2023 Dam Safety Review

Lupin Mine Tailings Containment Area (TCA)

Lupin Mines Inc.

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Making Sustainability Happen

Revision Record

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Executive Summary

This report presents the results of a Dam Safety Review (DSR) carried out by SLR Consulting (Canada) Ltd. (SLR) for the Lupin Mine Tailings Containment Area (TCA) for Lupin Mines Inc. (LMI). SLR is an independent party that has not been involved in the design, construction, or operation of the facilities. This is the third DSR conducted for this facility, with the previous DSR's completed in 2004 by Golder Associates and 2015 (SRK, 2016).

Site Description

The Lupin Mine is located 285 kilometres (km) southeast of Kugluktuk, Nunavut, 400 km and north of Yellowknife, Northwest Territories (NWT). The Site is on the western shore of Contwoyto Lake, approximately 60 km south of the Arctic Circle.

The surficial geology consists of predominantly silty sand till, with gravel and boulders, occasionally overlain by glacio-fluvial and glacio-lacustrine sand and gravel deposits. Bedrock consists of a mixture of low-grade metamorphosed argillite, siltstone, slate, greywacke, and quartzite; generally described as phyllite.

The mine operated from 1982 until 2005 as an underground mining operation. On-site milling produced tailings that were deposited in the TCA, which functioned as a closed system that allowed for tailings accumulation and some supernatant water storage within five main cells, and treatment of water prior to discharge to the environment.

Containment in the TCA is provided by frozen core perimeter dams and internal dams that split the TCA into five tailings cells and three water ponds. Excess water is treated as required to meet discharge quality requirements prior to release to the environment. The TCA has no external spillways and excess water is managed by active pumping and/or siphoning.

The site was placed under care and maintenance following operations in 2005 and remained as such until about 2018 when the final closure plan was developed. Currently the site is in the active phase of closure, which includes covering exposed tailings with granular esker fill and managing water.

Dam Safety Evaluation

SLR visited the site in September 2023 to inspect the TCA and found the dams to be generally in satisfactory condition for the current active phase of closure. The pond levels are currently maintained at an historically low level providing ample freeboard. Seepage was not observed from any of the perimeter dams. The dams are noted to experience erosion from surface runoff including several large, deep gullies. These are repaired by the construction contractor. The TCA does not have any spillways and relies on active pumping and/or siphoning to manage water.

Final closure of the TCA will include spillways will be constructed through Dam 1A and J Dam, complete covering of tailings with esker sand, and dam regrading to ensure physical stability. Chemical stability of the facility will need to be demonstrated before the spillways are constructed.

Dam design and construction records are limited and are best summarized in the original closure plan by Holubec (2005) and previous DSR (SRK, 2016). The dams have aggraded permafrost since construction and thermistor strings have measured the depth of permafrost to about 2 to 3 m below surface.

Slope stability analyses have been carried out on all of the dams under the current permafrost conditions. In addition, select dams were assessed for a potential thawed scenario based on projected future climate conditions in accordance with climate change modelling. The analyses found that two dams require a flatter slope to meet the minimum required factors of safety while the other dams were in compliance.

SLR note that M Dam and N Dam were constructed on deposited tailings and recommend stability analyses with consideration for the current climate change modelling.

Human & Environmental Safety

A dam breach analysis has not been conducted for the TCA. The tailings are known to be acid generating and the water stored in the TCA does not meet water quality standards. A dam breach could potentially release both poor quality water and acid generating tailings to the environment.

An Operations, Maintenance, and Surveillance (OMS) manual has been reported to be developed in the past, but no documentation was not available for SLR review, and it remains unclear if the outdated OMS manual referenced in the 2015 DSR (SRK, 2016) was ever updated. An OMS manual should be in place for the TCA and should be reflective of the current conditions of site including active closure activities, routine maintenance, and surveillance actions.

An Emergency Response Plan (ERP) has been developed for the TCA but mainly deals with personal injuries and emergencies. Dam safety emergencies that could jeopardise the physical stability are not considered in this document. It is recommended that the ERP be updated to develop specific responses to potential dam safety emergencies.

A Failure Modes and Effects Analysis (FMEA) has not been carried out for site. It is reported that informal risk assessments have been done but not well documented. A formal FMEA would provide an opportunity to clearly document and assess the potential risks, develop suitable mitigations, and ensure that information can be carried forward for potential changes in personnel.

Management Systems

There is a clear organizational structure that is summarized in an organization chart. In general, LMI are responsible for site and have appointed contractors and consultants to support them in managing the TCA and complying with regulators. The organization chart outlines the communication channels between the various groups.

The site does not currently have a dam safety corporate policy. It is understood that the owner has specific policies for other properties and are in the process of developing one for this site.

An Engineer of Record (EoR) was appointed for the TCA following the previous DSR (2016) and has provided support for dam safety management. During this DSR, the EoR was in the process of internal succession. The incoming EoR is supported by staff who have a long history with the site and maintains communication with the outgoing EoR.

A Responsible Tailings Facility Engineer (RTFE) and Accountable Executive have not formally been identified although it appears that the functions of these roles are being carried out. Appointing personnel to these roles would strengthen governance and provide greater clarity on responsibilities and communication.

Conclusions

Overall, the TCA appears to have been operated and maintained well over the years despite changes in ownership, staff, and consultants who have worked at this site. During operations, the mine was proactive with regard to progressive reclamation and long-term monitoring to support the closure plan.

Currently, as a site that is regularly monitored and maintained, it is our view that the systems and staff in place are well equipped to manage the TCA and continue in a state of active closure. However, looking ahead towards passive closure, we believe there remain some risks and uncertainties that will require technical judgement to implement and demonstration of effectiveness before the site should transition to passive closure. The main risks to physical stability are erodible dam slopes and lack of emergency spillways.

Closure spillways are planned to be constructed once water quality objectives are met. It remains unclear how long the TCA will remain in its current configuration (i.e., no spillways) and require active treatment and pumping/siphoning to manage tailings pond water levels. In the interim, it would be prudent to construct an emergency spillway to further mitigate the risk of dam overtopping.

Erosion of the dam slopes is attributed to a number of factors including the fill materials, slope gradients, lack of vegetation, and drainage area and channelization. The approach to make the slopes erosion resistant in the long term could use a variety of engineered solutions. Whatever is constructed will need to be monitored for period of time to demonstrate effectiveness.

SLR believe the site has been historically managed well and are confident that the teams in place to manage the TCA are well equipped for the task. Recommendations are provided to support LMI as the site moves towards passive closure.

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1.0 Introduction

SLR Consulting (Canada) Ltd. (SLR) was retained by Lupin Mines Incorporated (LMI) to complete a Dam Safety Review (DSR) for the Lupin Mine Tailings Containment Area (TCA) in Nunavut, Canada (Figure 1). The mine is 100% owned by Lupin Mines Incorporated (LMI), a wholly owned indirect subsidiary of Mandalay Resources Corporation.

A DSR is a periodic review of the dam design, construction, operation, and safety management systems to confirm that the facilities are safe, operated safely, maintained in a safe condition, and surveillance program is adequate to detect a developing safety problem (CDA, 2013). The last DSR completed for the TCA was in 2015 by SRK Consulting and have historically been completed about every 10 years.

SLR is an independent party that has not been involved in the design, construction, or operation of the facilities. This is understood to be the third DSR conducted for this facility since the current mine began operations in 1982. A list of structures reviewed under this scope is provided in Table 1. Sewage Lagoon Dam is excluded from this DSR.

1.1 Project Status

The Lupin Gold Mine operated intermittently between 1982 and 2005. After an extended period of active care and maintenance (from approximately 2005 to 2018), the site entered into active closure with the approval and implementation of the Final Closure and Reclamation Plan (FCPR: LMI, 2018 and updated LMI, 2020 Rev1). Tailings produced by the underground mining and on-site milling operations were stored in a remote tailings containment area (TCA).

Key approved closure activities related to the TCA include covering exposed tailings beaches with a granular cover (esker sand), some regrading/flattening a various containment structures, lowering tailings pond water levels and constructing permanent closure spillways at Dam 1A and Dam J. Details of the TCA configuration and management practices are described in greater detail in Section 3.

At the time of the site inspection much of the exposed tailings had been covered with granular esker sands from a local borrow source; however, the tailings pond water levels were being actively managed by siphoning and pumping. When required, slurried lime is added prior to discharge from the TCA. Closure spillways have been sited in Dam 1A and J Dam but have yet to be designed or constructed and will only be implemented once TCA water quality has stabilized to consistent meet discharge water quality standards. The site maintains a small fleet of construction equipment to support ongoing closure and reclamation activities and maintenance of the TCA dams.

The property consists of five contiguous mining leases on crown land under the Territorial Lands Act. LMI currently holds a Type A Water License 2AM-LUP2032 (Water Licence) for the Lupin Gold Mine. The Water Licence is valid until 27 February 2032. The Final Closure and Reclamation Plan (FCRP: LMI, 2020) was approved for implementation by the Nunavut Water Board (NWB or Board) in accordance with Part I, Item 2 of water licence 2AM-LUP2032.

2.0 Methodology

The objective of the review is to identify any gaps in dam safety stewardship or governance for the dam safety protocols implemented by LMI. The DSR process included a site inspection by senior SLR personnel and review of available pertinent documents. The site visit comprised of general walk-around inspection, observation of construction activities, interviews with relevant site personnel, and discussions with the Engineer of Records (EoR). Detailed reviews of the design and assessment or calculations have not been carried out. Rather, the level of review was sufficient to form an independent opinion of the design, construction practices, and suitability and adequacy of the investigations, analyses, and surveillance.

The site inspection was undertaken by Eric Sellars, P.Eng., of SLR between September 13 and 16, 2023.

3.0 Site Description

The Lupin Mine is located in the Kitikmeot Region, 285 kilometres (km) southeast of Kugluktuk, Nunavut, 400 km and north of Yellowknife, Northwest Territories (NWT). The Site is on the western shore of Contwoyto Lake, approximately 60 km south of the Arctic Circle (Figure 1). The Lupin Mine property is accessible by winter road or by fixed wing or rotary aircraft and maintains a 1,950 metres (m) long gravel airstrip suitable for Boeing 737 and C-130 Hercules sized aircraft.

The underground mining operations and associated on-site milling produced tailings that are stored in the TCA, located to the south-east of the milling and camp complex (Figure 1). Tailings were discharged in a closed system that allowed for tailings accumulation and some supernatant water storage within five main cells, and treatment of water prior to discharge to the environment.

Figure 2 shows the general arrangement of the current TCA while Table 1 presents a description of the TCA dams. The TCA containment consists of a number of frozen core perimeter dams and internal dams that divided the TCA into five main cells, with excess water ultimately reporting to Pond 2 where water quality is monitored and adjusted as required (lime addition) to meet discharge quality requirements prior to release to the environment. The TCA has no external spillways and excess water is currently managed by active pumping and/or siphoning. Passive closure spillways are planned as part of permanent closure but have not yet been designed.

3.1 Climate

Climate in this region is classed as semi-arid subarctic, with an average annual precipitation of approximately 300 millimetres (mm). August is the wettest month with average rainfall of 59.8 mm. The annual average temperature is -10.9 degrees Celsius (°C); July is the warmest month with average temperature of 11.7 °C, whereas January is the coldest month with a monthly average of -29.7 ºC (LMI, 2020).

Snowfall represents about 46% of the total annual precipitation. Snowfall can occur during any month, although heaviest snowfalls generally occur in October. The prevailing winds in the Lupin Mine area are from the northwest.

The winter climate at this latitude is severe in intensity and duration and is followed by a short, warm summer. In winter, between 1 and 3 m of ice develop on the surface of the lakes, and it is the rate of melting of this ice that greatly influences summer conditions. The interaction between climate and morphology of the individual lakes gives rise to great differences in the thermal regime of the lakes.

3.1.1 Climate Change Considerations

Climate change was evaluated in connection with the FRCP (LMI, 2020) to consider predictions for the 100 years between 2000 and 2100. The mean annual temperature was projected to increase by approximately 4 to 5 °C by the end of the century (2100) based on the CGCM3/T47 model using the IPCC SRES A1B scenario. The projected change in mean annual temperature for the project is consistent with the range of projected increases from Canada's Changing Climate Report (CIRNAC TC No.9).

Thermal modelling results for of the TCA dams was analyzed in Stantec (2019d). The modelling considered three emissions scenarios (low, high, and average) to estimate the change in depth to the active layer (i.e. top of permafrost). In both the low and average scenarios, the active layer would recede by 2100 by 0.5 m and 1.6 m, respectively. In the high emissions scenario, annual frost penetration will not penetrate to the active layer and long-term permafrost thaw is initiated. The depth to the active layer in this scenario was estimated to be 14 m by 2100. The authors stated that the low emissions scenario was considered more realistic than the high emissions scenario. Nevertheless, stability modelling was conservatively checked for two dams using the high emissions scenario (i.e. 14 m of thaw).

3.2 Topography & Drainage

The area has numerous shallow lakes and marsh-like depressions. The drainage pattern is deranged or poorly defined but ultimately, the streams drain to Contwoyto Lake. Water within these lakes generally varies between 1 to 6 m (Holubec, 2005).

The TCA was developed in a rolling topography with majority of the terrain lying between elevation 480 m and 490 m and the high ground being on the north side with maximum elevation being about at elevation 505 m. The construction of two relatively small dams (Dam 1A and Dam 2) on the west side and a saddle dam (Dam 4) on the east side created an enclosed watershed with an area of 616 ha. The watershed contained 18 small lakes varying in surface area from about 0.6 ha to 19.7 ha.

3.3 Surficial Geology

The Contwoyto Lake area lies within the Upland unit of the Kazan physiographic region of the Canadian Shield. The area was glaciated during the Pleistocene Epoch (Blake 1963). The area is overlain by predominantly a silty sand till, with gravel and boulders, occasionally overlain by glacio-fluvial and glacio-lacustrine sand and gravel deposits. Esker and abandoned beaches are common landforms. Bedrock belongs to the Yellowknife Super group of the Achaean Epoch. The rock consists of a mixture of low-grade metamorphosed argillite, siltstone, slate, greywacke, and quartzite; generally described as phyllite.

3.4 Downstream Environment

Figure 1 shows a site location map and the surrounding area. It is reported in the FCRP (LMI, 2020) that all drainage ultimately reports to Contwoyto Lake to the north of site. Presently and at closure, discharge from the TCA will be across Dam 1A to Dam 1 Lake and would appear to then flow west through watercourses to Contwoyto Lake.

Other areas of the TCA would drain to different lakes downstream of the TCA including:

- Dam 2 Lake downstream of Dam 2;
- Lori Lake downstream of Dam 6;
- Ferguson Lake and Long Lake downstream of Dam 4; and
- Boomerang Lake downstream of Dam 3

SLR have not reviewed the hydrology of the downstream environment but rely on the work done by others who have reported that all these lakes ultimately drain to Contwoyto Lake.

4.0 TCA Development Overview

Development of the TCA began in 1981 with construction of perimeter dams Dam 1A, 1B, 1C, and 2. Mining operations commenced in 1982 and continued to 2005. Mine production ramped up in 1985 and continued until 1995, followed by intermittent operations in the late 90's and early 00's, before suspending in 2005. The site has been on care and maintenance since then. Plans to restart the mine have been considered but never realized.

Presently the site in the process of transitioning to closure. Almost all of the tailings beaches have been covered with a sand and gravel esker material and the current water levels in the TCA have been drawn down relative to years past.

Table 2 summarizes the development of the TCA including construction, operations, and closure activities. Figure 3 illustrates the development of the TCA during operations including when dams were constructed and where tailings were deposited or covered. The historical information was largely sourced from Holubec (2005) and SRK (2016).

The 2015 DSR (SRK, 2016) provided a good summary of the TCA dam configuration and construction records at that time. This summary, and associated dam cross-section figures is reproduced herein for convenience in Appendix B. Additional commentary regarding subsequent modifications to the TCA dams, including regrading of some dams and the capping TCA tailings beaches with granular cover, is presented in Section 4.2.

4.1 Evolution of the TCA

The depositional strategy in the TCA has had two phases during mining operations. Initially, from the start of operations in 1982 until 1985, tailings were discharged from higher ground on the north side of the TCA towards a central pond. Containment was provided by perimeter dams, but generally the tailings were allowed to settle in the TCA basin and the perimeter dams contained the ponds.

Beginning in 1985, internal dams were introduced to contain tailings within cells that were separate from the pond areas. This was done in response to higher mine throughput rate. This continued until mining operations ceased in 2005. It is noted that the mine shut down early and plans to continue depositing tailings and raising dams were never fulfilled.

Progressive reclamation was carried out during operations with the first soil cover completed for Cell 1 by 1995. Figure 3 provides several snapshots of the evolution of TCA configuration showing areas of active tailings deposition and placement of tailings cover from pre-development through 2004.

4.2 TCA Configuration During Active Care and Maintenance

The TCA has been on care and maintenance since 2005 and began transitioning to active closure around 2018. The following works has occurred during that time:

- Construction of a 1 m thick sand and gravel esker cover on the exposed tailings of Cell 1, 2, 3, and 5
- Regrading the downstream slope of K Dam and flattening to 2.1H:1V
- Construction of outflow structures on the surface of Cell 3 and 5

- Removal of the gated culvert in the Divider Dyke and construction of a spillway to allow passive drainage from Cell 4 to Pond 1
- Decomissioning of the arsenic treatment plant located on J Dam
- Maintenance of the dams to address erosion from surface runoff
- Water treatment and discharge to manage water levels in the TCA and draw down the pond in preparation of closure.

4.3 TCA Transition to Closure

It is understood that the TCA is currently in a status of active closure and working towards passive closure. Final closure covers at the TCA have been under construction starting as early as the mid-1980's and have continued intermittently until present day. There still remain areas of exposed tailings that are intended to be covered but are below the pond levels. It is understood that in around 2018, a decision was made to fully close the site (including closure of the underground workings) and could be said to be the start of active closure.

The transition from active to passive closure at the TCA is generally understood to consist of (LMI, 2020):

- Complete cover of deposited tailings
- Regrading of M Dam Slope to 2.1H:1V
- Constructing closure spillways through J Dam and Dam 1A

The implementation schedule presented in the FCRP (LMI, 2020) and the Post Closure Monitoring Plan (LMI, 2021) both indicate that passive closure was initially scheduled to commence in 2022; however, the site is anticipated to remain in active closure for at least the next several years before the closure spillways can be constructed.

The closure spillways are intended to allow passive drainage of the TCA and restore the natural drainage patterns of the site. Prior to constructing the closure spillways, water quality will need to be demonstrated to be acceptable without further treatment. It is understood this hasn't been achieved yet and the site remains in active closure.

