Klohn Crippen Berger

Tahltan Central Council

Red Chris Mine Site

Review of Tailings Impoundment Design

October 2014

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CANADA'S BEST MANAGED

Klohn Crippen Berger

October 10, 2014

Tahltan Central Council
PO Box 69
Dease Lake, British Columbia
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Ms. Nalaine Morin, BASc
Threat – Project Manager

Dear Ms. Nalaine Morin:

Red Chris Mine Site
Review of Tailings Impoundment Design

This is the review report of the Red Chris tailings impoundment as per your request for proposal. Thanks to you and Mr. Patrick Hudson for your comments on our draft report.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Bryan D. Watts, M.Sc., P.Eng., P.Geo., FEIC
Project Manager

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BEST MANAGED

Tahltan Central Council

Red Chris Mine Site

Review of Tailings Impoundment Design

EXECUTIVE SUMMARY

This is a review of the tailings impoundment design, water quality predictions, and geohazards at the Red Chris copper/gold deposit in northwestern British Columbia near Iskut on Highway 37. The project is at an advanced stage of construction. This tailings impoundment review was instigated by the Tahltan Central Council following the failure of the Mount Polley tailings impoundment which released pond water and tailings to the environment. Any technical lessons to be learned from Mount Polley cannot be applied to this facility because the forensic investigation into the cause of that failure has not yet been completed. At the same time, any failure of the Red Chris impoundment will likely have a much more significant environmental impact than the Mount Polley failure.

The tailings will be stored in a valley about 400 m lower than and to the east of the mill. This valley is underlain by over 90 m of permeable glaciofluvial sands and gravels with interlayers of at least one glacial till unit. The valley is at the headwaters of Trail and Quarry Creeks. The impoundment will be formed by centreline tailings dams on the north and south and an earthfill dam in a northeast tributary in the latter stages of mining. These two tailings dams will be nominally 100 m high. Similar tailings dams have been constructed using centreline construction techniques at several sites in British Columbia. We consider that this design is feasible and will be stable statically and dynamically if constructed properly. To date, only the detailed design of the North Starter Dam has been completed. The detailed design of the North and South Dams has not yet been completed.

A major design issue for the tailings impoundment is the high permeability of the foundation soils. The designers are relying on a fine grained tailings blanket to limit seepage into the pervious foundation. This design will likely succeed but there has not been enough work on the potential for tailings fines piping into the foundation, internal piping instability of the foundation itself, and the potential for large seepage losses through temporarily unlined (no tailings) pond areas for the concept to be certain. In our opinion, during the early stages of development before tailings inundate the more pervious South Dam, the mine and their tailings designers need to monitor the water balance for the tailings impoundment carefully to prove their design concept.

The tailings dams will be constructed of rough, de-pyritized tailings which will also be spigotted upstream of the dams subaerially to form beaches. The pyrite from the rough tailings will be mixed with clean PAG tailings which will be discharged into the pond. The designers are relying on a pond water cover to prevent oxidation of the tailings through operation and closure.

All contact water from the mine, mill and waste dumps will be collected and conveyed to the pond. Tailings transport water and precipitation/runoff will mix with this water in the pond. The water balance shows that there will be excess water to mill and water cover requirements so pond water will have to be released to the environment. Red Chris is planning to release water by pumping to the environment 7 months of the year. With this release, Red Chris contends that a 12 day PMF can be contained with their intended freeboard.

In order for this untreated water release to be acceptable, the water quality must meet permit requirements. There is a detailed water quality model that predicts water quality will be acceptable during, at least, the operation of the mine. While this may be true, detailed documentation of the measures to be followed in the event that water quality fails to meet compliance is required. This should include an emergency response, identification of causes, secondary mitigation plans such as capture and pumping systems and inclusion of short and long-term water treatment.

As with any new site, the hydrology has been compiled from limited site information, nearby weather stations, and regional trends. We consider that another weather station is needed in the tailings impoundment valley as a minimum. The water balance will have to be updated as site experience is gained.

Presently, the site lacks an Operating, Maintenance and Surveillance Manual for the tailings impoundment. This document must be prepared recognizing the role of the observational approach on the water balance, seepage flows, and water quality. The site also lacks an inundation study for both the North and South Dams. Emergency preparation and emergency response plans are also lacking. We understand that both documents are being prepared.

The access road to the site from Highway 37 is through relatively stable terrain and does not require any attention other than relatively routine maintenance appropriate for this area. At the other end of the spectrum, the Kluea landslide, whose crest is about 300 m from the eventual pit rim, is poorly understood. The landslide requires basic characterization using techniques such as field mapping, bare earth Lidar, and movement estimates from satellite imagery. Then a risk assessment needs to be completed that considers the effects of the landslide on the project and the reverse.

This summary is intended to highlight the major issues identified in our report. It does not substitute for our report which must be read in its entirety to appreciate our opinion on site issues. This report preparation together with a site visit and partial review of a large number of documents was completed within about a one month. Our opinions in no way relieve Red Chris and its consultants of their sole responsibility for the safe and regulation-compliant operation and performance of the tailings impoundment.

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1 INTRODUCTION

1.1 General

This is a review of the design of the tailings disposal at the Red Chris mining project near Iskut, BC which is currently in development. The project is owned and will be operated by Red Chris Development Company, a subsidiary of Imperial Metals Ltd. Red Chris will be a copper/gold mine with a milling rate of 30,000 tpd. The scope of this review broadly follows the request for proposal from the Tahltan Central Council, given in Appendix I. Red Chris intends to start mining and milling once transmission power is available at site and construction is complete.

This review of the design of the Red Chris tailings impoundment was precipitated by the failure of the Mount Polley tailings dam, also owned by Imperial Metals Ltd. At the time of writing, the Panel appointed by the government to review the causes of the Mount Polley tailings dam failure has not released its findings nor do the reviewers have any specific knowledge of the Mount Polley tailings impoundment failure. Thus, it is not possible to transfer lessons from the Mount Polley failure to the Red Chris tailings impoundment design. At the same time, any failure of the Red Chris impoundment will likely have a much more significant environmental impact than the Mount Polley failure.

This review seeks to compare the design of the Red Chris tailings impoundment against good engineering practice. Our work comprises: review of relevant design documents, a site visit, and discussions with the designers and the mine owners, and preparation of this report. Also included in our scope is a review of the geohazards at the site; specifically the access road and the Kluea slide which is just 300 m or so from the eventual pit rim. This is not a calculation check but a concept check to the extent that the schedule allowed. Some issues are given more attention than others.

Our review comprised three progressive steps. The first was an audit which compares available project documents against documents which are required by various standards or procedures. The second is a review which compares the engineering and science against our opinion of standard engineering practice. The third is to compare the management systems promoted by the Mining Association of Canada (MAC) against those in place at the time of writing. Imperial Metals Ltd is a member of the MAC. Mine tailings management systems only become fully developed after the milling starts so much of our MAC review is a review of documentation and reiteration of those practices that need to be in place as the project proceeds.

This review follows the request for proposal in Appendix I from the Tahltan Central Council. As stated in our proposal, we are not qualified to offer advice on insurance and bonding. Imperial Metals Ltd made available all documentation requested and much more. Given the schedule, there was not time to review the hundreds of documents that were available nor was there time to identify document gaps other than the obvious. We also advise that technical reviews are relevant at the time of preparation and can be quickly outdated by decisions taken by others.

1.2 Consultant Roles

Traditionally, tailings storage dam design is done by specialist consultants and that is the case here. Our understanding of the role of the consultants involved in the tailings dam design is given in

Table 1.1. The organizations listed below have designed such facilities previously and, in our opinion, all are conversant with the standard of practice in their respective technical fields. We have not checked calculations or even design procedures of the consultants listed below. At this level of review we can only check on the reasonableness of calculations and procedures. It would be beneficial if all consultants were qualified under the Organization Quality Management (OQM) Program of the Association of Professional Engineers and Geoscientists of British Columbia. This is a voluntary quality management program for companies and institutions that employ Professional Engineers and Geoscientists.

Table 1.1 List of Consultants

Function	Organization	Subconsultant	Current Involvement
Tailings Dam Design	Originally, AMEC, now BGC Engineering		Now BGC
Engineer of Record Tailings	BGC Engineering	All North for laboratory testing during construction	On-going
Hydrology	AMEC	Clearwater Consultants	On-going
Hydrogeology	AMEC	None	On-going
Geochemistry	AMEC	SRK	As needed
Geohazards	AMEC	None	Quiescent

In our opinion the Engineer of Record (EOR) must be fully conversant with all aspects of the tailings impoundment design including hydrology, hydrogeology, and geochemistry. Presently, these disciplines are split between companies which will require more communication effort by the EOR to ensure consistency with project requirements.

1.3 Documents Reviewed

Imperial Metals prepared an FTP site on which they posted documents that would be useful to this review. A large number of documents were available but, because of time constraints, it was not possible to review all of this material. Thus we had to choose the most useful materials to review. Selected documents from that extensive FTP site are given in Table 1.2. Some of these references are in larger submissions to the government.

Table 1.2 Key Documents

Source	Year	Title	Comments
BGC	07/2014	Tailings Impoundment Area 2013 Construction Records Report - Draft	
AMEC	06/2011	Tailings Storage Facility Detailed Design Report	Plus Appendices
AMEC	2011	Water Balance Memo	
AMEC	2011	Water Quality Write-Up	
AMEC	2011	Water Management and Sediment Control	
AMEC	2011	Water Monitoring Plan	
AMEC	05/2014	Hydrogeology of North and South Dam Areas	Partial Response to Robertson report

Source	Year	Title	Comments
AMEC	07/2014	Update of the Hydrological Parameters for the Water Balance Model	
Red Chris	04/2012	Surface and Groundwater Monitoring Plan	
Red Chris		Water Quality Review – PPT Presentation	
Robertson Geoconsultants	11/2012	Independent Third-Party Review – Hydrogeology of Red Chris Tailings Storage Facility, BC	
SRK	2010	Kinetic Test Update Report	
SRK	06/2012	Metal Leaching and Acid Rock Drainage Prediction and Prevention Plan	
SRK	04/2014	Source Term Predictions	Draft

1.4 Organization of the Report

Following this section is a brief description of the Red Chris tailings impoundment and the basic design assumptions. Section 3 describes the visit to site by Messrs. Watts and Keegan. Section 4 is a document audit between required and available, recognizing that the mine is not yet in operation. Section 5 is a review of the design of the tailings impoundment. The geochemistry and predicted water quality work is described in Section 6. Section 7 is a discussion of tailings dam design standards. Geohazards, primarily the Kluea landslide, are described in Section 8. Section 9 is a description of an overall tailings management system. Section 10 is a list of recommendations.

2 RED CHRIS PROJECT DESCRIPTION

Figure 2.1 is a plan of the Red Chris mining project. The open pit, mill, waste rock dump, and other appurtenant facilities are located on the Todagin Plateau. An 18 kilometre long access road connects the site to Highway 37. The tailings facility is sited in the headwaters of Trail Creek and Quarry Creek to the east of the mill and mine which are located on the higher Todagin Plateau. The base of the tailings facility is nominally 400 m lower than the mill. Thus the tailings will flow by gravity to the pond and the reclaim water will be pumped from the pond up the slope to the mill. Excess water will be pumped from the pond directly to Quarry Creek downstream of the North Dam with no treatment.

