and 255 in the tailings. Initiates on the road
256	Till cover?	Crest	Till?	Deep		0	Combines with 253, 254, and 255 in the tailings. Initiates on the road initiates from the road, drainage coming down the slope develops smaller gullies within the tailings.
257	Till cover?	Crest	Till?	Deep		0	Initiates from the road, drainage coming down the slope develops smaller gullies within the tailings. Cut through the road and has reached the other side.
258	Till cover?	Crest	Till?	Deep	16	60	Cut through the road and has reached the other side. Cut through the road and has reached the other side.
259	Till cover?	Crest	Till?	Moderate		0	Cutes through the road very small , beside road
260	Waste rock dump	Crest	Waste rock	Moderate		0	Very small , beside road
261	Waste rock dump	Crest	Waste rock	Moderate		0	Small , beside road water from line 214
262	Waste rock dump	Downslope	Waste rock?	Moderate		0	Water from line 214 small , beside road
263	Waste rock dump	Crest	Waste rock	Shallow		0	Small , beside road beside the road unsure if this was machine generated, 2 parts
264	Waste rock dump	Crest	Waste rock	Shallow		0	Beside the road unsure if this was machine generated, 2 parts small , beside road, spill over?
265	Waste rock dump	Crest	Waste rock	Moderate		0	Small , beside road, spill over?
266	Waste rock dump	Crest	Waste rock	Moderate	0	6	Small, beside road
267	Road	Downslope	Road fill/waste rock?	Shallow	36	76	Base of slope, enters into a creek. Side of the road
268	Road	Crest	Road fill/waste rock?	Moderate		0	Small , beside road water from line 214
269	Waste rock dump	Downslope	Waste rock?	Moderate		0	Water from line 214 beside road, wider scarp than others.
270	Road	Crest	Road fill/waste rock?	Deep		0	Beside road, wider scarp than others. Small , beside road
271	Road	Crest	Road fill/waste rock?	Shallow		0	Small, beside road
272	Road	Crest	Road fill/waste rock?	Moderate		0	Side of the road small , beside road