It is understood that studies are ongoing to evaluate the impacts of a lowered water level within the TCA on the long-term discharge water quality from the TCA as the tailings are known to be potentially acid generating. It is understood that and areas of acid seepage have already been identified within the TCA and plans are in development to mitigate adverse impacts. Lowering the TCA pond level will expose additional tailings which will need to be either relocated or capped to mitigate geochemical risks. This has been considered in the current closure plan.

A decision matrix was developed (Stantec, 2019c) and supporting information provided (Stantec, 2020a) regarding exposed tailings. The decision matrix has considered the potential risks to dam safety of excavating or removing tailings at the toes of dams and provides rationale for when the tailings should be covered in place or relocated. There remains some uncertainty regarding how long it will take to demonstrate that the lowering of the TCA ponds will not adversely impact discharge water quality. The ability to effectively mitigate geochemical risks within the TCA is a pre-requisite for constructing the closure spillways.

5.0 Hazard Potential Classification

The standard of care expected of dam owners is dependent on the potential consequences of the failure of a dam. Dams that present a greater hazard or downstream impacts are to be designed to higher hydrologic and seismic loading criteria and managed with a greater degree of vigilance. CDA (2013) recommends that the design criteria for mining dams under operation be based on the potential consequences of failure, or Hazard Potential Classification (HPC).

The following sections outline the context for the HPC and the existing classification of the TCA structures. The HPC of the TCA based on the current conditions and technical guidance is reviewed in Section 6.6.

5.1 Context for Hazard Potential Classification

5.1.1 Regulatory Guidelines

The Canadian Dam Association (CDA) guidelines are considered as the standard. The DSR is being carried out with the following CDA guidelines:

- Dam Safety Guidelines (CDA, 2013)
- Application of Dam Safety Guidelines for mining dams (CDA, 2014)
- Dam Safety Reviews (CDA, 2016)

5.1.2 Definition of a Dam

The Canadian Dam Safety Guidelines (CDA.2013) define a dam as follows:

> *"A barrier constructed for the retention of water, water containing any other substance, fluid waste, or tailings, provided the barrier is capable of impounding at least 30,000 m^3 of liquid and is at least 2.5 m high. Height is measured vertically to the top of the barrier (i) from the natural bed of the stream or watercourse at the downstream toe of the barrier, in the case of a barrier across a stream or watercourse; or (ii) from the lowest elevation at the outside limit of the barrier, in the case of a barrier that is not across a stream or watercourse.*
>
> *In these guidelines, the term dam included appurtenances and systems incidental to, necessary for, or connected with the barrier. The definition may be expanded to include dams less than 2.5 m high or with an impoundment capacity of less the 30,000 m^3 if the consequences of dam operation or failure are likely to be unacceptable to the public, such as dams that create hydraulic conditions posing a danger to the public; dams with erodible foundations that, if breached, could lower the reservoir by more than 2.5 m; or dams retaining contaminated substances."*

The 2014 CDA technical bulletin for application of dam safety guidelines to mining dams provides the following additional commentary to the 2013 definition:

> *"…the definition of a dam includes dams less than 2.5 m high if the consequence of failure is likely to be unacceptable to the public, such as dams retaining contaminated substances. Hence, in the context of mining dams, there is no minimum size if they contain contaminated substances (fluids and/or solids) where the consequence of failure could be unacceptable to the public."*

The 2014 CDA bulletin continues:

> *"If a breach of the perimeter containment, regardless of the triggering mechanism, can trigger liquefaction or flow of the contents of the stack can extend beyond the perimeter containment, then the perimeter containment must be considered a dam, even if there is no visible water on the surface of the stack (i.e., no pond)."*

The likelihood of a failure is not a consideration when assessing if a structure is or is not a dam. It is the consequence in the event of failure that must be considered.

5.2 Hazard Classification

The CDA Guidelines (2013) outline the classification system for dams according to the incremental consequence of a potential failure. The incremental consequences of failure are defined as the total damage from an event with dam failure minus the damage that would have resulted from the same event had the dam not failed (CDA, 2013).

The incremental failure consequences are assessed according to four categories: potential loss of life, economic losses, environmental losses, and cultural losses. Estimates of potential consequences of failure are categorized to distinguish dams where the risk is much higher than others. The class should be determined by the highest potential consequences, whether loss of life or environmental, cultural, or economic losses. The hazard classification provides guidance on dam design criteria and the standard of care expected of dam owners. The basic aspects of the criteria set out in CDA (2013) for establishing the HPC are summarized (minus notes and details) below.

The TCA dams were first classified during the 2004 DSR (document was not reviewed by SLR) and considered again during the 2015 DSR (SRK, 2016). In general, the structures have been classified according to their location in the TCA (i.e., internal vs. external dam) and function (i.e., retention of tailings vs. water). On this basis, perimeter dams have been classified 'Significant' as a breach would impact the downstream environment while internal dams have been classified as 'Low' as a breach would be contained in the TCA by the perimeter dams. Overall, the TCA would be classified according to the highest classification of the dams, in this case 'Significant'

6.0 Dam Safety Assessment & Analyses

SLR conducted a site visit to visually inspect the TCA and conduct staff interviews for the purpose of understanding the site conditions and current construction and maintenance activities, followed by review and assessment of the provided documents.

6.1 Site Inspection Observations

The following sections summarize the observations made while touring the site and should be read in conjunction with the referenced photographs (Appendix A). Additional comment and typical cross-sections for each of the dams is presented in Appendix B.

6.1.1 Perimeter Dams

Dam 1A, 1B, and 1C

These three dams were generally in good condition. Dam 1A is the largest of the three structures with an estimated height of 5 m while Dams 1B and 1C were estimated to be 1.5 m and 1.0 m high, respectively. Dam 1A is also noted to be the only dam with water against the dam on the upstream side **(Photo 1)**.

The crest appeared level and approximately 5 m wide. The upstream slope was covered with a zone of angular rock riprap and sloped to about 3H:1V. The bulk of the dam and downstream slope was comprised of broadly graded esker with a steeper slope of about 1.5H:1V **(Photo 2)**. Erosion rills were present on the downstream slope of Dam 1A **(Photo 3)**. Perimeter roads along the toe of the dams provide a buttress to the dams.

No seepage was observed from the downstream toe of the dams.

Vegetation has been established on the downstream slope of Dam 1B consisting of small shrubs and bushes **(Photo 4)**. This vegetation may aid in preventing erosion. Root penetration is not expected to be a problem as the area only supports small plants.

Animal burrows noted in Dam 1A and Dam 1C **(Photo 5)**.

The TCA discharge syphons are located across Dam 1A **(Photo 6)**. Three approximately 0.45 m diameter HDPE pipes extend from Pond 1A over the dam to beyond the perimeter road downstream of the dam. A mixing tank is located on the crest of the dam for producing a soda ash slurry to dose the pond, if required, prior to discharge **(Photo 7)**.

Dam 2

Dam 2 was generally in good condition. The dam was estimated to be about 6 m high relative to the surrounding topography. The crest appeared level with an approximate width of 5 m and appeared to be a well compacted sand and gravel esker **(Photo 11)**. The upstream slope was covered with a zone of angular rock riprap and sloped to about 3H:1V **(Photo 12)**. The downstream slope of the dam was comprised of a broadly graded esker sloped to about 1.5H:1V **(Photo 13)**.

Water in Pond 2 was present along the upstream toe of the dam but appeared to be at least 5 m below the crest of the dam.

A few large erosion rills were noted from the downstream shoulder of the crest into the downstream slope **(Photo 14)**. The upstream slope appears to have an area of scour that appeared to be related to the high-water mark of the pond (approximately 1.5 m below the dam crest) **(Photo 12)**.

No seepage was observed from the downstream dam toe. However, it is understood that historically seepage reported from the dam abutments and was captured and pumped back from two small ponds. At the time of the visit, the southern seepage pond was dry while the northern pond remained **(Photo 15)**.

A road along the downstream toe of the dam provides containment for the seepage pond and likely provides a buttress support for the dam structure.

Dam 3

Dam 3 was generally in good condition. The actual location of the dam was hard to gauge as the covered tailings generally sloped towards the north and then gradually became steeper where the TCA abuts Boomerang Lake **(Photo 17)**. The upstream slope has been buried by the tailings cover and a swale has been constructed parallel to the upstream side of the dam **(Photo 18)**. Drainage chutes have been constructed at different locations to allow surface runoff to drain into the Lake **(Photo 19, 20)**. Perhaps as a result of this, less erosion was observed on the outer slope of this dam.

The downstream slope on the west end of the dam has been covered with riprap and sloped to about 1.5H:1V with no evidence of erosion. On the east end of the dam, the downstream slope is comprised of esker sand and gravel with a shallower slope of around 2.5H:1V. Erosion rills were noted in this section of the dam outside of drainage chutes **(Photo 21)**.

No seepage was observed from the downstream toe. Some minor longitudinal cracks were observed on the downstream mid-slope area **(Photo 22)**.

Dam 4

Dam 4 was generally in good condition. The dam was estimated to have a maximum height of about 5 m. The crest appeared level with an approximate width of 5 m. The bulk of the dam appeared to be constructed with esker sand and gravel. The upstream slope was covered with a zone of angular rock riprap and sloped to about 2.5H:1V and was generally in good condition **(Photo 25)**.

The downstream slope appears to be esker sand and gravel with a varying slope. The area of dam on Ferguson Lake had a shallow slope of perhaps 4H:1V and appeared different than the rest of the dam **(Photo 26)**. It is understood this slope has undergone repairs to address erosion rills. Currently the slope is in good condition and no erosion was observed. The section of dam further east on Long Lake has a steeper slope of around 1.5H:1V and noted here to have a few large erosion gullies where a fan of washed-out sand and gravel have been deposited at the dam toe **(Photo 27, 28)**.

Water was observed upstream of the dam around 5 m below the crest. On the downstream side, Ferguson Lake extends up to the toe of the dam while Long Lake is some distance away from the dam. No seepage was observed from the dam toe.

Dam 5

Dam 5 was generally in good condition. The dam was estimated to be around 1.5 m high. The crest appeared to be level and approximately 5 m wide. The entire dam appeared to be constructed with well compacted esker sand and gravel. Upstream and downstream slopes appeared to be about 2H:1V and generally in good condition **(Photo 30)**.

Upstream of the dam appears to be native ground without any tailings or cover placed to at least within 50 m of the dam **(Photo 31)**.

Dam 6

Dam 6 was generally in good condition. The dam was estimated to be around 1.5 m high relative to the surrounding topography. The crest appeared level and approximately 6 m wide comprised of well compacted sand and gravel. The upstream slope has been buried and the top of the tailings cover is generally flush with the dam crest. A small area upstream of the dam had a shallow pond where runoff had collected **(Photo 32)**. The downstream slope was comprised of the same sand and gravel esker but lacking the larger particles seen at Dams 1A and 2 with an approximate slope of 2H:1V.

A few minor erosion rills were noted from the crest through the downstream slope **(Photo 33)**. A small longitudinal crack approximately 5 m long was observed near the upstream edge of the crest at the sound end of the dam **(Photo 34)**.

The north abutment of the dam was noted to have a riprap drainage swale which was reported to be a repair of a former erosion channel created by water flowing over the dam **(Photo 35)**.

6.1.2 Internal Dams

Dam 3D

Dam 3D is generally in good condition. The dam is understood to have an approximately 10 m wide waste rock buttress covering the original dam. The original dam and upstream slope are buried under the tailings cover, so it is just the waste rock buttress that is still visible. The downstream slope is in good condition with a slope of about 1.5H:1V **(Photo 36)**. No evidence of erosion was observed.

A berm of esker sand and gravel has been constructed along the presumed upstream side of the original dam crest. This would appear to create a drainage divide, with only a small area reporting to Pond 1 and the larger area of Cell 1 and 2 draining towards the north (or infiltrating the cover) **(Photo 37)**.

A culvert was noted exiting the dam from about the base level of the dam at the east end of Dam 3D **(Photo 38)**. It is not known whether this culvert provides any functional use. No water was observed to be flowing from the culvert. On the other hand, the area around the culvert appears to have been cut back, whether by erosion or intentionally is unclear. It is presumed that this culvert was intended to allow tailings contact water in Cell 1 to drain into Pond 1.

J Dam

J Dam appears structurally sound but is in general hard to assess with uneven crest and varying slopes **(Photo 41)**. The dam appears to be mainly comprised of rockfill with a sand and gravel running course along the crest **(Photo 42)**. As noted, the slopes vary but appear to be around 1.5H:1V on average. Some scour erosion was noted near the top of dam slope and assumed to be related to the former high-water level **(Photo 43)**. At the time of inspection, water levels appeared to be about 2 m and 4 m below the crest on the Pond 1 and Pond 2 sides, respectively.

The internal syphons are located over J Dam and consist of 2 PVC pipes **(Photo 41)**. Four 0.15 m diameter PVC pipes were observed about 0.5 m below the crest that passed through the dam **(Photo 42)**. These have been understood to provide an overflow outlet to prevent the dam from overtopping. It is unclear whether these have been designed and sized, but they appear to be undersized for the catchment area.

K Dam

K Dam is in good condition and has recently undergone construction to repair and regrade the downstream slope to 2.1H:1V **(Photo 44, 45)**. No erosion was observed of the slope at the time of the inspection. The dam slope was constructed with esker sand and gravel. It is noted that the downstream crest shoulder has a small berm to prevent runoff from the top of Cell 5 from flowing down the slope and potentially eroding it.

The Pond 1 level during the site visit was low enough that did not touch the dam **(Photo 44)**. The dam appeared to be about 8 m high at its tallest.

L Dam

L Dam is generally in good condition but appears to have experienced erosion along the slope from Pond 1 and runoff from the top of Cell 3. The Pond 2 level during the site visit was approximately 5 m below the crest of the dam. The maximum dam height could not be assessed due to the pond at the toe. The upstream crest has been buried under the tailings cover material, with is flush with the top of the dam. It’s noted that there is no berm structure to control surface runoff from flowing off the crest and down slope.

The downstream slope is comprised of esker sand and gravel sloped at around 1.5 to 2H:1V **(Photo 46)**. It appears steeper in the middle of the dam where it is exposed to Pond 2 and appears to have been undercut by wave action. One large erosion gully was observed at around the midpoint of the dam **(Photo 47)**.

An area of previously identified uncovered tailings was observed around the northern abutment **(Photo 48)**. It is understood that this area is planned to be covered once water levels allow for it and has been described in a technical memorandum issued in relation to Part E Item 27 of the project water license (2 AM-LUP2032).

An outflow structure constructed in 2021 on the surface of Cell 3 and drains over L Dam. The outlet of this outflow structure is a wide channel armoured with boulder sized rocks that appear to be suited for the purpose **(Photo 49)**. The outflow structure channel further upstream narrows and is constructed as a channel in the esker cover material **(Photo 50)**. This section of the outflow structure appears to be more prone to erosion and slumping of the channel side slopes **(Photo 51)**.

M Dam

M Dam is in satisfactory condition but requires maintenance to address several large erosion gullies along the downstream slope of the dam **(Photo 52 to 54)**. This is reported to be part of the plan for active closure activities in 2025. The dam appeared to be about 7 m high and did not have any pond at the toe during the visit **(Photo 55)**. The upstream slope and crest have been covered with esker gravelly sand. The bulk of the dam appears to be comprised of a broadly graded esker sand with a variable quantity of cobbles and boulders with an approximately slope of 1.5H:1V **(Photo 56)**. It is noted that there is no berm structure to reduce surface runoff from flowing off the crest and down slope **(Photo 56)**.

No seepage was observed from the downstream toe. There is a relatively large area on the surface of the covered tailings that had ponded water **(Photo 57)**. This is understood to be considered within the closure plan and will be eliminated through additional esker gravelly sand and grading the surface to promote drainage.

It is understood that this dam was constructed on deposited tailings and the soil downstream of the dam was a reddish silty sand which appears to be tailings **(Photo 58, 59)**.

An outflow structure was constructed in 2021 on the surface of Cell 5 and drains over M Dam. The outlet of this outflow structure is a wide trapezoidal channel armoured with boulder sized rocks that appear to be suited for the purpose **(Photo 60)**. Farther upstream the channel narrows and is constructed in the esker cover material **(Photo 61)**.

N Dam

N Dam is generally in good condition. The crest and upstream slope have been covered with esker gravelly sand. The crest of the dam was approximately 5 m above Pond 2 water level **(Photo 62)**. The downstream slope was comprised of esker gravelly sand, although some areas have a riprap cover with small boulder sized rocks (~0.3 m diameter) **(Photo 62),** whereas other areas were mostly sand and gravel **(Photo 63)**. No significant erosion gullies were observed on the downstream slope. The slope did however exhibit a stepped shape, perhaps indicating some erosion at the former high-water levels in the pond **(Photo 63)**.

No seepage was observed from the downstream slope. The toe of the dam was not visible due to Pond 2 level.

It is understood that this cell was recently backfilled or covered with esker gravelly sand and had previously been a separate small pond. The cover was generally in good condition but noted to have a small area of ponded water on its surface **(Photo 64)**. This is understood to be considered within the closure plan and will be eliminated through additional esker gravelly sand and grading the surface to promote drainage. The current condition of this dam, without a contained pond, could be considered to be an extension of M Dam rather than a separate dam. In effect, it is acting as a toe berm to M Dam.

Divider Dyke

The Divider Dyke is generally in good condition. The dam crest appeared level and approximately 5 m wide **(Photo 65)**. The dam appears to be a homogeneous embankment constructed with esker gravelly sand. The side slopes were estimated as 1.5H:1V. The maximum dam height appeared to be 3 m. The southern segment of the dyke had water on both sides (Cell 4 upstream and Pond 1 downstream) at approximately the same elevation.

No erosion was observed although it is understood that this structure was recently repaired to address previous erosion issues. It is also understood that the dyke had formerly had a gated culvert to control the flow from Cell 4 to Pond 1 that was recently removed and replaced with an operating spillway **(Photo 66)**. During the visit, the water level of Cell 4 was lower than the spillway invert and there was no flow between ponds **(Photo 67)**.

The spillway channel generally appeared in good condition. It is lined with cobble sized riprap through the dam then appears to be cut into bedrock in a channel downstream of the dam.

6.2 Review of Design Criteria

Assessment of dam safety includes a review of design criteria against current guidelines and regulations, evaluation of the objectives and the design basis considering the closure objectives. The design criteria are summarized in Table 3.

6.2.1 Dam Stability Criteria

The dam stability criteria are summarized in Table 3A. Slope stability has been assessed by Holubec in the original TCA Closure Plan (2005) and subsequently in 2019 by Stantec (2019a, 2019b). No original dam design documents are available to review slope stability as it informs the actual dam design.

