



# Tailings Storage Facility and Snow Gulch Reservoir – Early Stage FMEA Workshop

Prepared for

Donlin Gold



Prepared by



SRK Consulting (Canada) Inc.  
181202.010  
March 2015

# Tailings Storage Facility and Snow Gulch Reservoir – Early Stage FMEA Workshop

March 2015

## Prepared for

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# 1 Introduction

Donlin Gold LLC (Donlin Gold) is proposing to construct a tailings storage facility (TSF) and fresh water reservoir (Snow Gulch) as part of the development of the Donlin Gold Project. The project is currently undergoing environmental review and permitting. Potential environmental impacts and project alternatives are being evaluated in an Environmental Impact Statement under development by the US Army Corps of Engineers (USACE). The draft EIS is to be available for public review in fall 2015. Concurrently, Donlin Gold is developing applications for project permits and approvals.

Donlin Gold submitted initial application materials for the TSF Dam, the Snow Gulch Reservoir Dam, and five other project-related dams to the Alaska Department of Natural Resources (ADNR) Dam Safety Program. ADNR Dam Safety and Construction Unit commented on the initial application materials and noted that a technical risk assessment in the form of a Failure Modes and Effects Analysis (FMEA) will ultimately be required for dams having a Class 1 hazard potential (as defined in state regulations), which may include both the TSF Dam and the Snow Gulch Reservoir Dam.

Donlin Gold subsequently commissioned SRK Consulting to facilitate an early stage FMEA for these two dams. The early stage FMEA will inform subsequent stages of site investigation and design. It may also provide inputs to the EIS and dam permitting processes, but a later stage FMEA may be required to fully meet the expectations of the ADNR Dam Safety Program.

This report summarizes the early stage FMEA workshop objectives, participants, methodology, and outcomes.

# 2 Workshop Objectives

The overall objective of the early stage FMEA workshop was to identify and evaluate risks associated with the TSF and the Snow Gulch Reservoir, with a view to ensuring that these risks are addressed in the current and future stages of investigation and design.

# 3 Workshop Participants and Methodology

SRK hosted and facilitated the early stage FMEA workshop at its offices in Vancouver, BC, on December 2 and 3, 2014.

The two-day workshop included participation by representatives from Donlin Gold, the Alaska Dam Safety Unit, AECOM (formerly URS, consultants for the USACE), the landowners (the Kuskokwim Corporation and Calista Corporation), and engineers involved in the design of the TSF and Snow Gulch Reservoir dams (BGC Engineering). The participants are listed in Table 1.

The workshop was facilitated by Daryl Hockley, PE, a civil engineer with over 25 years of experience, including facilitation of FMEAs for tailings facilities at other mines in Alaska, northern Canada and overseas.

**Table 1: FMEA Workshop Participants**

| Name                      | Affiliation                  | E-mail                                                                         |
|---------------------------|------------------------------|--------------------------------------------------------------------------------|
| Nick Enos                 | Donlin Gold                  | <a href="mailto:renos@donlingold.com">renos@donlingold.com</a>                 |
| James Fueg                | Donlin Gold                  | <a href="mailto:jfueg@donlingold.com">jfueg@donlingold.com</a>                 |
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| Clint Logue               | BGC                          | <a href="mailto:clogue@bgcengineering.ca">clogue@bgcengineering.ca</a>         |
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| Bob Bachus                | Geosyntec                    | <a href="mailto:rbachus@geosyntec.com">rbachus@geosyntec.com</a>               |
| Dan Johnson               | Tetra Tech                   | <a href="mailto:dan.johnson@tetrattech.com">dan.johnson@tetrattech.com</a>     |
| Jeff Bruno                | State of Alaska – DNR/OPMP   | <a href="mailto:jeff.bruno@alaska.gov">jeff.bruno@alaska.gov</a>               |
| Charlie Cobb              | State of Alaska – Dam Safety | <a href="mailto:charles.cobb@alaska.gov">charles.cobb@alaska.gov</a>           |
| Pete McGee (by phone)     | State of Alaska – DEC        | <a href="mailto:william.mcgee@alaska.gov">william.mcgee@alaska.gov</a>         |
| Carolyn Curley (by phone) | State of Alaska – DNR        | <a href="mailto:carolyn.curley@alaska.gov">carolyn.curley@alaska.gov</a>       |
| Jeff Foley                | Calista                      | <a href="mailto:jfoley@calistacorp.com">jfoley@calistacorp.com</a>             |
| Rachel Klein              | TKC                          | <a href="mailto:rlk@kuskokwim.com">rlk@kuskokwim.com</a>                       |
| Nancy Darigo              | URS                          | <a href="mailto:nancy.darigo@urs.com">nancy.darigo@urs.com</a>                 |
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| Maritz Rykaart            | SRK                          | <a href="mailto:mrykaart@srk.com">mrykaart@srk.com</a>                         |
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A summary of the workshop objectives, scope and approach was distributed to all participants as part of an information package issued prior to the workshop. At the beginning of the workshop, the FMEA approach was reviewed with the group. It was noted that the FMEA process uses very coarse categories of “likelihood” that do not attempt to distinguish between very low probability levels. Participants agreed that, because the dams are still in the design process, the focus should be on identifying as many risks as possible rather than precisely quantifying each one. The slides used by the facilitator to introduce the session and review the approach are included in Appendix A1.

BGC staff then presented information on the TSF dam, investigations to date, and the state of design as presented in the Feasibility Study Update 2. In a later session, BGC provided a similar presentation on the Snow Gulch Reservoir. It was noted that the Snow Gulch Reservoir Dam is in a much earlier stage of design, and that other variants are still under consideration. The BGC presentations are also included in Appendix A1, and selected drawings in Appendix A2.

After the introductory presentation on each facility, participants were asked to create lists of risks related to its construction and operation period, its closure and post-closure period, and a hypothetical premature closure. Groups of participants then reviewed each list and identified key risks for discussion and evaluation. The selection of risks to carry through further discussion was left up to the participant groups, with only the guidance that examples should be selected to cover the range of risks.

The process of evaluating each risk began with a single participant describing how the risk would lead to a failure scenario. The facilitator assisted in reducing the scenario to a short sentence that was entered into a risk register used for recording the workshop results, and then evaluating the scenario using a set of risk rating tools:

- A consequence-severity matrix that rates the severity of different types of adverse consequence;
- A likelihood chart used to rate the probability of the scenario and negative consequences being realized;
- A confidence level table used to express the level of certainty in the consequence and likelihood ratings; and
- A risk matrix used to summarize consequence severity and likelihood in terms of risk level.

The risk rating tools that were used in the FMEA workshop are provided in Appendix B.

In total, over 80 scenarios were assessed. For each scenario, discussion continued until a consensus was reached. The final position of the scenario on the consequence-severity, likelihood and confidence scales was then recorded in the risk register. After the first few risk scenarios had been analyzed, it became evident that there was a close correlation between scenario types and the most important consequence categories. Subsequent evaluations focused on only those categories that generated the highest severity ratings.

## 4 FMEA Results and Limitations

The risk register for the TSF is provided in Appendix C. The risk register for the Snow Gulch Reservoir is presented in Appendix D. Each appendix also includes summary risk matrices showing where each scenario plotted in terms of likelihood and consequence severity.

It is worth noting again that the process used in the workshop was intended to capture as many risks as possible, rather than precisely characterizing each one. Therefore the results shown in the risk registers should be treated with appropriate caution. Specifically, there are certain to be other failure modes or at least ones that differ in some detail from those assessed, and many of the likelihood or severity designations could arguably be shifted to an adjacent box. However, despite those weaknesses, the results do accurately reflect what an informed and reasonable group of people, representing many perspectives, found to be the significant risks associated with the current designs for these two facilities.

Furthermore, it bears repeating that the early stage FMEA reviewed designs presented in the project documents available at the time, and many of the risks will be addressed or modified in subsequent stages of design. This was particularly the case for Snow Gulch Reservoir, for which the available documents represented an even earlier stage of design.

## 5 Closure

At the close of the workshop, SRK prepared a first draft of this report for review, initially by Donlin Gold and subsequently by all other participants. Review comments were reviewed and addressed in the final version.

It was also noted that participants in the workshop will use the results in different ways. The project team, for example, might use them to assign priorities to future investigation and design efforts. Other participants might use the results to inform their contributions to the project environmental review. SRK has deliberately avoided trying to summarize the results from any particular perspective, preferring instead to let the results produced by the entire group stand on their own merits. SRK cautions against using any of the scenarios or risk ratings without considering the full context and limitations of the workshop process.

This report, Tailings Storage Facility and Snow Gulch Reservoir – Early Stage FMEA Workshop, was prepared by:

**SRK Consulting (Canada) Inc.**

ORIGINAL SIGNED BY

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SRK Consulting (Canada) Inc. has prepared this document for Donlin Gold. Any use or decisions by which a third party makes of this document are the responsibility of such third parties. In no circumstance does SRK accept any consequential liability arising from commercial decisions or actions resulting from the use of this report by a third party.

The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

## Appendix A1 – PowerPoint Presentations

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## Workshop Overview

- Introductions & Objectives
- Assessment Methodology
- Tailings Storage Facility
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis
- Snow Gulch Freshwater Reservoir
  - Design Presentation
  - Failure Mode Brainstorming
  - Failure Mode & Effects Analysis



## Introductions & Objectives

- Introductions



## Introductions & Objectives

- Objective
  - Identify and evaluate all significant risks associated with the TSF Dam and Snow Gulch Reservoir Dam with a view to ensuring that these risks are addressed in current and future design ...



## Assessment Methodology

- ISO 31000 "Risk – effect of uncertainty on objectives"
  1. An effect is a deviation from the expected – positive and/or negative
  2. Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and processes)
  3. Risk is often characterized by reference to potential events (2.19) and consequences, or a combination of these.
  4. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstance) and the associated likelihood of occurrence.
  5. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood



## Assessment Methodology

- Risk assessment – "Overall process of risk identification, risk analysis and risk evaluation"
  - Risk identification – process of finding, recognizing and describing risks
  - Risk analysis – process to comprehend the nature of risk and determine the level of risk
  - Risk evaluation – process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable



## Assessment Methodology

- Consequence-Severity methods
  - Failure Mode and Effect Analysis (FMEA)
  - Failure Mode Effect and Criticality Assessment (FMECA)
- Common characteristics
  - Assesses the likelihood of a risk coming to fruition, and the severity of its consequences
  - Considers consequences in many categories



## Consequence Severity Scale

| Consequence Categories         | Severity Descriptors                                                                           |                                                                                                              |                                                                                                     |                                                                                                         |                                                                                                |
|--------------------------------|------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
|                                | Very Low                                                                                       | Minor                                                                                                        | Moderate                                                                                            | Major                                                                                                   | Critical                                                                                       |
| 1. Environmental Impact        | No impact.                                                                                     | Minor localized or short-term impacts.                                                                       | Significant impact on valued ecosystem component.                                                   | Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.      | Serious long-term impairment of ecosystem function.                                            |
| 2. Traditional Use             | Some disturbance but no impact to traditional land use.                                        | Minor or perceived impact to traditional land use.                                                           | Some mitigable impact to traditional land use.                                                      | Significant temporary impact to traditional land use.                                                   | Significant permanent impact on traditional land use.                                          |
| 3. Regulatory Impact           | Informal advice from a regulatory agency.                                                      | Technical/Administrative non-compliance with permit, approval or regulatory requirement.                     | Breach of regulations, permits or approvals (e.g. 1 day violation of discharge limits).             | Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). | Major breach of regulation – willful violation.                                                |
| 4. Consequence Costs           | < \$100,000                                                                                    | \$100,000 - \$1 Million                                                                                      | \$1 - \$5 Million                                                                                   | \$5 - \$25 Million                                                                                      | > \$25 Million                                                                                 |
| 5. Community/ Media Reputation | Local concerns, but no local complaints or adverse press coverage.                             | Public concern restricted to local complaints or local adverse press coverage.                               | Heightened concern by local community, criticism by NGOs or adverse local regional media attention. | Significant adverse national public, NGO or media attention.                                            | Serious public outcry/demonstrations or adverse international NGO attention or media coverage. |
| 6. Human Health and Safety     | Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment. | Objective but reversible disability/impairment and/or medical treatment. Injuries requiring hospitalization. | Moderate irreversible disability or impairment to one or more people.                               | Single fatality and/or severe irreversible disability or impairment to one or more people.              | Multiple fatalities.                                                                           |