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
273	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
274	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
275	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
276	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
277	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
278	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
279	Road	Crest	Road fill/waste rock?	Moderate		0	Small , beside road clear cut, suggested water source
280	Waste rock dump	Downslope	Waste rock	Shallow	6	87	Clear cut, suggested water source clear cut, suggested water source
281	Waste rock dump	Crest	Waste rock	Shallow	6	67	Clear cut, suggested water source estimated water source
282	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
283	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
284	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
285	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
286	Road	Crest	Road fill/waste rock?	Shallow		0	Small, beside road
287	Road	Crest	Road fill/waste rock?	Shallow		0	Small, beside road
288	Road	Crest	Road fill/waste rock?	Moderate		0	Small, beside road
289	Road	Crest	Road fill/waste rock?	Deep		0	Small , beside road small , beside road, over spill?
290	Road	Crest	Road fill/waste rock?	Deep		0	Small , beside road, over spill? Small , beside road
291	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road
292	Road	Crest	Road fill/waste rock?	Deep	24	11	Small, beside road
293	Road	Crest	Road fill/waste rock?	Deep	6	6	Small, beside road
294	Road	Crest	Road fill/waste rock?	Deep		0	Small , beside road small , beside road, splits into 2
295	Road	Crest	Road fill/waste rock?	Deep		0	Small , beside road, splits into 2 small , beside road
296	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road
297	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
298	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road
299	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road
300	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road
301	Road	Crest	Road fill/waste rock?	Deep		0	Small, beside road
302	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
303	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
304	Road	Crest	Road fill/Waste rock?	Deep		0	Small , beside road small , made?
305	Road	Crest	Road fill/Waste rock?	Deep		0	Small , beside road, machine made?
306	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
307	Road	Crest	Road fill/Waste rock?	Deep		0	Small , beside road more traditional gully formation, located in road fill material at a river crossing.
308	Road	Crest	Road fill/Waste rock?	Deep		0	Small , beside road, more traditional gully formation, located in road fill material at a river crossing. Small , beside road
309	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
310	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
311	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
312	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
313	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
314	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
315	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
316	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
317	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
318	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
319	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
320	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
321	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
322	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
323	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
324	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
325	Road	Crest	Road fill/Waste rock?	Moderate		0	Small , beside road small , beside road, unsure if this was machine generated, width of channel is pretty uniform.
326	Road	Crest	Road fill/Waste rock?	Moderate		0	Small , beside road, unsure if this was machine generated, width of channel is pretty uniform. Small , beside road
328	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
329	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
330	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
331	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
332	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
333	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
334	Road	Crest	Road fill/Waste rock?	Moderate		0	Small, beside road
335	Till cover?	Downslope	Till?	Shallow	0	5	Small, beside road
336	Road	Crest	Road fill	Moderate		0	Small, beside road
337	Road	Crest	Road fill	Moderate		0	Small, beside road
338	Road	Crest	Road fill	Deep		0	Small, beside road
339	Road	Crest	Road fill	Deep		0	Small, beside road
340	Road	Crest	Road fill	Shallow		0	Small, beside road
341	Till cover?	Crest	Till	Shallow		0	Side of road
342	Road	Crest	Road fill	Deep		0	Side of the road side of the road
343	Road	Crest	Road fill	Moderate		0	Side of the road top of bench
344	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
345	Till cover?	Crest	Till	Shallow		0	
346	Till cover?	Downslope	Till	Shallow	34	20	
347	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
348	Till cover?	Crest	Till	Shallow		0	
349	Till cover?	Crest	Till	Shallow		0	Side of road
350	Waste rock dump	Crest	Waste rock	Shallow		0	Side of road side of road
351	Waste rock dump	Crest	Waste rock	Deep		0	Side of road beside road
352	Waste rock dump	Crest	Waste rock	Moderate		0	Beside road estimated, draining from the road, path is not visible
353	Waste rock dump	Crest	Waste rock	Shallow		0	Estimated, draining from the road, path is not visible top of bench
354	Till cover?	Crest	Till	Moderate		0	Top of bench
355	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench two combine into one half way downslope
356	Waste rock dump	Crest	Waste rock	Moderate		0	Two combine into one half way downslope, top of bench
357	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
358	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
359	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench
360	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench top of small vegetated bench
361	Waste rock dump	Crest	Waste rock	Moderate		0	Top of small vegetated bench
362	Waste rock dump	Crest	Waste rock	Moderate		0	Top of small vegetated bench
363	Waste rock dump	Crest	Waste rock	Deep		0	
364	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench
365	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
366	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
367	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
368	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
369	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
370	Waste rock dump	Crest	Waste rock	Deep		0	Edge of road of the developed area, not sure what is going on here?
371	Waste rock dump	Crest	Waste rock	Deep		0	Edge of road of the developed area, not sure what is going on here?
372	Waste rock dump	Crest	Waste rock	Shallow		0	
373	Waste rock dump	Crest	Waste rock	Shallow		0	
374	Waste rock dump	Crest	Waste rock	Shallow		0	
375	Waste rock dump	Crest	Waste rock	Shallow		0	Possibly a spill over top of bench
376	Waste rock dump	Crest	Waste rock	Moderate		0	Possibly a spill over top of bench
377	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench channel banks, might start further up slope
378	Till cover?	Crest	Till	Moderate		0	Channel banks, might start further up slope channel banks, start of water source areas hard to located
379	Till cover?	Crest	Till	Moderate		0	Channel banks, start of water source areas hard to located channel banks, start of water source areas hard to located
380	Till cover?	Crest	Till	Moderate		0	Channel banks, start of water source areas hard to located
381	Waste rock dump	Crest	Waste rock	Moderate		0	Beside road
382	Waste rock dump	Crest	Waste rock	Deep		0	Beside road top of bench
383	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench not visible on ortho.
384	Waste rock dump	Crest	Waste rock	Shallow		0	Not visible on ortho. Off the side of the road heading into the pit. Water is coming from the road
387	Waste rock dump	Crest	Waste rock	Moderate		0	Off the side of the road heading into the pit. Water is coming from the road off the side of the road heading into the pit, water comes from the road
388	Waste rock dump	Crest	Waste rock	Moderate		0	Off the side of the road heading into the pit, water comes from the road
389	Waste rock dump	Crest	Waste rock	Moderate		0	

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
390	Waste rock dump	Crest	Waste rock	Moderate		0	
391	Waste rock dump	Downslope	Waste rock	Moderate	38	17	Crest at the end of a bench ramp
392	Waste rock dump	Downslope	Waste rock	Deep	0	4	Water source is probably influenced by surrounding gullies. Base of gullies developed at the crest
394	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench
395	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench
396	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
397	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
398	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
399	Waste rock dump	Crest	Waste rock	Deep		0	Top of bench
400	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench off the side of the road off the side of the pit, water comes from the road.
401	Waste rock dump	Crest	Waste rock	Moderate		0	Off the side of the road off the side of the pit, water comes from the road. D in cliff
407	Waste rock dump	Crest	Waste rock	Moderate	26	14	D in cliff base of cliff above.
413	Waste rock dump	Downslope	Waste rock	Shallow	37	53	Closer to the top at berm close to the top of the bench
414	Waste rock dump	Downslope	Waste rock	Shallow	36	47	Close to the top of the slope starts at the berm close to the top of the bench
415	Waste rock dump	Crest		Moderate		0	In cleared area. Close to the top of the slope
416	Waste rock dump	Downslope	Waste rock	Shallow	35	82	Close to the top of the slope
417	Road	Crest	Waste rock/road fill?	Moderate		0	Appear man made, multiple shallow gullies on bank.
418	Waste rock dump	Crest	Waste rock	Shallow		0	Multiple shallow gullies on bank. Close to the bottom
419	Waste rock dump	Downslope	Waste rock	Shallow	35	53	Close to the bottom top of bench slope
420	Waste rock dump	Downslope	Waste rock	Shallow	46	16	Close to the top