The design criteria employed by both Holubec and Stantec were per CDA guidelines, current to the time the analyses were completed. Seismic criteria were per the dam HPC; in 2005, the highest HPC was 'Low', while in 2019 the highest HPC was 'Significant'.

6.2.2 Flooding Criteria

The previous DSR (SRK, 2016) reviewed the HPC of the dams and recommended flood design criteria for dams classified as 'Low' and 'Significant' dams based on guidance in CDA (2014) for the construction, operation, and transitions phases and the closure-passive care phase. SLR considers the flood design criteria proposed by SRK for the TCA under care and maintenance as appropriate but recommends a large magnitude event, such as the Probable Maximum Flood (PMF), is considered for the post closure phase to ensure the long-term physical stability of the facility and to minimize potential environmental risks.

Design for a large magnitude flood during post closure is consistent with guidance in the Global Industry Standard on Tailings Management (GISTM) which recommends a 10,000-year event is considered regardless of the consequence classification of the tailings facility. Flood design criteria recommended by SLR are presented in Table 3B.

SLR has reviewed the estimates of precipitation depths corresponding to the above design criteria from previous DSR's (SRK, 2016) and agrees with values presented for the 24-hour precipitation depths with return periods of 100 and 1,000 years. However, a higher estimate of the Probable Maximum Precipitation (PMP) was calculated using the statistical method outlined in WMO (2009) from 1982 to 2006 daily rainfall records for Environment and Climate Change Canada's (ECCC) Lupin A climate station (ID: 23026HN).

Further, while independent calculations have not been completed, SLR believes the value presented by SRK for the freshet may be an underestimate and the value presented by Golder may be more appropriate. This is based on review of the daily temperature, snowfall and snow-on-ground records for the Lupin station, and daily discharge records for two ECCC hydrometric stations, Izok Lake Inflow (ID: 10PB002) and Burnside River near the Mouth (ID: 10QC001).

Design precipitation depths are presented in Table 3C for the recommended flood design criteria. The duration of the freshet is not provided in SRK (2016) but this is expected to occur over several (30 or more) days.

The precipitation depths presented in Table 3C do not consider the effects of climate change, which is particularly important to planning for the permanent closure of the TCA. Climate change predictions include an increased likelihood of precipitation falling as rain rather than snow as the climate warms, particularly in northern Canada (Zhang *et al* 2019). Zhang *et al* present median projected changes in annual maximum 24-hour precipitation in North Canada of +29.8%, +30.0%, and +30.1% for storms with return periods of 10, 20, and 50 years respectively.

6.3 Dam Stability Evaluation

SLR reviewed stability evaluations completed in the past from the documents made available. The evolution of stability criteria and scenarios modelled for the TCA dams have been studied and a summary of the evolution is provided in this section.

6.3.1 Holubec (2005)

The impact of climate change had been considered while assessing stability of the Lupin dams by Holubec (2005). Although it is reported that the Mean Annual Air Temperature has been increasing since 1951 and the rate of increase has amplified since 1980, precipitation at Lupin has experienced a smaller change over the period of mining operations from 1982 to 2004.

- Perimeter dams were not taken into consideration for stability checks since their functionality as water retaining structures had been proposed to be terminated at the closure of the TCA (i.e. Dam 2 would be breached and small remnant ponds would be left behind).
- The stability of three internal dams (Dam 3D, K Dam, and M Dam) were assessed assuming complete thaw of permafrost.
- The factor of safety for long term stability of 1.5 or greater was adopted as the minimum criteria.
- Three scenarios were modelled –

  - As-built dam with permafrost at ground surface
  - As-built dam with fully thawed soil conditions
  - Regraded dam slopes with fully thawed soil conditions
- The material properties for frozen and thawed soil strength were based on published literature and tailings dams constructed in similar climatic conditions.
- Pseudo-static conditions were not assessed

The analyses found that for each dam studied, the existing slope did not meet the minimum factor of safety of 1.5 for a fully thawed condition. A regraded slope of 2.5H:1V was found to meet the minimum factor of safety for all three dams assessed and was proposed to be constructed as part of final closure of the TCA. It is understood that this was not carried out for the dams, although later Stantec (2019a, 2019b) would re-evaluate the TCA dams and make separate recommendations in support of the Final Closure and Reclamation Plan (LMI, 2020).

It does not appear that a pseudo-static analysis was conducted by Holubec. However, based on the later analysis by Stantec (2019a, 2019b), pseudo-static conditions do not appear to drive the stable slope gradient.

6.3.2 Stantec (2019)

Dam stability analyses were conducted using static and pseudo-static loading conditions (Stantec, 2019a, 2019b). The salient features of the stability criteria are as follows.

- As-built scenario with an active thaw zone extending 2 m below the ground surface. The sections were generated using 2019 bathymetry and surface survey data.
- Seismic condition (PGA = 0.05g) at a probability of 2% in 50 years based on NRC (2015).
- Dam cross-sections were based on sections previously presented in the DSR report by SRK (2016).
- Material properties used in the modelling have been reported to be based on previous working experience with similar materials.
- Closure water levels used in the modelling are: 480 m (Pond 1), 481 m (Pond 2) and 485 m (Cell 4).

SLR understands that the analyses focused on long-term loading conditions which appear to be in good engineering judgement for closure design. The rationale for selecting a target factor of safety of 1.3 for static analyses for local failures (i.e. shallow/surficial failures) is not clear and should be reviewed. CDA (2014) notes the following regarding adoption of a factor of safety of 1.3:

> *"A factor of safety of 1.3 may be acceptable during construction of a dam where the consequences could be minor and measures are taken during construction to manage the risk such as a detailed inspection, instrumentation, etc. But the factor of safety of 1.3 should not simply be adopted because it is 'End of construction.' A factor of safety of 1.5 has typically been adopted for tailings dams because of the potential consequences of failure."*

A lower factor of safety for local failures is considered acceptable under the current status of site, in that there are annual inspections and equipment available to carry out maintenance work as needed. However, given that some of the slopes do not meet the long-term minimum factor of safety of 1.5 and the dams suffer from chronic erosion, flatter slopes may provide a solution that both meet the long-term stability requirements and are less prone to erosion by runoff.

M Dam and N Dam are reported to be constructed on deposited tailings (SRK, 2016). This is consistent with observations made during the site visit where the area downstream of M Dam appeared to be tailings. However, it is noted that the sections analyzed by Stantec (2019a, 2019b) show the dams founded on till. SLR recommend confirming whether the dam is founded on tailings and if so, also recommend that an Undrained Stress Analyses (USA) also be carried out for the long-term condition as a best practice.

A risk assessment has been carried out to analyse stability for two dams using the worst-case scenario for thermal modelling with the active zone extending to a depth of 14 m by the year 2100. The dams analysed (Dam 4 and Dam 3D) were selected ultimately because they had existing instrumentation to correlate with other studies and represented a perimeter and internal dam. It is noted that both the overall stability analysis with current permafrost conditions (Stantec, 2019a) and the risk assessment analysis of two dams with thawed conditions (Stantec, 2019b) were issued a few days apart and presumably completed simultaneously. However, it would seem prudent to consider a thawed stability analysis on the sections that had identified low factors of safety (i.e. K Dam and M Dam). In particular, M Dam with it potentially being constructed on tailings and reports made of deformation cracking and sinkholes (2015, 2020), would appear to warrant stability analyses under thawed conditions.

The adopted dam stability criteria have evolved after the period of operation of the TCA in line with changing practice. It appears that criteria compliant with a "Significant" HPC have been adopted by the engineer. This is considered satisfactory for the current phase of the project as the site has equipment and staff on site regularly to address slope failures or dam deformations. However, it is recommended for the passive closure and post-closure phases that the engineer consider conducting stability analyses for the thawed condition for other dams and adopting a higher classification seismic criteria commensurate with the permanent nature of the dams.

6.4 Flood Conveyance Checks

SLR has computed high-level estimates of the peak flows with Annual Exceedance Probabilities (AEPs) of 1/100, 1/1,000 and 1/10,000 to be conveyed through the open channel conveyance (outflow) structures on the covered tailings cells (Cells 1, 2, 3, and 5) and the spillways proposed Pond 1 and Pond 2 on J-Dam and Dam 1A respectively. These estimates are presented in Table 5, and were obtained by pro-rating peak flow estimates for the Environment and Climate Change Canada (ECCC) hydrometric station Burnside River near the Mount (IDQC001).

The peak flow estimates do not consider the effects of climate change. Bonsal *et al* (2019) suggest that projected higher temperatures could result in shifts from nival toward pluvial flow regimes, earlier floods associated with spring snowmelt, ice jams, and rain-on-snow events, and increasing winter base flows.

Stantec (2019a) provides design criteria for the open channel conveyance (outflow) structures on Cells 3 and 5. It was proposed that these structures are designed to convey the peak flow from a 100-year return period event. This design flood may be low for the post closure TCA and SLR recommends considering the Probable Maximum Flood (PMF) as discussed in Section 6.2.2.

Stantec designed a shallow armoured trapezoidal channel with a base width of 5 m, depth of 0.3 m, and side slopes of 2H: 1V (Figure 7), and minimum and maximum grades of 0.5% and 10%. The design included armour consisting of rock with a mean stone size of 260 mm. SLR's independent calculations of the hydraulic capacity of the channel indicate that it can convey a maximum flow of 1.26 m^3/s with a freeboard of 0.18 m. A flow of 1.26 m^3/s is an order of magnitude greater than the 1/10,000 AEP peak instantaneous flows in Table 5 for Cells 1, 2, 3, and 5 which suggests that Stantec's channel design is appropriate for the post closure TCA.

LMI (2020) proposes a typical cross section and a typical profile for the post closure TCA spillways on J-Dam (Pond 1) and Dam 1A (Pond 2) (Figure 7). Final spillway designs, including dimensions, will be provided to the Nunavut Water Board (NWB) at least 60 days prior to the proposed start of construction, in accordance with the current Water Licence (#2AM-LUP2032).

6.5 Dam Breach Analyses

No dam breach analyses have been conducted for the TCA. The rationale for this decision was related to the HPC of the tailings containment structures (low) and due to the fact that the impounded tailings had aggraded permafrost, and therefore were considered immobile.

Prior to placement of the cover, the exposed tailings were frozen in the top 1 to 2 m. This may not continue to be the case in the long-term, particularly given the predictions for a warming climate. Further, the tailings are silt-sized and may be liquefiable. Therefore, SLR recommends that a liquefaction assessment and dam breach study is undertaken for the post closure TCA configuration.

6.6 Hazard Potential Evaluation

SLR have reviewed the Hazard Potential Classification (HPC) of the TCA in accordance with CDA guidelines (CDA, 2013) and technical bulletin for mining dams (CDA, 2014). The current overall classification of 'Significant' was determined during the previous DSR (SRK, 2015) and is considered valid for the TCA.

Currently, classified internal dams as 'Low' and perimeter dams as 'Significant' on the basis that a breach of an internal dam would be contained within the TCA while a breach of a perimeter dam would release contact water into the downstream environment. In addition, the deposited tailings are not considered to be mobile due to the permafrost conditions that currently exist. This is reasonable in the current care and maintenance state of the TCA, which is an enclosed basin that is regularly monitored and maintained as needed. The overall classification of 'Significant' is appropriate for the consequence of a perimeter dam breach releasing low pH water to the downstream environment for this site.

At closure, the perimeter dams will be breached to restore natural drainage patterns and the internal dams will effectively become the perimeter dams of each tailings cell. Based on current climate modelling suggesting warming conditions, the permafrost conditions may be expected to thaw in long-term to a greater depth than present; therefore, tailings and containment structures that have been frozen since the operational phase may progressively thaw.

The consequence of a breach of a tailings dam structure would result in the release of potentially low pH contact water and/or acid generating tailings. Environmental losses resulting from a breach are the primary driver for hazard potential classification and would be considered unacceptable to the public.

Additionally, the spillways constructed through Dam 1A and J Dam at closure will lower the water level of the remaining ponds inside the TCA. The closure ponds may be lower than the base of the perimeter dams; therefore, some of these dams may no longer meet the definition of a dam and could be declassified.

The proposed hazard potential classifications for each dam in the current care and maintenance status are summarized in Table 6B. However, the classifications of individual structures should be reviewed again in the context of the post-closure condition of the TCA.

7.0 Risk Assessment

SLR has enquired with the Engineer of Record whether a failure modes and effects analysis (FMEA) or risk assessment has been carried out for this site. It is understood that informal risk assessment(s) have been conducted in the past. Documentation of these assessments has not been provided and it's not clear whether the risk assessment has considered the current active closure or future post-closure conditions.

It is recommended that a formal risk assessment be carried out to address a number of outstanding risks (both physical and geochemical) and identify optimal risk mitigation strategies for both the ongoing active treatment phase and the transition to passive closure.

8.0 Operations, Maintenance, and Surveillance

8.1 OMS Manual

SLR has not been provided a copy of the Operations, Maintenance, and Surveillance (OMS) Manual for the TCA. The previous DSR (SRK, 2016) noted that the OMS Manual was prepared in 2004 and only discussed the perimeter dams. It was recommended that the OMS Manual be updated using current guidelines and reflecting the current status of site. It is not clear whether this recommendation was carried out and no OMS documentation was available for review by SLR..

SLR note that the OMS Guide (MAC, 2021) states that an OMS Manual should be maintained throughout the closure phase and reflective of the current site conditions. SLR recommend updating the OMS Manual to reflect the current status of site or developing a new OMS Manual if the previous version cannot be located. This is particularly relevant given the fact that the TCA continues to experience problematic water quality and has no spillways to protect dams against overtopping. It also remains unclear how long the site could potentially remain in the current configuration (which requires active pumping and treatment is required to manage pond levels) before the closure spillway is constructed and final closure measures implemented.

In lieu of the OMS Manual, SLR have reviewed the Post Closure Monitoring Plan (PCMP) for the site (LMI, 2021), which provides a schedule for surveillance monitoring and inspections. The following inspections are noted for the active closure phase per the water license:

- Bi-weekly inspections during the freshet period (approximately May to June)
- Monthly inspections during the remainder of open water period (approximately July to October)
- Annual inspection by a geotechnical engineer

Instrumentation readings and records are also collected during the annual geotechnical inspection.

It is noted that the PCMP has not been updated to reflect the current closure status of site. The closure schedule in this document indicates that passive closure would commence in 2022; however, the site remains in active closure with the timeline for transition to passive closure unknown.

8.2 Water Management

8.2.1 Water Management Systems

Currently, Cells 1 and 2, and much of the exposed tailings in Cells 3 and 5 have been covered with a 1 m thick layer of esker sand and gravel. Contouring of the cover promotes surface runoff into open channel conveyance structures which direct water away from the perimeter dams, and across internal dams into two water management ponds (Cell 4 and Pond 1). A typical cross section of the Cell 3 and Cell 5 outflow structures is shown on Figure 7. Runoff from Cell 3 is directed into Cell 4, and runoff from Cells 1, 2, and 5 is directed into Pond 1 (Figure 2). The only water retained in these covered cells occurs in low lying areas.

Cell 4 maintained a gated culvert through the Divider Dyke which, when opened, allowed water to be released to Pond 1. This was removed in 2021 and replaced with a swale lined with riprap on geotextile to protect against erosion. Water is syphoned from Pond 1 to Pond 2, a third water management pond, and from Pond 2 to the receiving environment. Buried HDPE pipes in J Dam act as an overflow structure for Pond 1 whereas Pond 2 has no overflow structure.

Pond 1 acts as a buffering pond to manage chemistry. A water treatment plant is located on J Dam between Pond 1 and Pond 2 which was used to treat water in Pond 1 prior to its transfer to Pond 2. Pond 2 is the final point of control prior to discharge into the receiving environment. Current treatment consists of adding slurried lime into Pond 2 before syphoning the water over Dam 1A.

Water is impounded in Cell 4 by the Divider Dyke, L Dam, and natural topography, in Pond 1 by J Dam, Dam 3D, and natural topography, and in Pond 2 by Dams 1A, 1B, 1C, and 2, and M Dam and N Dam (Figure 7)

Water management at the TCA currently relies on human intervention to syphon water over J-Dam (Pond 1) and Dam 1A (Pond 2). For permanent closure of the TCA, the syphons and culverts will be removed, J-Dam and Dam 1A will be breached and open channel spillways will be constructed establishing natural drainage through the TCA to Seep Creek and into Inner Sun Bay of Contwoyto Lake. As the tailings cover is completed, acid generation will be controlled by the saturated zone near the base of cover. The spillways will be constructed once it has been established that treatment is no longer required to achieve water quality objectives.

A typical section and a typical profile of the spillways are shown on Figure 7. The proposed spillway elevations are 481 m (Pond 1) and 480 m (Pond 2). The Pond 2 spillway will be engineered to prevent the migration of fish species into the TCA through a vertical barrier.

8.2.2 Pond Levels and Freeboard

The Lupin mine currently operates under an approved Type A Water Licence (#2AM-LUP2032), which requires that a minimum freeboard of 1.0 m shall always be maintained. Based on a review of historical documents, SRK (2016) noted that this requirement has typically been interpreted to apply to the perimeter dams.

The previous DSR (SRK, 2016) noted that between 1985 and 2005 (when the mine went into care and maintenance) Pond 1 water levels were generally managed between elevations 481 m and 485 m and Pond 2 water levels between 480 m and 483 m. Water levels at elevations 485.5 m (Pond 1) and 484.4 m (Pond 2) were observed in 2015 which represented the maximum elevations in the available record at that time. In 2020, water levels were higher at elevations 487.5 m (Pond 1) and 484.3 m (Pond 2) and have since come down to 484.2 m (Pond 1) and 480.4 m (Pond 2) in 2022. Minimum freeboards of some dams was not met during the higher water periods in 2020. The TCA does not have an emergency spillway to protect the perimeter dams around Pond 2 from overtopping.

It is noted that no records were available for 2015 to 2020.

8.2.3 Water Discharges

The frequency of water discharge from Pond 2 has been variable since the mine went into care and maintenance in 2005. The previous DSR (SRK 2015) noted four water treatment and discharge campaigns to reduce the volume of water stored in the TCA in 2005, 2009, 2012, and 2015. An additional campaign occurred in 2020.

8.3 Dam Instrumentation

Instrumentation has been installed in the dams and tailings cover. This includes thermistor strings and Volumetric Moisture Content (VMC) sensors. Table 7 summarizes the instrumentation installed in the TCA. As of 2021, the following instrumentation were being actively monitored:

- 11 thermistor strings
- 2 VMCs

The purpose of these instruments are to assess the active zone above permafrost in the dams and stored tailings, and to confirm saturation of the stored tailings. Permafrost in the TCA enhances the overall physical and chemical stability. The VMC's were installed to provide insight for the performance of the covers and in particular whether the deposited tailings remain saturated.