The primary retention dams are the North and South Dams which will store 300 million tonnes of tailings. The third retention dam, the Northeast dam, will be a low earthfill dam in the northeast portion of a Y-shaped valley. The North and South Dams will be raised using centreline construction with compacted cyclone tailings underflow forming the downstream slope and the overflow to the beach. De-pyritized rougher tailings will be cycloned for dam construction. The cleaner tailings with pyrite from the rougher tailings will be discharged to the pond where they are intended to be permanently covered by the pond water to reduce oxidation. The stability of the nominal 100 m high North and South Dams tailings dams depends on the compaction achieved in the hydraulic fill cell construction forming the downstream slope.

The foundation of both dams consists of pervious glaciofluvial sands and gravels with glacial till horizons to depths of 80 m. in a glacial U-shaped valley. The foundation soils are very pervious. The designers are relying on the upstream tailings to reduce flow of the pond water to the foundation and out through the base of the dams.

There will be diversion ditches that limit fresh water flowing to the pond but the hydrology still shows that there will be excess water that will have to be continually released over the life of the project. The geochemistry work to date predicts that the pond water can be pumped directly to the environment while still meeting water quality guidelines.

The core of the North Dam will limit seepage through the centerline section. There is no core planned for the South Dam. Other than the upstream glacial till blanket in the initial reservoir of the North Starter Dam, no cutoffs or liners are planned for the tailings impoundment. The designers rely on the low permeability of tailing discharged upstream of both the North and South Dams to limit pond seepage into the pervious foundation soils.

Only the North Starter Dam has progressed to the detailed design stage. The detailed design of the North Dam and the South Dam are to come. As with all tailings impoundments, we expect that the dam sections may change with time in response to site condition but that the design criteria and basis will still be met.

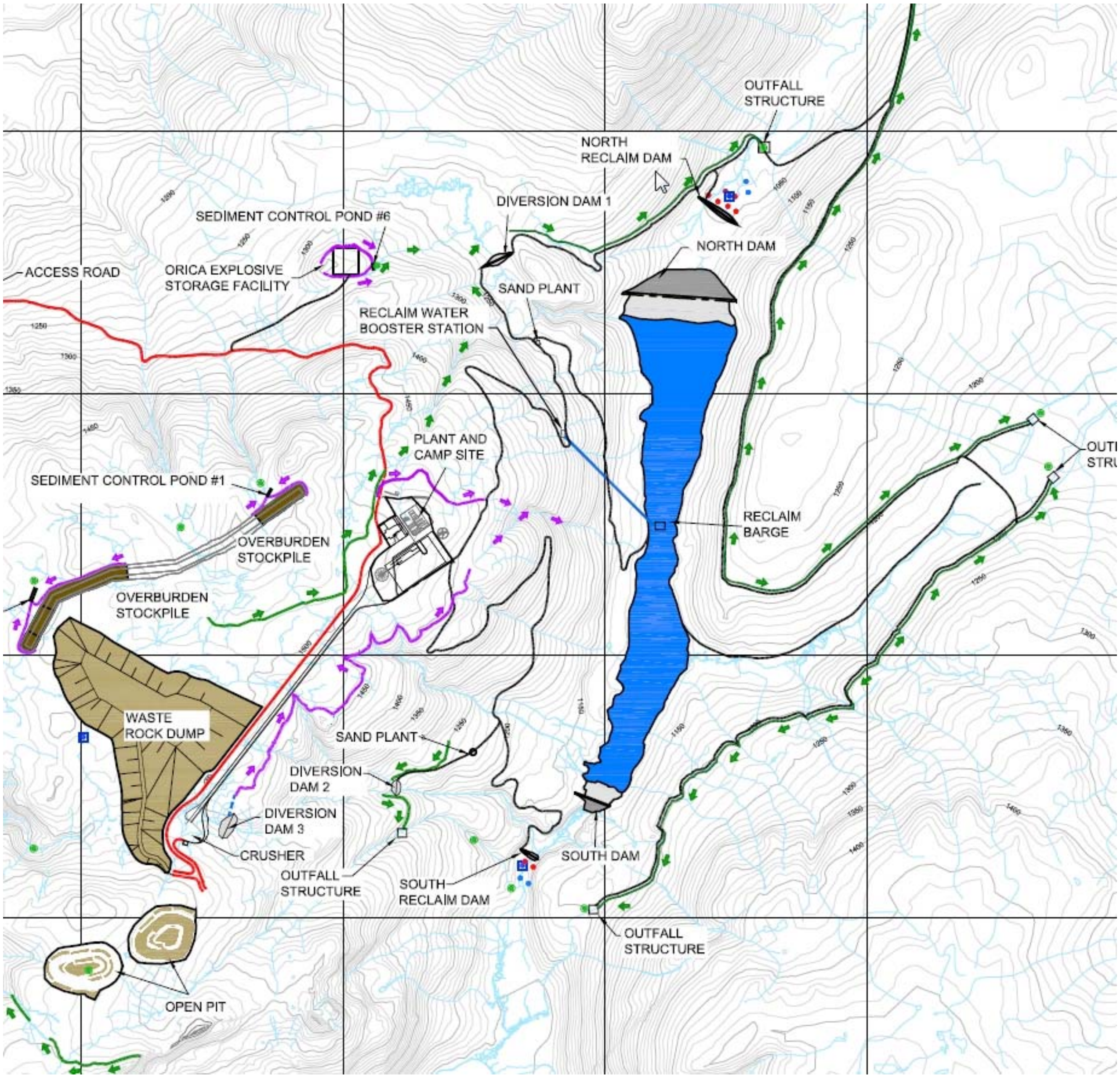

Figure 2.1 Site Plan at Year 3. Grid is 1 km, north is up

The feasibility of the tailings storage design depends on key design assumptions which are:

- The 100 m high centreline tailings dams at the north and south ends of the valley will be stable under static and seismic loading.
- During operations there will be sufficient freeboard to store and discharge by pumping a PMF. During closure the PMF will be routed through the Northeast Dam spillway.

- The foundations of the tailings dams are dense and will not liquefy during the design seismic event.
- The fine tailings upstream of the centreline of both dams will reduce seepage through the pervious sand and gravel foundation without piping.
- A pond can be retained above the fine tailings without a liner limiting seepage flow into the pervious side walls of the valley.
- All seepage discharging at the toe of dams can be controlled by groundwater pumping.
- Excess water collecting in the pond can be safely discharged by pumping only. No gravity discharge is required until closure.
- Excess water can be discharged directly to the environment during mining while maintaining water quality within permit requirements.
- The site rock is potentially acid generating but will not be acidic for decades. A water treatment plant will be eventually required.
- The PAG tailings will be permanently covered with water.

3 SITE VISIT

3.1 General

Dr. Tim Keegan, P.Eng. and Mr. Bryan D. Watts, P.Eng. arrived at the Red Chris site in the late afternoon of September 2, 2014 and left on the morning of September 5, 2014. We were joined by Mr. Patrick Hudson, a consultant to the Tahltan Central Council, late in the day on September 2. Mr. Todd Martin, P. Eng., of BGC accompanied us during the entire site visit. Mr. Martin was the designer of the tailings impoundment while at AMEC and is now the Engineer of Record for the design at BGC Engineering Ltd. Mr. Tim Fisch, Mine Manager, made all arrangements for us at site. On the afternoon of the first day, Mr. Fisch gave us a general site tour by truck and introduced us to his site staff. During the next two days, we walked over the North Dam construction area, the North Reclaim Dam, the perimeter of the impounded water behind the North Dam, borrow areas in the valley, and the future South Dam to the future South Reclaim Dam. On September 4 Mr. Fisch arranged a helicopter which we used to fly over the Kluea Slide east of the future open pit, the access road to site from Highway 37 and the tailings impoundment area.

On September 3, we drove down the access road to the North Starter Dam. The tailings delivery line and the reclaim water line parallel this road. There are pressure reducers on the tailings delivery line as the elevation drops around 400 m to the tailings impoundment. The cyclone house is being constructed near the bottom of the slope. A single stage of cycloning will be used to produce tailings for hydraulic fill construction instead of the two stages originally planned.

3.2 North Starter Dam

The North Starter Dam (NSD) was constructed to El. 1097 m from June to October 2013. From a stripped foundation elevation of 1075 m, the dam was nominally 22 m high at the end of 2013. The dam section comprises an upstream impervious zone of glacial till (Material 1), a sloping chimney drain (Material 3A), a second transition filter/drain (Material 3B) and a less pervious downstream shell (Material 2). Finger drains at the foundation level are intended to convey seepage collected in the chimney drain to the toe of the dam.

An upstream blanket of about 1 m of glacial till to 1097 m extends upstream to the cofferdam. The upstream blanket was originally planned to be HDPE but was changed to glacial till because of the savings realized by using locally available suitable materials (Pers. Com. – Todd Martin). This type of design change to take advantage of locally available material is routine. We consider that the glacial till blanket will meet the design objective. Without a blanket, the NSD would not retain water. Once the water level in the pond exceeds the top of the blanket without intervening tailings, seepage past the dam will increase markedly as will foundation piezometer readings. See the North Starter Dam and Reclaim Dam on Figure 3.1. This local liner will have little effect on the long term seepage through the North Dam.

The 2013 construction of the NSD and its appurtenant structures (North Reclaim Dam, cofferdam, ditches, blanket, etc.) are documented in the 2013 BGC construction records report listed on

Table 1.1. Our review of the adequacy of construction is limited to our field inspection, conversations with BGC staff, and reading of the aforementioned report. The design section and slopes are appropriate for a starter dam in this context. There are no signs of settlement, slope bulging, cracking or other indications of instability evident at the dam. The dam appears well-constructed.

Figure 3.1 North Starter Dam

We are aware that the fines content for Zone 3A was increased, 5% to 6.5%, during construction in 2013 because the sand and gravel broke down slightly during construction. The compaction specification for Zone 3A was changed to minimize crushing of sand grains. Fines contents in filters/drains are normally kept to less than 5%, sometimes 3%, to ensure that the filter/drain has the drainage capacity to convey seepage from the impervious zone to the toe of the dam. The increase in fines in this case will reduce the capacity of the drain but tailings will envelope the dam long before the full capacity of the drain is required. The second reason for limiting fines content is to prevent a crack in the core or Zone 1 progressing through the drain and thereby bypassing its function. Cracks most often occur in dams that are poorly compacted, are on compressible foundations, or on foundations where the underlying rock profile changes rapidly. None of these operate at this site so we do not consider that the increase in fines content will impair the function of the drain.

At the time of our site visit, construction on the dam at the interim crest at El. 1097 m had just started. The dam surface was being prepared but fill was not being placed. We understand that the dam will be raised to El. 1104 m this year and, if the weather is favourable, to El. 1109 m and higher if weather permits. We consider that the equipment, construction techniques, and monitoring personnel are appropriate for this type of dam. The dam is being constructed by mine personnel.

Another consultant retained by the Tahltan Central Council, Mr. Michael J. Pauletto, an experienced engineer and contractor also reviewed the construction records and construction techniques. His comments also need to be considered by the owner.

3.3 Upstream of North Starter Dam

We walked along the east side of the Quarry Creek Valley south to the end of the borrow areas and returned along the west side to the NSD. A pond was rising against the NSD. We understand from Mr. Tim Fisch that the pond was “7 m” deep at the upstream face of the dam. The pond was accumulating from runoff, a deliberate breach in the Beaver Creek diversion channel and pumping from the North Reclaim Dam. No measurements of any of these flows were being taken. Flow measurements should be taken because inflow versus pond level will give an indication of the effectiveness of the glacial till blanket (liner), much more meaningfully than theoretical discussions of HDPE versus glacial till. There was significant seepage discharge downstream of the toe of the NSD which is thought to be natural groundwater discharge but could be due to a defect in the blanket. This is not likely in our opinion but simple measurements of this water balance will yield valuable insights into the performance of the system as it now exists.