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
421	Waste rock dump	Downslope	Waste rock	Shallow	37	46	Towards the bottom
422	Waste rock dump	Crest	Waste rock	Shallow		0	Combines with other channels combines with other channels
423	Waste rock dump	Crest	Waste rock	Shallow		0	Combines with other channels middle of the slope
424	Waste rock dump	Downslope	Waste rock	Shallow	37	44	Middle of the slope
425	Waste rock dump	Downslope	Waste rock	Shallow	26	18	Middle-crest
426	Waste rock dump	Crest	Waste rock	Shallow	49	14	Towards the top of the slope
427	Waste rock dump	Crest	Waste rock	Shallow		0	Appear man made
428	Road	Crest	Waste rock/road fill?	Shallow		0	Appears man made
429	Road	Crest	Waste rock/road fill?	Moderate		0	Appears man made
430	Road	Crest	Waste rock/road fill?	Moderate		0	Appears man made, side of road
431	Road	Crest	Road fill/waste rock?	Moderate		0	Side of road small , gully?
432	Road	Crest	Road fill/waste rock?	Moderate		0	Small , gully? Flows down the road
433	Road	Crest	Road fill/waste rock?	Moderate		0	Flows down the road edge of road located in the middle of the whole cleared slope
455	Waste rock dump					0	Edge of road located in the middle of the whole cleared slope machine developed or gully?
456	Till cover?	Downslope	Till?	Deep	11	17	Machine developed or gully? Water flows downslope above and road (ramp?) Way
457	Waste rock dump	Crest		Deep		0	Side of the road in the middle of the main slope
460	Till cover?	Crest	Till?	Shallow		0	Side of the road in the middle of the main slope middle of main slope
461	Till cover?	Downslope	Till?	Shallow	5	35	Middle of main slope
462	Till cover?	Crest	Till?	Shallow		0	Side of road, second tear of the slope
463	Till cover?	Downslope	Till?	Shallow	11	79	
464	Till cover?	Downslope	Till?	Shallow	4	30	Clear cut, machine generated?
465	Till cover?	Downslope	Till?	Shallow		0	Clear cut, machine generated? Clear cut, machine generated?
466	Till cover?	Downslope	Till?	Shallow	5	33	Clear cut, machine generated?

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
467	Till cover?	Downslope	Till?	Shallow	4	31	Clear cut, machine generated?
468	Till cover?	Downslope	Till?	Shallow	4	42	Clear cut, machine generated?
469	Till cover?	Downslope	Till?	Shallow	3	14	Clear cut, machine generated?
470	Till cover?	Downslope	Till?	Shallow	2	11	Clear cut, machine generated?
471	Till cover?	Downslope	Till?	Shallow	8	12	Clear cut, machine generated?
472	Natural	Crest	Glacial fluvial?	Deep	9	356	Natural gully locations
473	Natural	Crest	Glacial fluvial?	Deep	11	252	Natural gully locations
474	Natural	Downslope	Glacial fluvial?	Deep	11	270	Natural gully locations
475	Waste rock dump	Crest		Shallow		0	
476	Unknown?	Crest	Glacial fluvial?	Deep		0	Top of bench, area coved with vegetation
477	Till cover?	Crest	Till?	Deep		0	Top of bench, area coved with vegetation bank of tailings pond, off road
479	Road	Downslope	Waste rock/road fill?	Moderate	38	5	From road at tailings pond
480	Road	Downslope	Waste rock/road fill?	Deep	0	9	From road at tailings pond
481	Till cover?	Downslope	Till?	Moderate	8	15	On road water flowing down road
483	Till cover?	Crest	Till?	Deep		0	Flat cleared area entering into vegetated area within cleared areas.
484	Till cover?	Downslope	Till?	Moderate	9	13	Entering into vegetated area within cleared areas.
485	Till cover?	Downslope	Till?	Deep	14	10	Machine made?, in cleared area.
486	Till cover?	Crest	Till?	Moderate		0	Flows into tailings pond beside road
487	Till cover?	Crest	Till?	Deep		0	Beside road
488	Till cover?	Crest	Till?	Deep		0	Beside road in tailings
489	Till cover?	Downslope	Till?	Deep	14	12	In tailings
490	Till cover?	Crest	Till?	Deep	15	58	Cut through road crest from road
492	Till cover?	Crest	Till?	Deep		0	On the road side of road
493	Waste rock dump	Crest	Waste rock	Deep		0	Side of road top of incline; gulling? Or machine generated?
494	Waste rock dump	Crest	Waste rock	Moderate	1	57	Top of incline; gulling? Or machine generated? Flowing from road