The first thermistors were installed in 1984 and provide a record of subsurface temperatures within the upper ~10 m of the TCA. In general, the data indicates that the active layer (i.e. unfrozen zone) extends to a depth of between 2.5 to 3 m below the surface. Readings are currently collected annually during the annual geotechnical inspection. Previously, during operations when the site was staffed full time, readings occurred on a monthly basis.

The VMCs were installed in 2018 to assess the level of saturation around the contact between the esker cover and underlying tailings. The VMC instruments are equipped with data loggers that collect readings every 12 hours. The data collected on the data loggers is downloaded annually during the annual geotechnical inspection. The VMC's cannot measure moisture content in frozen conditions, so only technically operate during the warmer seasons when the active zone thaws. The data collected up to the last annual inspection report provided (Stantec, 2021) generally confirm that the bottom of the cover and top of tailings have a moisture content that remains above 85% and should effectively prevent oxidation from occurring (MEND, 2009).

9.0 Dam Safety Governance

9.1 Corporate Policy

LMI does not currently have a dam safety corporate policy for the TCA, but it is understood that one is being developed. As noted in CDA (2013), the owner's dam safety policy should clearly demonstrate the organization's commitment to safety management throughout the dam's life cycle. This policy should define the following:

- The safety practices and criteria to be used, taking into account any applicable regulations, industry practice (such as the CDA technical bulletins), and due diligence
- Ultimate accountability and authority for ensuring that the policy is implemented
- The delegation of responsibility and authority for all dam safety activities
- The process for making decisions related to dam safety

It is acknowledged that dam safety governance standards were less well defined during the operational period of the mine and the site may be considered low risk in its current state. However, the intent of having a dam safety corporate policy is to ensure that dam safety doesn't take back seat to business objectives and to provide a structure for responsibility and accountability of the tailings facility.

9.2 Organizational Structure

Lupin Mine is owned by LMI., a subsidiary of Mandalay Resources Corp. The day-to-day site operations (when the site is staffed) are carried out by contractors (JDS – construction, DMS – camp management and logistics), who are hired and managed by LMI in Yellowknife. LMI have overall responsibility for managing the site and regulatory compliance with support from consultants. An organizational structure was provided and clearly illustrates the communication linkages between groups. It is important for each member in this structure to understand their role and with whom to communicate in emergency situations, particularly for a remote site.

It is unknown whether a Responsible Tailings Facility Engineer (who is responsible for the integrity of the tailings facility) and an accountable executive (accountable to CEO) have been appointed. These roles are seen as providing a commitment to ensuring good governance of tailings facilities as well as reinforcing communication between the different groups.

The facility has an Engineer of Record (EoR) that was appointed following the previous DSR (SRK, 2016). The current EoR and deputy EoR are Steve Bundrock and Michael Mahoweld, respectively, from Stantec. Stantec also act as the design engineer for the TCA.

It is noted that Steve is assuming the EoR role from Alvin Tong, who had previously been EoR for a number of years. In the succession of EoR, SLR has observed that there is continuity provided by Michael, who had been resident engineer during construction activities for the past few years and worked closely with Alvin previously.

The site has not had an Independent Technical Review Board (ITRB) to date. Consideration may be given to establishing an ITRB for the final closure design of the TCA depending on the outcome of the recommended updated TCA risk assessment (Section 7) .

9.3 Management Systems

A significant number of reports had to be reviewed to gain an understanding of the site history, design, and conditions encountered during construction. Records from the operational phase of the mine were very limited and no design or as-built records have been provided for review. Rather, our understanding of the dam design and foundation conditions come from summaries prepared by others, in particular Holubec (2005) and SRK (2016).

It is suggested that LMI consider a process of consolidating and archiving the information available in preparation of the final stages of care and maintenance and the extended post-closure period.

10.0 Emergency Preparedness

SLR have reviewed an Emergency Response Plan (ERP) for the TCA (DMS, 2022). It is understood from the previous DSR (SRK, 2016) that an Emergency Preparedness Plan (EPP) has also been developed but was not provided to SLR for review.

The ERP document provides procedures for employees to follow in an emergency situation. It is limited to communicating an emergency and providing directions for muster locations. The document includes relevant emergency phone numbers and addresses as well as instructions for directing rescue operations to the airstrip. The types of emergencies that seem to have been considered in this document are personnel injury/medical incidents.

The ERP does not address emergencies related to the TCA (i.e., dam breach, overtopping, etc.). Emergency response and preparedness was discussed during interviews with the construction manager while on site and the responses were generally in line with an appropriate response to a dam safety emergency. It was noted that:

- Site personnel are involved in surveillance during routine work around the TCA and instructed to notify of any deviations or potential hazards noted
- The site currently has construction equipment and operators for part of each year and can carry out emergency construction if needed
- The esker borrow is still open and can provide large quantities of fill as needed
- The EOR would be notified of any hazard or emergency condition

In general, the current staff personnel appeared to be prepared for potential emergency scenarios. However, in the absence of a documented plan, future staff may not be fully prepared to respond to a dam emergency. It is recommended that the ERP be updated to consider potential dam safety emergencies.

11.0 Conclusions & Recommendations

Overall, the TCA appears to have been operated and maintained well over the years despite changes in ownership, staff, and consultants who have worked at this site. During operations, the mine was proactive with regard to progressive reclamation and long-term monitoring to support the closure plan.

Currently, as a site that is regularly monitored and maintained, it is our view that the systems and staff in place are well equipped to manage the TCA and continue in a state of active closure. However, looking ahead towards passive closure, we believe there remain some risks and uncertainties that will require technical judgement to implement and demonstration of effectiveness before the site should transition to passive closure.

The main dam safety risks are considered to be erodible dam slopes that were observed throughout site during the site visit and lack of emergency spillways. Both of these are manageable with ongoing human intervention. However, without continual site presence they could lead to eroding the dams/exposing tailings and overtopping the TCA. Closure spillways are planned to be constructed when water quality is met. In the interim, it would be prudent to construct an emergency spillway to further mitigate the risk of dam overtopping.

Erosion of the dam slopes is attributed to a number of factors including the fill materials, slope gradients, lack of vegetation, and drainage area and channelization. The approach to make the slopes erosion resistant in the long term could use a variety of engineered solutions. Whatever is constructed will need to be monitored for period of time to demonstrate effectiveness.

Recommendations include:

1 Assess the liquefaction potential for the tailings. As there is potential for the frozen deposited tailings to thaw and it is known that at least M Dam is founded on tailings, the liquefaction potential should be assessed to understand whether the tailings could flow in a dam breach scenario.

2 Perform dam stability analysis of M Dam considering thawed conditions and verify whether the dam is underlain by tailings. If tailings are present under the dam, consider an Undrained Strength Analysis of thawed tailings.

3 Conduct a dam breach analysis for the TCA. Presently the highest consequence would be a perimeter dam breach releasing contact water into the downstream environment. In the long-term and depending on the findings of the liquefaction potential assessment, a dam breach could release liquefiable tailings into the downstream environment.

4 Construct a temporary emergency spillway to reduce the risk of dam overtopping before the closure spillway is constructed. The closure spillway could make use parts of the temporary emergency spillway (e.g., the outlet channel). In effect, parts of the closure spillway would be constructed now and later the spillway invert would be lowered to the closure elevation.

5 Design erosion resistant slopes or drainage features for the dams to ensure long term physical stability of the TCA.

6 Adopt large magnitude events (in exceedance of those required according to the HPC) for seismic and flood design criteria for closure.

7 Perform a formal risk assessment for the TCA and document with a risk register. This risk assessment must recognize both the physical and interconnected geochemical risks and cover the transition from active closure to passive closure.

8 Update or develop a new OMS Manual for the TCA that reflects the current status of the site and is updated regularly as site conditions change and the site transitions to a state of passive closure.

9 Update the Emergency Response Plan to provide clarity and direction for dam safety emergencies.

10 Develop a dam safety corporate policy and identify a responsible tailings facility engineer and accountable executive.

It is recommended that the next Dam Safety Review occur within two years of transitioning to passive closure or 10 years from now (2033), whichever comes first.

12.0 Closing Remarks

SLR appreciates the support from LMI, Stantec, and Discovery Mining in the preparation of this Dam Safety Review and gives thanks to the Steve Bundrock and Michael Mahowald for accompanying SLR during the site inspection and providing responses in the interviews.

We trust the recommendations provided in this report will be well received and used to enhance dam safety and stewardship of the TCA.

If there are any questions, please do not hesitate to contact the undersigned.

Regards,

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Tables

2023 Dam Safety Review

Lupin Mine Tailings Containment Area (TCA)

Lupin Mines Inc.

SLR Project No.: 209.065024.00001

April 26, 2024

Table 1: Description of TCA Dams

Name	Location	Construction Year	Crest Elev. (m)	Foundation	Dam Fill	Slopes	
						Upstream	Downstream
1A	Perimeter	1981	486.27	Deep Silty Sand Till	Compacted Silty Sand Till, upstream Esker zone, Riprap	2.5H:1V	2.5H:1V
1B	Perimeter	1981	485.83	Silty Sand Till	Compacted Silty Sand Till, upstream Esker zone, Riprap	2.5H:1V	2.5H:1V
1C	Perimeter	1981	485.88	Silty Sand Till	Compacted Silty Sand Till, upstream Esker zone, Riprap	2.5H:1V	2.5H:1V
2	Perimeter	1981	486.3	Deep Silty Sand Till	Compacted Silty Sand Till, upstream Esker zone, Riprap	2.5H:1V	2.5H:1V
3	Perimeter	1983	490.2	Silty Sand Till	Compacted Silty Sand Till, upstream Esker zone, Riprap	2.5H:1V	2.5H:1V
4	Perimeter	1992	489.59	Fractured bedrock	Esker Sand and Gravel, upstream and downstream Riprap	2.3H:1V	1.5H:1V
5	Perimeter	1992	491.54	Silty Sand and Gravel Till	-	3H:1V	2H:1V
6	Perimeter	1992	490.25	Silty Sand and Gravel Till	-	3H:1V	2H:1V
3C	Internal	1985	491.2	-	-	-	-
3D	Internal	1986	490.5	Bedrock	Esker Sand and Gravel, downstream Mine Rock, additional Esker on crest	-	1.6H:1V
3E	Internal	1985	491.2	-	-	-	-
J	Internal	1985	485.6	Shallow Till over bedrock	Mine Rock, upstream Esker Sand and Gravel, Tailings	1.5-2H:1V	Approx. 1.4H:1V
K	Internal	1990	491	Bedrock/Competent foundation	Esker Sand and Gravel, downstream Riprap	3H:1V	1.5-2H:1V
L	Internal	1992	490.8	-	Esker Sand and Gravel, upstream and downstream Riprap	1.5H:1V	1.5H:1V
M	Internal	1992	488.8	Tailings over bedrock	Esker Sand and Gravel, downstream Riprap	1H:1.1V	1H:0.6V
N	Internal	1997	483.9	-	Esker Sand and Gravel, downstream Riprap	-	-

Notes:

1. Information sourced from SRK (2016) and Stantec (2021).
2. Crest Elevations for Dams 1A, 1B, 1C, 2, 4, 5, 6, J, K have been reported from SRK (2016).
3. Crest Elevations for Dams 3, 3C, 3D, 3E, L, M, N have been reported from Holubec (2005).

Table 2: Operational History of Lupin Mine Site

Year	Ownership	Operation Status	TCA Construction	Tailings Cover Activities	Annual Tailings Deposition (m^3)
1980	Echo Bay Mines Ltd.	Initial construction			
1981			Dam 1A and 2		
1982		Operations start, tailings dishcarged in north end of TCA. Tailings and water mixed in the TCA basin.	Dam 3		202,000
1983					354,000
1984			Raise Dam 1A and 2		257,000
1985		Tailings deposited in cells Tailings cells and water ponds separated by internal dams	Dam 3C and J		254,000
1986					263,000
1987					276,000
1988				Partial cover on Cell 1 with Gravelly Sand Tailings	277,000
1989					281,000
1990			Dam K and Cell 4		282,000
1991					296,000
1992			Dam 4, 5, 6, L, M		309,000
1993					341,000
1994				Partial cover on Cell 1 with Waste Rock	332,000
1995				Complete cover on Cell 1 Partial cover on Cell 2	156,000
1996					201,000
1997			Dam N		216,000
1998		Site in care and maintenance.			9,000
1999					4,000
2000		Tailings deposited in cells Tailings cells and water ponds separated by internal dams	Dam M raised		173,000
2001					212,000
2002	Kinross Gold Corp.				209,000
2003		Site in care and maintenance.		Partial cover on Cell 3	13,000
2004				Complete cover on Cell 2 Partial cover on Cell 3	68,000
2005		Production ceased. Site in care and maintenance.	Dam N and adjacent small cell	Partial cover on Cells 3 and 5	
2006	Lupin Mines Inc. Parent ownership during this time: 2006: Wolfden Resources 2006 - 2008: Zinifex Ltd. 2008: Oz Minerals Ltd. 2009 - 2011: MMG Resources Inc. 2011 - 2014: Elgin Mining Inc. 2014 - present: Mandalay Resources Corp.			Ongoing cover construction	
2007					
2008					
2009					
2010					
2011					
2012					
2013					
2014					
2015					
2016					
2017					
2018					
2019		Active closure			
2020					
2021			K Dam regraded Cell 3 outflow structure Cell 5 outflow structure		
2022					
2023					
Total					5,120,000

Notes:
1. Information sourced from SRK (2016) and Holubec (2005).
2. Tailings deposition volumes based on Table 2-3, Holubec (2005).
3. Echo Bay Mines Ltd., TVX Gold, and Kinross Gold Corp. merged in 2002. Kinross assumed control of operations.
4. Active closure assumed to have begun in 2018 with development of the Final Closure and Reclamation Plan (LMI, 2020)

Table 3: TCA Design Criteria

Table 3A: Geotechnical Design Criteria

Criterion	Value	Source
Factors of Safety		
During or at end of construction	> 1.3	CDA (2014)
Long term (steady state seepage, normal WL)	1.5	
Pseudo-Static	1.1	
Design Earthquake Loadings		
Seismic event return interval	1 in 2,500 years	Stantec (2019)
Seismic load	PGA = 0.05g	

Notes

1. Earthquake event is in accordance with dam classification of 'Significant'
2. Peak ground acceleration (PGA) is suitable for the site seismic hazard per National Building Code Seismic Hazard Tool
3. End of construction criteria has been used to assess shallow (surficial) slope failures. This may be justified in the current site status where the dams are maintained. The long term FoS is recommended for passive closure phase.

Table 3B: Flood Design Criteria

Dam Classification	Annual Exceedance Probability (AEP) - Floods	Source
Low	1/100	CDA (2013)
Significant	Between 1/100 and 1/1,000	

Notes

[1] Selected on basis of incremental flood analysis, exposure, and consequences of failure.

Table 3C: Recommended Design Precipitation Depths

Flood Event	Precipitation Depth [1] (mm)	Source
24-hr rainfall with 1/100 AEP	56	SRK 2016
24-hr rainfall with 1/1,000 AEP	66	SRK 2016
24-hr rainfall with AEP between 1/100 and 1,000	61	n/a [2]
24-hr Probable Maximum Precipitation (PMP)	260	SLR 2024
Freshet	136	Golder 2004

Notes

[1] Values do not consider the effects of climate change.

[2] Not applicable.

Table 4: Dam Stability Analyses

Name	Location	Loading conditions	Permafrost depth (m)	Regraded slope	*Holubec (2005)* Factor of Safety			*Stantec (2019)* Factor of Safety		
					Min.	Local	Global	Min.	Local	Global
1A	Perimeter	Static, local failure	2	-	-	-	-	1.3	2.6	-
		Static, global failure	2	-	-	-	-	1.5	-	3.6
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	3.5
1B	Perimeter	-	-	-	-	-	-	-	-	-
1C	Perimeter	-	-	-	-	-	-	-	-	-
2	Perimeter	Static, local failure	2	-	-	-	-	1.3	1.3	-
		Static, global failure	2	-	-	-	-	1.5	-	2.6
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	2.3
3	Perimeter	Static, local failure	2	-	-	-	-	1.3	4.0	-
		Static, global failure	2	-	-	-	-	1.5	-	8.3
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	6.2
4	Perimeter	Static, local failure	2	-	-	-	-	1.3	2.9	-
		Static, global failure	2	-	-	-	-	1.5	-	3.3
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	2.9
		Static, local failure	14	-	-	-	-	1.3	2.9	-
		Static, global failure	14	-	-	-	-	1.5	-	5.8
		Pseudo-static, global failure	14	-	-	-	-	1.1	-	4.7
5	Perimeter	-	-	-	-	-	-		-	-
6	Perimeter	Static, local failure	2	-	-	-	-	1.3	1.3	-
		Static, global failure	2	-	-	-	-	1.5	-	2.4
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	2.4
3C	Internal	-	-	-	-	-	-	-	-	-
3D	Internal	Static, local failure	0	-	1.3	1.4	-	-	-	-
		Static, global failure	0	-	1.5	-	6.8	-	-	-
		Static, global failure	thawed	-	1.5	-	1.5	-	-	-
		Static, global failure (regraded)	thawed	2.5H:1V	1.5	-	2.0	-	-	-
		Static, local failure	2	-	-	-	-	1.3	1.3	-
		Static, global failure	2	-	-	-	-	1.5	-	3.7
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	3.3
		Static, local failure	14	-	-	-	-	1.3	1.3	-
		Static, global failure	14	-	-	-	-	1.5	-	3.6
		Pseudo-static, global failure	14	-	-	-	-	1.1	-	3.2
3E	Internal	-	-	-	-	-	-	-	-	-
J	Internal	-	-	-	-	-	-	-	-	-
K	Internal	Static, global failure	0	-	1.5	-	8.9	-	-	-
		Static, global failure	thawed	-	1.5	-	1.2	-	-	-
		Static, global failure	thawed	-	1.5	-	1.0	-	-	-
		Static, global failure (regraded)	thawed	2.5H:1V	1.5	-	2.1	-	-	-
		Static, local failure	2	-	-	-	-	1.3	0.8	-
		Static, local failure (regraded)	2	2.1H:1V	-	-	-	1.3	1.3	-
		Static, global failure	2	-	-	-	-	1.5	-	1.8
		Static, global failure (regraded)	2	2.1H:1V	-	-	-	1.5	-	1.8
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	1.5
		Pseudo-static, global failure (regraded)	2	2.1H:1V	-	-	-	1.1	-	1.6
L	Internal	Static, local failure	2	-	-	-	-	1.3	1.6	-
		Static, global failure	2	-	-	-	-	1.5	-	2.1
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	1.9
M	Internal	Static, global failure	0	-	1.5	-	8.1		-	-
		Static, global failure	thawed	-	1.5	-	1.3		-	-
		Static, global failure (regraded)	thawed	2.5H:1V	1.5	-	1.9		-	-
		Static, local failure	2	-	-	-	-	1.3	1.0	-
		Static, local failure (regraded)	2	2.1H:1V	-	-	-	1.3	1.3	-
		Static, global failure	2	-	-	-	-	1.5	-	3.0
		Static, global failure (regraded)	2	2.1H:1V	-	-	-	1.5	-	3.1
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	2.6
		Pseudo-static, global failure (regraded)	2	2.1H:1V	-	-	-	1.1	-	2.7
N	Internal	Static, local failure	2	-	-	-	-	1.3	1.6	-
		Static, global failure	2	-	-	-	-	1.5	-	2.6
		Pseudo-static, global failure	2	-	-	-	-	1.1	-	2.5

Notes:

1. Analyses with permafrost assumed frozen conditions at ground surface in Holubec (2005) and 2 m below ground surface by Stantec (2019)
2. Analyses with thawed conditions assumed fully thawed in Holubec (2005) and using the worst-case modelled scenario (i.e. ~14 m depth) by Stantec (2019)
3. Dams 3C and 3E have tailings on each side level with the crest of the dam. Therefore there is no slope to analyze.
4. Dam 1B, 1C, and 5 are small structures that currently do not retain any tailings or water.