## Likelihood Scale

| Likelihood     | Frequency Descriptor 1                         | Frequency Descriptor 2                               | Probability of occurrence over twenty years |
|----------------|------------------------------------------------|------------------------------------------------------|---------------------------------------------|
| Almost Certain | Happens often                                  | High frequency (more than once every 5 years)        | 98%                                         |
| Likely         | Could easily happen                            | Event does occur, has a history, once every 15 years | 75%                                         |
| Possible       | Could happen and has happened elsewhere        | Occurs once every 40 years                           | 40%                                         |
| Unlikely       | Hasn't happened yet but could                  | Occurs once every 200 years                          | 10%                                         |
| Very Unlikely  | Conceivable, but only in extreme circumstances | Occurs once every 1000 years                         | 2%                                          |



## Risk Matrix

| Likelihood     | Consequence Severity |                 |                 |                 |                 |
|----------------|----------------------|-----------------|-----------------|-----------------|-----------------|
|                | Very Low             | Minor           | Moderate        | Major           | Critical        |
| Almost Certain | Moderate             | Moderately High | High            | Very High       | Very High       |
| Likely         | Moderate             | Moderate        | Moderately High | High            | Very High       |
| Possible       | Low                  | Moderate        | Moderately High | High            | High            |
| Unlikely       | Low                  | Low             | Moderate        | Moderately High | Moderately High |
| Very Unlikely  | Low                  | Low             | Low             | Moderate        | Moderately High |



## Confidence Level

| Confidence Level | Description                                                                                                                           |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Low              | Do not have confidence in the estimate or ability to control during operations.                                                       |
| Medium           | Have some confidence in the estimate or ability to control during operations; conceptual level analyses.                              |
| High             | Have lots of confidence in the estimate or ability to control during operations; detailed analyses following a high standard of care. |



## Assessment Methodology

- Brainstorming



## Assessment Methodology

- Brainstorming
- Scenarios
  1. One individual proposes a **scenario**
    - Consequence severity
    - Likelihood
    - Risk matrix
  2. We debate any of the above steps and if necessary change the rating
  3. The we record the result on the risk register



## Assessment Methodology

- Risk register for TSF
  - Construction & Operation
  - Planned Closure and Post-Closure
  - Premature Closure
- Risk register for Snow Gulch FWRD
  - Construction & Operation
  - Planned Closure and Post-Closure
  - Premature Closure



## Next Steps

- SRK will prepare a Draft FMEA Report
  - Introduction
  - Limitations
  - Workshop methodology
  - Risk register
- Review by participants
  - Comments appended to report
- Revised FMEA Report
- Further stages of design and review →



## Questions?



## Workshop Overview

- Introductions & Objectives ✓
- Assessment Methodology ✓
- Tailings Storage Facility
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## Next Steps

- Draft report
  - Introduction
  - Limitations
  - Workshop methodology
  - Risk register
- Review by participants
  - Comments appended to report
- FMEA Report
- Further stages of design and review →



## Feedback Comments

21 of XX



Thank you!



## Project Overview Presentation

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## Donlin Gold Project





BGC Engineering Inc.

### Donlin Gold FMEA Workshop

**Project Summary**  
December 2-3, 2014

Alaska, USA

## Donlin Gold Project





### Project Location



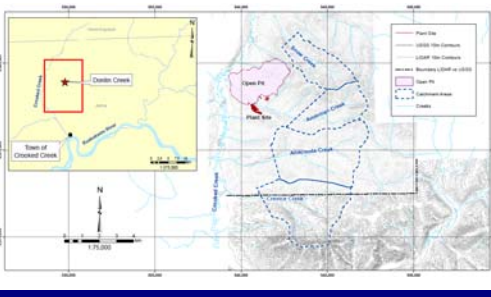
Alaska, USA

## Donlin Gold Project

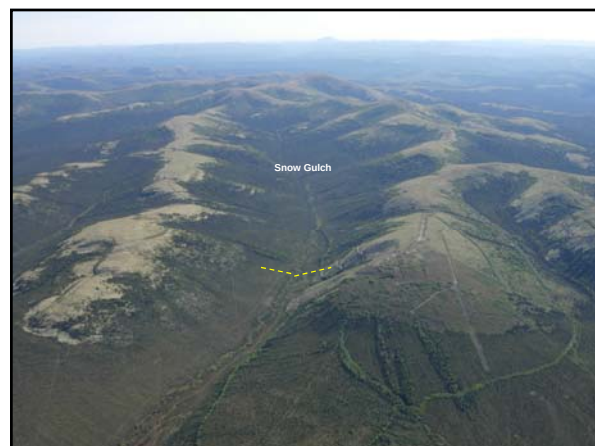


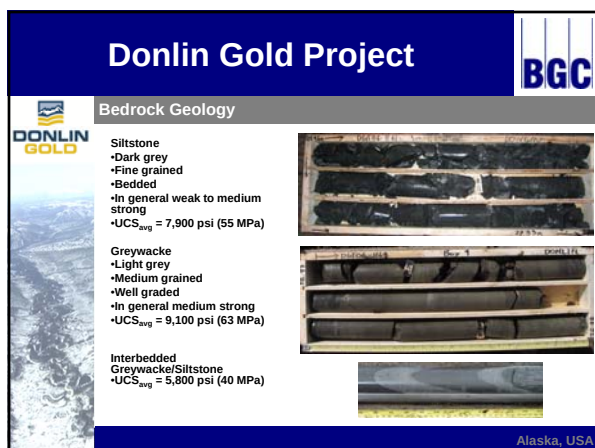
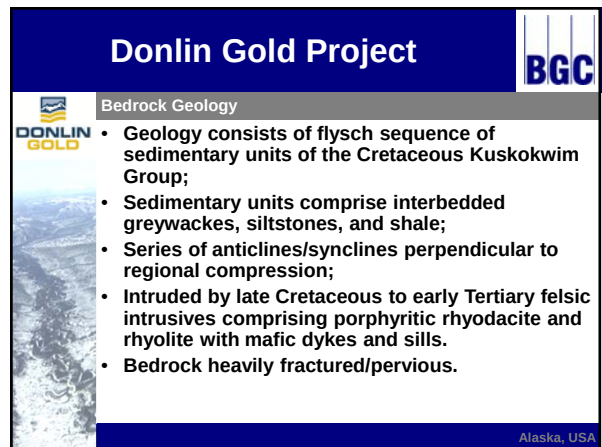
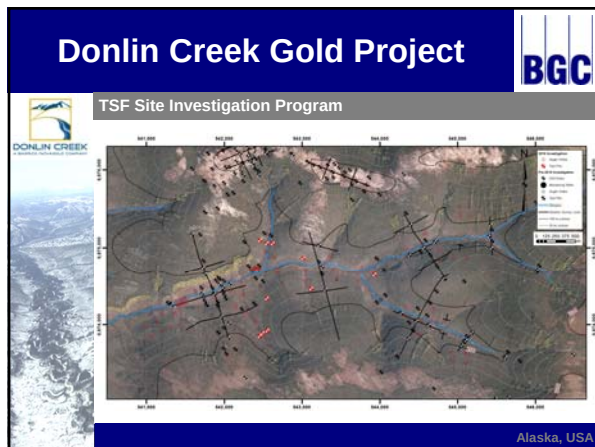
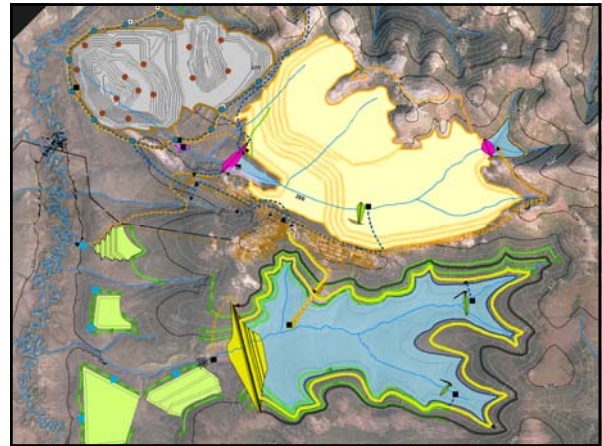
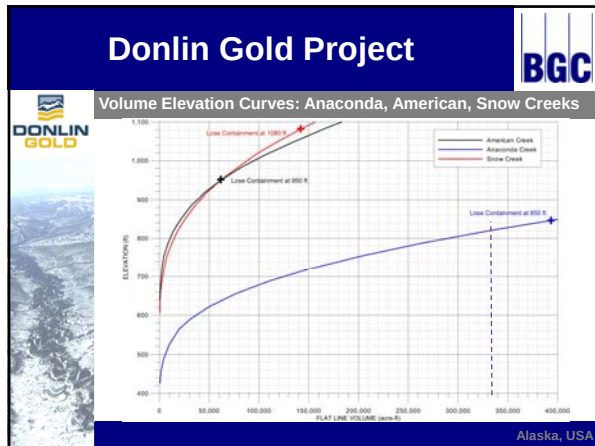


### Site Layout



Alaska, USA





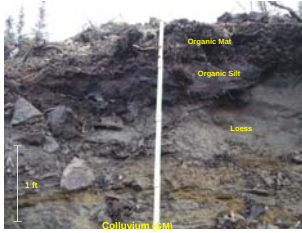
## Donlin Gold Project



### Surficial Geology

Surficial geology comprises colluvial, fluvial (Holocene and Tertiary), and aeolian deposits with overlying organic deposits;

- Approx. 20 ft thick in valley bottom
- Approx. 7 ft thick at higher elevations




Alaska, USA

## Donlin Gold Project



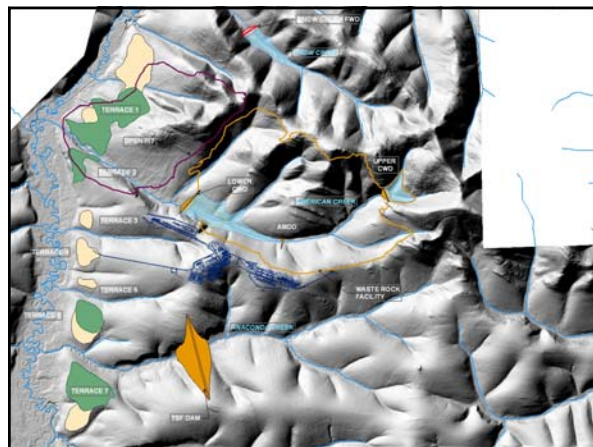
### Permafrost

Site is located in the sporadic discontinuous permafrost zone:

- Where present, typically confined to lower portions of valley, in overburden with organic cover, and is warm (31.6 °F)
- Thickness generally less than 20 ft, can be up to 105 ft
- Low ground ice content
  - typically <1 to 2% segregated ice, with discrete zones of 5 to 10%




Alaska, USA





BGC TSF and Snow Gulch Presentation

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## Donlin Gold Project

BGC Engineering Inc.