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
495	Waste rock dump	Crest	Waste rock	Deep		0	Man made? On road near buildings. Close to top
496	Waste rock dump	Downslope	Waste rock	Moderate	32	6	Close to top tope of slope, near buildings
497	Waste rock dump	Crest	Waste rock	Moderate	6	20	Top of bench
498	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench middle-top of bench slope
499	Waste rock dump	Downslope	Waste rock	Moderate	33	13	Middle-top of bench slope top of bench
500	Waste rock dump	Downslope	Waste rock	Moderate	19	6	Top of bench
501	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
502	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
503	Waste rock dump	Crest	Waste rock/rock?	Moderate		0	Top of bench. Combines with another gully
504	Waste rock dump	Downslope	Waste rock/rock?	Moderate	32	63	Combines with another gully top of small ledge
506	Till cover?	Downslope	Till	Deep	39	16	Side of road
508	Till cover?	Crest	Till	Deep		0	Channel bank
509	Till cover?	Crest	Till	Deep		0	Channel bank
511	Till cover?	Downslope	Till	Moderate	0	8	Channel bank top of channel's bank
513	Till cover?	Crest	Till	Moderate		0	Channel bank
514	Till cover?	Crest	Till	Moderate		0	Channel bank
515	Till cover?	Crest	Till	Moderate		0	Channel bank
516	Till cover?	Crest	Till	Moderate		0	Channel bank top of channel bank, might go into the trees.
517	Till cover?	Crest	Till	Deep		0	Top of channel bank, might go into the trees. Side of the road.
518	Waste rock dump	Crest	Waste rock	Moderate		0	Side of the road. On the side of the road.
519	Waste rock dump	Crest	Waste rock	Moderate		0	On the side of the road. Top of bench.
520	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench. Location difficult to find on ortho image

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
521	Waste rock dump	Downslope	Waste rock	Shallow	43	16	Location difficult to find on ortho image path not visible, estimated location
522	Waste rock dump	Downslope	Waste rock	Shallow	49	13	Hard to find on ortho image
523	Waste rock dump	Downslope	Waste rock	Shallow	25	14	Hard to see in ortho image
524	Waste rock dump	Downslope	Waste rock	Shallow	11	16	Close to the top of the slope beside road on the top of a bench.
525	Waste rock dump	Downslope	Waste rock	Shallow	8	12	Close to the top of bench. Off the road on top of a bench.
526	Waste rock dump	Downslope	Waste rock	Shallow	6	13	Close to the top of the bench. Side of the a bench road
527	Waste rock dump	Downslope	Waste rock	Moderate	20	10	Close to the top of the slope crest on the top of a bench.
528	Waste rock dump	Downslope	Waste rock	Moderate	40	11	Near the top of the slope. Top of bench
529	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench
530	Waste rock dump	Crest	Waste rock	Shallow		0	Multiple shallow gullies appear on the Google earth image; not visible on the ortho.
534	Waste rock dump	Downslope	Waste rock	Shallow	46	11	Multiple shallow gullies appear on the Google earth image; not visible on the ortho. Top of bench slope
536	Waste rock dump	Crest	Waste rock	Shallow		0	On bench's edge middle of slope
546	Waste rock dump	Downslope	Waste rock	Moderate	41	76	Middle of slope top of bench
547	Waste rock dump	Downslope	Waste rock	Shallow	41	20	Middle of slope from the berm beside the bench ramp
548	Waste rock dump	Downslope	Waste rock	Shallow	33	20	Middle of slope from the berm beside the bench ramp
549	Waste rock dump	Downslope	Waste rock	Shallow	41	29	Middle of the slope from the berm beside the bench ramp
550	Waste rock dump	Downslope	Waste rock	Shallow	26	20	Middle of the slope from the berm beside the bench ramp
551	Waste rock dump	Downslope	Waste rock	Deep	0	5	Close to top of the slope from the road
552	Waste rock dump	Crest	Waste rock	Deep		0	Beside of bench ramp
553	Road	Crest	Waste rock/road fill?	Shallow		0	Top of bench

Id	Geographical location	Location of head of gully	Material	Depth of cut	Slope angle, %	Planview distance (m)	Comments
554	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
555	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench
556	Waste rock dump	Crest	Waste rock	Moderate		0	Top of bench middle of slope
557	Waste rock dump	Downslope	Waste rock	Moderate	41	16	Middle of slope top of bench
558	Waste rock dump	Crest	Waste rock	Shallow		0	Top of bench, it appears to diverts into more channels downslope. Small , beside road
560	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
561	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
562	Unknown?	Crest	Glacial fluvial?	Moderate		0	Small size, beside road
563	Road	Crest	Road fill/Waste rock?	Deep		0	Small, beside road
564	Road	Crest	Road fill/Waste rock?	Moderate		0	Side of the road small , beside road
572	Road	Crest	Road fill/Waste rock?	Deep		0	Small , beside road natural gully locations
573	Natural	Crest	Glacial fluvial?	Moderate		0	Natural gully locations
574	Waste rock dump	Downslope	Waste rock	Shallow	27	34	Top of bench
575	Natural	Downslope	Glacial fluvial?	Deep	28	41	Natural gully locations
576	Natural	Downslope	Glacial fluvial?	Moderate	11	58	Natural gully locations
577	Natural	Crest	Glacial fluvial?	Deep	62	34	Natural gully locations
578	Natural	Downslope	Glacial fluvial?	Moderate	13	78	Natural gully locations
579	Natural	Crest	Glacial fluvial?	Deep	26	46	Natural gully locations
580	Natural	Crest	Glacial fluvial?	Deep		0	Natural gully locations
581	Natural	Crest	Glacial fluvial?	Deep		0	Natural gully locations