Table 5: Peak Flow Estimates

Facility	Drainage Area (ha) [1]	Peak Instantaneous Flow (m^3/s) [2]		
		1/100 AEP	1/1,000 AEP	1/10,000 AEP
Cell 5	58.5	0.135	0.166	0.194
Cell 2	82.81	0.191	0.235	0.274
Cell 1	130.01	0.3	0.369	0.431
Cell 3	58.94	0.136	0.167	0.195
Cell 4	116.74	0.27	0.332	0.387
Pond 1	354.53	0.819	1.007	1.175
Pond 2	600.13	1.386	1.705	1.989

[1] Values for Cells 3, 4 and 5 and Ponds 1 and 2 were sourced from SRK 2016.

[2] Values do not account for the effects of climate change.

Table 6A: Hazard Potential Classification

DAM CLASS	POPULATION AT RISK	INCREMENTAL LOSSES		
		LOSS OF LIFE	ENVIRONMENTAL AND CULTURAL VALUES	INFRASTRUCTURE AND ECONOMICS
Low	None	0	Minimal short-term No long term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary Only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	Significant loss or deterioration of *important* fish or wildlife habitat Restoration or compensation in kind is highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities
Very High	Permanent	100 or fewer	Significant loss or deterioration of *critical* fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities, for dangerous substances)
Extreme	Permanent	More than 100	Major loss of *critical* fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services, (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

Notes:
1. See Table 2-1 in the CDA 2007 Guidelines for notes related to population at risk and implications of loss of life
2. Source: CDA Guidelines, 2014 Technical Bulletin, Application of CDA Dam Safety Guidelines to Mining Dams, Table 3.1.

Table 6B: TCA Dam Classification

Dam	Retains	Classification
Dam 1A	Water	Significant
Dam 1B	Water	Significant
Dam 1C	Water	Significant
Dam 2	Water	Significant
Dam 3	Tailings	Low
Dam 4	Water	Significant
Dam 5	Water	Low
Dam 6	Tailings	Low
Dam 3D	Tailings	Low
J Dam	Water	Low
K Dam	Tailings	Low
L Dam	Tailings	Low
M Dam	Tailings	Low
N Dam	Tailings	Low
Divider Dyke	Water	Low

Notes:
1. The dam classification is based on the current status of site with full containment provided by perimeter dams
2. The classification should be reassessed for passive closure when the perimeter dams will be breached

Table 7: List of Instrumentation

Location	Dam	Thermistor ID	Thermistor Status (Note 2)	VWC Sensors ID	VWC Sensors Status (Note 2)
Dam 1A	Perimeter	D1A-00-1S	Active	-	-
		D1A-00-1N	Inactive/damaged	-	-
Dam 1B	Perimeter	-	-	-	-
Dam 1C	Perimeter	-	-	-	-
Dam 2	Perimeter	D2-00-2n	Active	-	-
		D2-00-3	Inactive/damaged	-	-
Dam 3	Perimeter	-	-	-	-
Dam 4	Perimeter	D4-1	Active	-	-
		D4-2	Inactive/damaged	-	-
		D4-3	Active	-	-
		D4-4	Active	-	-
Dam 5	Perimeter	-	-	-	-
Dam 6	Perimeter	-	-	-	-
Dam 3C	Internal	-	-	-	-
Dam 3D	Internal	D3D-1	Active	-	-
Dam 3E	Internal	-	-	-	-
J Dam	Internal	-	-	-	-
K Dam	Internal	DK-3	Active	-	-
L Dam	Internal	-	-	-	-
M Dam	Internal	-	-	-	-
N Dam	Internal	-	-	-	-
Cell 1	-	TC1-1	No caibration data	C1-1VWC	Active
		TC1-2	No caibration data		
		TC1-3	Active		
		TC1-4	Inactive/damaged		
		TC1-5	No caibration data		
		TC1-6	Active		
		TC1-7	Active		
Cell 2	-	TC2-1	Inactive/damaged	-	-
Cell 3	-	TC3-1	Active	C3-1VWC	Active
Cell 4	-	-	-	-	-
Cell 5	-	-	-	-	-

Notes:

1. Information sourced from SRK (2016) and Stantec (2021).
2. Instrument status is based on 2021 Annual Geotechnical Inspection report

Figures

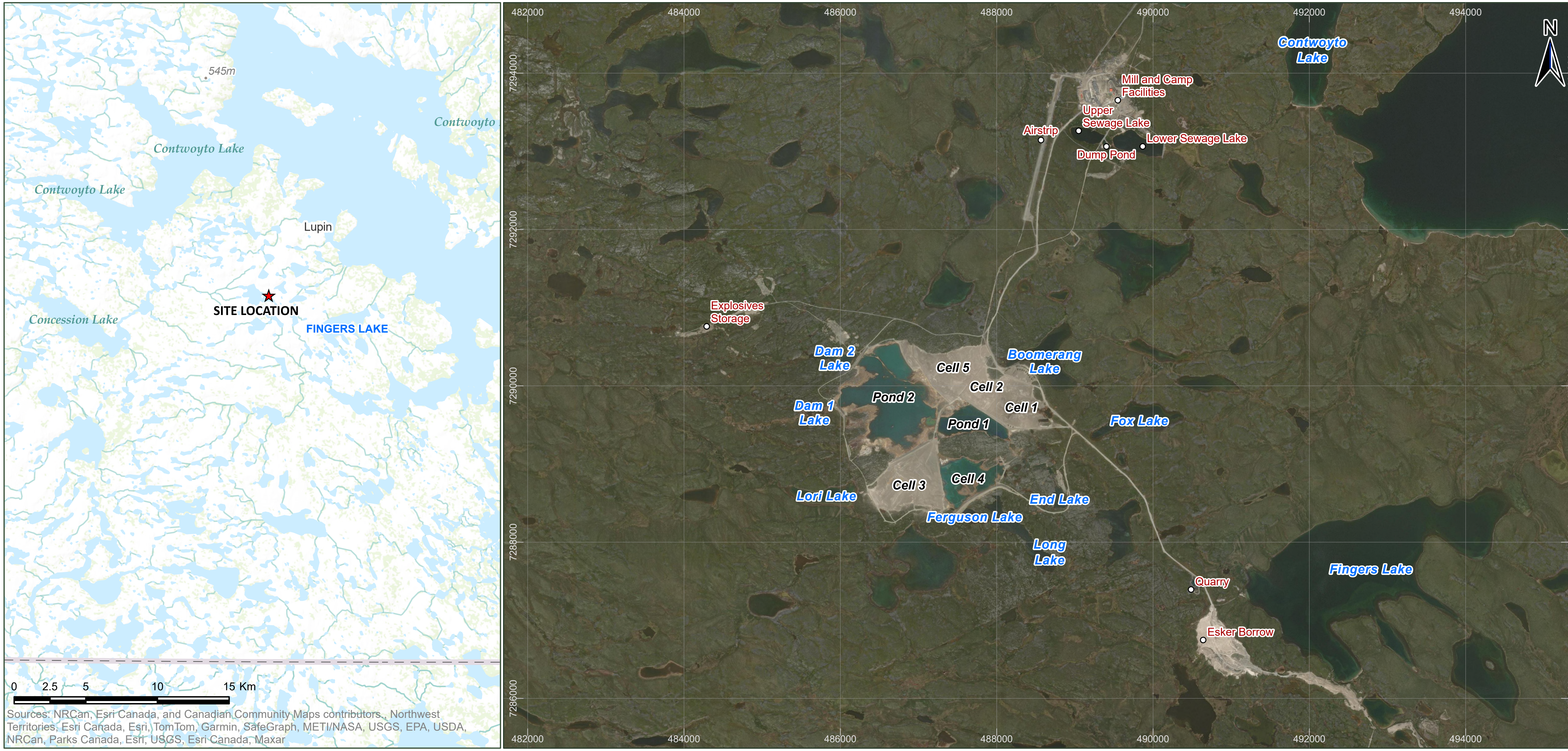
2023 Dam Safety Review

Lupin Mine Tailings Containment Area (TCA)

Lupin Mines Inc.

SLR Project No.: 209.065024.00001

April 26, 2024



NOTES:
SATELLITE IMAGERY MAXAR 2024-07-27

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SCALE 1:50,000
PAGE SIZE 11 x 17
NAD 1983 UTM Zone 12N
THIS MAP IS FOR CONCEPTUAL PURPOSES ONLY AND SHOULD NOT BE USED FOR NAVIGATION

LUPIN MINES INC.
LUPIN MINE
CONTWOYTO LAKE, NUNAVUT

2023 DAM SAFETY REVIEW

SITE PLAN

SLR

FIGURE NO:
1

DATE: March 18, 2024
PROJECT NO: 209.40298.00001

Last Saved: March 18, 2024 1:31 PM by tcohen

GIS PATH: G:_Projects\209_065024_Lupin_Mine\1_Maps\RPT\RPT_20240312\RPT20240312_LupinMine\RPT20240312_LupinMine.aprx || Site Plan

NOTES:
SATELLITE IMAGERY MAXAR 2023-07-27

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NAD 1983 UTM Zone 12N

THIS MAP IS FOR CONCEPTUAL PURPOSES ONLY
AND SHOULD NOT BE USED FOR NAVIGATION

LUPIN MINES INC.
LUPIN MINE
CONTWOYTO LAKE, NUNAVUT

2023 DAM SAFETY REVIEW

TCA GENERAL ARRANGEMENT

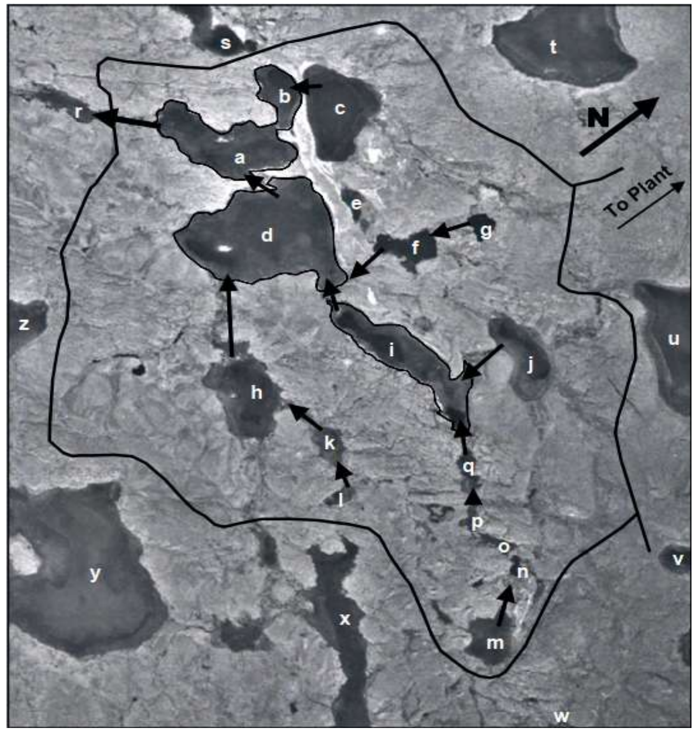
SLR

FIGURE NO:
2

DATE: March 18, 2024
PROJECT NO: 209.065024.00001

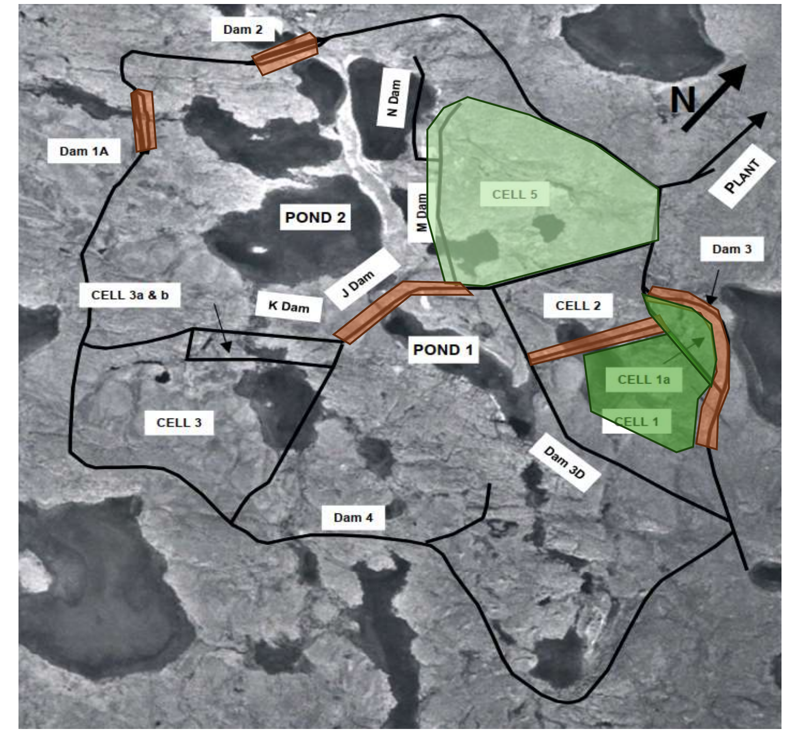
Last Saved: March 18, 2024 1:31 PM by tcohen

GIS PATH: G:_Projects\209_065024_Lupin_Mine\1_Maps\RPT\RPT_20240312\RPT20240312_LupinMine.aprx || TCA General Arrangement