### Donlin Gold FMEA Workshop

Tailings Storage Facility and Snow Gulch  
December 2-3, 2014

Alaska, USA

## Donlin Gold Project

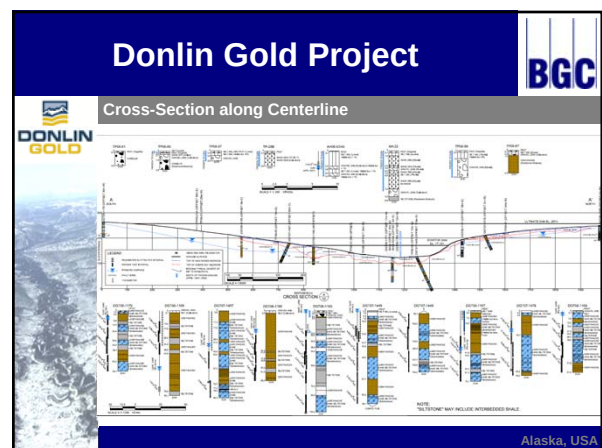
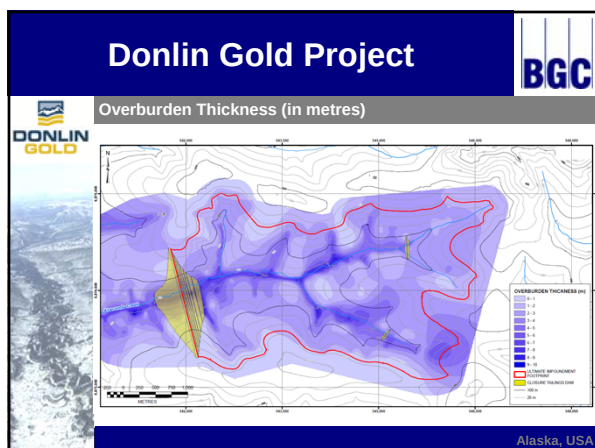
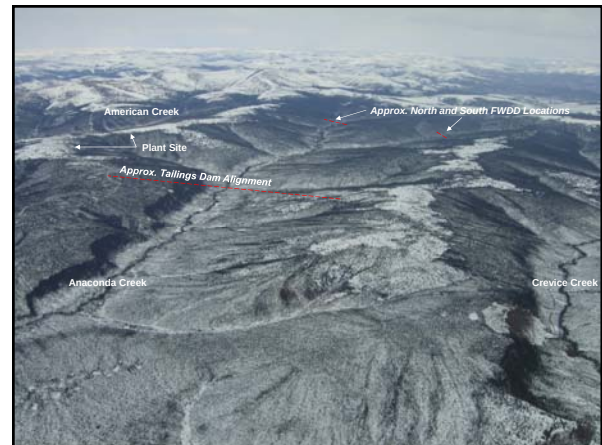
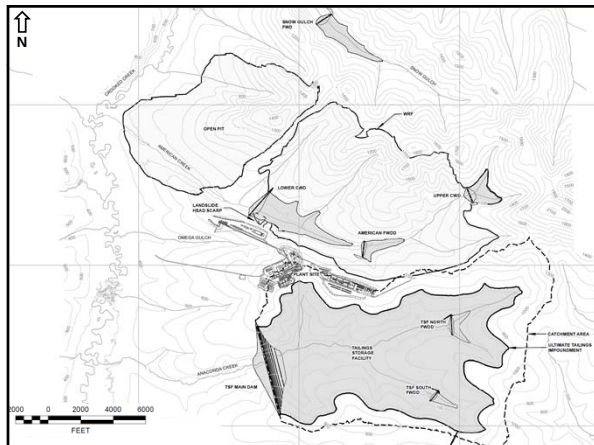




### Dams - Summary

- Seven dams under DNR jurisdiction :
  - Lower Contact Water Dam
  - Upper Contact Water Dam
  - American Freshwater Diversion Dam
  - Snow Gulch Freshwater Dam
  - North and South TSF Freshwater Dams
  - Anaconda TSF Dam
- Class I Dams:
  - Snow Gulch Freshwater Dam
  - Anaconda TSF Dam

Alaska, USA



## Donlin Gold Project

BGC

### Dam Design Criteria

- Meet or exceed requirements in:
  - Alaska DNR Dam Safety Guidelines
  - USBR, USACE, FEMA, ICOLD, CDA
- Design Earthquake
  - MCE
    - Deterministic MCE – 0.36g from Magnitude 7.8
    - Probabilistic MCE – 0.44g from 10,000-year event

Alaska, USA

## Donlin Gold Project

BGC

### Dam Design Criteria

- Static Safety Factors
  - Steady state = 1.5
  - End of Construction = 1.3
  - Temporary excavation and rapid drawdown = 1.3
- Seismic Deformation
  - Max. deformation of half filter thickness = 5'

Alaska, USA

## Donlin Gold Project

BGC

### Tailings Storage Facility Design – Storage Capacity

- During Operations, store LOM tailings plus:
  - Starter - 1 yr Tailings (12,400 ac-ft)
  - Ultimate Tailings (334,000 ac-ft)
  - IDF = 200-yr Snowmelt + 24-hr PMP (6,700 ac-ft)
  - Ultimate Operating Pond (24,000 ac-ft)
  - Freeboard (above maximum stored flood)
- Freeboard calculated as the maximum of:
  - 3 ft above maximum beach elevation;
  - Wave run-up and wind set-up above maximum stored flood elevation; or
  - Maximum seismic settlement at upstream face of dam plus 3 ft above operating pond

Alaska, USA

## Donlin Gold Project

BGC

### Tailings Storage Facility Design – Storage Capacity

- Wave action on stored flood dominates freeboard
  - Ultimate dam crest : 841 ft
- Closure spillway to pass PMF
  - Sill elevation: 834 ft
  - Details to be worked out at next stage of design as timing of closure cover and pond size has a significant impact on the layout of the spillway.
- Dam downstream face flattened to 3H:1V at closure.
- Saddle elevation at 850 ft on south east side of Anaconda.

Alaska, USA

## Donlin Gold Project

BGC

### TSF Operating Pond

Alaska, USA

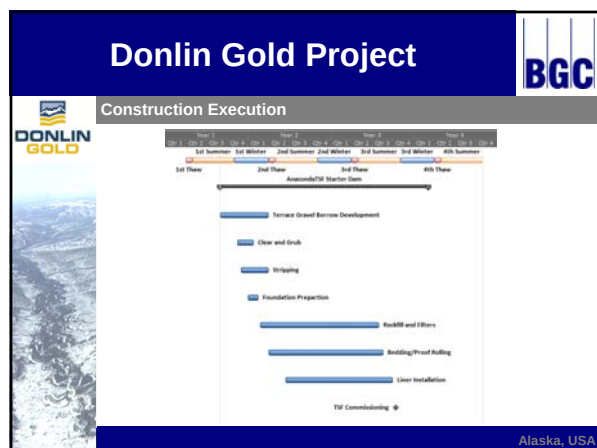
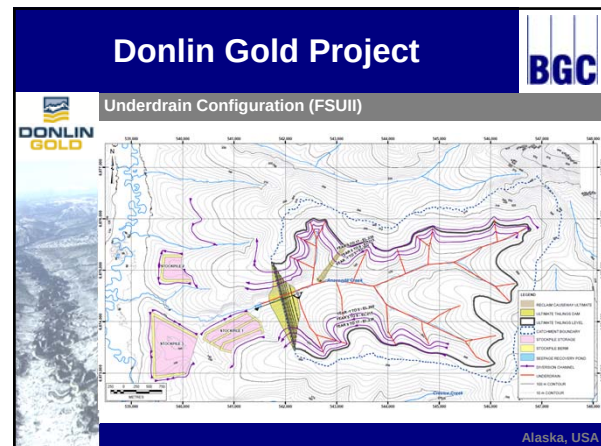
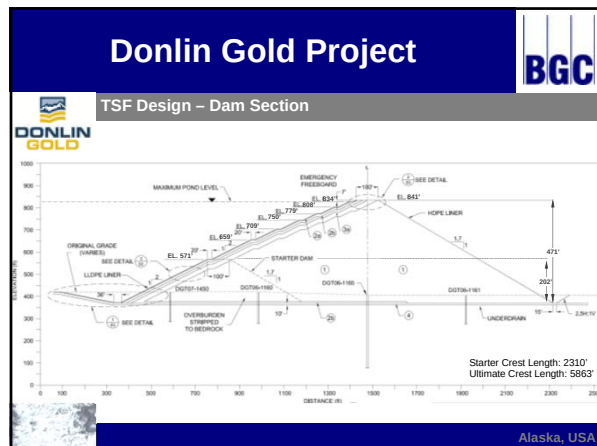
## Donlin Gold Project

BGC

### Tailings Dam Design – Summary

| Name     | Height /Crest El. | Length   | Dam Volume (Mcuyds) | Storage Requirements (acre-ft) |                |       |         | Outlet                                           |
|----------|-------------------|----------|---------------------|--------------------------------|----------------|-------|---------|--------------------------------------------------|
|          |                   |          |                     | Tailings                       | Operating Pond | Flood | Total   |                                                  |
| Starter  | 202 ft/<br>571 ft | 2,310 ft | 3.7                 | 12,400                         | 1,700          | 6,700 | 20,800  | Reclaim barge pumps                              |
| Ultimate | 471 ft/<br>841 ft | 5,863 ft | 43.1                | 334,000                        | 16,200         | 6,700 | 356,900 | Emergency spillway; PMP capacity. Reclaim pumps. |

Alaska, USA



## Donlin Gold Project

**BGC**

Construction Execution - continued

- **Summer 1** - May to October
  - Continue construction of dams
  - Continue/complete diversion ditches.
- **Winter 2**
  - Clearing, grubbing, stripping of impoundment and reclaim causeway
  - Complete underdrain
  - Liner bedding placed and compacted
  - Complete seepage recovery system
  - Continue/complete construction of dams and diversion ditches.

Alaska, USA

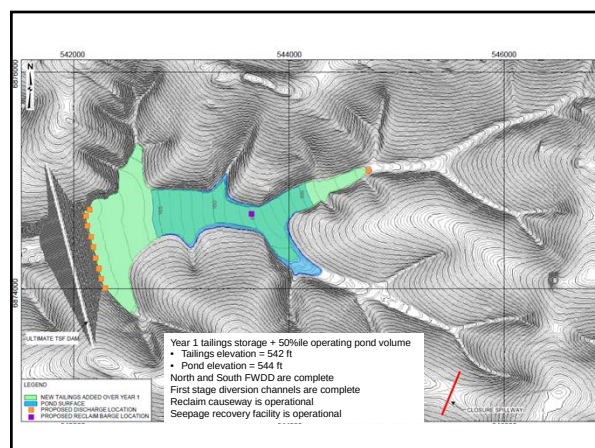
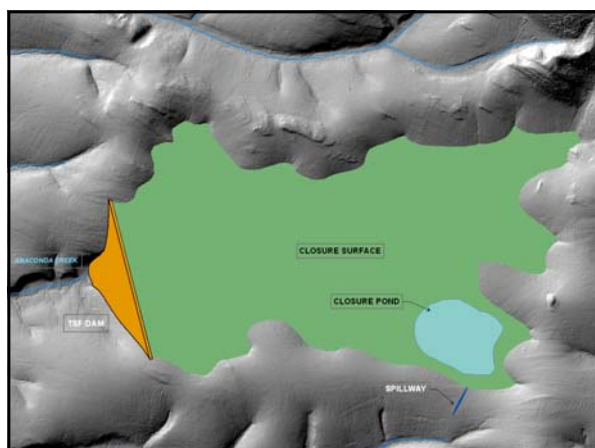
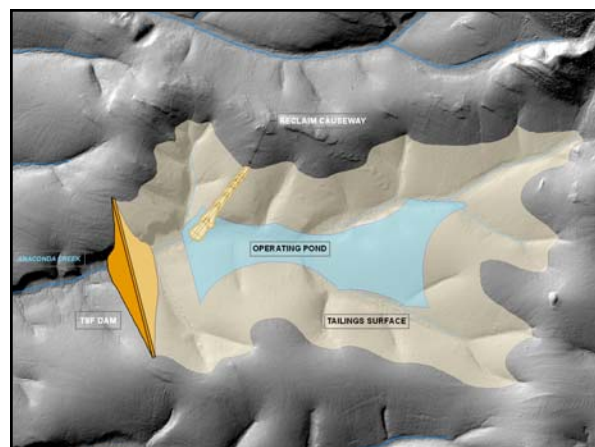
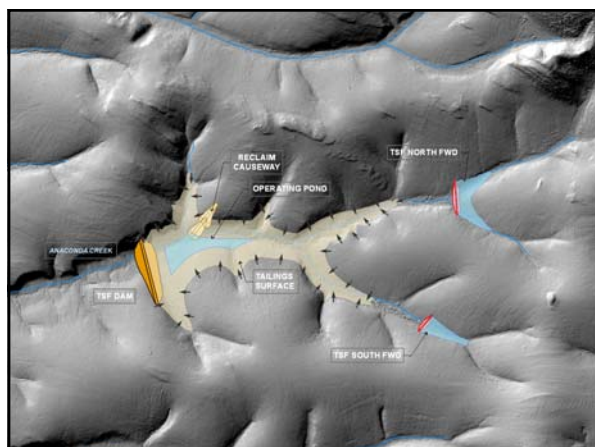
## Donlin Gold Project