Appendix C. Photojournal

Plate C-1. Natural area and seep at base of angle of repose waste rock dump at Faro Mine. Note segregation and erosion of finer grained angle-of-repose waste rock slope in background and apron of coarse waste rock at base of slope that provides good sediment catchment in the foreground. Landform designs should seek to protect natural areas within the disturbed footprints as mature "islands" that offer seed sources and some habitat.

Plate C-2. A small slump in on the resloped till capped Vangorda waste rock dump. Note scarp of larger slump in upper right hand corner of the photograph. Note also the near lack of vegetation on this resloped dump even after many years of recolonization and the formation of small rills and accumulation of erosional debris in small fans at base of slope. The geotechnical stability of all slopes is an important design element.

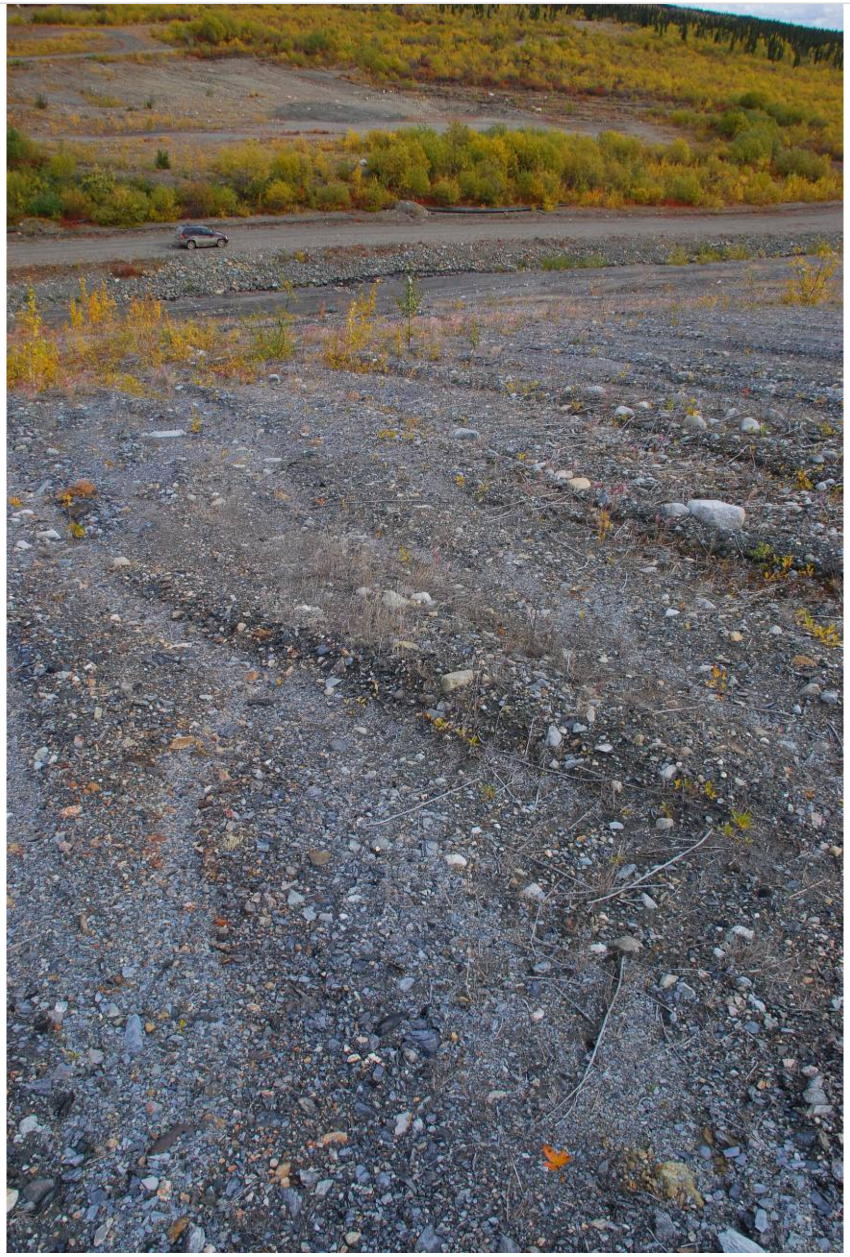	
Plate C-3. Rilling on north dump of resloped overburden dump. Erosion rates are much faster where slopes exceed a threshold of about 20 degrees (3H:1V).	**Plate C-4.** A small gully, partially stabilized on the north slope of the overburden dump. This is some of the densest vegetation growth on the dumps, yet is still sparse.