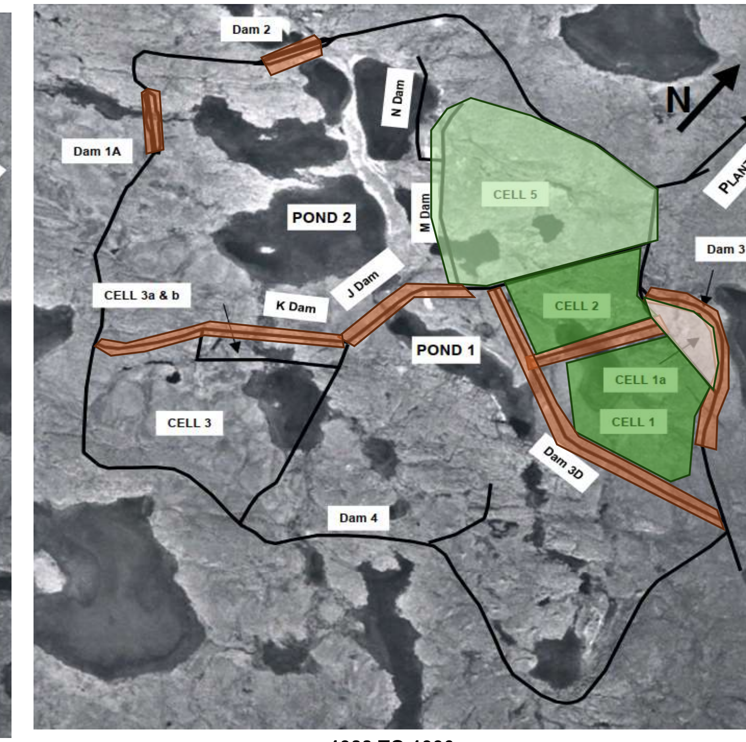


PRE-DEVELOPMENT LAKES AND DRAINAGE

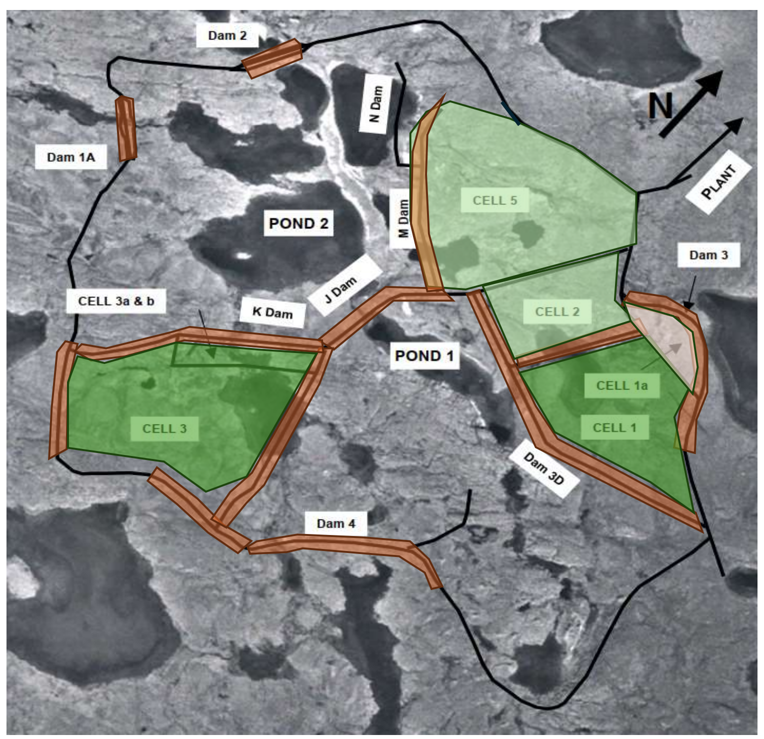
1981 TO 1984



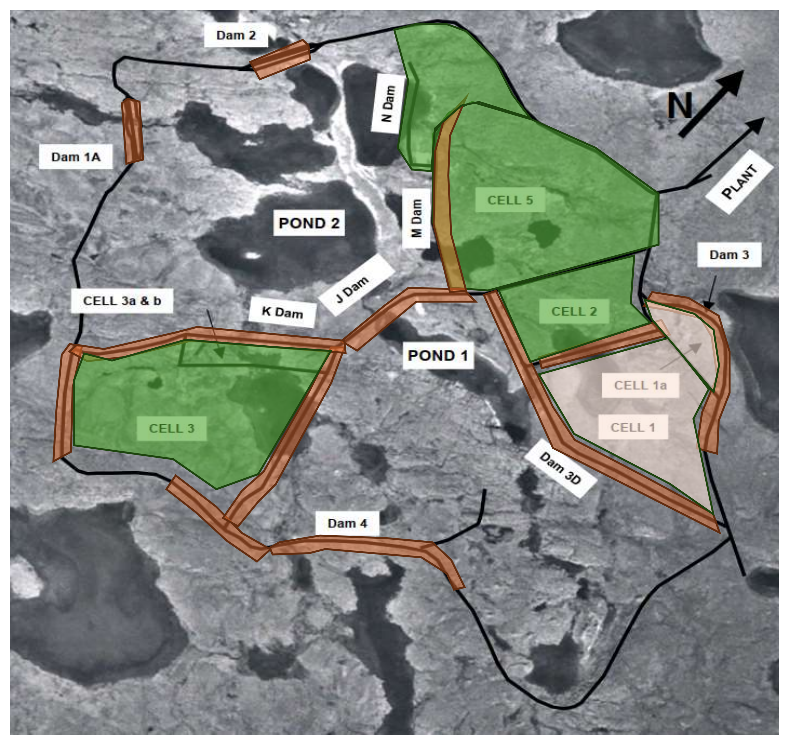
1985 TO 1987



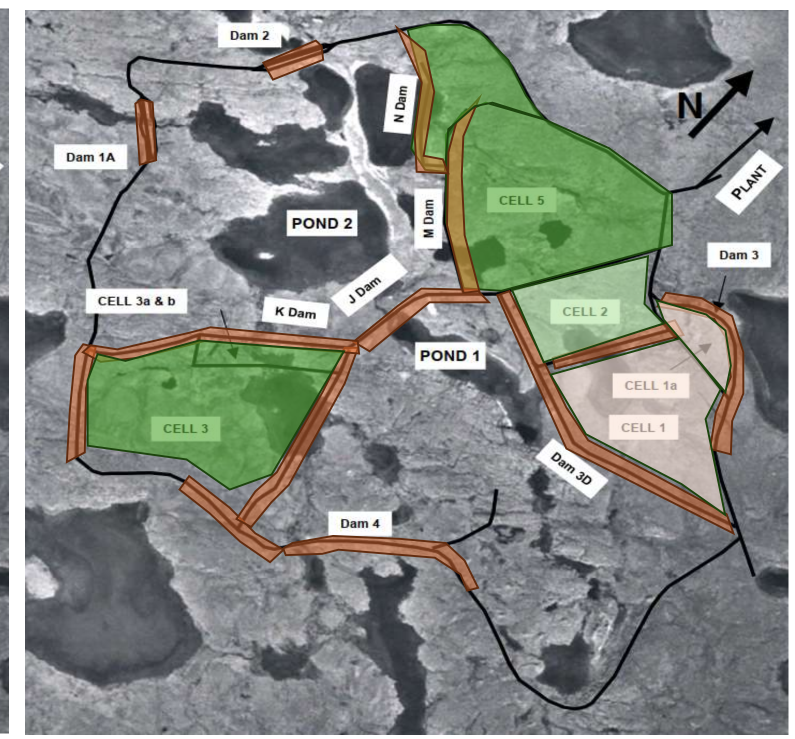
1988 TO 1990



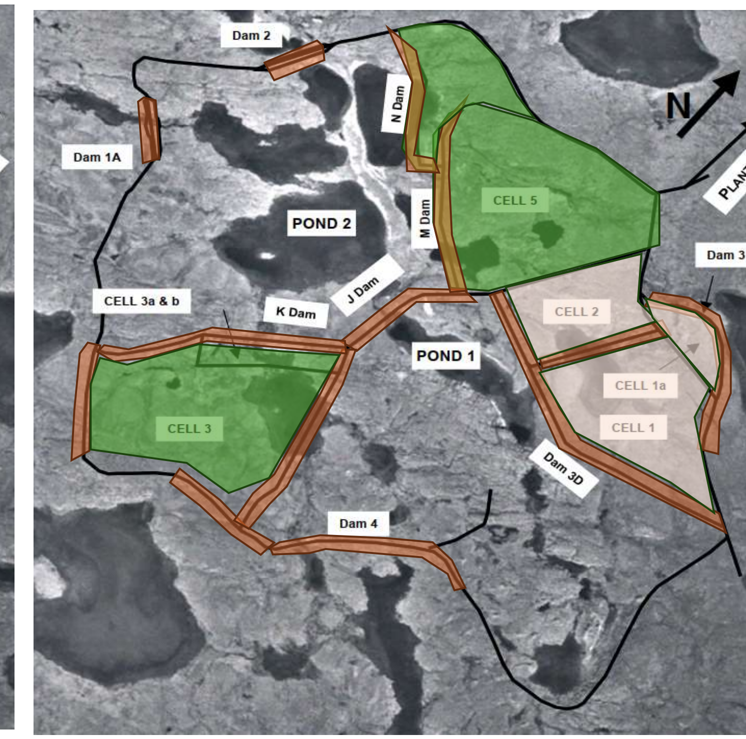
1991 TO 1992



1993 TO 1996



1997 TO 2002



2003 TO 2004

LEGEND

- DAM
- ACTIVE TAILINGS DEPOSITION
- INACTIVE TAILINGS CELL
- COVERED TAILINGS CELL

NOTE: DAMS AND TAILINGS AREAS ARE APPROXIMATE BASED ON HISTORICAL RECORDS AND RECENT SITE OBSERVATION. FIGURE IS INTENDED FOR ILLUSTRATATIVE PURPOSES

REFERENCES:

1. AERIAL PHOTOGRAPHS EXTRACTED FROM TCA CLOSURE PLAN (HOLUBEC, 2005)

CLIENT LOGO

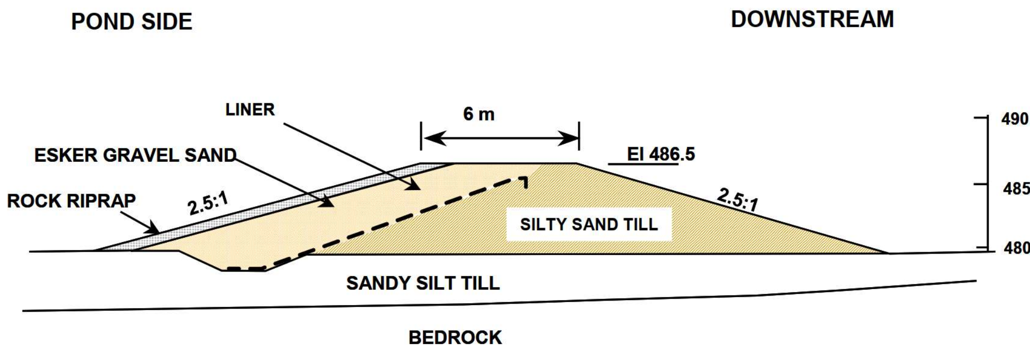
CLIENT

LUPIN MINES INC.

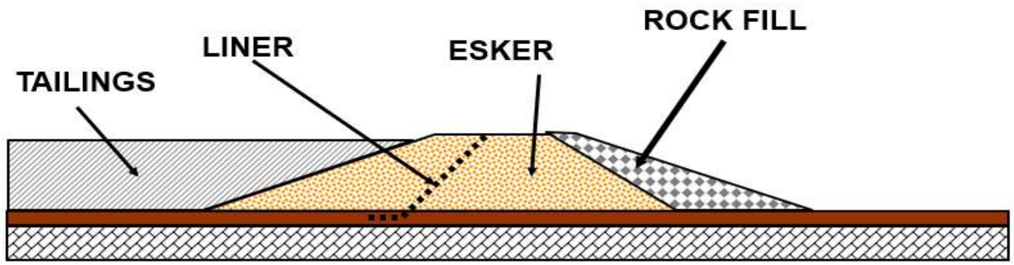
SLR Consulting
55 University Ave., Suite 501
Toronto, ON, Canada

SLR

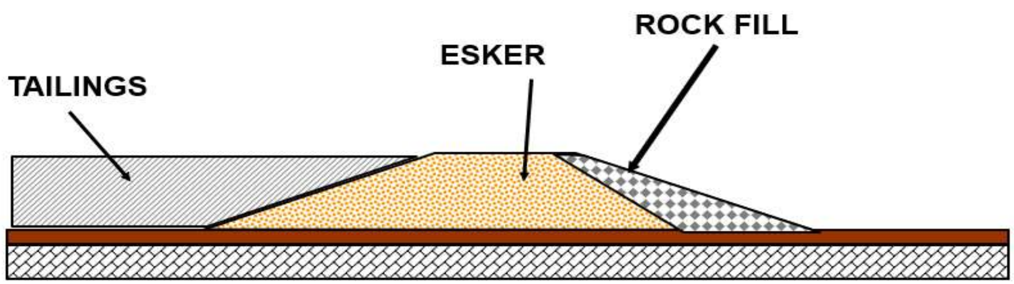
DWN BY: ES	PROJECT: LUPIN MINE TCA 2023 DAM SAFETY REVIEW	DATE: MAR. 2024	
CHK'D BY: JT		PROJECT NO: 209.065024	
DATUM: N/A	TITLE: TAILINGS CONTAINMENT AREA DEVELOPMENT OF TCA DURING OPERATIONS	REV. NO.: A	
PROJECTION: N/A		FIGURE NO: 3	
SCALE: AS SHOWN			



Perimeter Dams (1, 2, 3, 4, 5, 6)



Internal Dams K and J Dams



Internal Dams 3D, M, & N Dams

NOTES:

1. This figure is intended to show the general concepts that are common to the TCA dams. Many of the dams have unique as-built or field fit features that are not shown here.
2. The tailings upstream of the internal dams have been covered with 1 m of esker gravelly sand which is not shown.
3. The foundation conditions vary between the dams. Some dams are on native soil or bedrock, while others (M and N Dams) are founded on deposted tailings.

SLR CONSULTING

CLIENT: LUPIN MINES INC.

PROJECT: 2023 DAM SAFETY REVIEW

TITLE: TAILINGS CONTAINMENT AREA TYPICAL DAM CROSS-SECTIONS

DATE	JOB No:	FIGURE:	REVISION
Mar. 2024	209.065024	4	A

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Rock Berm	21	0	36	1	0
Upper Tailings	14	0	30	1	0
Esker	20	0	34	1	0
Rock	21	0	36	1	0
Lower Tailings	15	5	31	1	0
Bedrock	(Infinitely Strong)				

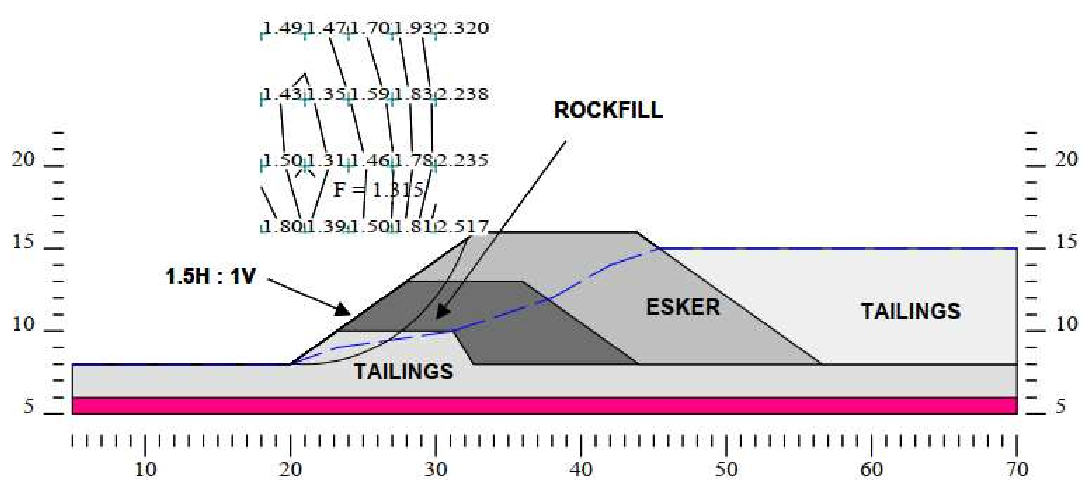


Figure D 10. M Dam, thawed dam

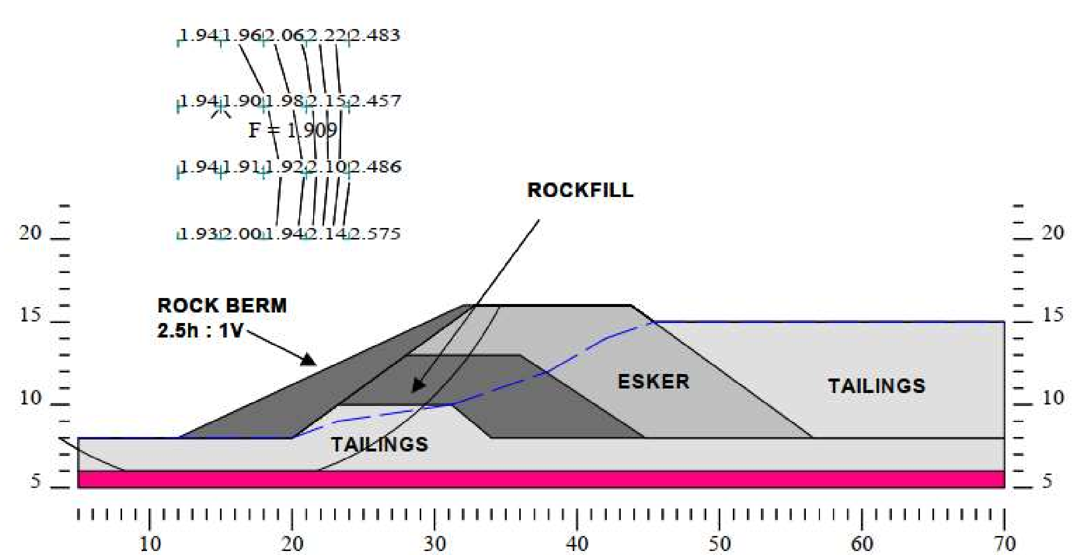
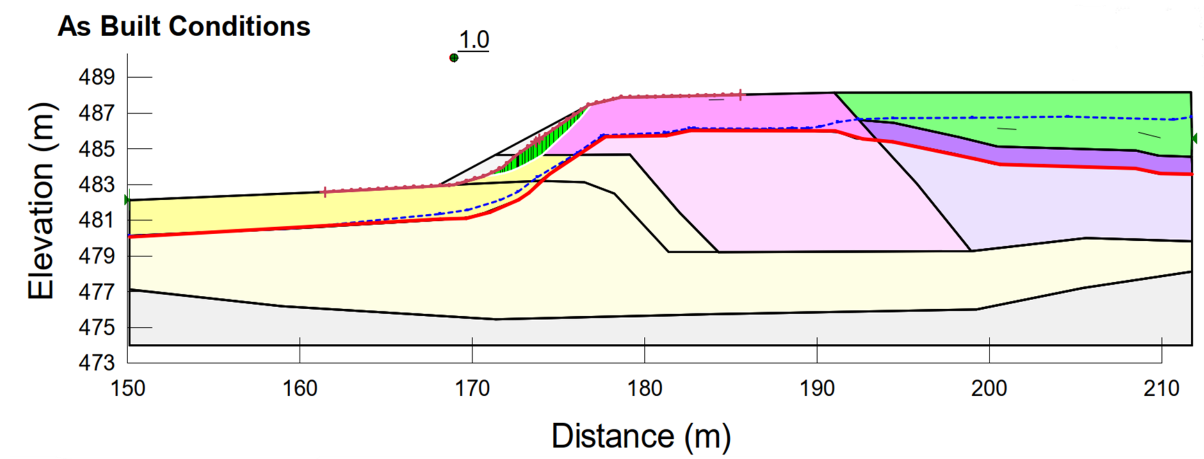
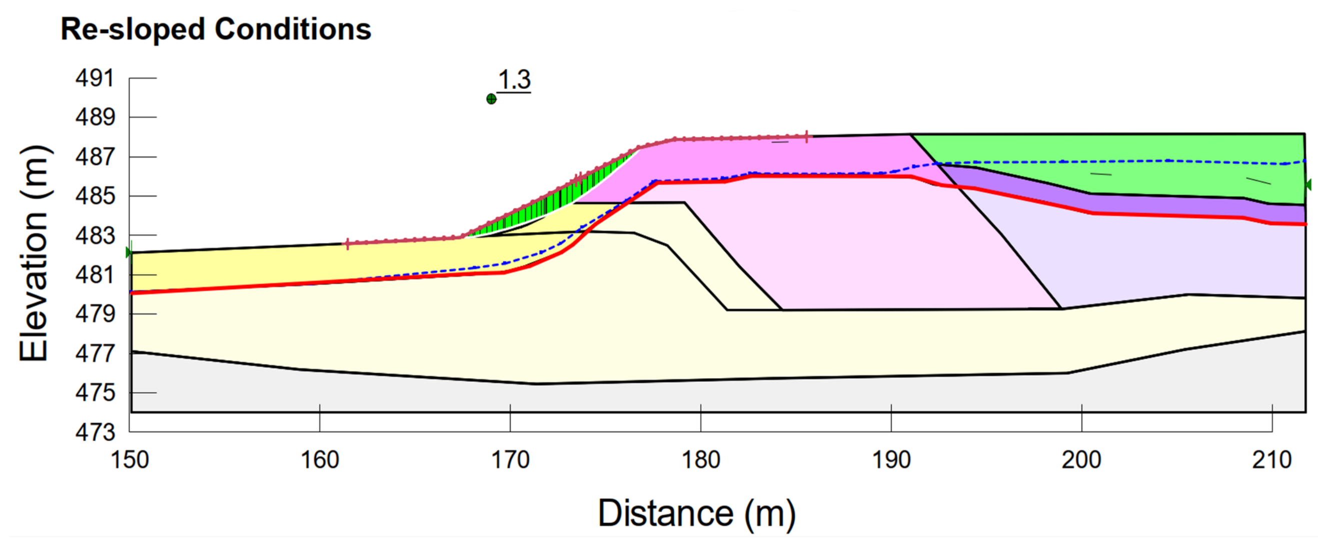


Figure D 11. M Dam, stabilized with 2.5h : 1v rock berm

Material	Unit Weight (kN/m³)	Drained Parameters: Friction Angle (°)	Drained Parameters: Cohesion (kPa)	Undrained Parameters: Minimum Strength (kPa)	Undrained Parameters: Tau/Sigma Ratio
Esker	30	35°	0	N/A	
Gravelly Sand	30	35°	0	N/A	
Rockfill	20	39°	0	N/A	
Tailings (Drained)	18	30°	0	N/A	
Tailings (Undrained)	18	N/A		20	0.24
Till	18	30°	0	N/A	
Bedrock	Impenetrable				
Permafrost	N/A				
Geotechnical Liner	N/A				





NOTES

1. Both stability analyses found the existing slope of M Dam not meeting the minimum requirements. Holubec recommended flattening to 2.5H:1V to get a FS of 1.9 while Stantec recommended a slope of 2.1H:1V to get a FS of 1.3
2. The Holubec analysis (2005) and previous DSR (SRK, 2016) state that M Dam is founded on tailings.