Our traverse around the valley upstream of the NSD showed many exposures of coarse sands and gravels and some glacial tills. The fluvial structure in the sands and gravels was ubiquitous confirming their glacio-fluvial origin. The entire exposed area appeared very pervious. There were few instances of standing water on the surface. Also evident was the compactness of the exposed materials. In summary, the exposed surficial soils were pervious, dense sands and gravels. These soils will not liquefy during seismic shaking. There would be much value in mapping the entire exposed area so that the geological model could be updated and confirmed.

It is important to reiterate that it would not be possible to construct a water retaining dam at this location without an impervious blanket or full cutoff of the foundation beneath the North Dam. The designers are relying on the fine tailings filling the voids of the natural soils at the interface to reduce seepage flux. We suggest that the filter compatibility between the fine tailings and the foundation soils be checked. That is, the designers need to be content that the fine tailings will not migrate into the voids of the natural soils and progress to the toe of the dam.

3.4 Downstream of North Starter Dam

Downstream of the toe of the North Starter Dam is the North Reclaim Dam which retains a pond with a spillway. Between the reclaim pond and the toe of the NSD is the future footprint of the downstream section of the North Dam. A blanket drain is planned in this area beneath the compacted tailings sand.

There is not much seepage discharging from the finger drains at the toe of the NSD. The location of the finger drains are not marked in the field. Despite the temporary exposure of this downstream slope, there should be a toe ditch which collects the seepage from the finger drains and directs it through a weir for flow measurement. We observed linear, horizontal wet spots on the downstream slope which are thought to result from precipitation exiting along lower permeability lifts. The seepage discharge from the finger drains and the wet spots on the downstream face are well within the expected behaviour of the dam.

Proceeding downstream towards the reclaim pond, the seepage discharge from the foundation soils increases significantly. This seepage discharge has filled the reclaim dam pond to the spillway invert where it is discharging downstream of the dam. The spillway flow, the reclaim pond elevation, and the pump back volume at the reclaim dam should all be measured to understand the efficacy of the upstream blanket and the permeability of the foundation. The seepage estimate from the start-up NSD pond was estimated to be 32 liters/sec. This needs to be checked against actuals.

The future drainage blanket beneath the downstream compacted tailings has to be able to capture and convey this foundation seepage to the toe. This seepage could increase significantly as the dam is raised so the drain needs to be designed for future significant seepage. The phreatic surface must be retained within the drain so that toe erosion of the dense tailings sand dam fill does not occur. It must convey tailings transport water and precipitation also. Despite large flows, the toe of the drain needs to be protected against freezing. We also see benefit to constructing the blanket drain well before the hydraulic fill construction starts. We recognize that these are detailed design issues that the designers will have to consider.

3.5 North Reclaim Dam

We walked the crest of the reclaim dam which was completed in 2013 together with a lined spillway on the right abutment. The reclaim pond is full and discharging through the spillway. Downstream of the dam are several deep groundwater monitoring wells. All of the wells that we observed were flowing from the top of pipe. The groundwater well closest to the toe of the dam is capped but there is a jet of water discharging from the top of the cap. We did not observe any attempt at pressure measurement of these wells which is a simple matter of fixing a pressure gauge to the well. This should be done so that the water balance in this area can be properly appreciated. We understand that groundwater pumping wells are planned for this area in future.

We walked the toe of the reclaim dam which has a pond against a portion of it. The writer noted that the foundation soils at the toe were loose which usually indicates upward seepage at the toe. In most circumstances, we would recommend an inverted filter be placed against the downstream to prevent uplift. However, the design shows that Zone 3A, the filter extends 3 m beyond the toe which is likely the source of seepage. The loose saturated soils may thus be caused by seepage through the filter. However, uplift at the toe may increase as the North Dam is raised so an inverted filter may be necessary.

We understand that construction of the outlet for the spillway was delayed from 2013 until 2014. Presently, the discharge is to native ground.

3.6 South Dam

Construction on the starter dam for the South Dam will start several years from now. Accordingly, the only indication of activity in this area are the numerous groundwater well installations. We walked the areas to the end of the road but far enough along to see the toe of the east portion of the Kluea Slide.

As per the drill hole logs, the foundation soils are coarse, pervious sands and gravels. The valley is markedly narrower than the Quarry Creek valley. The sides of the valley were relatively steep (no measurements were taken; likely at the angle of repose of the dense surficial soils.

3.7 Helicopter Tour

Mr. Tim Fisch arranged for a helicopter tour of the tailings site and the Kluea landslide complex. Messrs. Martin, Hudson, Keegan and Watts left at 12:30PM on September 4, 2014 and returned about one hour later. The flight took us south along the crest of the Kluea landslide east of the future open pit on the Todagin Plateau, back north along the toe of the landslide, over the future South Dam and the future Northeast Dam, over the construction works for the North Dam, and finally along the access road to Highway 37.

The primary purpose of the tour was to observe the Kluea landslide and access road from the air. These observations are described in another section.

Figure 3.2 Kluea Slide - East Section from Helicopter

4 AUDIT OF REQUIRED DOCUMENTATION AGAINST CDA AND MAC

4.1 Canadian Dam Association

The following is a summary of the documents recommended in the Canadian Dam Association Dam Safety Guidelines and Mining Association of Canada Operational, Maintenance and Surveillance Manual for Tailings and Water Management Facilities. These guidelines overlap in their procedural and documentation recommendations and both apply to the future Red Chris Tailings Dam.

The Dam Safety Guidelines (DSG), published by the Canadian Dam Association (CDA), clearly state that "*Dam safety management is the management of risks associated with dams, including release of fluids as a result of structural failure, mis-operation, planned operation, or any other cause. For dams that retain contaminants of any sort, protection of the public and the environment should extend to seepage and pathways not necessarily associated with catastrophic failure of the retaining structure*".

The framework outlined in the DSG defines the system for the development of safety policies, planning, reporting, surveillance and corrective actions for all dams. Key elements of this framework are:

- Dam Safety Management: primary objective is to prevent a dam failure.
- Operation, Maintenance and Surveillance: procedures and practices for the safe management of the dam.
- Inundation study: estimate pond and tailings runout to determine design criteria and basis for the emergency preparation and response.
- Emergency Preparedness: establish a clear emergency response system.
- Dam Safety Review: evaluate and review of all aspects of design, construction, maintenance, operation, processes and systems.
- Analysis and Assessment: hydrotechnical, seismic, geotechnical, structural, mechanical and electrical.

Documents recommended in the DSG include, but are not limited to, those summarized in Table 4.1. It should be noted that the DSG also requires that the closure requirements for tailings dams be considered at the initial design stage and all subsequent phases.

Table 4.1 CDA Dam Safety Guidelines

Document	Provided	Notes
Site investigation, geological and environmental baseline reports	Y	Meets requirements
Design reports	Y	Detailed design not done
As-constructed drawings and reports	Y	NSD
Hydrological and meteorological reports	Y	Limited information at site
Dam inspection and dam safety review reports	N	Too early except for NSD

Document	Provided	Notes
Environmental control and monitoring	Y	Plans in place
Instrumentation, surveillance and monitoring manuals and reports	N	Not done
Risk assessments and reports	Y	Only for tailings dams, very rudimentary
Inundation Study	N	Need separate inundation studies for the North and South Dams that includes solids runout
Emergency preparedness, response and contingency plans	N	Not done
Decommissioning and closure plan	N	Conceptual only
Quality control records and statistical summaries	N	Done for NSD

4.2 Mining Association of Canada

The MAC Operational, Maintenance and Surveillance (OMS) Manual for Tailings and Water Management Facilities summarizes the rationale, organization and contents for an OMS manual and describes the procedures that should be addressed.

An OMS manual is a controlled document that includes procedures for:

- distributing and filing the manual and supporting documents;
- reviewing and updating the manual;
- removing and archiving out-of date materials; and
- roles and responsibilities.

An OMS manual needs to cover:

- facility description;
- operations and maintenance;
- surveillance; and
- emergency planning and response.

Facility Description

A summary of the documents recommended for a complete description of tailings and water management facilities is given in Table 4.2. Maintaining an up-to-date record of design and supporting documents and reports will allow important information relating to the facilities to be accurately passed on to future operators.

Table 4.2 Facility Description Documents

Document	Provided	Notes
Site investigation, geological and environmental baseline reports	Y	Available
Environmental Assessment	Y	Available
Laboratory and field testing results	Y	Available
Design reports	Y	Available
Construction reports	Y	Available
Hydrological and meteorological reports	Y	Available but limited
Vendor manuals and drawings	N	
Tailings deposition and water management plans	Y	Limited information
Dam inspection and dam safety review reports	N	NA
Environmental control and monitoring	Y/N	Monitoring plan, no mitigation plan
Instrumentation, surveillance and monitoring manuals and reports	N	Being prepared
Risk assessments and reports	N	Only for geotechnical aspects
Serious incident reports	N	NA
Emergency preparedness, response and contingency plans	N	Being prepared
Decommissioning and closure plan	N	Concept only

Operations and Maintenance

During the operational phase, a number of documents are recommended as summarized in Table 4.3. These documents should define operating standards and procedures in accordance with the design criteria, regulatory requirements, sound operating practices for the economical, safe and environmentally responsible operation of tailings and water management facilities and be tailored to the unique facility characteristics and site conditions.

Table 4.3 Operations and Maintenance Documents

Document	Notes
Quality control records and statistical summaries	To be done(TBD)
Instrumentation records, daily diary records	TBD
Up-to-date equipment logs	TBD
Communications and activity records	TBD
Photographic summaries and/or videos	TBD
Schedules	TBD
Work history	TBD
Frequency and cause of problems	TBD
Component reliability	TBD
Change orders, memos, reports	TBD
As-constructed drawings and reports	TBD
Inventory of spares, materials, tools and equipment	TBD
Critical spares list	TBD

Surveillance

Surveillance can provide early indication of performance trends through inspection and monitoring of the operation, structural integrity and safety of a facility. Documents for surveillance should include:

- observations from routine visual observation (departures from or exceptions to normal conditions);
- instrumentation monitoring and testing; and
- evaluations, inspections and reviews.

It is important at this site that the Observational Approach be used for the geotechnical, groundwater, surface water, and water quality measurements through an integrated model. These issues are interdependent so an integrated approach is needed to properly identify deficiencies.

Inundation Study

An inundation study needs to be completed for this site that includes an estimate of pond release, tailings release, and the effect of loss of cover on the PAG tailings in the impoundment.

Emergency Preparedness and Response Plans

Emergency preparedness and response (EPR) plans should identify actions to be taken and responsibilities assigned to individuals at the site, agencies and affected parties. Typical contents of an EPR plan includes: identification of failure modes; identification of roles and responsibilities; identification of requirements of legislation, codes of practise, notification and reporting obligations; identification of available resources; mutual aid agreements; public relation plans; telephone lists; establishment of communication system for notifications and for post-notification purposes; risk analysis for on-site and off-site effects; inundation study, maps and table for both physical and environmental releases (including dam break); basis for activation of emergency response plan and emergency decision making; training of personnel; investigation and evaluation of incidents and accidents; contingency plans; restoration of safe operating conditions; and validation drills and tests of the system.