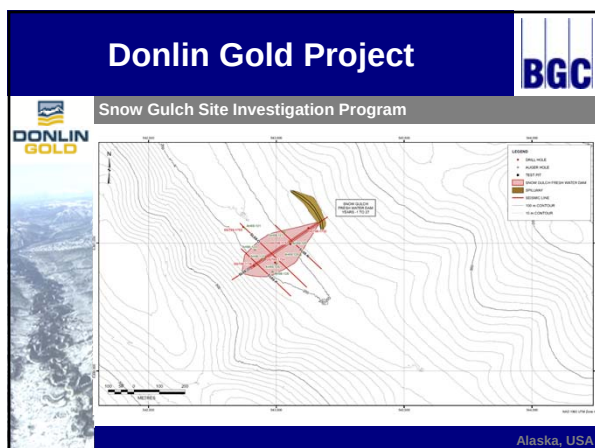
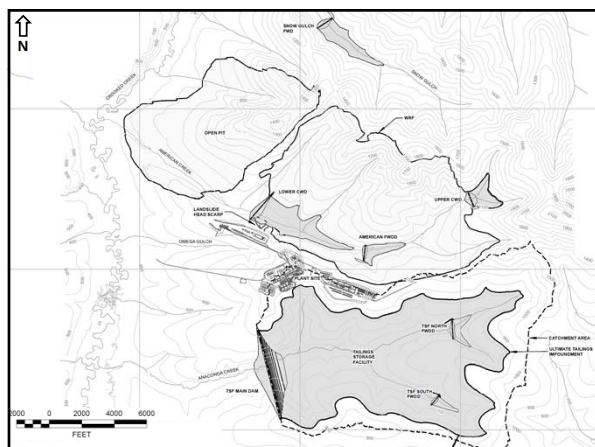
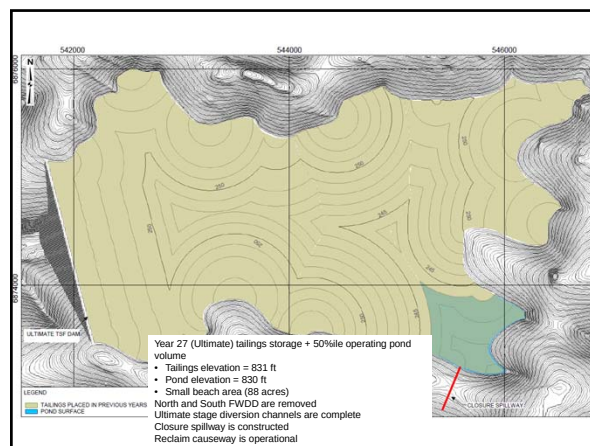
**BGC**

Construction Execution - continued

- **Summer 2**
  - Re-grade and re-compact/proof-roll liner bedding as required
  - Complete construction of all elements
  - Place liner
- Portion of the valley above bottom 80 ft of the creek can be constructed independent of season

Alaska, USA







Water Dams Design – Summary



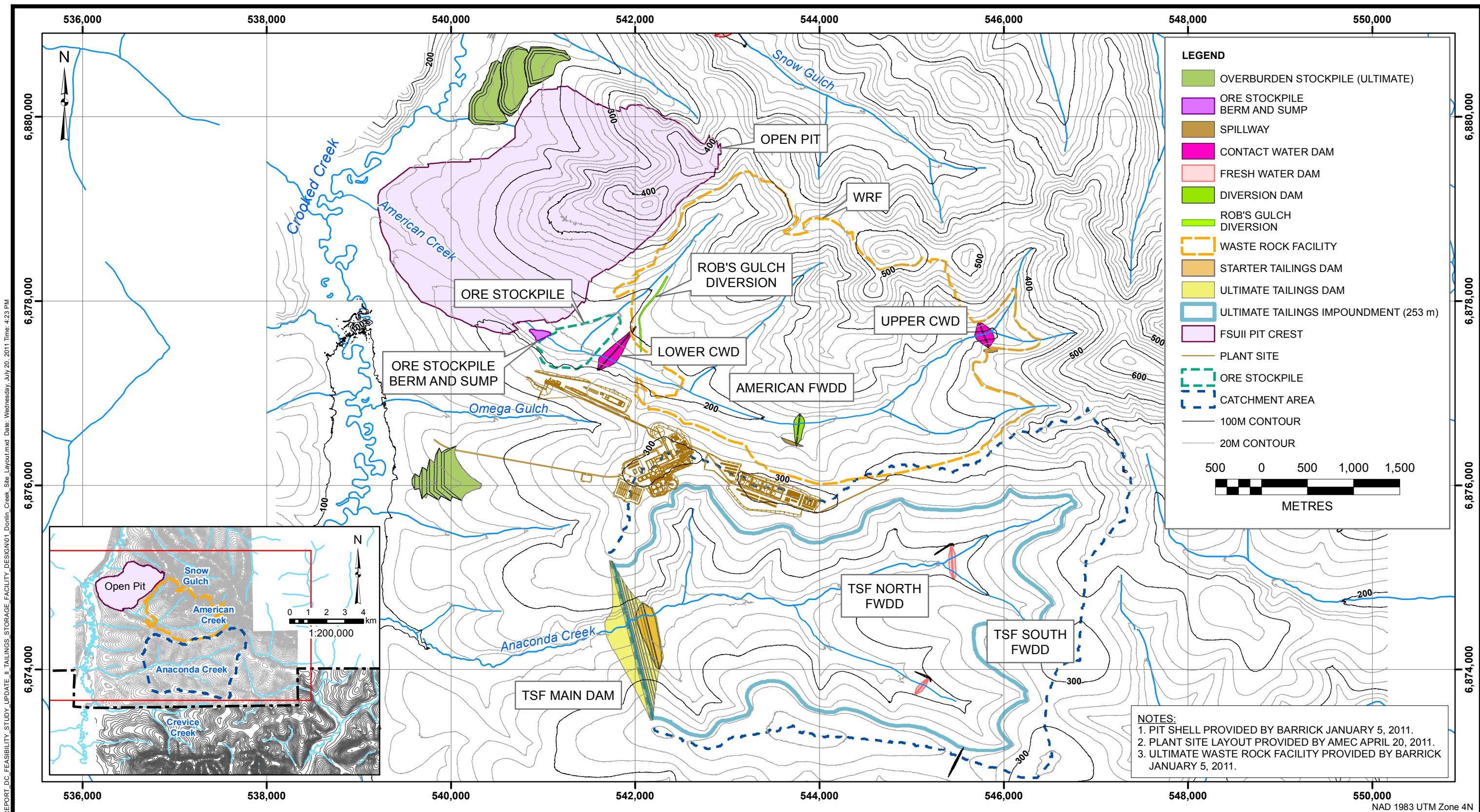
| Name           | Height /Crest EL. | Length | Dam Volume (M cu.yds) | Max. Operating Pond | Storage Requirements                       | Outlet                                             |
|----------------|-------------------|--------|-----------------------|---------------------|--------------------------------------------|----------------------------------------------------|
| Lower CWD      | 150' / 673'       | 2303'  | 1.5                   | 811 acre-ft         | PMP + max. operating pond. (7,150 acre-ft) | Operating pumps to Upper CWD.                      |
| Upper CWD      | 189' / 1114'      | 1024'  | 1.1                   | 2,432 acre-ft       | Lower CWD outflow.                         | Emergency spillway; PMP capacity. Operating pumps. |
| American FWD   | 95' / 761'        | 1142'  | 0.4                   | 868 acre-ft         | Stays full, supplies FW to plant           | Operating spillway; 1:100 year capacity            |
| Snow Gulch FWD | 154' / 756'       | 1211'  | 1.04                  | 3,243 acre-ft       | Stays full, supplies FW to plant.          | Operating spillway; PMP capacity                   |
| North FWD      | 74' / 656'        | 1280'  | 0.3                   | 478 acre-ft         | 100-yr snowmelt                            | Pump to diversion channels emergency spillway      |
| South FWD      | 66' / 656'        | 856'   | 0.14                  | 211 acre-ft         | 100-yr snowmelt                            | Pump to diversion channels emergency spillway      |



## Appendix A2 – Selected Drawings

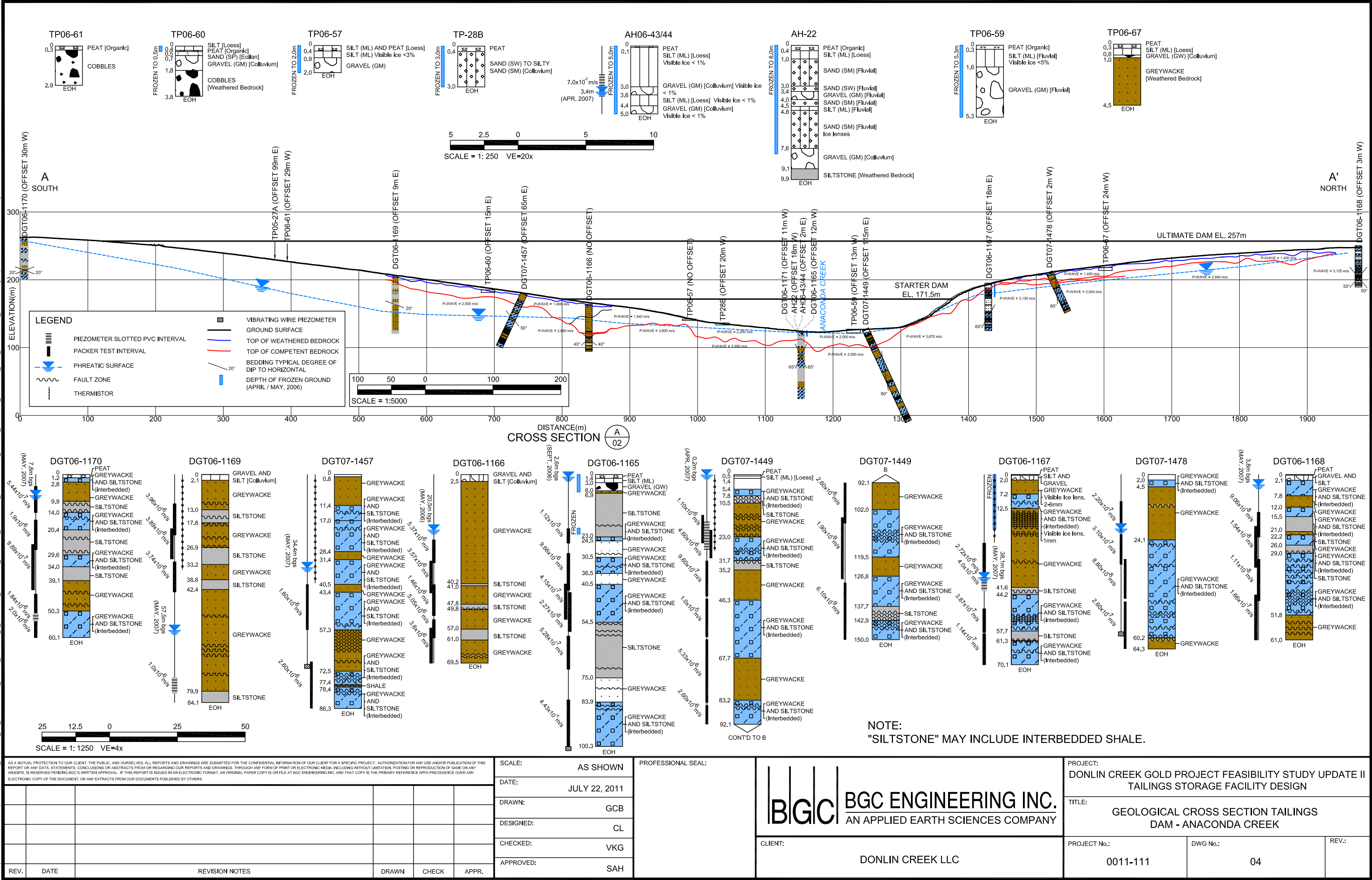
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X:\Projects\00111111\workspace\20110429 REPORT DC FEASIBILITY STUDY UPDATE II TAILINGS STORAGE FACILITY DESIGN\01 Donlin Creek Site Layout.mxd Date: Wednesday, July 20, 2011 Time: 4:23 PM