	
Plate C-5. Roads can be converted into channels to drain the dump areas	**Plate C-6.** The grainsize of the rock at repose plays an important role in erosion.

	
Plate C-7. Vegetation preferentially growing in the wet are at the toe of a small dump slope	**Plate C-8.** Good performance of a diverted creek above the pit.

	
Plate C-9. Natural downslope drainage on rocky ground in the region.	**Plate C-10.** Natural swale south of the mine.

	
Plate C-11. Gullying on repose slopes due to water flowing over the crest	**Plate C-12.** The construction of the dumps lends itself to considerable diversity. Efforts should be maintained to work with the existing diversity where practical.

Plate C-13. Some of these slopes should likely be left at repose to avoid damaging vegetation at the toe.

Plate C-14. There are a wide variety of rock types in the dumps. These will need to be mapped as a first step of landform grading design.

Plate C-15. Coarser rock segregates and self-armour the base of some slopes.

Plate C-16. Much of the natural drainage is on bedrock, soils are generally very thin and poorly developed in the region.

	
Plate C-17. Water ponding on this bench is causing a large gully.	**Plate C-18.** Sparse vegetation on the resloped overburden dump. Vegetation is not dense enough to provide erosion protection for the slope.

BGC

	
Plate C-19. Rilling on the overburden slope above the creek.	**Plate C-20.** Rilling on the overburden slope above the creek.

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Plate C-21. Instrumented plateau with microtopography. The microtopography likely enhances percolation and should be used only on plateaus for which percolation is not a concern.

Plate C-22. Instrumented plateau with microtopography. The microtopography likely enhances percolation and should be used only on plateaus for which percolation is not a concern.

	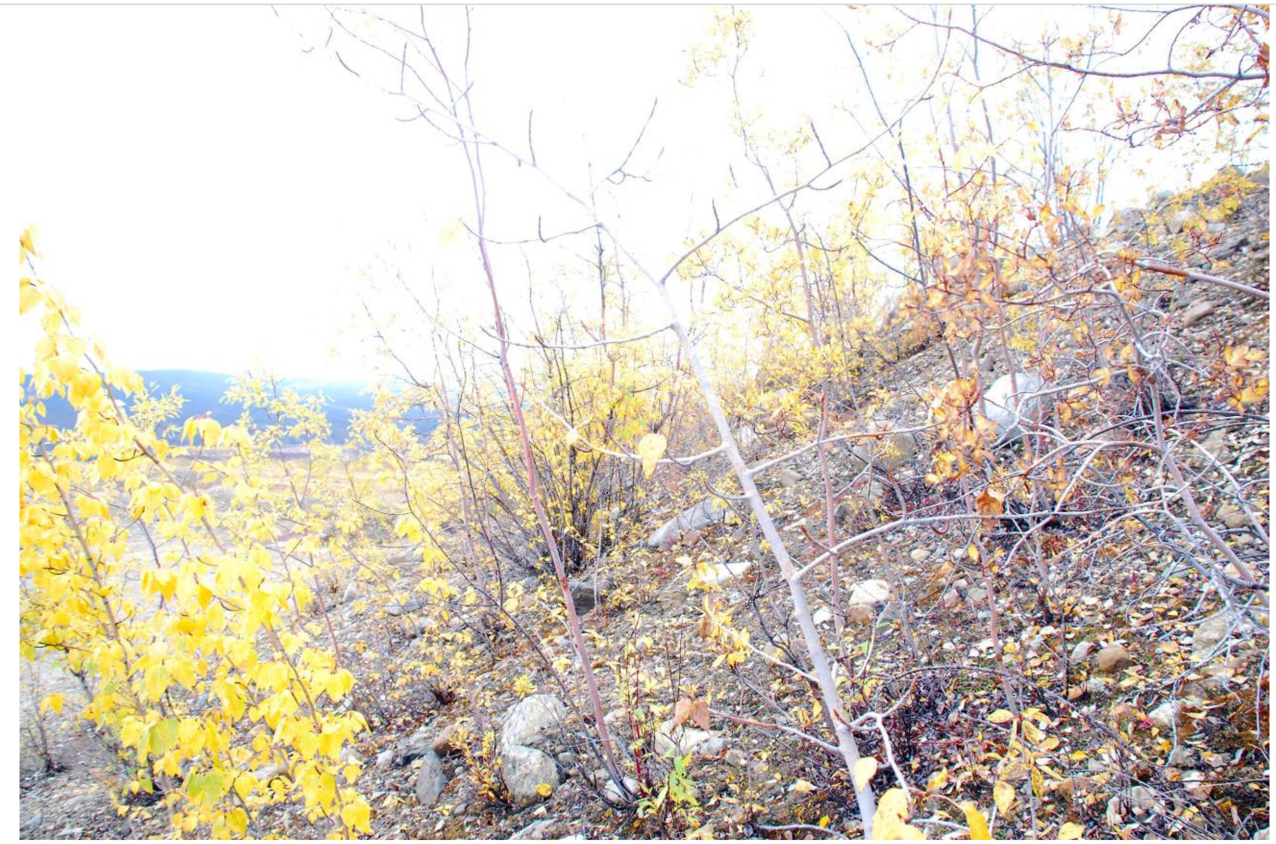
Plate C-23. Vegetation invading the finer grained materials on a repose slope.	**Plate C-24.** An area of good vegetation growth, good invasion, and fairly good erosion protection. This area deserves a joint investigation by the engineers and soils/vegetation people to determine why it is performing so well.