4.3 Summary

The mine is not yet operational so many of the documents listed above are not yet completed. However, the most obvious deficiencies in the documentation at the time of writing are the OMS manual and an inundation study. Both are necessary to develop Emergency Response Plan and Emergency Preparation Plan. The inundation study must include an estimate of the tailings runout. It should also recognize that any failure will release the pond and expose the remnant and runout tailings to oxidation.

The OMS manual should include an integrated approach to hydrologic, geotechnical, and water quality monitoring at the site. All observations and instrumentation readings need to be part of a comprehensive monitoring program where trigger levels are set for various actions and mitigations as circumstances warrant. Setting reading frequencies for various instruments is only the start of a monitoring program.

5 TAILINGS DAM DESIGN REVIEW

5.1 Static Stability

The Red Chris tailings storage facility will be in the valley to the east of the site at the headwaters of Quarry Creek to the north and Trail Creek to the south. The north end of the impoundment in Quarry Creek is lowest so it will be raised first. The starter dam is intended to be raised to a final crest elevation of 1118 m. The south dam construction will start after a few years before the pond reaches the headwaters of Trail Creek. As the south and north dam are being raised the pond will eventually spread to the northeast where an earthfill dam, the Northeast dam will retain the pond.

The basic tailings dam design, as shown in section on Figure 5.1 is to raise the north and south dams using centerline construction above the starter dam. What follows is a description of our understanding of the design and operation of the North Dam. The South Dam is a similar design, except that there is presently no plan to include a core in this dam.

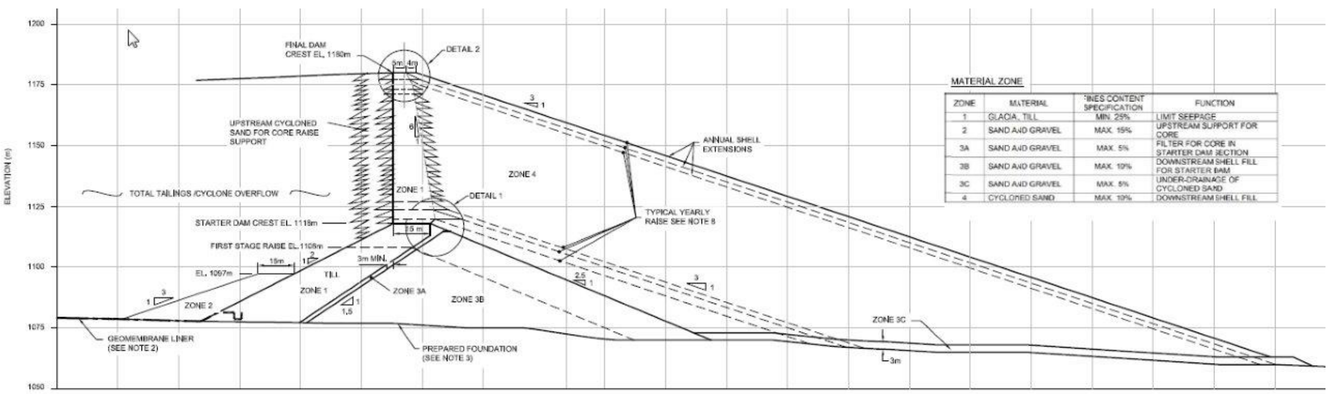

Figure 5.1 Final Design Section for North Starter Dam

The design and construction of the starter dam is described in Section 3 so we will start with a review of the design of the tailings dam above that. The North Dam will be constructed with the tailings themselves. The rougher tailings will be stripped of pyrite and cycloned to produce a coarser non-acid generating angular sand. This cyclone underflow sand will then be used to construct sand cells first on the downstream toe of the starter dam, then to raise the dam using cell construction on the downstream side and spigotting on the upstream side of the crest. Cleaner tailings will be discharged directly into the pond. The dam will eventually be about 100 m high.

A compacted glacial till core will be raised with the dam to reduce seepage in the downstream cell constructed zone. Except for a drain on the foundation from the downstream toe of the starter dam to the downstream toe of the hydraulic fill section, no other drains/filters are planned for the downstream hydraulic fill section. As described in Section 3, the blanket foundation drain downstream of the North Starter Dam is an important element that still requires detailed design.

The successful construction of centreline dams requires detailed planning so the three zones; hydraulic fill sand, glacial till core, and the upstream beach are raised simultaneously. The crest must always have adequate freeboard to retain the Probable Maximum Flood. This technology has been used in British Columbia since the 1970s at the Brenda mine (closed) near Peachland, the Gibraltar Mine (active) near Williams Lake and the HVC mine (active) south of Kamloops. We have no reason to believe that this established technology will not work here but, as elsewhere, operating/construction procedures will have to be developed and implemented for the site-specific conditions.

The basic dam design is thus compacted or dense sand at a slope of 3H:1V with an underdrain and a core. The foundation is dense glaciofluvial sand and gravel with discontinuous glacial till layers.

The designers state that the dam has been designed to the standards of the CDA (2007). Strength parameters are given in AMEC (2011). The Factor of Safety design criteria for static stability is 1.5. That is, the strength of the foundation and the dam has a 50% reserve to resist the shear stresses imposed by the downstream slope. The designers state that the FOS using standard analytical techniques is 1.7. We did not repeat the stability analyses but the strength parameters used for the dam and the foundation are reasonable. We agree that the North and South Dam will have acceptable downstream slope stability. We note that no consideration of artesian pressures in the foundation were included in the stability analyses.

To achieve a FOS of 1.7, the hydraulic cell construction must achieve the densities specified. This requires careful construction techniques to achieve densities and prevent slope face erosion. Also the downstream blanket drain must control the foundation seepage as assumed. Again, this drain is an important part of the design.

5.2 Seismic Stability

The designers have chosen the Maximum Credible Earthquake (MCE) for design of this facility. This was done in an absence of an inundation study which is normally used to evaluate the consequences of failure of the structure. Irrespective, the MCE is the highest earthquake load that the dam would experience.

The site is in the relatively inactive Coast Shear zone. The potentially active Chatham Strait Fault is more than 250 km away and the active Queen Charlotte Fault is more than 350 km away. The 2012 Haida Gwaii M7.8 EQ occurred more than 350 km from the site.

Using the historical seismic database AMEC adopted a median PGA of 0.11 g. The corresponding mean PGA is likely around 0.15 g. Although the historical seismic record in this area is very short, it does not support any higher values and there is no evidence of any active faults close to the site. KCB may have chosen 0.15 g for the design motions at this site but the seismic stability results would have been the same as AMEC.

A key consideration of tailings dam design is the liquefaction potential of the foundation and the tailings dam itself. Liquefaction is complete loss of strength due to a rapid buildup of pore pressure (the pressure in the water in the space between the soil grains). The foundation soils are very dense because of prior glacial loading or soil loading which has been removed. Our walk around the North Starter Dam confirmed the foundation soils are indeed very dense. These soils are so dense that liquefaction is not possible given any level of earthquake shaking.

Equally, the cell constructed tailings downstream of centreline are designed to be compacted simultaneously with placement. If that is achieved, then the downstream section of the dam will not liquefy under any earthquake motions.

5.3 Seepage Control

AMEC remains responsible for the on-going hydrogeology of the tailings impoundment. That work is documented in the AMEC (2011) design report, Appendix D, and the subsequent AMEC (2014) report. Between these two reports was a review report by Robertson Geoconsultants (2012). In the latter report are references to other reviews of the hydrogeological work. This level of scrutiny is appropriate given that no manufactured liner is planned for this very pervious foundation.

We have chosen not to review the hydrogeological work in detail because the review by Robertson Geoconsultants (2012) already serves that purpose. We note that the work documented by AMEC (2014) is partially in response to the Robertson Geoconsultants (2012). We also note that the AMEC (2014) report refers to an updated modelling report which we have not seen.

The ultimate purpose of the seepage and hydrogeological work is to confirm that the tailings impoundment can retain water on such a pervious foundation, that resulting pore water pressures in the retaining dams can be controlled without causing instability, and that any contaminants that are carried by the seepage from the system either meet requirements or can be captured and reduced to acceptable levels.

The designers are relying on the fine grained tailings to form a blanket to restrict flow through the pervious foundation and out beneath the foundations of both the North and South Dams. The designers have completed two seepage analyses to estimate this seepage; SEEP/W 2-D and MODFLOW 3-D. The 2-D analyses included two cases; the start-up free water pond at the NSD. The MODFLOW analyses included three cases; the start-up case; an intermediate case, and the closure case.

The start-up case is live now. The pond is filling; helping to cause significant seepage discharge to the future footprint of the downstream section of the North Dam. As we have stated before in this report, the flows into and out of the NSD area should be measured and all measurements incorporated into a calibration of the hydrogeological model.

The designers are relying on the upstream tailings to limit seepage through the dams. In fact, they predict that seepage losses through the North Dam will reduce as the pond rises from 27 litres/sec (a partially lined NSD pond without tailings) to a total seepage loss of 13 litres/sec to 25 litres/sec from both the North and South Dams for the intermediate development condition.

The MODFLOW results for the intermediate case are somewhat obscure in that it is not certain what percentage of the reservoir is covered with tailings. As the dams are raised tailings will be spigotted from the dams at a very flat subaqueous slope of 1% or less. Thus the pond level will always reach beyond the end of the tailings slope until the tailings from the North and South Dams coalesce. This free water in contact with a stripped foundation could contribute much to the seepage flow out of the impoundment. We also recognize that cleaner PAG tailings will be discharged to the pond independently of the dam spigotting. The designers need to use tailings deposition modelling with a program such as Muck 3-D to predict the extent of the free water pond with time. This may influence the location of future borrow areas.

The illustration below (Figure 5.2) shows the extent of the water pond and the red tailings outline at 1120 m. This is for a tailings slope overall of 1%, a beach width of 100 m and no PAG tailings deposition. If the tailings slope were flatter then the unlined water pond outline will be less. The steeper the subaqueous tailings slope the greater the free water pond size (without tailings liner). This simple illustration demonstrates that seepage loss estimates are dependent on the deposition plan.

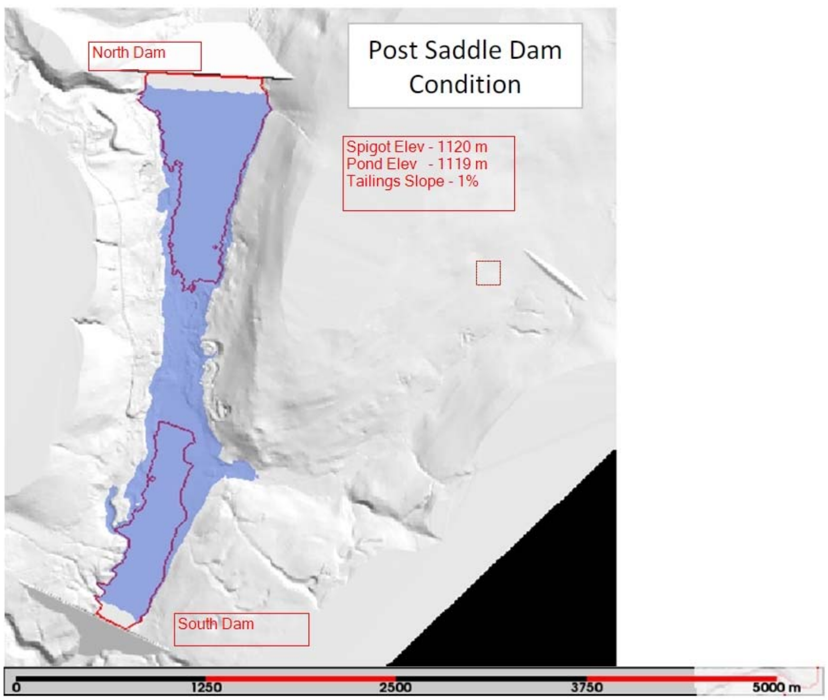

Figure 5.2 Tailings Deposition from Muck 3D at El. 1120 m

A large area upstream of the NSD has been opened up for borrow of dam materials. These areas should be mapped and correlated with the existing geologic model. In addition, the surface should be scoured for open work gravels where tailings could be lost to the pervious foundation soils. This surficial geological mapping exercise should be used by the designers to confirm that the tailings will not pipe into the pervious foundation soils. The water balance and seepage models need to be continually updated to confirm the integrity of the tailings liner.