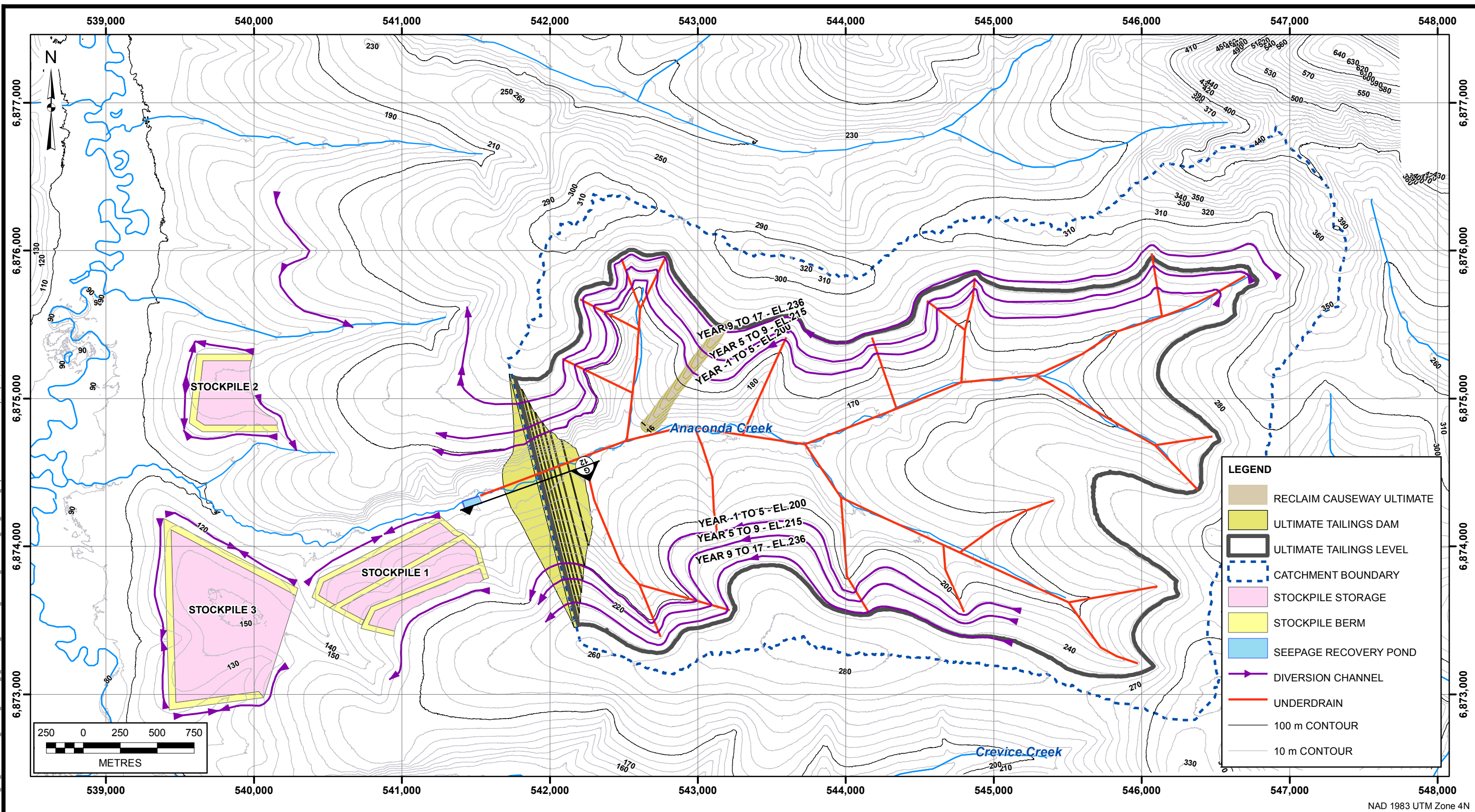


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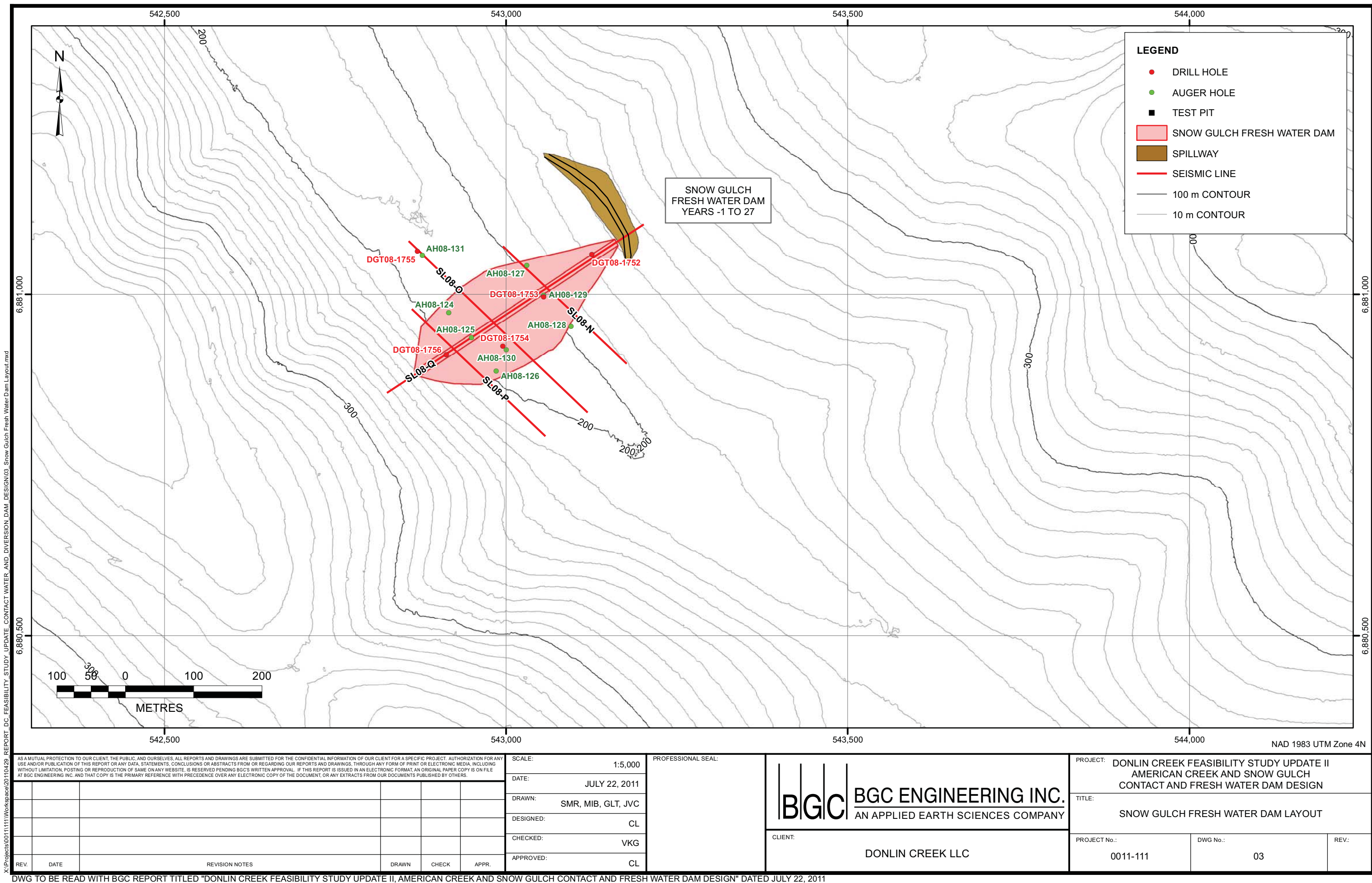


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PROJECT:  
DONLIN CREEK GOLD PROJECT FEASIBILITY STUDY UPDATE II  
TAILINGS STORAGE FACILITY DESIGN



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| REV.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | DATE | REVISION NOTES |  | DRAWN | CHECK |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |      |                |  | APPR. |       |

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|-----------|--------------------|
| SCALE:    | 1:5,000            |
| DATE:     | JULY 22, 2011      |
| DRAWN:    | SMR, MIB, GLT, JVC |
| DESIGNED: | CL                 |
| CHECKED:  | VKG                |
| APPROVED: | CL                 |

PROFESSIONAL SEAL:

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|                                                                                                                          |             |       |
|--------------------------------------------------------------------------------------------------------------------------|-------------|-------|
| PROJECT: DONLIN CREEK FEASIBILITY STUDY UPDATE II<br>AMERICAN CREEK AND SNOW GULCH<br>CONTACT AND FRESH WATER DAM DESIGN |             |       |
| TITLE: SNOW GULCH FRESH WATER DAM LAYOUT                                                                                 |             |       |
| PROJECT No.: 0011-111                                                                                                    | DWG No.: 03 | REV.: |





## **Donlin Gold TSF and Snow Gulch Early Stage FMEA Workshop – Risk Rating Tools**

This appendix presents the tools that form the basis of the risk rating method used in the FMEA workshop held on December 2 and 3, 2014.

In general, risk rating methods used in FMEA's are expert-based rather than analytical. In other words, assessments of consequence severity (how bad could it be?) and likelihood (could it really happen?) are based on the consensus of expert opinion rather than on detailed calculation of probabilities. This approach allows a much wider range of risks to be considered as efficiently as possible. Differences of opinion about consequence severity and likelihood are tracked and, where they prove to be significant to a design decision, more rigorous analysis is a common follow-up requirement.

The proposed process begins with a participant describing a failure scenario. With guidance from the facilitator, the wording of the failure mode and effect are crystallized for evaluation with the risk rating tools. These tools comprise three tables and a risk matrix; shown in Tables 1 through 4 below.

Table 1 presents six categories of consequences along with severity ratings ranging from 'Very Low' to 'Critical'. For each category, the table includes narrative descriptions of the types of negative outcomes that would be typical for each severity rating; during the workshop these descriptions help participants determine the appropriate severity rating to be assigned to each failure scenario.

Table 2 presents descriptors used to aid participants in assigning a 'Likelihood' rating for each scenario. The 'Likelihood' rating reflects the participants' view of the probability that both the failure mode and consequence (from the previous chart) will be realized. The 'Likelihood Terminology' table consists of one column containing likelihood ratings that range from 'Very Unlikely' to 'Almost Certain', along with four other columns which give examples to guide the selection of the appropriate rating.

Table 3 presents the 'Confidence Levels' used to reflect the participants' confidence in the consequence and probability categories selected for each scenario.

Table 4 presents the 'Risk Matrix' which assigns a risk rating (and color) to each combination of likelihood (from Table 1, identified by row on Table 4) and severity (from Table 2, identified by column on Table 4). The risks range from low (in green) to moderate (in yellow) to moderately high (in pale orange) to high (in dark orange) to very high (in red).

**Table 1: Consequence-Severity Matrix**

| Consequence Categories               | Severity Descriptors                                                                           |                                                                                                             |                                                                                                     |                                                                                                         |                                                                                                |
|--------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
|                                      | Very Low                                                                                       | Minor                                                                                                       | Moderate                                                                                            | Major                                                                                                   | Critical                                                                                       |
| <b>1. Environmental Impact</b>       | No impact.                                                                                     | Minor localized or short-term impacts.                                                                      | Significant impact on valued ecosystem component.                                                   | Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.      | Serious long-term impairment of ecosystem function.                                            |
| <b>2. Traditional Use</b>            | Some disturbance but no impact to traditional land use.                                        | Minor or perceived impact to traditional land use.                                                          | Some mitigable impact to traditional land use.                                                      | Significant temporary impact to traditional land use.                                                   | Significant permanent impact on traditional land use.                                          |
| <b>3. Regulatory Impact</b>          | Informal advice from a regulatory agency.                                                      | Technical/Administrative non-compliance with permit, approval or regulatory requirement.                    | Breach of regulations, permits, or approvals (e.g. one-day violation of discharge limits).          | Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). | Major breach of regulation – willful violation.                                                |
| <b>4. Consequence Costs</b>          | < \$100,000                                                                                    | \$100,000 – \$1 Million                                                                                     | \$1 – \$5 Million                                                                                   | \$5 – \$25 Million                                                                                      | > \$25 Million                                                                                 |
| <b>5. Community/Media/Reputation</b> | Local concerns, but no local complaints or adverse press coverage.                             | Public concern restricted to local complaints or local adverse press coverage.                              | Heightened concern by local community, criticism by NGOs or adverse local/regional media attention. | Significant adverse national public, NGO or media attention.                                            | Serious public outcry/demonstrations or adverse International NGO attention or media coverage. |
| <b>6. Human Health and Safety</b>    | Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment. | Objective but reversible disability/impairment and/or medical treatment injuries requiring hospitalization. | Moderate irreversible disability or impairment to one or more people.                               | Single fatality and/or severe irreversible disability or impairment to one or more people.              | Multiple fatalities.                                                                           |