Plate C-25. An area of natural ground at the toe of a dump showing very good performance.

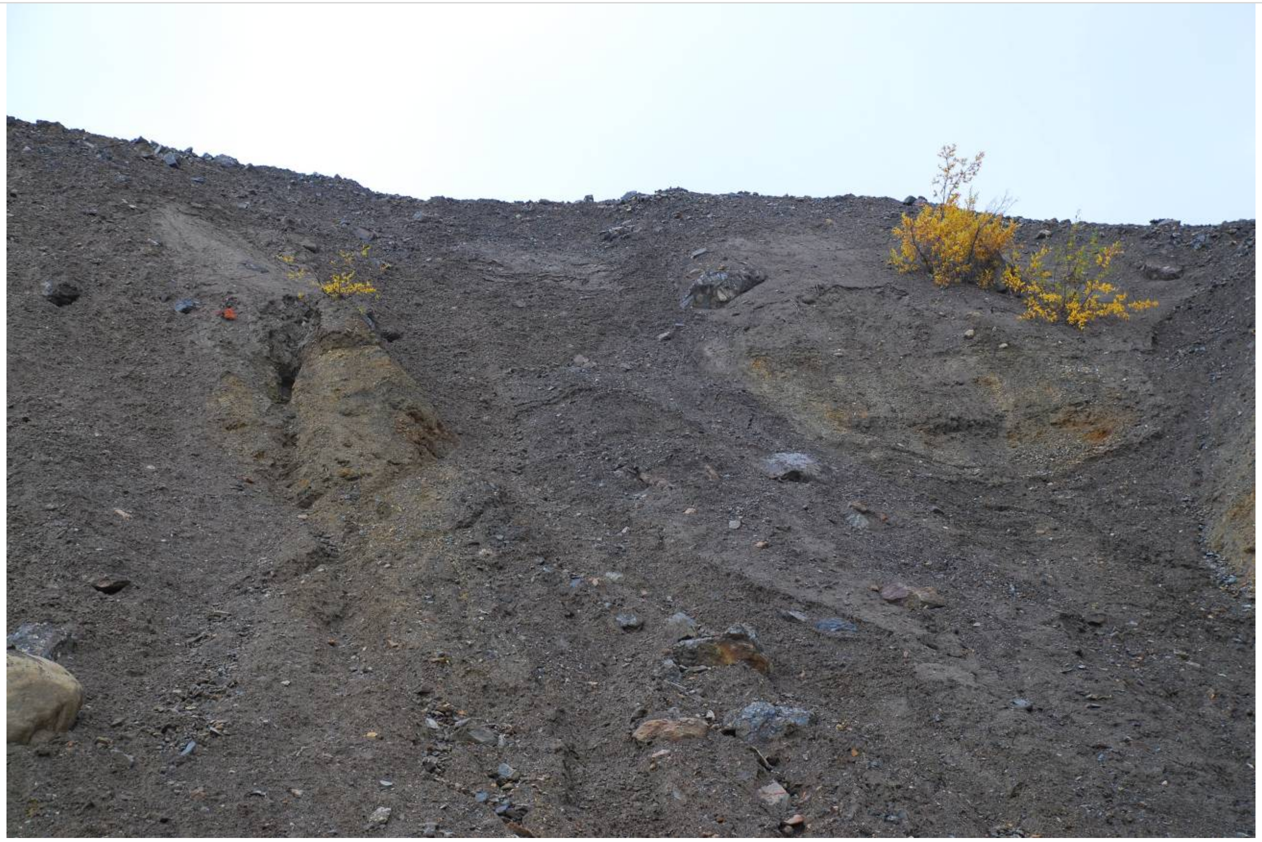

Plate C-26. Slip-off failure scars in fine grained angle of repose dump faces.

Plate C-27. Slip-off failure scars in fine grained angle of repose dump faces.

	
Plate C-28. Dense vegetation on a small area of one dump.	**Plate C-29.** Sparse vegetation on shallow glaciofluvial slope (old borrow pit).