Calibration and update of the hydrogeological model to monitoring results is a continual process for a tailings impoundment given these conditions. The modelling done to date may not have identified the stage in the life of the impoundment where seepage beneath the dams is the highest. Estimating this seepage discharge value is important because it is a key parameter in the design of the blanket drain beneath the downstream slopes of both the North and South Dams.

For the seepage control design to work, three important assumptions must be true. The first is that a pond can be retained over highly pervious foundation when no tailings are available to line the reservoir. The second is that the fine tailings must not pipe into the coarse pervious foundation. Thirdly, the internal stability of the foundation soils themselves will be adequate given the new flow regime. We do not see documentation that these issues have been considered adequately. However, this does not mean that the tailings liner will not work as intended.

The existing situation at the North Starter Dam with a rising fresh water pond, seepage discharge downstream of the toe of the North Starter Dam, and artesian pressures beyond the toe of the Reclaim Dam is an opportunity to calibrate the groundwater seepage model. This calibration would help confirm the designer's decision that an artificial liner was not needed at this site.

5.4 Hydrology and Water Balance

5.4.1 Hydrology

The Red Chris tailings storage facility is located in the Skeena Region on the border of the Stikine Plateau and Northern Central Uplands hydrologic zones (Ministry of Environment 2013). Hydrologic zones are defined as an area where runoff characteristics are relatively uniform. Hydrologic zone boundaries can be identified by either statistical analysis of hydrologic data or physical mapping of physiographic and hydrologic features. Due to limited hydrologic data, physical mapping is often applied and relies on professional judgement. In locations where a project is located near a hydrologic zone border, collection of climatic and hydrometric data is required for site specific hydrologic characterization.

This, together with the 450 m difference in elevation between the mill and the base of the tailings, area argues for more hydrologic weather stations than normal. We note that there are only two weather stations at the site, both on the Todagin Plateau. We consider that there should be at least two more; perhaps one in the valley and one to the east of the tailings impoundment near the Northeast Dam. We also consider that hydrometric stations should be installed in drainages that are in the same hydrologic zone as the weather stations to confirm the catchment runoff characteristics.

The inclusion of additional climate stations is further supported by the recommendations of the most recent update to hydrology in the AMEC Memorandum of July 8, 2014 to RCDC. From the limited rainfall data presented in the memo for the Upper WX and Lower WX stations, it appears that orographic effects occur within the site.

The AMEC memo brings together updates to hydrology for the site, which has been progressively updated since the submission of the 2004 Application for an Environmental Assessment Certificate.

The memo also mentions a workshop involving Imperial Metals, BC MOE, CCL and AMEC at which it was agreed that a mean annual precipitation of 620 mm was to be used for the project. The annual precipitation value was initially estimated during the EA and was subsequently reviewed and revised by several experts. This process is a supportable standard of practice.

It is noted that in the documents reviewed, there is little information available on design storm event assessment. The AMEC memo noted that rainfall at the Upper WX station had a good correlation (0.99) to Dease Lake data for the period of overlap. This implies that the intensity-duration-frequency data available through Environment Canada for Dease Lake could be adopted for the design of water management structures at Red Chris. The source of design storm event precipitation used for sizing of spillways, ditches, pond etc. is unclear.

It is also unclear what method was used for the estimation of the probable maximum precipitation (PMP) and probable maximum flood (PMF) for the tailings storage facility. In the AMEC 2011 Design Report it is noted that prior to finalizing the closure spillway design a detailed flood routing and freeboard analysis is required. We consider that this analysis should have been done at the initial design stages of for the tailings dam, in accordance with the CDA Dam Safety Guidelines.

5.4.2 Water Balance Spreadsheet

The purpose of a tailings water balance is to predict the pond level within the impoundment with consideration given to inflows such as precipitation and tailings transport water, and outflows such as groundwater and releases to the environment. The water balance, tailings mass loading to the impoundment and topography determine the rate of rise of the North and South retention dams with time.

AMEC is responsible for the water balance and hydrology of the tailings impoundment and currently predict a net surplus of water to the system. This means that pond water must be discharged to the environment so that the dams are not overtopped as they are raised. It has been suggested that discharge would need to occur over a minimum 7 month period with higher discharges potentially occurring during freshet, when greater dilution is available.

AMEC has prepared, and updates, a multiple worksheet spreadsheet that accounts for inflows and outflows to the system. We have reviewed this extensive set of worksheets but the assumptions which underlie key values are not readily apparent.

The water balance should be a stand-alone document that be readily reviewed by internal and external parties. It should also form part of the documentation under the CDS and MAC guidelines. The manual for the water balance needs to be updated as changes are made to clearly indicate the assumptions made and the source of the assumptions so that its basis becomes part of the institutional memory of the organization. Furthermore, the manual should clearly indicate parameters that can and cannot be adjusted by the user.

As the project progresses, some inputs and outputs will require revision to include changes in operations, observations made on site, and additional data collection. A review of the water balance should be made on a regular basis with updates to include a review of assumptions and adjustments to the flow path schematic, where required. The water balance manual should also be updated at the same time so that it is readily available in accordance with the CDA and MAC guidelines.

There is value in developing a GoldSim water balance model (or equivalent) to increase the level of transparency. It is difficult to review the present set of worksheets. Another approach to presentation would be to use a GIS to record results and compare against predictions. In any management system, it must be relatively easy for skilled professionals to check key elements of that system.

5.5 Volume Elevation Curve for Tailings Impoundment Raising

The water balance spreadsheet includes a pond filling curve but there is no crest raise line above this pond filling schedule. Normally, retention dams of this type are raised at least one year ahead of the level that the dam needs to be to retain the design storm, in this case the PMF. The only discussion of freeboard to retain PMF is the mention of 2 m in the AMEC (2011) report. The basis for this value is not known, e.g. it is not known whether the wave run-up estimates are included.

More importantly, there is no discussion in any of the reports about the crest level of the North Dam versus the South Dam. We acknowledge that this is a detailed design issue for which there is still much time to deliberate. Nonetheless, we consider that the South Dam, without a core, should always be higher than the North Dam. Pond water can inundate the beach and rise against the North Dam core without compromising the dam. As the South Dam has no core (at this conceptual level of design), once the pond rises above the beach, seepage through the dam will rapidly increase. Thus, it should be higher so this does not happen. The crest of the North Dam can be rapidly raised if required.

6 WATER QUALITY

6.1 General Geochemical Character of Red Chris Waste Rock and Tailings

The Red Chris deposit has been characterised as a typical porphyry deposit. Specifically the deposit appears to be a calc-alkaline porphyry with elevated sulphides and metals, as is common for these deposits. Pyrite, a common sulphide and the most common producer of acid rock drainage (ARD) has been confirmed as the major sulphide at the mine. Based on the observed sulphide content and the apparent excess of sulphide compared to neutralizing minerals, there is a definite possibility of acid generation. Assessments to date have indicated that the potentially acid generating rock (PAG) greatly exceeds the potentially non-acid generating (NAG) waste rock.

Importantly for this project, there are several similar calc-alkalic porphyry deposit and mines in British Columbia (BC) which can serve as suitable analogues for the expected water quality from the waste rock and tailings from Red Chris. Similar to other calc-alkalic porphyry mines in BC, Red Chris is expected to generate waste that has the potential for acid rock drainage and metal leaching (ARD/ML).

For the tailings, the characterization concluded that whole tailings were PAG but that the rougher tailings with an additional de-pyritization step would be NAG. Three major types are considered typical of the Red Chris tailings, namely rougher tailings, cycloned sand tailings and cleaner tailings. From the geochemical characterisation completed on these tailings, the rougher tailings are considered non-PAG and the cyclone sand material derived from these rougher tails are also considered to be non-PAG. The so-called cleaner tails are high in sulphide (mostly pyrite) and are considered strongly PAG. Red Chris has committed to depositing these tailings subaqueously and managing the TSF in manner that keeps the tailings saturated and sufficiently removed from oxygen to prevent sulphide oxidation and acidification. Final beaches will be created using de-pyritized tails with low sulphide-sulphur content which have been demonstrated to be NAG (AMEC 2004).

Acid base accounting (ABA) data collected over several phases of the project have confirmed that most of the waste rock is PAG. The ABA has also indicated that the rock contains carbonate in variable quantities. These carbonates are expected to allow a relatively long “lag time” of decades before acidic conditions are observed from the waste rock. Red Chris intrusive and associated rocks are expected to remain dominantly non-acidic during operation and progression of ARD onset is expected to take decades to centuries while some of the Bowser sediments reacting more rapidly and expected to become acidic during the operational period of the mine (SRK 2012).

6.2 Geochemical Testing Characterisation and Testing

Several stages of specific ARD/ML investigations have been undertaken at Red Chris. These include studies undertaken in 1994, 1995, 1996 and 1998. The more recent characterisation of waste rock and tailings stretches back to 2003, with ongoing kinetic geochemical testing since then.

Although it is not entirely clear which samples were subjected to different types of geochemical testing, the supporting data (AMEC 2004) suggests that in excess of 900 rock samples have been subjected to ARD/ML testing and acid base accounting (ABA).

Although the data has not been reviewed in detail, the geochemical characterisation reports suggest that the number of samples for waste rock characterisation are adequate, although insufficient detail is available for how waste rock management will occur and how the waste management plan will be implemented based on different waste rock classes.

The ARD/ML testing has confirmed that much of the waste rock can be regarded as PAG. In addition, the static testing indicates that there is potential for elevated salinity (sulphate) and elevated metals to occur in the mine drainage. Metals of concern include Al, As, Cd, Cu, Mn and Se which are significantly elevated in the waste and have also been found to be elevated in waters sampled from mineralized zones in the area.

The testing has confirmed the presence of several sulphide minerals including pyrite and chalcopyrite with lesser galena and sphalerite (several other sulphides are also present in minor quantities). The neutralisation in the rock is provided by several calcium-containing carbonates, with ankerite likely to be the dominant carbonate mineral.

In addition to static testing on the waste rock and tailings, several kinetic tests (at least 15 waste rock and twenty-four tailings tests) to assess the rates of reaction for different waste materials have been put in place. Humidity cell tests, which include a weekly leaching of the material followed by cycles of dry and humidified air, have been selected as the kinetic testing method at Red Chris. These tests have been run for an extended period of time with 15 tailings tests and 10 waste rock tests running for more than years from 2004.