**Table 2: Likelihood Terminology**

| Likelihood            | Frequency Descriptor 1                         | Frequency Descriptor 2                               | Probability of occurrence over twenty years | Probability of occurrence in any one year |
|-----------------------|------------------------------------------------|------------------------------------------------------|---------------------------------------------|-------------------------------------------|
| <b>Almost Certain</b> | Happens often                                  | High frequency (more than once every 5 years)        | 98%                                         | 17.8%                                     |
| <b>Likely</b>         | Could easily happen                            | Event does occur, has a history, once every 15 years | 75%                                         | 6.7%                                      |
| <b>Possible</b>       | Could happen and has happened elsewhere        | Occurs once every 40 years                           | 40%                                         | 2.5%                                      |
| <b>Unlikely</b>       | Hasn't happened yet but could                  | Occurs once every 200 years                          | 10%                                         | 0.5%                                      |
| <b>Very Unlikely</b>  | Conceivable, but only in extreme circumstances | Occurs once every 1000 years                         | < 2%                                        | 0.1%                                      |

**Table 3: FMEA Confidence Levels**

| Confidence Level | Description                                                                                                                           |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| <b>Low</b>       | Do not have confidence in the estimate or ability to control during operations.                                                       |
| <b>Medium</b>    | Have some confidence in the estimate or ability to control during operations; conceptual level analyses.                              |
| <b>High</b>      | Have lots of confidence in the estimate or ability to control during operations; detailed analyses following a high standard of care. |

**Table 4: Risk Matrix**

| Likelihood            | Consequence Severity |                 |                 |                 |                 |
|-----------------------|----------------------|-----------------|-----------------|-----------------|-----------------|
|                       | Very Low             | Minor           | Moderate        | Major           | Critical        |
| <b>Almost Certain</b> | Moderate             | Moderately High | High            | Very High       | Very High       |
| <b>Likely</b>         | Moderate             | Moderate        | Moderately High | High            | Very High       |
| <b>Possible</b>       | Low                  | Moderate        | Moderately High | High            | High            |
| <b>Unlikely</b>       | Low                  | Low             | Moderate        | Moderately High | Moderately High |
| <b>Very Unlikely</b>  | Low                  | Low             | Low             | Moderate        | Moderately High |

## Appendix C – TSF Risk Register

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## TSF Construction and Operation

| <u>Likelihood</u> | <u>Consequence Severity</u> |                         |                                     |                                        |                                |
|-------------------|-----------------------------|-------------------------|-------------------------------------|----------------------------------------|--------------------------------|
|                   | Very Low                    | Minor                   | Moderate                            | Major                                  | Critical                       |
| Almost Certain    |                             |                         |                                     |                                        |                                |
| Likely            |                             | 23C, 23R, 36C, 38C, 42C |                                     |                                        |                                |
| Possible          |                             | 14C, 33C, 43C           | 7C, 9E, 25C, 31C, 4C, 35C, 38R, 39C | 9C, 21C, 49R                           |                                |
| Unlikely          |                             | 32C                     | 8E, 14E, 18C, 19C, 32C, 47C, 38T    | 1E, 1C, 1T, 1R, 8T, 46E, 46R, 46M, 47R | 1M                             |
| Very Unlikely     |                             |                         | 20E, 26E                            | 1H, 44C, 49E                           | 2E, 2H, 4E, 24C, 24H, 37E, 37H |

## TSF Closure &amp; Post-Closure

| <u>Likelihood</u> | <u>Consequence Severity</u> |       |               |                        |          |
|-------------------|-----------------------------|-------|---------------|------------------------|----------|
|                   | Very Low                    | Minor | Moderate      | Major                  | Critical |
| Almost Certain    |                             |       |               |                        |          |
| Likely            |                             | 41C   |               |                        |          |
| Possible          |                             |       | 27C, 29C, 40E | 40R, 40T, 49R          |          |
| Unlikely          |                             | 30C   |               | 5C, 16C, 30T, 30E, 45C | 22C      |
| Very Unlikely     |                             |       |               | 12C, 48E               | 11E, 11H |

## TSF Premature Closure

| <u>Likelihood</u> | <u>Consequence Severity</u> |       |          |              |          |
|-------------------|-----------------------------|-------|----------|--------------|----------|
|                   | Very Low                    | Minor | Moderate | Major        | Critical |
| Almost Certain    |                             |       |          |              |          |
| Likely            |                             |       |          |              |          |
| Possible          |                             | 28C   | 10E      | 3E, 15C, 17C |          |
| Unlikely          |                             |       |          | 10T, 13R     |          |
| Very Unlikely     |                             |       |          | 6E           |          |

**Consequence Types**  
**E** Environmental Impact  
**T** Traditional Use  
**R** Regulatory Impact  
**C** Consequence Costs  
**M** Community/Media/Reputation  
**H** Human Health and Safety

**Risk Level**  
■ Low  
■ Moderate  
■ Moderately High  
■ High  
■ Very High

|    | TSF                                                                                                                                                                         |               |                |          |               |                 |                  |                                                                                                                                                                                                                            |
|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------------|----------|---------------|-----------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | Scenario                                                                                                                                                                    | Project Stage | Consequence    |          | Likelihood    | Risk Rating     | Confidence Level | NOTES                                                                                                                                                                                                                      |
|    |                                                                                                                                                                             |               | Type           | Severity | Descriptor    | Descriptive     |                  |                                                                                                                                                                                                                            |
| 1  | Downstream failure of dam due to material variability results in partial breach and loss of material (2 million cu.m.) that reaches Crooked Creek.                          | Const. & Op   | Env. Imp.      | Major    | Unlikely      | Moderately High | M                | Rock fill material is currently uncharacterized. Crooked Creek is valuable ecosystem. Scenario assumed to occur near end of mine life with full pond, so that even a partial breach leads to significant tailings release. |
| 1  |                                                                                                                                                                             | Const. & Op   | Com/Media/Rep. | Critical | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                            |
| 1  |                                                                                                                                                                             | Const. & Op   | Cons. Costs    | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                            |
| 1  |                                                                                                                                                                             | Const. & Op   | Human H&S      | Major    | Very Unlikely | Moderate        | M                |                                                                                                                                                                                                                            |
| 1  |                                                                                                                                                                             | Const. & Op   | Trad. Use      | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                            |
| 1  |                                                                                                                                                                             | Const. & Op   | Reg. Imp.      | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                            |
| 2  | Poor QA/QC during construction of filter/liner materials results in a leak and ultimately a piping failure and a catastrophic breach                                        | Const. & Op   | Env. Imp.      | Critical | Very Unlikely | Moderately High | M                | Some participants thought likelihood could be "Unlikely". Poor QA has happened elsewhere, but this mode requires both filter and liner to fail.                                                                            |
| 2  |                                                                                                                                                                             | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | M                | Any complete breach of dam will also have very significant costs                                                                                                                                                           |
| 3  | Excessive water accumulation with no spillway in place leads to overtopping and loss of water                                                                               | Prem.Cl.      | Env. Imp.      | Major    | Possible      | High            | L                | Net water balance is positive, but liklelihood is "Possible" because it requires assuming no mitigation for 1-2 years                                                                                                      |
| 4  | Liner rupture directly above the underdrain leads to sinkhole and outflow of tailings through underdrain                                                                    | Const. & Op   | Env. Imp.      | Critical | Unlikely      | Moderately High | M                | Loss of 20% of tailings would be enough to lead to critical consequences                                                                                                                                                   |
| 5  | Deformation along a fault in the valley leads to rupture of liner resulting in increased seepage and water treatment costs                                                  | Cl. & P.Cl.   | Cons. Costs    | Major    | Unlikely      | Moderately High | L                |                                                                                                                                                                                                                            |
| 6  | Excessive water accumulation with no spillway in place leads to controled unauthorized discharge                                                                            | Prem.Cl.      | Env. Imp.      | Major    | Very Unlikely | Moderate        | M                | "Very Unlikely" because water would be sent to pit                                                                                                                                                                         |
| 7  | Clogging of underdrain due to excessive weight/chemical reactions leading to build-up of pore pressures resulting in liner damage, construction delay and need for repairs. | Const. & Op   | Cons. Costs    | Moderate | Possible      | Moderately High | M                |                                                                                                                                                                                                                            |
| 8  | Weather event exceeds design criteria leading to overtopping and discharge of contaminated water (but no breach)                                                            | Const. & Op   | Env. Imp.      | Moderate | Unlikely      | Moderate        | M                | Extreme event assumed to occur during normal operations. Hydrological analysis suggests "Very Unlikely" but could be limiations to data.                                                                                   |
| 8  |                                                                                                                                                                             | Const. & Op   | Trad. Use      | Major    | Unlikely      | Moderately High | M                | "Major" consequence would be the temporary loss of fishing                                                                                                                                                                 |
| 9  | Pond levels builds up over time, reducing available freeboard and then a extreme weather event occurs leading to overtopping resulting in discharge of contaminated water   | Const. & Op   | Env. Imp.      | Moderate | Possible      | Moderately High | M                | Extreme event assumed to be preceded by period of abnormal operations, with no response by operator                                                                                                                        |
| 9  |                                                                                                                                                                             | Const. & Op   | Cons. Costs    | Major    | Possible      | High            | L                | Mitigation costs for early raise of dam, pumping to pit, treating for discharge                                                                                                                                            |
| 10 | Cover construction delays leading dust releases to the surrounding lands for a 3-4 years.                                                                                   | Prem.Cl.      | Trad. Use      | Major    | Unlikely      | Moderately High | M                | Assumes no dust control measures in place during 3-4 years of surface flooding                                                                                                                                             |
| 11 | Spillway blockage by ice and snow leads to overtopping and breach of the dam                                                                                                | Cl. & P.Cl.   | Env. Imp.      | Critical | Very Unlikely | Moderately High | M                | Spillway is at Crevice Creek but failure would be at Main Dam                                                                                                                                                              |
| 11 |                                                                                                                                                                             | Cl. & P.Cl.   | Human H&S      | Critical | Very Unlikely | Moderately High | M                |                                                                                                                                                                                                                            |
| 12 | Long-term degradation of the liner leads to increased seepage and water treatment costs                                                                                     | Cl. & P.Cl.   | Cons. Costs    | Major    | Very Unlikely | Moderate        | M                | Scenario refers to liner on the dam face, and possible degradation due to slope creep on the 1.7H:1V slope. Underlying material could be metal leaching.                                                                   |
| 13 | Waste rock on dam face remains uncovered leading to contaminated run-off                                                                                                    | Prem.Cl.      | Reg. Imp.      | Major    | Unlikely      | Moderately High | M                | Assumes dam face remains uncovered and rock leaches metals                                                                                                                                                                 |