Plate C-30. Blowout style slumping at the toe of a slope caused by groundwater seepage.

Plate C-31 Constructed creek showing good performance.

Appendix D. Field database of gully observations

This appendix provides a database of field measurement of gullied and ungullied slopes. The sample is not large enough for a statistical analysis.

Table D-1: Database of field measurements regarding dump slope performance

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
1	585307	6914015	3982	Phyllite	0	No	S	83	37	75	1.3	0.4	0,1	0				 2529	

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
2	50 m end of 1			Phyllite/ Gneiss	50	No	S	33	36	73	1.4	1.5	0.1	1				 2532	
3	585371	6914165	4111	dark metamorp hic rock	30	No	E	*11*	34	67	1.5	0.4	0.1	0					
4	585511	6914211	4146	dark meta-morphic rock	10	No	S	*160*	36	73	1.4	1	*5*	0					

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
																		2533	
5					60	No		*120*	36	73	1.4	0.4	0.1	10					vegetation: mix cotton wood/aspen willow
6	585688	814346	435	Soil: silty sandy gravels, trace clay 1-2%	90	Yes	S	*108*	32	62	1.6	no data	no data	1		0.4		 2539	Entire slope riddled with rills, 3m spacing and coalescing, reason for rilling perhaps subsurface flow.
7	595674	6914434	4108	Phyllite some glaciofluvial quartzite clasts	30	Yes		*112*	36	73	1.4	0.3	0.005	5	6	0.5	1.2		Vegetation: willows, cotton wood, spruce, 100.5m

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
8	585544	6914622		sandy gravel igneous intrusive rocks, some glaciofluvial	20	Yes	SE	42	34	67	1.5	0.6	0.05-0.1	1	5	0.4	1.5	 2543	
9	585624	6914711	4185	Sandy gravels	10	Yes	S	20	32	62	1.6	0.4	0.1	30	6	0.3	7	 2544	

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
10	585396	6914881	4232	Silty, sandy gravels, glaciofluvial	10	No		15	27	51	2.0	1	0.1	50				 2545	
11	585298	6914853	4215		20	Yes	E	38	35	70	1.4	0.6	0.1	5		0.7	3		broad gully lobe at bottom

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
12	585156	6914221	3925	silty sandy gravel trace clay	60	Yes	NE	62	36	73	1.4			10	6	0.4	1	 2559,  2560	

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
13	585180	6914298	4026	unknown, slightly cohesive	90	Yes		75	35	70	1.4			0		0.3	0.4	 2561	
14	584849	6914215	3812	silty sand, trace clay	60	No		58	39	81	1.2	1	0.2	0					
15	584849	6914281		yellowish silty sand, Phyllite	90	Yes		21	43	93	1.1	0.5	0.1	0	10	0.2	0.5		
16	584666	6914419	3774	Phyllite	80	Yes		62	38	78	1.3	0.6	0.1	0	10	0.5	0.5		slope appears to be a landslide 1.5 m thick
17	5932032	6903555		Phyllite , silty platy gravels	0	No		40	34	67	1.5	1	0.1	0					
18				till cover	50, lower 90	Yes		84	20	36	2.7	0.2	0.1	*50*	4	0.2	0.3		
19	593168	6902776	3732		90	Yes	E	88	24	45	2.2	0.2	0.05	1	5	0.05	0.2		

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
20	593683	6902448	3684		50	Yes	S	105	23	42	2.4	1	0.1	2	6	1.2	4	 2587	
21	593951	6903810	3879		50	Yes	S	33	24	45	2.2	0.8	1.6	1	10	0.15	1	 2589	

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
22	592597	6904321	4022		50	No	N	26	20	36	2.7	0.3	0.05	0				 2590	coordinates taken at bottom
23	584190	6913413		Phyllite cover	20	No		72	37	75	1.3	0.5	0.2	0				 2591	

ID	Easting m	Northing m	Elev (ft)	Material	% fines	Gully?	Slope aspect	Slope length (m)	Slope angle α (deg)	Slope angle α (%)	Slope angle α (xH:1V)	Max clast diameter (m)	Min clast diameter (m)	% Veg cover	Gully length, m	Gully depth, m	Gully width, m	Photo #	Comments
24	583849	6913699	3899	veneer of Phyllite cover, yellow-fine grained clasts, silty sand, matrix cohesive	30	Yes	S	100	35	70	1.4	1.2	0.1	0	10	0.4	3	 2592  , 2593 (w)	

Table D-2 GPS Measurement Points

#	Easting	Northing
701	453,429	6,832,203
702	582,529	6,914,467
703	585,277	6,914,065
704	585,587	6,914,416
705	585,435	6,914,909
706	585,067	6,914,259
707	584,942	6,914,166
708	584,846	6,914,212
709	587,071	6,899,917
710	586,994	6,902,778
711	593,902	6,902,817
712	593,952	6,903,510
UTM Zone 8		