In addition both saturated and aerated column testing for tailings have been operated for over 300 weeks of testing. SRK have reported updates on the results and interpretation of these tests (SRK 2010 and SRK 2012) and it understood that this testing is ongoing.

The testing regime to support the understanding of the geochemistry at Red Chris is considered extensive and appropriate, with the large and long-running kinetic testing data providing far more extensive data that usually encountered at many mine sites of similar size/stage of the project. Ongoing consideration of the implications of the kinetic testing results, together with the site water monitoring plan (AMEC 2011) and the commitments made by Red Chris for waste management and monitoring as part of the ARD/ML management plan (SRK 2012) should serve to provide the mine with a robust data set that can be used to understand the expected behaviour of the mine waste and can assist in Red Chris in employing an ongoing adaptive management plan for the site to reduce the risk of water quality deterioration.

6.3 Approach to Water Quality Modelling

The water quality modelling for the site is contained in spreadsheet which combines the proposed mine site water balance and a series of water qualities and geochemical source terms to provide the projected water quality over the life of mine. The approach to the water quality and the assumptions in the methodology are described briefly in AMEC 2004, in the Red Chris updates undertaken by AMEC in 2011 and most recently by SRK 2014.

The water quality model relies on the accuracy of the water balance and superimposes the geochemical loadings in a mass-balance approach to obtain water quality (SRK 2014 and AMEC 2011). To capture the likely range of potential qualities that arise at similar mines, the water quality model uses data from analogous mines and provides a statistically-derived water quality for each water quality parameter. This approach has been used at several mines and is often appropriate when kinetic data is lacking and when sufficient analogue mines' water quality is available. The Red Chris water quality modelling approach uses eight mines with similar characteristics in terms of deposit and climatic conditions.

It is considered that the discussion of trends in the water quality data from these analogues provides good basis for forming the conceptual water quality models and for understanding the likely constraints on water quality expected to arise from the different mining components such as the waste rock dump and the tailings storage facility. The analogue data appears to be consistent with theoretical considerations of porphyry-hosted rocks but additional pH/solubility controls have been identified and included in the model (AMEC 2011 and SRK 2014). Additional controls due to sorption/co-precipitation are highlighted but it is unclear how or if these are included in the model. The reports (SRK 2014 and AMEC 2011) provide the source-term equations and assumptions for each facility and waste type.

The overall approach does not appear to have fatal flaws but has limitations due to the use of non-site specific data. Inspection of the water quality shows that many of these source-terms appear valid but are largely static and lack any indication of being dynamically implemented.

While conservatism is preferred in these models, the acidic concentrations of copper are higher than expected for this type of environment and appear to be significantly higher than observed in the already acidified humidity cell tests. In addition, the source-terms concentrate largely on the dissolved concentrations with limited discussion on how to calculate total concentrations dynamically as conditions change.

A few aspects can be highlighted from the water quality model and the review of data and results from these models. Although the source-term discussions are clear, the linkages to the water balance and the basis for the water balance assumptions is difficult to follow. The water balance uncertainties will have direct impact on the water quality in the TSF pond and across the site and this aspect is not clearly defined in the reports or in the model itself. The model also makes assumptions of constant water quality from the mill (at pH ~11) and that the alkalinity in the TSF water will remain high enough to maintain the pond at pH~8.5. While these are likely appropriate assumptions, the impact that the consistency of these pH's have on metal solubility and meeting ongoing discharge compliance is not adequately illustrated in the reporting on the model results.

The 2011 AMEC report also refers to a reduced "conservatism" by using half detection limits rather than detection limits. This is likely appropriate and consistent with common practice but it not clear why this was implemented (basis) and this decision may be contrary to the stated aim and assertion of the model being considered to be ultra-conservative. The AMEC 2011 report includes a statement that refers to base case and conservative case (95^{th} centile case) being so similar that the base case can be used for assessment and management. This is somewhat counterintuitive and the basis for this has not been provided.

The source water chemistry is given as dissolved metals as only dissolved metals were measured for process streams but the water quality model updates provide no clear indication on how total concentrations are derived over time. The associated water quality monitoring report from AMEC 2011 suggests that the suspended solid content (TSS) of the water flowing through the ponds will have a total suspended solids maximum of 50 mg/L and average monthly concentration of 30 mg/L. This will need confirmation as the TSS may have major implications on total metal concentrations in the receiving water bodies.

The results from the water quality modelling suggest that the predicted TSF water quality meets all BC water quality guidelines except for:

- Sulphate (operations and post-closure);
- Cadmium (operations and post-closure);
- Selenium (operations and post-closure); and
- Copper (post-closure only).

As indicated in previous reviews such as RGC 2012 indicate that the water quality predictions are based on full implementation of the ARD mitigation measures and even with all these in place the tight bounds between predictions and BC water quality guidelines suggest that there is a risk of further exceedances (RGC 2012). This is especially relevant as the basis for many of the water balance assumptions is unclear and the adherence to the water quality and ARD management plan will require tight control for both dissolved and total concentrations to remain within compliance and fit for release under all conditions.

Based on KCB's review of the water quality model and associated data, a further concern or observation, is that many of the sources and inputs in the model are completely static and that there appears to have been no attempt to implement updated kinetic testing data for many of the source terms. As a result the water quality model relies on a statistical value from analogue sites rather than site specific data for the water quality results. No sensitivity analyses on these impact of this analogue data has been reported; the limited capacity in the TSF pond between predicted quality and water quality criteria means that an assessment of using site-specific kinetic data may be more appropriate to provide greater level of certainty that the water quality projections indicate the release will be possible.

6.4 ARD/ML Management Plan and Monitoring

SRK 2012 describe the details of the RCDC ARD/ML plan. This allows for identification of rock with higher potential for ARD, for segregation of this material and for mine waste management plans.

The ARD/ML management plan includes geochemical segregation based on neutralisation potential to acid potential ratios based on carbonate and total sulphur on site. Conservatively PAG is considered to be all rock with less than double the equivalent amount of carbonate as sulphur (SRK 2012). Pit operations will segregate waste and low grade ore based on geological domains and operational testing. Mine drainage from the waste rock and low grade ore will be collected and transferred to the TSF. All testing will be performed on site with off-site checks to validate site results.

SRK 2012 provide a detailed plan for the monitoring commitments to support the geochemical management plan. This includes specifics on the mining facility, the purpose of the testing, details of the program to be followed, the testing to be undertaken and the required frequency of the testing. Detailed plans are included for overburden, waste rock, low grade ore, pit walls and different tailings types. Water quality results should be included in a GIS where results can be easily displayed and compared to predictions.

6.5 Water Quality Recommendations

Based on KCB's review of the available data and reports, a reasonable amount of detail is available to support the geochemical characterisation and to provide a sound basis for management of the mine waste. In broad terms, the approach followed appears to be sound, and the long-duration and number of kinetic tests for the site provide a robust and site-specific indication of the expected behavior of the mine waste, and the likely water quality challenges that may arise.

Red Chris has a mature site water quality model (WQM). The description of the WQM and the source-term definition is available. This WQM provides water quality projections over life of mine and into closure. While many of the assumptions for the water balance and WQM appear reasonable, the basis for many of these, and the supporting data has not been clearly provided as yet.

Some of the considerations for Red Chris in terms of the TSF water quality are the limitations and implications of this WQM. Many of the predictions are near the proposed water quality criteria and while the reports imply conservatism in predictions, it is not clear if this can be justified. The model predictions are dynamic but many of the inputs are static which may limit the applicability of the results. The narrow gap between base case predictions and water quality criteria and the fact that some downstream sites already exceed water quality guidelines suggests that the assumption of continued release of pond water without treatment needs to be revisited, particularly if this release will carry a significant portion of suspended tailings material.

The mine has committed to an extensive mine waste and mine water monitoring plan. Once operations commence, a significant body of data from site operations, monitoring and laboratory testing will be available that can be used to calibrate and verify the water quality predictions and also be used to undertake sensitivity analysis. RCDC must implement these measures as they are all designed to provide very useful information and timely indications of potential issues. The reliance on the pond water remaining at a pH above 8 on restricting metal solubility is an important part of the mine water quality plan and anything that could lead to significant pH changes may lead to water quality not being fit for release.

Efforts to undertake the sensitivity analysis in light of improved understanding of the behavior of the tailings of the waste rock and tailings have not been documented in the reports and WQM reviewed to date, and there is no evidence of the sensitivity/uncertainty analysis recommended by RGC having been incorporated in the water quality model. In operations, ongoing calibration and verification of the WQM projections will also be required to allow the WQM to function properly as an aid to mine water and mine waste management at Red Chris.

Specific items that should be considered at this stage are related to improvements in the confidence in the WQM and the implementation of plans to act as early warning for potential water quality changes. This should be tied to more explicit criteria to identify when water treatment may be needed and the level of treatment required. Higher priority aspects include model verification of firstly the water balance and then the water quality predictions. RCDC should identify and implement specific criteria to act as early warning system of acidification from the waste rock systems, identify and implement specific criteria in the TSF pond and seepage to act as trigger for instituting water management/mitigation and focus on not only dissolved but also total concentrations of parameters of concern. Assessment of likely TSS from TSF and TSF infrastructure and identification of specific TSS criteria for downstream compliance should form part of this assessment. Undertake/provide further sensitivity assessment of water quality modelling.

As indicated in previous reviews, with all the mitigation in place and all systems operating optimally, the water quality remains only just in compliance. Most exceedance events on mine sites occur due to a sequence of events and some of these should be assessed to provide an indication of the highest risk events which may occur from minor breaches in operating procedures or changes in the nature of the water balance/geochemical properties.

Finally, while this may be available, detailed documentation of the measures to be followed in the event that water quality fails to meet compliance is required. This should include an emergency response, identification of causes, secondary mitigation plans such as capture and pumping systems and inclusion of short and long-term water treatment.

7 STANDARDS FOR TAILINGS DAM DESIGN AND CONSTRUCTION

The request for proposal asks for our opinion on the adequacy of dam safety legislation in Canada. The design of tailings impoundments is guided by regulation and standard of practice. Campbell et al. (2010) lists dam and tailings dam legislation across Canada while Priscu et al. (2009) compare Canadian dam safety legislation in Canada and other jurisdictions. Dam safety legislation includes similar requirements across all jurisdictions. As far as we are aware, none of these comparisons have identified any weaknesses in Canadian legislation. The ultimate measurement of dam safety legislation is the extent to which it prevents dam failure. There are very few dam failures in Canada so by this measure the legislation is adequate.

In Canada, many jurisdictions reference the Canadian Dam Safety Guidelines (2007) which now (2014) includes a supplement for mine tailings dams. Although this is a practice guideline, not a regulation, the civil courts look to the CDA as a standard of practice. The International Commission on Large Dams (ICOLD) and other jurisdictions such as Australia and the US have similar practice guidelines. Many Canadians have been involved in the drafting of the ICOLD guidelines so there are common features. The CDA have also produced suggested technical procedures for the CDA (2007) guidelines. The Association of Professional Engineers and Geoscientists have prepared a Profession Practice Guideline for Dam Safety Reviews in BC, including tailings dams. There is no shortage on practice guidelines for the design of dams and review of the performance of water retaining and tailings dams in British Columbia and Canada.

All these guidelines and others usually describe the dam safety management system and the design criteria or standards. Design criteria stipulate the factor of safety against static slope failure, overtopping by flooding, and earthquake shaking. To the former, the CDA guidelines require a factor of safety of 1.5 against static failure; the predicted factors of safety at the North and South Dams exceed 1.5.