REFERENCES:

1. STABILITY ANALYSES EXTRACTED FROM TAILINGS CONTAINMENT AREA CLOSURE PLAN APPENDIX D(HOLUBEC, 2006) AND 2 AM-LUP TECHNICAL MEETING COMMITMENT NUMBER 6 RESPONSE - GEOTECHNICAL REVIEW ON LONG-TERM STABILITY OF TCA DAMS (STANTEC, 2019)

CLIENT LOGO

CLIENT: LUPIN MINES INC.

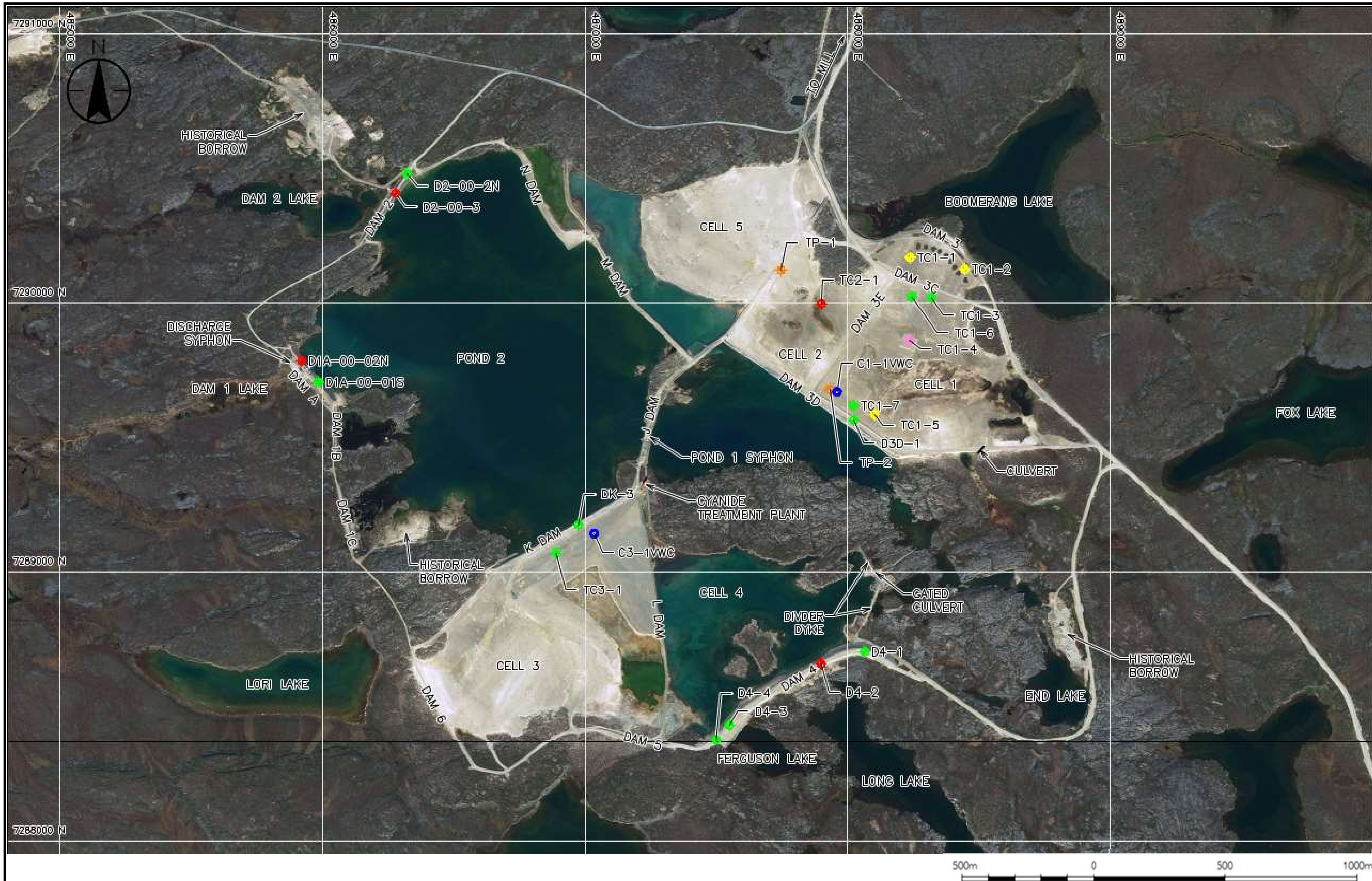
SLR Consulting
55 University Ave., Suite 501
Toronto, ON, Canada

DWN BY: ES
CHK'D BY: JT
DATUM: N/A
PROJECTION: N/A
SCALE: AS SHOWN

PROJECT: LUPIN MINE TCA
2023 DAM SAFETY REVIEW

TITLE: TAILINGS CONTAINMENT AREA
TYPICAL DAM STABILITY ANALYSIS

DATE: MAR. 2024
PROJECT NO: 209.065024
REV. NO.: A
FIGURE NO: 5



LEGEND

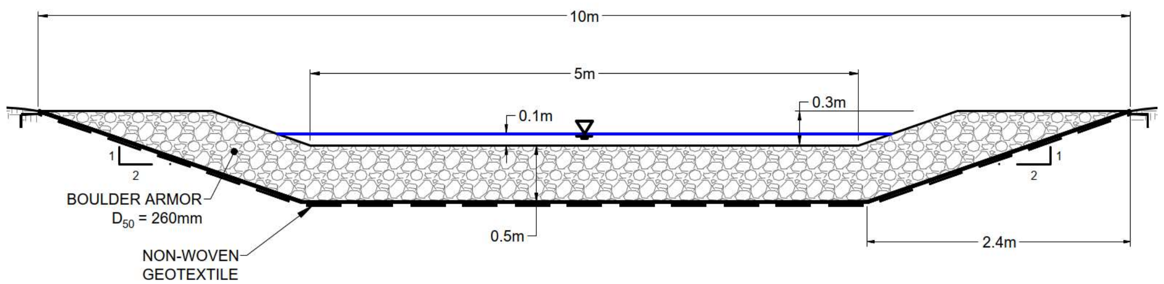
THERMISTORS STATUS

- ACTIVELY MONITORED
- DAMAGED
- MONITORED DURING DSR-NO CALIBRATION DATA
- UNLOCATED-LOCATION ESTIMATED FROM HISTORICAL MAP
- VOLUMETRIC WATER CONTENT SENSOR STRINGS
- TEST PITS

REFERENCES:

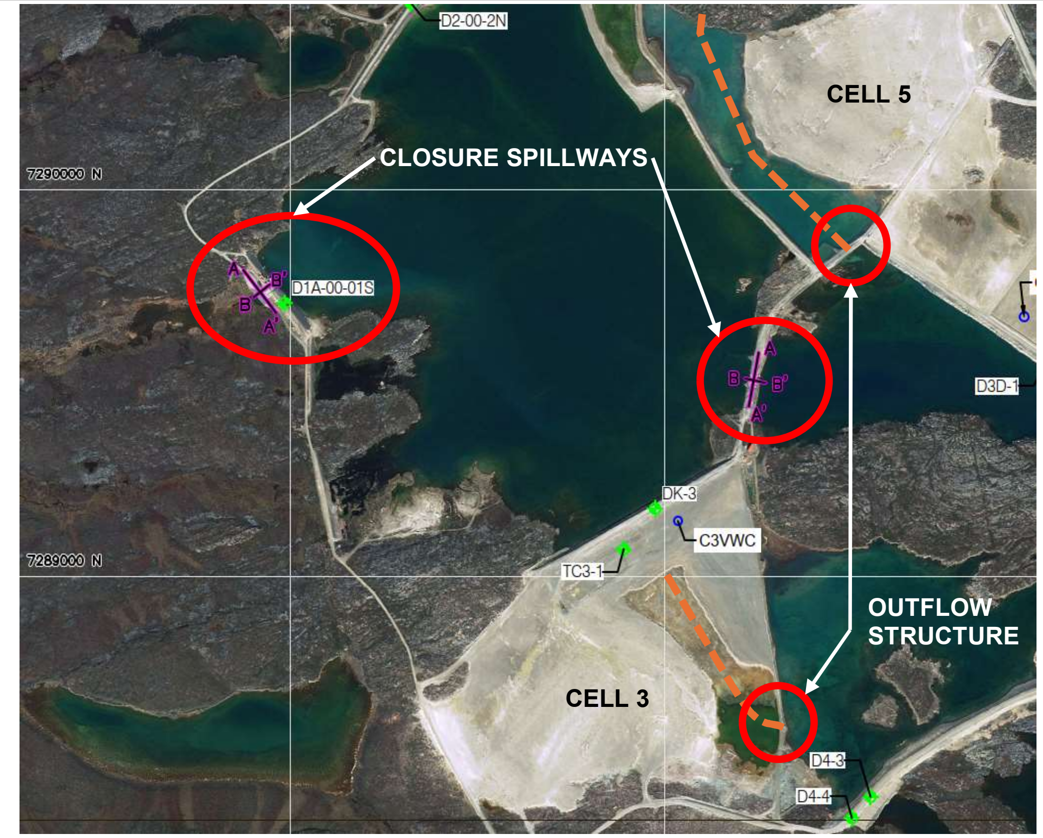
1. FIGURE EXTRACTED FROM 2021 LUPIN MINE TAILINGS AREA INSPECTION REPORT (STANTEC, 2021)

CLIENT LOGO	
CLIENT	LUPIN MINES INC.
SLR Consulting 55 University Ave., Suite 501 Toronto, ON, Canada	SLR
DWN BY:	ES
CHK'D BY:	JT
DATUM:	N/A
PROJECTION:	N/A
SCALE:	AS SHOWN
PROJECT	LUPIN MINE TCA 2023 DAM SAFETY REVIEW
TITLE	TAILINGS CONTAINMENT AREA INSTRUMENTATION LOCATION PLAN
DATE:	MAR. 2024
PROJECT NO:	209.065024
REV. NO.:	A
FIGURE NO:	6

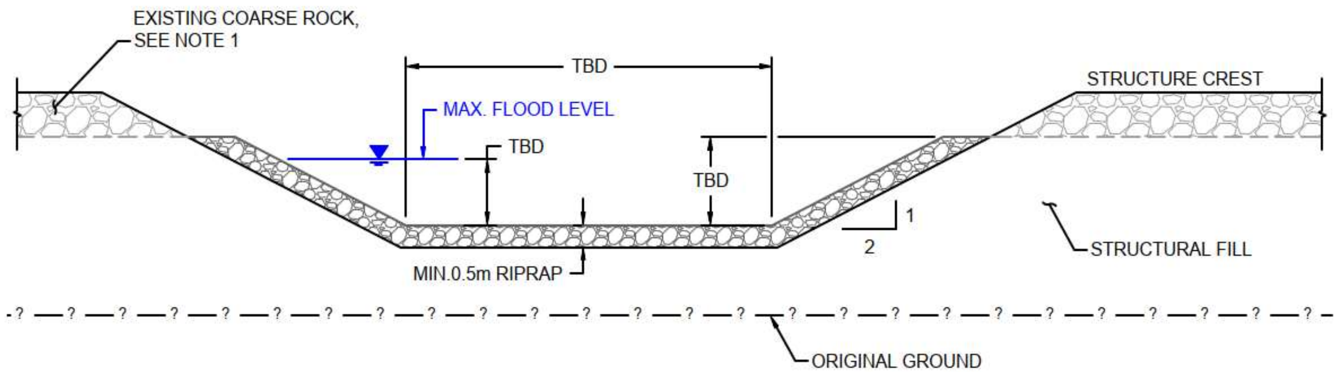


TYPICAL OUTFLOW STRUCTURE DETAIL

N.T.S

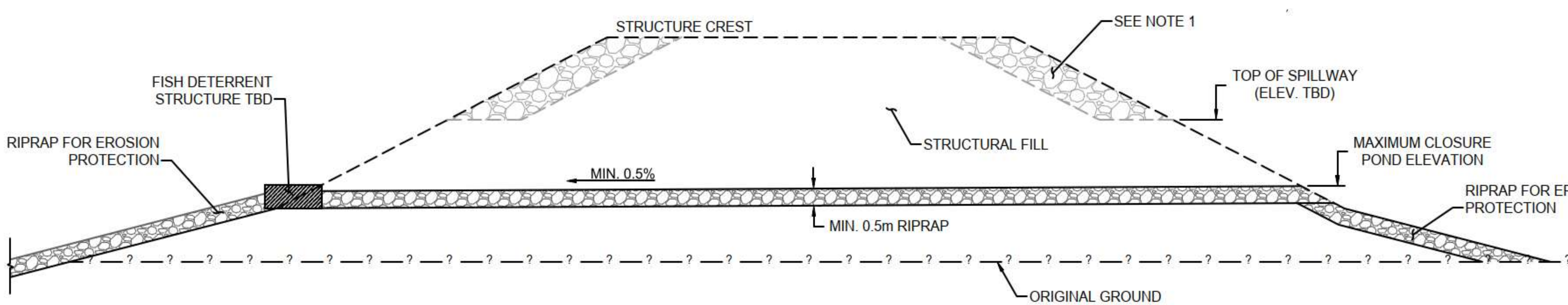


PLAN



SECTION A-A'

SCALE 1:200



5m 0 5 10m

SCALE 1:200

SECTION B-B'

SCALE 1:200

REFERENCES:

1. OUTFLOW STUCTURE DETAIL EXTRACTED FROM 2 AM-LUP TECHNICAL MEETING COMMITMENT NUMBER 6 RESPONSE - GEOTECHNICAL REVIEW ON LONG-TERM STABILITY OF TCA DAMS (STANTEC, 2019).
2. CLOSURE SPILLWAY SECTIONS EXTRACTED FROM FINAL CLOSURE AND RECLAMATION PLAN, REV1 (LMI, 2020)

CLIENT LOGO	
CLIENT	LUPIN MINES INC.
SLR Consulting 55 University Ave., Suite 501 Toronto, ON, Canada	SLR
DWN BY:	ES
CHK'D BY:	JT
DATUM:	N/A
PROJECTION:	N/A
SCALE:	AS SHOWN
PROJECT	LUPIN MINE TCA 2023 DAM SAFETY REVIEW
TITLE	TAILINGS CONTAINMENT AREA OUTFLOW STRUCTURE AND CLOSURE SPILLWAY SECTIONS AND DETAILS
DATE:	MAR. 2024
PROJECT NO:	209.065024
REV. NO.:	A
FIGURE NO:	7

Appendix A Site Visit Photographs

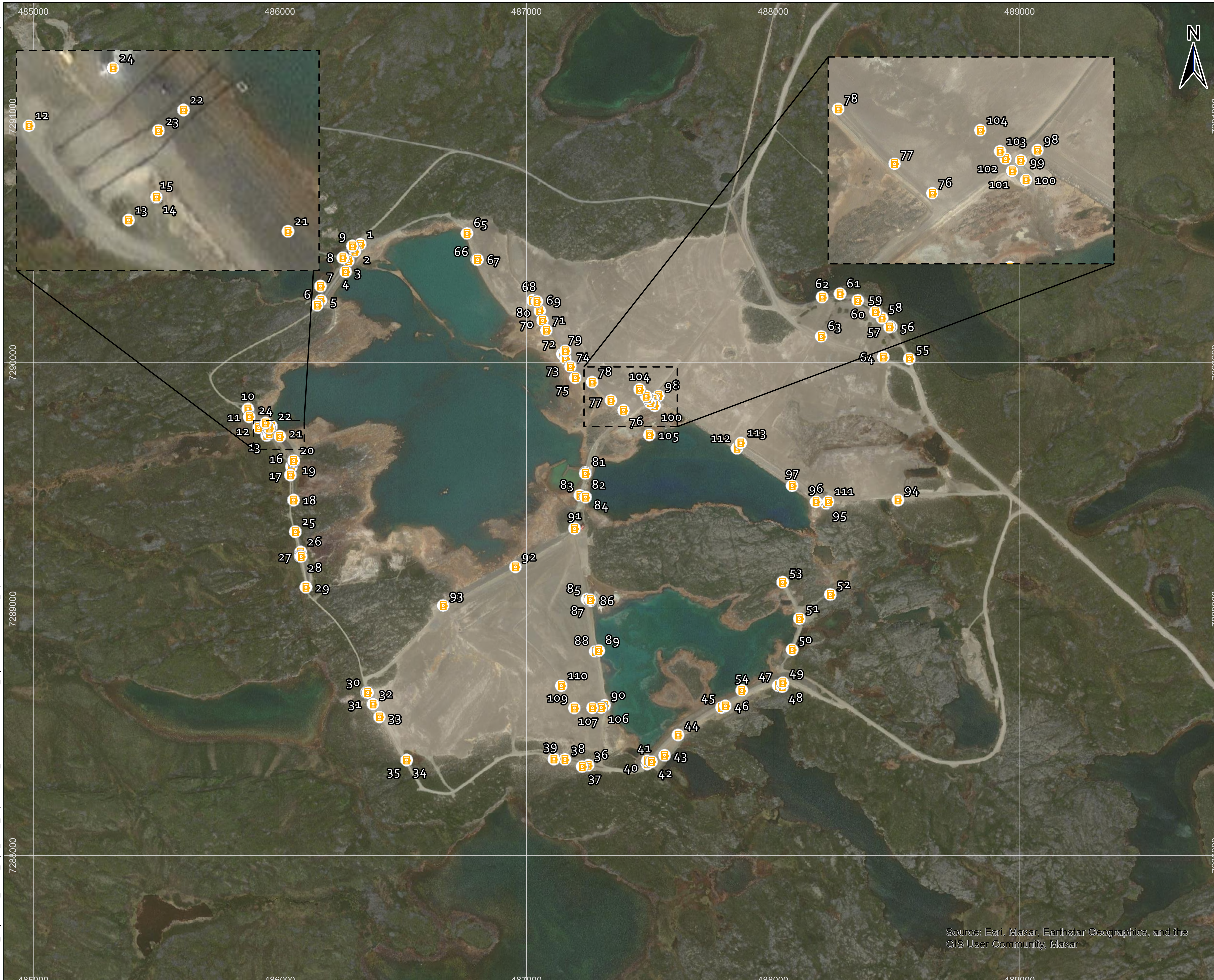
2023 Dam Safety Review

Lupin Mine Tailings Containment Area (TCA)

Lupin Mines Inc.