|    | TSF                                                                                                                                                  |               |             |          |               |                 |                  |                                                                                                                                                       |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------|----------|---------------|-----------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | Scenario                                                                                                                                             | Project Stage | Consequence |          | Likelihood    | Risk Rating     | Confidence Level | NOTES                                                                                                                                                 |
|    |                                                                                                                                                      |               | Type        | Severity | Descriptor    | Descriptive     |                  |                                                                                                                                                       |
| 14 | Liner damage due to an ice sheet results in increased seepage that exceeds seepage recovery system and poor water quality downstream                 | Const. & Op   | Env. Imp.   | Moderate | Unlikely      | Moderate        | L                | Could be "Minor" if change to seepage volume is small                                                                                                 |
| 14 |                                                                                                                                                      | Const. & Op   | Cons. Costs | Minor    | Possible      | Moderate        | L                |                                                                                                                                                       |
| 15 | Spillway can't be constructed into Crevice Creek resulting in additional pumping costs                                                               | Prem.Cl.      | Cons. Costs | Major    | Possible      | High            | L                | Assumes inadequate financial security in place, or requirement to tunnel                                                                              |
| 16 | Pond water quality does not improve and pumping is required over the very long term                                                                  | Cl. & P.Cl.   | Cons. Costs | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                       |
| 17 | Lack of grading by spigotting leads to additional costs for mechanical grading for closure cover                                                     | Prem.Cl.      | Cons. Costs | Major    | Possible      | High            | L                | assumes inadequate bonding in place                                                                                                                   |
| 18 | Differential settlement due to thawing of previously unidentified permafrost leading to liner damage and increased seepage and water treatment costs | Const. & Op   | Cons. Costs | Moderate | Unlikely      | Moderate        | M                |                                                                                                                                                       |
| 19 | Differential settlement of alluvial soils under loading leads to liner damage and increased seepage and water treatment costs                        | Const. & Op   | Cons. Costs | Moderate | Unlikely      | Moderate        | M                |                                                                                                                                                       |
| 20 | Rupture of the liner leads to piping of native materials into the underdrain and release of tailings and formation of a sinkhole over time           | Const. & Op   | Env. Imp.   | Moderate | Very Unlikely | Low             | M                | Liner rupture is not dierctly above underdrain, so this requires piping of through alluvial soils                                                     |
| 21 | Missing construction window due to strike/weather delay/etc. results in one year delay                                                               | Const. & Op   | Cons. Costs | Major    | Possible      | High            | L                | Current schedule includes a 12 month storage contingency (except for Starter Dam). Costs very uncertain.                                              |
| 22 | Earthquake results in tailings liquefaction and cover damage resulting in need for repairs                                                           | Cl. & P.Cl.   | Cons. Costs | Critical | Unlikely      | Moderately High | M                | Depends on liquefaction potential of the tailings, but final slope will be 1-2% so damage could be less.                                              |
| 23 | Failure of surface water diversion (localized instability/glaciation/blockage) etc. results in need for repairs of diversion ditches                 | Const. & Op   | Reg. Imp.   | Minor    | Likely        | Moderate        | M                | Technical non-compliance, but no risk of discharging the water                                                                                        |
| 23 |                                                                                                                                                      | Const. & Op   | Cons. Costs | Minor    | Likely        | Moderate        | M                |                                                                                                                                                       |
| 24 | Mass wasting failure at the abutment (landslide) occurs following construction results in catastrophic failure of the dam and release of tailings    | Const. & Op   | Cons. Costs | Critical | Very Unlikely | Moderately High | M                |                                                                                                                                                       |
|    |                                                                                                                                                      | Const. & Op   | Human H&S   | Critical | Very Unlikely | Moderately High | M                |                                                                                                                                                       |
| 25 | Landslide within impoundment results in damage of the liner and need for repairs.                                                                    | Const. & Op   | Cons. Costs | Moderate | Possible      | Moderately High | M                | Some participants thought this secnario is "Unlikely". The consequence sevrity classification assumes that the liner damage is accessible for repair. |
| 26 | Mass wasting failure in the saddle area (spillway not yet built) leads to uncontrolled release of water and tailings                                 | Const. & Op   | Env. Imp.   | Moderate | Very Unlikely | Low             | M                |                                                                                                                                                       |
| 27 | Landslide into spillway plugs the spillway results in need for repairs                                                                               | Cl. & P.Cl.   | Cons. Costs | Moderate | Possible      | Moderately High | M                |                                                                                                                                                       |
| 28 | Degradation of the liner due to environmental exposure leads to seepage into the underdrain                                                          | Prem.Cl.      | Cons. Costs | Minor    | Possible      | Moderate        | M                |                                                                                                                                                       |
| 29 | Ice entrainment in tailings results in delay in construction of closure cover                                                                        | Cl. & P.Cl.   | Cons. Costs | Moderate | Possible      | Moderately High | L                | Other consequences dicussed at length, but design is based on total containment of water so little sensitivity to ice                                 |
| 30 | Soil cover over the downstream slope of the dam at closure performs worse than expected leads to downstream water quality issues                     | Cl. & P.Cl.   | Cons. Costs | Minor    | Unlikely      | Low             | M                |                                                                                                                                                       |
| 30 |                                                                                                                                                      | Cl. & P.Cl.   | Trad. Use   | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                       |
| 30 |                                                                                                                                                      | Cl. & P.Cl.   | Env. Imp.   | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                       |
| 31 | Temporary closure leads to need to store extra water and results in need to raise dam sooner and higher ultimate crest height.                       | Const. & Op   | Cons. Costs | Moderate | Possible      | Moderately High | M                |                                                                                                                                                       |
| 32 | Thermal expansion of liner causes folding and covering of folds with tailings leads to defects and increased seepage                                 |               | Cons. Costs | Minor    | Unlikely      | Low             | M                |                                                                                                                                                       |

|    | TSF                                                                                                                                                                        |               |                |          |               |                 |                  |                                                                                                                                     |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------------|----------|---------------|-----------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------|
|    | Scenario                                                                                                                                                                   | Project Stage | Consequence    |          | Likelihood    | Risk Rating     | Confidence Level | NOTES                                                                                                                               |
|    |                                                                                                                                                                            |               | Type           | Severity | Descriptor    | Descriptive     |                  |                                                                                                                                     |
| 33 | Construction related damage to the liner results in increased seepage                                                                                                      | Const. & Op   | Cons. Costs    | Minor    | Possible      | Moderate        | M                | Construction defects are "Almost Certain" but much less likely to lead to significant consequences                                  |
| 34 | Consolidation/settlment of tailings results in rupture of horizontal seam leading to increased seepage                                                                     | Const. & Op   | Cons. Costs    | Moderate | Possible      | Moderately High | M                |                                                                                                                                     |
| 35 | Gas bubble developing under the liner (impoundment area) leads to need for repairs                                                                                         | Const. & Op   | Cons. Costs    | Moderate | Possible      | Moderately High | M                | Stripping of organics prior to liner placement should limit methane generation                                                      |
| 36 | Wildlife causes damage to liner leads to need for repairs                                                                                                                  | Const. & Op   | Cons. Costs    | Minor    | Likely        | Moderate        | H                | Moose or bear                                                                                                                       |
| 37 | Deep-seated failure of the dam foundation due to undiscovered conditions leads to catastrophic failure of the dam                                                          | Const. & Op   | Env. Imp.      | Critical | Very Unlikely | Moderately High | M                | Any complete breach of dam will also have very significant costs                                                                    |
| 37 |                                                                                                                                                                            | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | M                |                                                                                                                                     |
| 38 | During the first year of starter dam operation, exceedance of regulatory freeboard requirements                                                                            | Const. & Op   | Reg. Imp.      | Moderate | Possible      | Moderately High | M                |                                                                                                                                     |
| 39 | Barge capsizes resulting in liner damage leading to need for repairs                                                                                                       | Const. & Op   | Cons. Costs    | Moderate | Possible      | Moderately High | M                |                                                                                                                                     |
| 40 | Failure of custodial care leads to exceedance of seepage pumpback system and uncontrolled release of contaminated water                                                    | Cl. & P.Cl.   | Env. Imp.      | Moderate | Possible      | Moderately High | M                | 3-5 days until the seepage system overtops. Assumption is that it is not mitigated, leding to significant releases over long period |
| 40 |                                                                                                                                                                            | Cl. & P.Cl.   | Reg. Imp.      | Major    | Possible      | High            | M                |                                                                                                                                     |
| 40 |                                                                                                                                                                            | Cl. & P.Cl.   | Trad. Use      | Major    | Possible      | High            | M                |                                                                                                                                     |
| 41 | Excessive vegetation in the spillway results in blockage of spillway and need for maintenance                                                                              | Cl. & P.Cl.   | Cons. Costs    | Minor    | Likely        | Moderate        | M                |                                                                                                                                     |
| 42 | Snow sliding on exposed liner causes damage                                                                                                                                | Const. & Op   | Cons. Costs    | Minor    | Likely        | Moderate        | M                |                                                                                                                                     |
| 43 | Inability to anchor HDPE liner on the downstream face of the dam due to wind                                                                                               | Const. & Op   | Cons. Costs    | Minor    | Possible      | Moderate        | M                |                                                                                                                                     |
| 44 | Reclaim water quality not meeting ore processing requirements                                                                                                              | Const. & Op   | Cons. Costs    | Major    | Very Unlikely | Moderate        | H                |                                                                                                                                     |
| 45 | Irregular consolidation leading to pond against the dam face                                                                                                               | Cl. & P.Cl.   | Cons. Costs    | Major    | Unlikely      | Moderately High | L                |                                                                                                                                     |
| 46 | Emergency discharge for any reason (pumping into creek)                                                                                                                    | Const. & Op   | Env. Imp.      | Major    | Unlikely      | Moderately High | M                |                                                                                                                                     |
| 46 |                                                                                                                                                                            | Const. & Op   | Reg. Imp.      | Major    | Unlikely      | Moderately High | M                |                                                                                                                                     |
| 46 |                                                                                                                                                                            | Const. & Op   | Com/Media/Rep. | Major    | Unlikely      | Moderately High | M                |                                                                                                                                     |
| 47 | Clogging of the underdrain at seepage recovery system leads to pore water pressure build-up in the dam and shallow slope failure and damage to the seepage recovery system | Const. & Op   | Cons. Costs    | Moderate | Unlikely      | Moderate        | M                |                                                                                                                                     |
| 47 |                                                                                                                                                                            | Const. & Op   | Reg. Imp.      | Major    | Unlikely      | Moderately High | M                |                                                                                                                                     |
| 48 | Degradation of rockfill leads to slope failure of the dam face and release of tailings (2 million cubic meters)                                                            | Cl. & P.Cl.   | Env. Imp.      | Major    | Very Unlikely | Moderate        | M                |                                                                                                                                     |
| 49 | Seepage recovery system does not function resulting in multi-day discharge into creek                                                                                      | Const. & Op   | Reg. Imp.      | Major    | Possible      | High            | M                |                                                                                                                                     |

## Appendix D – Snow Gulch Risk Register

## Snow Gulch Construction &amp; Operation

| <u>Likelihood</u> | <u>Consequence Severity</u> |          |                                       |                                                      |                                  |
|-------------------|-----------------------------|----------|---------------------------------------|------------------------------------------------------|----------------------------------|
|                   | Very Low                    | Minor    | Moderate                              | Major                                                | Critical                         |
| Almost Certain    |                             |          |                                       |                                                      |                                  |
| Likely            |                             | 3C       | 14M                                   |                                                      |                                  |
| Possible          |                             | 26R      | 6C, 19E, 19T, 23C                     | 8C, 10C, 34E                                         | 34H                              |
| Unlikely          | 27R                         | 28R, 29C | 2C, 17E, 17R, 17M, 18R, 27E, 27M, 28E | 7E, 11E, 12E, 13C, 17C, 21E, 26C, 30M, 31E, 32E, 33E | 7H, 11H, 12H, 21H, 31H, 32H, 33H |
| Very Unlikely     |                             |          |                                       | 1E, 1R, 20E, 25E                                     | 1H, 4H, 5H, 20H, 25H             |

## Snow Gulch Closure &amp; Post-Closure

| <u>Likelihood</u> | <u>Consequence Severity</u> |       |          |       |          |
|-------------------|-----------------------------|-------|----------|-------|----------|
|                   | Very Low                    | Minor | Moderate | Major | Critical |
| Almost Certain    |                             |       |          |       |          |
| Likely            |                             |       |          |       |          |
| Possible          |                             | 22E   | 16E, 24C |       |          |
| Unlikely          |                             |       |          |       |          |
| Very Unlikely     |                             |       |          |       |          |

## Snow Gulch Premature Closure

| <u>Likelihood</u> | <u>Consequence Severity</u> |       |          |       |          |
|-------------------|-----------------------------|-------|----------|-------|----------|
|                   | Very Low                    | Minor | Moderate | Major | Critical |
| Almost Certain    |                             |       |          |       |          |
| Likely            |                             |       |          |       |          |
| Possible          |                             |       |          |       | 15H      |
| Unlikely          |                             |       |          |       |          |
| Very Unlikely     |                             |       |          |       |          |

**Consequence Types**  
**E** Environmental Impact  
**T** Traditional Use  
**R** Regulatory Impact  
**C** Consequence Costs  
**M** Community/Media/Reputation  
**H** Human Health and Safety