Earthquakes and floods are transient, stochastic loads whose frequency and magnitude are a function of the natural environment. For instance earthquake loading is higher and more frequent in Vancouver than in Regina. Modern selection of these loads is based on the consequences of failure. That is, if the impoundment fails, what are the consequences to persons at risk, the environment, and the cost of repair and clean up. There are standard approaches to consequence estimation which usually involves inundation studies to predict tailings runout and flooding. In this case, the designers have assigned a “very high” category to the consequences. However, the designers and the mine have decided to design the impoundment to the highest consequence category. The dam is supposed to be designed to withstand the MCE or maximum credible earthquake and the PMF or the probable maximum flood. Thus, globally, there are no higher standards for these design criteria.

However, that does not mean that a tailings dam will be actually built to these standards. The engineering and scientific procedures to estimate these transient loads must follow good engineering practice in order for this to be true. There is no global standard for good engineering practice but there are a myriad of tailings design guidelines that collectively constitute set of the state of practice as described above. The tailings impoundment must be built to the specifications and drawings with appropriate QC/QA.

However, all of the above has not been sufficient to prevent the failure of tailings dams. To be successful, all of the above processes must be encapsulated within a management system. The Mining Association of Canada (MAC) recommends the management approach in Figure 7.1.

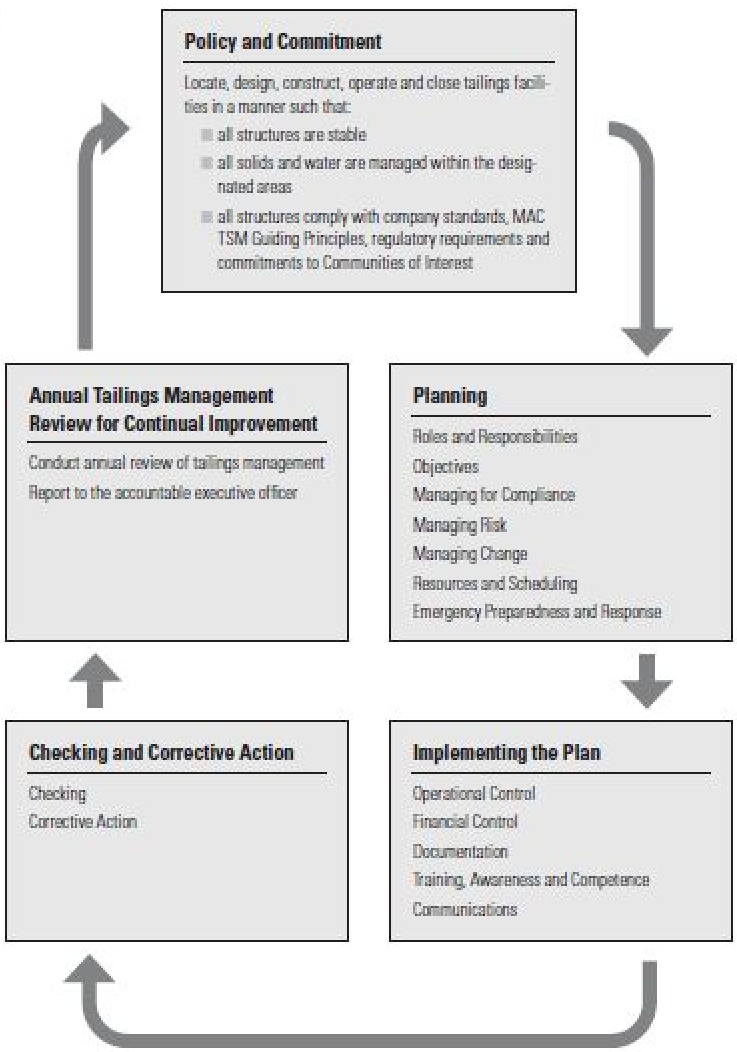

Figure 7.1 Mining Association of Canada Management System

In the opinion of MAC, it is the inadequacy of management systems, not technology that leads to the failure of tailings dams.

8 GEOHAZARDS

8.1 General

As stated in our proposal, Dr. Keegan was tasked with assessing geotechnical and geohazard issues across the project footprint. Geohazards are defined here as conditions and processes involving the ground, whether natural or manmade, that increase the likelihood of loss. The standards of practice in Canada, for the management of geohazards, encourage use of a systematic risk based approach to manage the risk to personnel, property and the environment. The Canadian standard for risk management, CSA Q850-97(CSA, 1997) provides six steps for a risk management. For geohazards these six steps are interpreted as follows:

1. **Initiation:** Realization of the risk to the organization associated with geohazards and a corporate decision to develop a risk management system.
2. **Preliminary Analysis:** Identification, characterization, and screening level risk assessment of geohazards
3. **Risk Estimation:** formal risk estimation of higher risk geohazards accounting for likelihood and consequence
4. **Risk Evaluation:** evaluation of the estimated risk against corporate and societal risk criteria and decisions to act based on risk tolerance.
5. **Risk Control:** Analysis of available risk control measures to most effectively manage the risk
6. **Action & Monitoring:** Plan and execute risk control measures. Ongoing monitoring of identified geohazards for changed causal factors (conditions and processes), effectiveness of risk control measures, and to support the observational approach.

The project components potentially affected by geohazards include the 18 kilometer access road, the open pit, and the tailings facility. The most significant geohazard issue identified during the review is the Kluea Lake Landslide Complex located between Kluea Lake and the planned open pit and downstream of the planned South Dam.

8.2 Access Road

The Engineering Geology and Terrain Stability Assessment completed for the Main Access Road (Terratech 2011), and follow up addendums (Terratech 2012), were reviewed and, aside from hydraulic erosion hazards that can be managed through ongoing road inspection and maintenance, there were no significant geohazard issues identified that weren’t addressed during construction of the road. This was confirmed during the helicopter inspection.

8.3 Tailings Facility

Geohazards that may affect the tailings facility are classified in CDA (2007) as either external hazards (originating from outside the boundary of the dam and reservoir system and are beyond the control of the dam owner) or internal hazards (arising from ageing process or from errors and omissions in the design, construction, operation, and maintenance of the dam and water conveyance structures).

Based on review of available documentations and confirmed during the helicopter inspection there were no significant external geohazards identified emanating from within the reservoir catchment.

8.4 Kluea Lake Landslide Complex

8.4.1 Geohazard Characterization

The only document available for the review that characterizes the Kluea Lake landslide complex is AMEC's report entitled Slope Stability Conditions Underlying Proposed Plant Site, Red Chris Mine Site, August, 2006 (AMEC File: VM00418). The purpose of their one day field reconnaissance and report was to determine the suitability of the proposed plant site location with respect to the possibility of slide activity. Only the accessible top areas of the complex were investigated. The landslide complex is contained in a Sackung feature (tectonic mountain scale gravitational feature) on the south facing slope above Kluea Lake. AMEC (2006) divided the landslide complex into the South and East Slides based on the apparent general horizontal movement component of the largest blocks. The pre-disturbance slope stability of the landslide complex, relative to the proposed plant site, is characterized in AMEC (2006) as follows:

> *The South Slide is located on the north valley slope of Kluea Lake. The slide extends for greater than 3 km beyond the south boundary of the previously undertaken terrain mapping. Brief review of satellite images suggests that the slide extends for approximately 6 km from the west end of the lake to beyond the east end of the lake. The overall height of the slide is approximately 450 m at average slopes (lake to crest) of approximately 15°.*
>
> *The main scarp of the South Slide is marked by a series of prominent steep slope segments near the crest of the slope. The total displacement of the slide is difficult to determine, but the heights of individual scarps along the crest are at least 150 m, so total displacement is likely several hundred metres. Fresh ground cracks and earth falls on the middle and lower parts of the slide indicate that movement is ongoing. The toe of the slide is not apparent and may be underwater in the Kluea Lake valley.*
>
> *The East Slide is located at a terrain "corner" near the northeast end of Kluea Lake, a short distance east of the Fall 2005 Plant Site location. The East Slide is moving predominantly toward the east and the headscarp is more strongly curved than the South Slide. The total crest length of the slide is approximately 500 to 750 m. The slide is part of the overall South Slide complex and the main scarps of the South Slide can be traced along the north edge of the East Slide. However, the movement directions in the East Slide area are appreciably are almost at right angles to the movement directions of the South Slide.*

Terrain near the intersections of scarps behind the South and East Slides is locally tending to move in two directions. For example, the locally prominent two peaks (two rock pinnacles, Photo 1, Drawing 2) are a result of the interaction of the two movement directions resulting in separation of what was originally a single rock knob. This tendency for movement in two directions is affecting the ground underlying the proposed site for Plant Site and tension features including grabens were traced in a variety of directions through and near the site. These varied directions are a result of the complex movement conditions that the ground in this area is being subjected to."

Additional observations and inference made by the review team include:

1. Dip and strike direction of the head scarps of both slides are coincident with the orientation and location of the mapped faults. The South Slide head scarp is consistent with the northeast-southwest striking South Boundary-fault and the East Slide head scarp is consistent with the northwest-southeast trending offset fault. The steepness of these scarps infer that both landslides are deep seated.
2. Observation of a series of recent tension cracks downhill of the South Slide head scarp near the West end of the open pit footprint.
3. Movements are iterative.
4. Large shear strains and active slide movements, with a crest to lake slope angle of 15°, implies the rupture surface is well developed and is at a low residual strength of phi' = 15°.
5. Deformed trees (5 to 10 years old) at the over steeped toe slope of the East Slide indicating recent movements. This also implies the East Slide toes out on the northwest side of the valley.
6. Lack of scarp features in the lower half of the South Slide and steepness of the slope entering the lake infers the toe of the basal rupture surface daylights below lake level.
7. Of particular note is that the southeast crest of the proposed open pit is within 300 m of the active back scarps of the South Slide and closer to inferred retrogressive scarps.

In summary, based on the AMEC report and our brief site visit it is apparent that both the South and East Slides:

- are currently active and meta-stable;
- have undergone significant movements (>100 m);
- are deep seated, structurally controlled, and complex;
- have undergone slow but significant deformation for resulting in Sackung features;
- show signs of retrogression; and
- are within 300 m of the rim of the final planned open pit.

The impact of the slide on the mine or the reverse cannot be assessed because there is a significant lack of understanding of the past movement rates, ground water conditions, geologic controls, kinematics, preparatory and trigger causal factors, ultimate failure mechanism, retrogression potential, and mobility and runout potential.

8.4.2 Geohazard Scenarios

A geohazard scenario maps the chain of hazard events from initiation to loss. Mapping the geohazard scenarios helps in understanding how the geohazard may affect the project and is key to risk managing the geohazard. Based on the information available the following geohazard scenarios are but two that could come out of a proper risk assessment of these features.

Scenario 1

Ongoing slow deformations of the rock mass until moving mass exceeds threshold stability conditions. Detached slide mass breaks down resulting in a debris avalanche. The head scarp of the slide may retrogress to the open pit. Possible triggers of the slide mobilization include:

- Significant antecedent precipitation or snow melt raising the pore pressures in the slide mass and/or filling cracks in the slide mass.
- Blasting vibrations or earthquake loading.
- Freeze and thaw cycles.

If the South Slide mobilizes, debris fills across the lake resulting in a flood wave downstream and impoundment of a landslide lake. If the East Slide mobilizes, debris fills across the valley resulting in possible damage to the South Reclaim Dyke and impoundment of a landslide dam that floods back to the South Dam.