**Risk Level**  
■ Low  
■ Moderate  
■ Moderately High  
■ High  
■ Very High

|    | Snow Gulch Reservoir                                                                                                                                                            |               |                |          |               |                 |                  |                                                                                                                                                                                                                                      |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------------|----------|---------------|-----------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | Scenario                                                                                                                                                                        | Project Stage | Consequence    |          | Likelihood    | Risk Rating     | Confidence Level | NOTES/ MITIGATIONS                                                                                                                                                                                                                   |
|    |                                                                                                                                                                                 |               | Type           | Severity | Descriptor    | Descriptive     |                  |                                                                                                                                                                                                                                      |
| 1  | Landslide blocks the spillway leading to overtopping and breach of the dam                                                                                                      | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | L                |                                                                                                                                                                                                                                      |
| 1  |                                                                                                                                                                                 | Const. & Op   | Env. Imp.      | Major    | Very Unlikely | Moderate        | L                | Erosion of spawning gravels                                                                                                                                                                                                          |
| 1  |                                                                                                                                                                                 | Const. & Op   | Reg. Imp.      | Major    | Very Unlikely | Moderate        | L                | Violation of fisheries protection and dam safety rules                                                                                                                                                                               |
| 2  | Landslide blocks the spillway leading to need for repairs                                                                                                                       | Const. & Op   | Cons. Costs    | Moderate | Unlikely      | Moderate        | L                | Small watershed and small flows limit likelihood of more serious consequences                                                                                                                                                        |
| 3  | Ice glaciation blocks the spillway leading to need for maintenance and increased pumping costs                                                                                  | Const. & Op   | Cons. Costs    | Minor    | Likely        | Moderate        | M                |                                                                                                                                                                                                                                      |
| 4  | Intentional blockage of the spillway due to operator misunderstanding and a large rainfall event leads to overtopping                                                           | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | M                |                                                                                                                                                                                                                                      |
| 5  | Landslide occurs above or under the abutment leads to lowering of the crest height and overtopping of the dam                                                                   | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | L                | Limited field investigation to date, only four boreholes                                                                                                                                                                             |
| 6  | Thawing of ice lenses leads to internal erosion in the abutments results in need for grouting                                                                                   | Const. & Op   | Cons. Costs    | Moderate | Possible      | Moderately High | L                | Thick ice lenses are unlikely to be missed but even thin ones could initiate piping                                                                                                                                                  |
| 7  | High seepage gradient at the upstream liner embedment leads to piping and failure of the dam (complete breach)                                                                  | Const. & Op   | Env. Imp.      | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                                      |
| 7  |                                                                                                                                                                                 | Const. & Op   | Human H&S      | Critical | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                                      |
| 8  | High seepage gradient at the upstream liner embedment leads to piping, drawdown of dam, and loss of use of reservoir                                                            | Const. & Op   | Cons. Costs    | Major    | Possible      | High            | M                | Loss of stored water could lead to production halt                                                                                                                                                                                   |
| 9  | Local community or landowner requests permanent dam and lack of long-term oversight or maintenance ultimately results in a breach (due to any of the failure modes noted above) | Cl. & P.Cl.   | Env. Imp.      | Major    | Unlikely      | Moderately High | L                | Dam is not being designed for very long term use, and is in fact designed to be removed after mine usage ends. But there are examples eslewhere of dams being re-purposed without adequate review of the initial design assumptions. |
| 9  |                                                                                                                                                                                 | Cl. & P.Cl.   | Human H&S      | Critical | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                                      |
| 10 | Foundation materials are more permeable than expected, resulting in need for grouting during construction or remedial grouting following construction.                          | Const. & Op   | Cons. Costs    | Major    | Possible      | High            | L                | Uncertain if grouting would work, and possible that reservoir would need to be abandoned                                                                                                                                             |
| 11 | Landslide into reservoir leads to large wave, overtopping of the dam, down-cutting and a complete breach                                                                        | Const. & Op   | Human H&S      | Critical | Unlikely      | Moderately High | L                |                                                                                                                                                                                                                                      |
| 11 |                                                                                                                                                                                 | Const. & Op   | Env. Imp.      | Major    | Unlikely      | Moderately High | L                |                                                                                                                                                                                                                                      |
| 12 | Internal erosion beneath the liner leads to loss of support causing a liner failure, and complete breach of dam                                                                 | Const. & Op   | Human H&S      | Critical | Unlikely      | Moderately High | L                | Some participants thought that likelihood should be"possible", given lack of filters on drains in current design                                                                                                                     |
| 12 |                                                                                                                                                                                 | Const. & Op   | Env. Imp.      | Major    | Unlikely      | Moderately High | L                |                                                                                                                                                                                                                                      |
| 13 | Steep liner slopes lead to poor construction quality and result in insufficient storage for mill operations                                                                     | Const. & Op   | Cons. Costs    | Major    | Unlikely      | Moderately High | M                |                                                                                                                                                                                                                                      |
| 14 | Higher than expected seepage results in concern from local community and regulators.                                                                                            | Const. & Op   | Com/Media/Rep. | Moderate | Likely        | Moderately High | M                | "Moderate" because of negative press coverage                                                                                                                                                                                        |
| 15 | Inadequate routine dam inspections do not detect slowly developing problems that lead to a breach failure of the dam                                                            | Prem.Cl.      | Human H&S      | Critical | Possible      | High            | M                |                                                                                                                                                                                                                                      |
| 16 | Sediment deposition during operations and erosion following decommissioning result in excessive sediment loading downstream                                                     | Cl. & P.Cl.   | Env. Imp.      | Moderate | Possible      | Moderately High | M                |                                                                                                                                                                                                                                      |

|    | Snow Gulch Reservoir                                                                                                                               |               |                |          |               |                 |                  |                                                                                          |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------------|----------|---------------|-----------------|------------------|------------------------------------------------------------------------------------------|
|    | Scenario                                                                                                                                           | Project Stage | Consequence    |          | Likelihood    | Risk Rating     | Confidence Level | NOTES/ MITIGATIONS                                                                       |
|    |                                                                                                                                                    |               | Type           | Severity | Descriptor    | Descriptive     |                  |                                                                                          |
| 17 | Extreme flood event in early stage of construction results in overtopping and dam failure                                                          | Const. & Op   | Env. Imp.      | Moderate | Unlikely      | Moderate        | L                |                                                                                          |
| 17 |                                                                                                                                                    | Const. & Op   | Reg. Imp.      | Moderate | Unlikely      | Moderate        | L                |                                                                                          |
| 17 |                                                                                                                                                    | Const. & Op   | Cons. Costs    | Major    | Unlikely      | Moderately High | L                |                                                                                          |
| 17 |                                                                                                                                                    | Const. & Op   | Com/Media/Rep. | Moderate | Unlikely      | Moderate        | L                |                                                                                          |
| 18 | Reservoir water quality compromised by waste rock, dust, etc. resulting in poor water quality and inability to discharge                           | Const. & Op   | Reg. Imp.      | Moderate | Unlikely      | Moderate        | L                |                                                                                          |
| 19 | Degradation of seepage water quality caused by ARD/ML issues with dam fill materials.                                                              | Const. & Op   | Env. Imp.      | Moderate | Possible      | Moderately High | L                | "Moderate" assumes metal release during spawning season                                  |
| 19 |                                                                                                                                                    | Const. & Op   | Trad. Use      | Moderate | Possible      | Moderately High | L                |                                                                                          |
| 20 | Seismic event larger than design results in breach of the dam                                                                                      | Const. & Op   | Env. Imp.      | Major    | Very Unlikely | Moderate        | M                |                                                                                          |
| 20 |                                                                                                                                                    | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | M                |                                                                                          |
| 21 | Motion along an undetected fault beneath the dam results in rupture of the liner and failure of the dam                                            | Const. & Op   | Human H&S      | Critical | Unlikely      | Moderately High | L                |                                                                                          |
| 21 |                                                                                                                                                    | Const. & Op   | Env. Imp.      | Major    | Unlikely      | Moderately High | L                |                                                                                          |
| 22 | Repeated drawdown and recharge leading to mass wasting failure in reservoir leading to discharge of suspended sediments                            | Cl. & P.Cl.   | Env. Imp.      | Minor    | Possible      | Moderate        | M                |                                                                                          |
| 23 | Sinking of the barge leads to need for replacement of the barge                                                                                    | Const. & Op   | Cons. Costs    | Moderate | Possible      | Moderately High | M                |                                                                                          |
| 24 | Repeated drawdown leads to mass wasting in the reservoir resulting in increased reclamation requirements on the failed slopes                      | Cl. & P.Cl.   | Cons. Costs    | Moderate | Possible      | Moderately High | L                |                                                                                          |
| 25 | Permeability of the rockfill is less than design leading to increased pore water pressures and a slope failure through crest resulting in a breach | Const. & Op   | Env. Imp.      | Major    | Very Unlikely | Moderate        | L                |                                                                                          |
| 25 |                                                                                                                                                    | Const. & Op   | Human H&S      | Critical | Very Unlikely | Moderately High | L                |                                                                                          |
| 26 | Rockfill shell degrades leading to excessive deformations and need for increased maintenance                                                       | Const. & Op   | Cons. Costs    | Major    | Unlikely      | Moderately High | L                |                                                                                          |
| 26 |                                                                                                                                                    | Const. & Op   | Reg. Imp.      | Minor    | Possible      | Moderate        | L                | Technical non-compliance                                                                 |
| 27 | Emergency discharge for any reason (pumping into creek)                                                                                            | Const. & Op   | Env. Imp.      | Moderate | Unlikely      | Moderate        | M                | Erosion damage, but stream is already impacted by placer mining                          |
| 27 |                                                                                                                                                    | Const. & Op   | Reg. Imp.      | Very Low | Unlikely      | Low             | M                | ADEC would allow discharge assuming water quality is good                                |
| 27 |                                                                                                                                                    | Const. & Op   | Com/Media/Rep. | Moderate | Unlikely      | Moderate        | M                | Any discharge from a mining-related dam, even clean water, could generate negative press |
| 28 | Poor rock quality leads to erosion and downcutting of the spillway                                                                                 | Const. & Op   | Env. Imp.      | Moderate | Unlikely      | Moderate        | M                |                                                                                          |
| 29 | Emergency discharge is required (for any reason) and the normal service pumps are unable to meet needed discharge rate                             | Const. & Op   | Cons. Costs    | Minor    | Unlikely      | Low             | M                | Cost for pumps and piping                                                                |

|    | Snow Gulch Reservoir                                                                                                               |               |                |          |            |                 |                  |                                                                                                                 |
|----|------------------------------------------------------------------------------------------------------------------------------------|---------------|----------------|----------|------------|-----------------|------------------|-----------------------------------------------------------------------------------------------------------------|
|    | Scenario                                                                                                                           | Project Stage | Consequence    |          | Likelihood | Risk Rating     | Confidence Level | NOTES/ MITIGATIONS                                                                                              |
|    |                                                                                                                                    |               | Type           | Severity | Descriptor | Descriptive     |                  |                                                                                                                 |
| 30 | Upstream blanket length is undersized leading to high seepage gradient resulting in excessive seepage flow                         | Const. & Op   | Com/Media/Rep. | Major    | Unlikely   | Moderately High | M                |                                                                                                                 |
| 31 | Poor quality rockfill and high seepage gradient leads to piping and failure of the dam.                                            | Const. & Op   | Human H&S      | Critical | Unlikely   | Moderately High | L                | Rock fill currently uncharacterized                                                                             |
| 31 |                                                                                                                                    | Const. & Op   | Env. Imp.      | Major    | Unlikely   | Moderately High | L                |                                                                                                                 |
| 32 | Limited understanding of hydrology results in undersized spillay and overtopping of dam during extreme storm events.               | Const. & Op   | Human H&S      | Critical | Unlikely   | Moderately High | M                |                                                                                                                 |
| 32 |                                                                                                                                    | Const. & Op   | Env. Imp.      | Major    | Unlikely   | Moderately High | M                |                                                                                                                 |
| 33 | High seepage gradient through the foundation leads to a piping failure through fractures and highly weathered bedrock and a breach | Const. & Op   | Human H&S      | Critical | Unlikely   | Moderately High | L                | Confidence is low due to the fact that only limited drilling has been completed for the current stage of design |
| 33 |                                                                                                                                    | Const. & Op   | Env. Imp.      | Major    | Unlikely   | Moderately High | L                |                                                                                                                 |
| 34 | Lack of detailed site investigations will lead to deficiencies in the dam design resulting in a breach                             | Const. & Op   | Human H&S      | Critical | Possible   | High            | M                | Scenario assumes that further investigations will not be completed                                              |
| 34 |                                                                                                                                    | Const. & Op   | Env. Imp.      | Major    | Possible   | High            | M                |                                                                                                                 |