Case example of this scenario, in a similar geologic setting, is provided by the Todagin Creek landslide which occurred on October 3, 2006 approximately 5 km southwest of Kluea Lake on the same side of the valley as the Kluea Lake landslide complex. Sakals et al (2011) investigated this landslide which they classified as an extremely rapid rock slide—debris avalanche (Cruden and Varnes 1996).

Scenario 2

Following active mining, the open pit fills with water creating a surcharge water load and increased pore water pressures in the slide mass triggering slide mobilization. Retrogression of the slide to the open pit would result in uncontrolled release of acidic and process water to the environment.

Please note that the likelihood of either of these two scenarios occurring is indeterminable due to the current lack of understanding of the landslide complex.

8.4.3 Geohazard Management

In order to manage the risk to the project associated with Kluea Lake landslide complex, additional investigation, analyses, and risk assessment necessary to attain a level of understanding of this geohazard commensurate with the assessed level of risk. The groundwater regime and landslide movements should be monitored to provide both warning of slide movement and calibration of stability models. The increased understanding and ongoing monitoring should be used in assessing and planning risk control measures to be implemented through the live cycle of the mine including reclamation.

Suggested techniques for movement monitoring include:

- Interferometric synthetic aperture radar (INSAR) or recent advances in this technology: may be very applicable in these circumstances given the lack of vegetation and the ability to access archived scans dating back to the 1990's. Moving forward satellites can be tasked to provide the most effective angle of scan.
- Bare earth LiDAR (airborne or terrestrial) applying recently developed change detection technology.

9 TAILINGS DAM SYSTEM MANAGEMENT

Morgenstern (2010) described the ideal procedures used at oilsands sites to manage their external tailings dams which usually dwarf the storage capacity of the Red Chris facility and, at the same time, are sited on much weaker foundations.

Morgenstern (2010) lists the components of the tailings management system used in the oilsands and elsewhere that we believe should be implemented at Red Chris:

- *Each owner is cognizant of its responsibilities to provide a tailings management system consistent with the MAC guidelines.* Commentary: Imperial is a member of the Mining Association of Canada which obligates them to follow the Towards Sustainable Mining (TSM) initiative of MAC
- *Each owner has staff qualified in the management of tailings dams.* Commentary: RCDC needs to assign a competent, experienced engineer to the management of all aspects of their tailings impoundment who reports to senior management.
- *Owners retain consulting engineers for design and construction supervision who are well-known for their expertise in tailings dam design with special reference to the circumstances associated with the oil sands industry; the designer acts as the Engineer-of-Record; senior internal review of design submissions is expected.* Commentary: Obviously, knowledge of the hard rock industry is required at Red Chris.
- *Designs are compliant with at least the CDA (Canadian Dam Association) Guidelines.* Commentary: The CDA has published a Mining Supplement (July 2014) which applies to Red Chris
- *Designs rely on the detailed application of the observational approach for risk management.* Commentary: This is especially true in this case as the piezometer readings, pond water levels, precipitation, stream gauges, water quality results must be continuously compared to expectations.
- *Designs are reviewed by the* **British Columbia** *Dam Safety Branch, the regulator, who have staff well-versed in dam design and construction.*
- *An annual report is submitted each year to the regulator by the owner, supported by the Engineer-*of*-Record, that the dam is behaving as intended; if not actions that have been or need to be taken are indicated.*
- *In accordance with CDA guidelines, approximately every five years the owner retains an engineer, other than the Engineer of Record, to undertake an independent assessment of dam safety.*
- *Each owner retains an Independent Geotechnical Review Board comprised of senior specialists, to provide on-going third party review of geotechnical issue of significance to the operation. One of the major responsibilities of such Boards is to review all aspects related to safety of tailings dams over the life cycle from design, construction, operation and closure.*

> Commentary: We strongly consider that the Red Chris site appoints a technical review board immediately that consists of senior, independent engineers and scientists in the following technical areas: geotechnical and tailings engineering, hydrology, hydrogeology, and geochemistry/water quality. Good practice is to have a management system in place that plans tailings disposal and, executes tailings disposal raises, monitors, and improves the performance of the system.

Together with the above technical requirements, a good tailings dam management system requires a good filing system of documents and instrumentation readings, a tailings engineer who reports to the mine manager or the most senior person on site with a direct link to the corporate office, and a commitment by corporate office to good tailings management.

10 RECOMMENDATIONS

The following table list the recommendations in the report. The referenced page numbers describe the recommendations in more detail.

Table 10.1 List of Recommendations

No.	Recommendation	Pages
1	Map exposed tailings impoundment area upstream of NSD to evaluate whether tailings fines will pipe into the glaciofluvial foundation.	9,20
2	Design drainage blanket beneath North Dam to safely discharge groundwater flow plus tailings transport water and precipitation.	10,17
3	Perform water balance on flows, pressures, and water levels at and downstream of NSD to confirm hydrogeological assumptions.	10
4	Prepare Emergency Preparation Plan and Emergency Response Plan.	13,15
5	Update risk register for tailings impoundment.	13
6	Prepare OMS manual that relies on the observational approach and integrates hydrology, water quality, geotechnical, and hydrogeological data.	13,14
7	Prepare inundation study that considers both water and tailings release plus acid generation of PAG tailings.	15
8	Perform hydrogeological flow model in conjunction with tailing deposition modeling.	19
9	Add at least two more climate stations to better understand orographic effects on precipitation.	20
10	Update water balance and hydrogeological seepage model as new observational data is obtained.	21
11	Confirm technical methods to obtain the PMP and the PMF.	22
12	Prepare a transparent means of displaying and comparing water quality, geotechnical, hydrological, and hydrogeological data against actuals. Use GIS to communicate data.	22, 27
13	Prepare dam raising schedules using tailings dam filling curves, mandatory pond levels over PAG, the PMF and assumption of at least a one year upset in construction.	22
14	Crest of South Dam (if no core included) should be higher than the North Dam.	22
15	Calibrate and verify the WQM projections as data becomes available to allow the WQM to function properly as an aid to mine water and mine waste management at Red Chris.	28
16	Undertake/provide further sensitivity assessment of water quality modelling.	28
17	Develop trigger levels for instituting water management/mitigation actions.	28
18	Document measures to be followed in the event that water quality fails to meet compliance criteria.	28
19	Perform additional investigation, analyses, and risk assessment necessary to attain a level of understanding of the Kluea landslide commensurate with the assessed level of risk.	35
20	Monitor groundwater regime and Kluea landslide movements and calibrate stability models.	35
21	Implement tailings management system consistent with MAC TSM and Morgenstern (2010).	36
22	Establish tailings review board at earliest opportunity.	37

11 CLOSING

Mr. Bryan D. Watts, P.Eng. led this review and was responsible for the geotechnical, hydrogeological, and standards assessment portions of the report. Ms. Mary-Jane Piggott, P.Eng. prepared the hydrological portions of the work. Dr. Brent Usher prepared the geochemistry work and Dr. Tim Keegan, P.Eng. prepared the geohazards assessment and visited the site.

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REFERENCES

Campbell et al. 2010. Regulation of Dams and Tailings Dams in Canada. CDA 2010 Annual Conference, Niagara Falls.

Canadian Dam Association. 2007, 2013 Revision. Dam Safety Guidelines with Mining Supplement (2014).

Canadian Standards Association. 1997. Risk management: Guidelines for decision makers, CAN/CSA-Q850-97, 1997., Canadian Standards Association, Etobicoke, Ontario, Canada.

Mining Association of Canada. 2011. A Guide to the Management of Tailings Facilities.

Mining Association of Canada. 2011. Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities.

Mining Association of Canada. 2011. A Guide to Audit and Assessment of Tailings Facility Management.

Ministry of Environment. 2013. Inventory of Streamflow in the Skeena Region.

Ministry of Environment, Lands and Parks. 2000. Streamflow in the Omineca-Peace Region.

Morgenstern. 2010. Improving the safety of mine waste impoundments. Tailings and Mine Waste'10.

Priscu et al. 2009. Mining Dams Safety Regulation – Where does Canada Stand? CDA 2009 Annual Conference, Whistler.

Sakals, M. E., Geertsema, M., Schwab, J.W., and Foord, V. N. 2011. The Todagin Creek landslide of October 3, 2006, Northwest British Columbia, Canada, Landslides, DOI 10.1007/s10346-011-0273-9, © Springer-Verlag.

APPENDIX I

Terms of Reference

RED CHRIS MINE REVIEW
TERMS OF REFERENCE
August 21, 2014

1. The selected consultant (the "Third Party Team") will conduct a review that:
    a. reviews the Red Chris tailings impoundment with reference to World Class Standards (as defined below);
    b. includes an assessment of all Red Chris Mine tailings facilities constructed to date and all quality control information sampled or collected to date;
    c. is carried out in accordance with Schedule A;
    d. is prepared for the Tahltan Central Council ("**TCC**"); and
    e. will be paid for by Imperial Metals Corporation and Red Chris Development Corporation (the "**Companies**".
2. The deliverable from this engagement will be a report that summarizes the result of the review and provides recommendations and actions to be taken or committed to by the Companies on or before September 30, 2014.
3. TCC will be meaningfully involved in all phases of the Review.
4. "**World Class Standards**" are world class standards that are international benchmarks for safety and environmental protection, to be determined by the Third Party Team (including, in the case of Ongoing Reviews, any successor consultant to the Third Party Team) and reasonably approved by TCC from time to time.

SCHEDULE A

1. <u>Geotechnical and Geo-hazard Issues across the project footprint.</u>
    a. Review of the current design and associated studies of the Red Chris Tailings Storage Facility (TSF) and construction undertaken to date, and make recommendations for World Class Standards for facility design, risk management and operational monitoring and management.
    b. Review of Terrain Stability, seismic and Geo-hazards assessments across the mine footprint, including the mine access road, and recommendations for world class proven contingencies for risk management and operational monitoring and management.
    c. Address other issues deemed relevant by the Third Party Team.
    d. Review the sufficiency and reasonableness of the tailings storage location, methods and approaches used by RCDC and provision of recommendations for world class tailings storage at the Red Chris Site.
    e. Review of all modeling and design assumptions and professional judgements used in the TSF design and operational protocols and recommendations for confirming those assumptions and judgements with monitoring data.
2. <u>Operational water management and environmental protection.</u>
    a. Review of the mine site water balance and source term predictions for tailings facility inputs and contact and non-contact flows across the project footprint and recommendations for world class contingencies for facility design, risk management and operational monitoring and management as it relates to surface and subsurface tailings facility inputs and outputs and waste characterization.
    b. Recommendations for mitigation measures in the event that the water quality does not meet water discharge criteria.
    c. Other issues deemed relevant by the Third Party Team.
3. <u>Insurance, bonding and contingency planning</u>
    a. Recommendations regarding appropriate levels of insurance and bonding for TSF.
    b. Recommendations regarding contingency plans (including any recommended systems or infrastructure) and disaster response preparation.

The Third Party Team will report to RCDC and Tahltan through the Red Chris Monitoring Committee (RCMC), and will prepare a report setting out the results of their review and recommendations. The Third Party Team will consider any reporting regarding the Mt. Polley dam breach. Should the final Mt. Polley report be released subsequent to the conclusion of the Review described in this Agreement, the Third Party Team will be engaged at the cost of the Companies to reconsider its findings in light of the final Mt. Polley report.