SLR Project No.: 209.065024.00001

April 26, 2024



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NOTES:
SATELLITE IMAGERY MAXAR 2023-07-27

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SCALE 1:15,000
PAGE SIZE 11 x 17
NAD 1983 UTM Zone 12N
THIS MAP IS FOR CONCEPTUAL PURPOSES ONLY AND SHOULD NOT BE USED FOR NAVIGATION

LUPIN MINES INC.
LUPIN MINE
CONTWOYTO LAKE, NUNAVUT

2023 DAM SAFETY REVIEW

SITE INSPECTION PHOTO MAP

SLR

FIGURE NO:
A1

DATE: March 15, 2024
PROJECT NO: 209.065024.00001

Site Visit Photographs

Photo 1: Dam 1A upstream slope and syphon inlets, facing northwest (Fig. A1 ID#21)

Photo 2: Dam 1A downstream slope, syphon pipes (Fig. A1 ID#11)

Photo 3: Dam 1A downstream slope erosion from runoff (Fig. A1 ID#13)

Photo 4: Dam 1B crest and upstream area, facing north (Fig. A1 ID#18)

Photo 5: Dam 1C animal burrow in crest, downstream shoulder (Fig. A1 ID#27)

Photo 6: Dam 1A syphon pipes in Pond 2 (Fig. A1 ID#22)

Photo 7: Dam 1A water treatment equipment on crest (Fig. A1 ID#24)

Photo 8: Dam 1B and upstream area, facing south (Fig. A1 ID#19)

Photo 9: Dam 1C erosion rill on upstream crest and slope (Fig. A1 ID#26)

Photo 10: Dam 1C crest and downstream slope, facing north (Fig. A1 ID#29)

Photo 11: Dam 2 crest in good condition (Fig. A1 ID#5)

Photo 12: Dam 2 upstream slope riprap (Fig. A1 ID#4)

Photo 13: Dam 2 downstream slope and north seepage collection pond (Fig. A1 ID#1)

Photo 14: Dam 2 erosion rill on downstream slope (Fig. A1 ID#2)

Photo 15: Dam 2 south seepage collection pond, now dry (Fig. A1 ID#6)

Photo 16: Dam 2 downstream slope sloughing (Fig. A1 ID#9)

Photo 17: Dam 3 crest facing north from left abutment (Fig. A1 ID#55)

Photo 18: Dam 3 drainage channel upstream of dam, facing northwest (Fig. A1 ID#57)

Photo 19: Dam 3 drainage channel in downstream slope, facing northeast (Fig. A1 ID#59)

Photo 20: Dam 3 drainage channel in downstream slope, facing north (Fig. A1 ID#60)

Photo 21: Dam 3 erosion rill in downstream slope, facing northeast (Fig. A1 ID#58)

Photo 22: Dam 3 longitudinal cracks near downstream toe, facing west (Fig. A1 ID#61)

Photo 23: Dam 3 downstream slope and Boomerang Lake, facing west (Fig. A1 ID#62)

Photo 24: Dam 3C crest facing southeast (Fig. A1 ID#63)

Photo 25: Dam 4 upstream slope, facing northeast (Fig. A1 ID#41)

Photo 26: Dam 4 downstream slope, facing northeast (Fig. A1 ID#42)

Photo 27: Dam 4 downstream slope erosion rills and sediment fans at toe (Fig. A1 ID#47)

Photo 28: Dam 4 erosion rill in crest and downstream slope, facing east (Fig. A1 ID#49)

Photo 29: Dam 4 downstream slope facing southeast towards Long Lake (Fig. A1 ID#45)

Photo 30: Dam 5 downstream slope facing east (Fig. A1 ID#39)

Photo 31: Dam 5 drainage feature upstream of dam (Fig. A1 ID#38)

Photo 32: Dam 6 ponded water upstream of dam, edge of tailings cover, facing north (Fig. A1 ID#34)


Photo 33: Dam 6 erosion rill in downstream slope, potential windblown tailings outside of TCA, facing southeast (Fig. A1 ID#32)

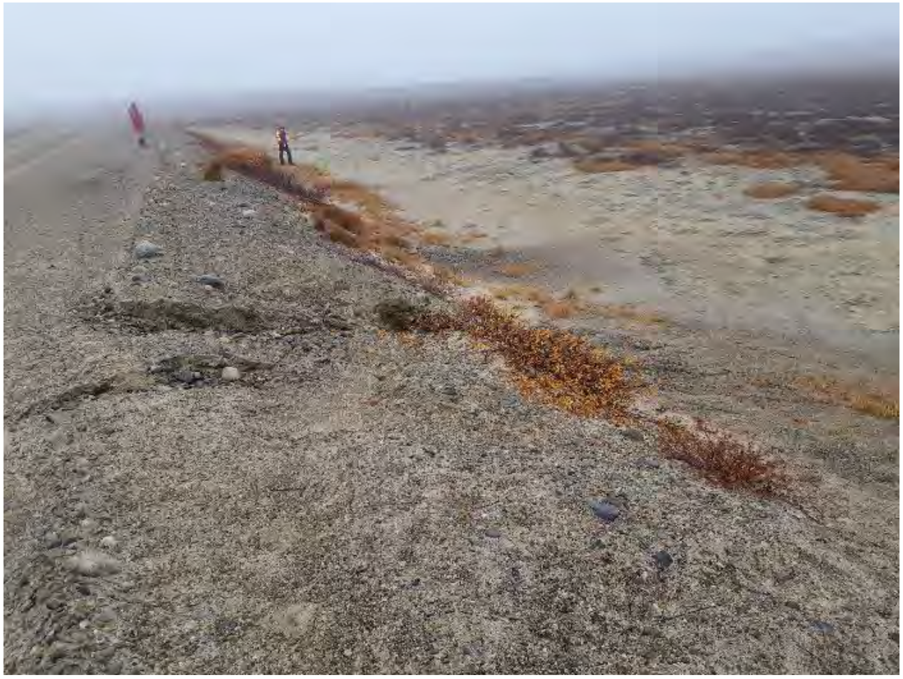

Photo 34: Dam 6 longitudinal cracks near upstream shoulder of crest, facing northwest (Fig. A1 ID#35)

Photo 35: Dam 6 former erosion channel repaired with cobble riprap (Fig. A1 ID#30)

Photo 36: Dam 3D downstream slope, facing northwest (Fig. A1 ID#97)

Photo 37: Dam 3D berm upstream of dam crest to reduce runoff over dam (Fig. A1 ID#111)

Photo 38: Dam 3D pipe exiting downstream slope, facing north (Fig. A1 ID#94)

Photo 39: Pond 1 high water mark, viewed from Dam 3D (Fig. A1 ID#111)

Photo 40: Dam 3D downstream slope, high water mark evident at toe (Fig. A1 ID#112)

Photo 41: J Dam syphons, Pond 1, facing south (Fig. A1 ID#82)

Photo 42: J Dam, four 0.2m diameter pipes throughgoing the dam for overflow control, appear undersized (Fig. A1 ID#83)

Photo 43: J Dam upstream slope erosion/scour at high water mark, facing southwest (Fig. A1 ID#101)

Photo 44: K Dam downstream slope, recently regraded, facing southwest (Fig. A1 ID#91)

Photo 45: K Dam downstream slope, recently regraded, facing northeast (Fig. A1 ID#93)

Photo 46: L Dam downstream slope, facing north (Fig. A1 ID#89)

Photo 47: L Dam downstream slope erosion rill, facing east (Fig. A1 ID#88)

Photo 48: L Dam exposed tailings downstream of dam, facing north (Fig. A1 ID#87)

Photo 49: Cell 3 outfall structure facing downstream to Cell 4 (Fig. A1 ID#106)

Photo 50: Cell 3 outfall structure erosion on channel slopes (Fig. A1 ID#107)

Photo 51: Cell 3 outfall structure, facing downstream (Fig. A1 ID#109)

Photo 52: M Dam erosion rills on downstream slope, facing northeast (Fig. A1 ID#71)

Photo 53: M Dam erosion rill in downstream slope, facing northeast from toe (Fig. A1 ID#72)

Photo 54: M Dam erosion rill facing southwest from crest, exposed tailings in background (Fig. A1 ID#79)

Photo 55: M Dam downstream slope, facing east (Fig. A1 ID#74

Photo 56: M Dam downstream slope facing southeast (Fig. A1 ID#69)

Photo 57: M Dam ponded water in cover upstream of dam, facing east (Fig. A1 ID#80)

Photo 58: M Dam downstream slope, facing northeast, exposed tailings in foreground (Fig. A1 ID#75)


Photo 59: M Dam downstream slope from crest, facing northwest (Fig. A1 ID#78)

Photo 60: Cell 5 outfall structure facing upstream (Fig. A1 ID#100)

Photo 61: Cell 5 outfall structure, facing downstream (Fig. A1 ID#104)

Photo 62: N Dam downstream slope, facing south (Fig. A1 ID#65)

Photo 63: N Dam downstream slope, facing north (Fig. A1 ID#66)

Photo 64: N Dam ponded water on cover upstream of dam, facing east (Fig. A1 ID#67)

Photo 65: Divider dyke crest and downstream slope, facing north (Fig. A1 ID#50)

Photo 66: Divider dyke spillway channel facing northeast (Fig. A1 ID#51)


Photo 67: Divider dyke spillway, facing southwest (Fig. A1 ID#52)


Appendix B TCA Dam Overview

Appendix B is a complete reproduction of Chapter 5 (Design and Construction) from "Lupin Mine Tailings Management Facility 2015 Dam Safety Review: Final Draft Report" (SRK, 2016)

2023 Dam Safety Review

Lupin Mine Tailings Containment Area (TCA)

Lupin Mines Inc.

SLR Project No.: 209.065024.00001

April 26, 2024

5 Design and Construction

5.1 General

This section provides a summary of the key components of each dam. Although no specific separation is provided with the subsections, Table 8 provides a summary of perimeter and internal dams associated with the TCA.

Table 8: Perimeter and Internal Dams

Perimeter Dams	Internal Dams
Dam 1A	Dam 3D
Dam 1B	J Dam
Dam 1C	K Dam
Dam 2	L Dam
Dam 3	M Dam
Dam 4	N Dam
Dam 5	Divider dyke
Dam 6	

5.2 Dam 1A

Dam 1A was designed as a frozen core dam due to the presence of a "relatively deep silty sand till foundation" (Holubec 2005) and to limit seepage. A PVC geomembrane was utilized along the upstream face of the original dam construction, and anchored into permafrost to reduce seepage gradients and allow for the aggradation of permafrost into the dam's core. The upstream face was riprapped and a drain was originally specified. Dam 1A was constructed to a crest elevation of approximately 485.0 m in 1981 and raised in 1984 to elevation 486.4 (Geocon 1981, Holubec 2005).

Syphons were added across the crest of Dam 1A in 1985 (Golder 1985). The original design section is illustrated in Figure 5, while Holubec (2005) provides an updated cross-section in Figure 6 and Figure 7 provides a schematic of the foundation profile. It should be noted that the crest elevations are variable in the design schematics, and a kinematic survey was completed in 2000 (BGC 2000) which indicated the as-built crest elevation was 486.27 m, while the previous as-built crest elevation was 486.1 m. The kinematic surveyed elevation matches the 2012 digital elevation model (DEM) provided to SRK by LMI.

Generally, past inspections noted erosion along the downstream face of the dam and cracking of the downstream toe, but have not noted seepage since the establishment of the permafrost core. Maintenance to the downstream toe of Dam 1a was most recently completed in 2010.

The dam currently has one active thermistor, D1A-00-1s, which is read on an annual basis.

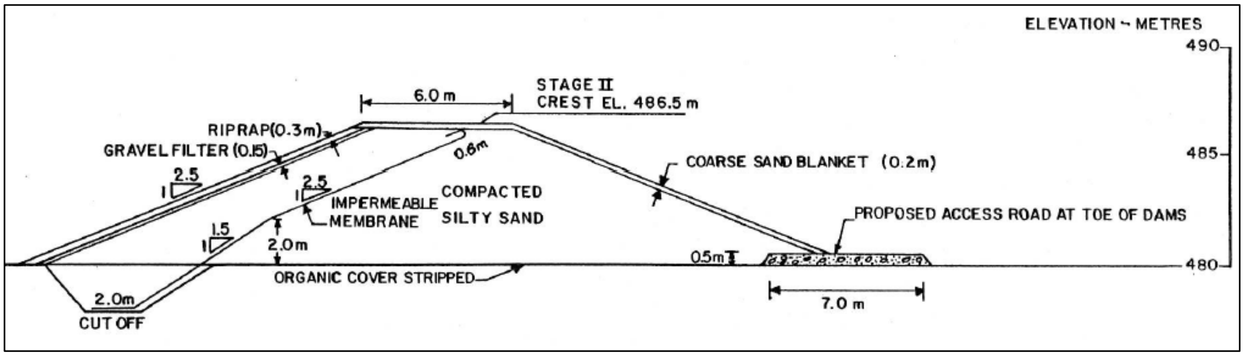

Figure 5: Dam 1A and Dam 2 Original Design Section (after Geocon 1981)

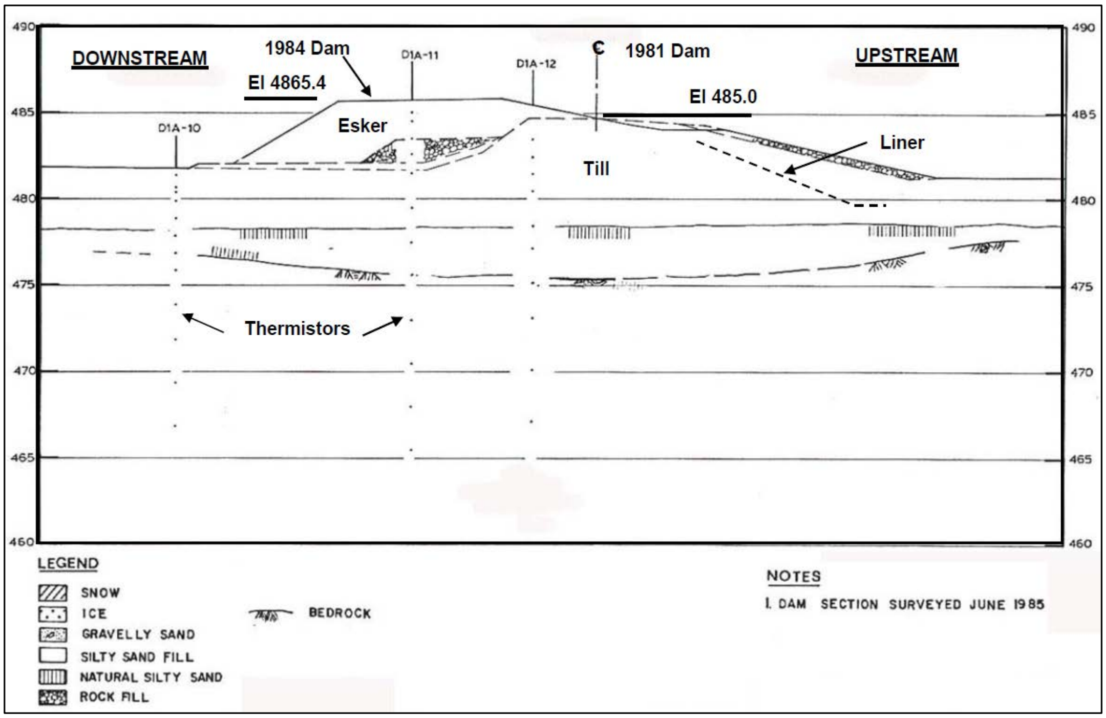

Figure 6: Dam 1A Section (after Holubec 2004)

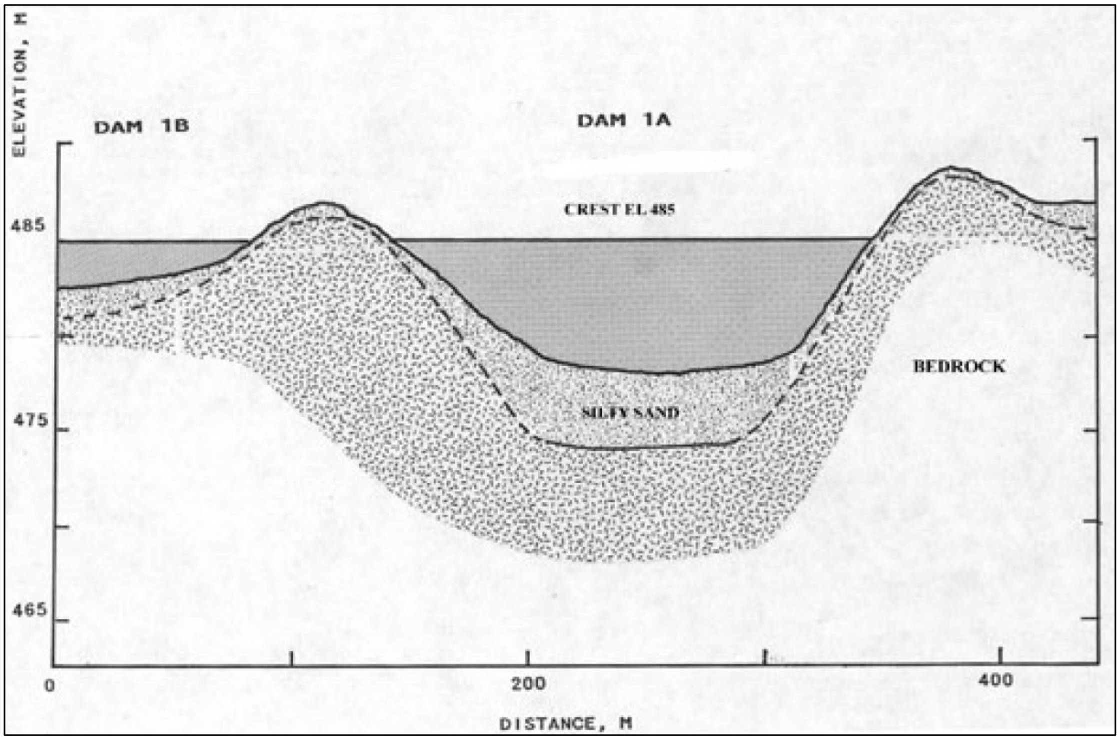

Figure 7: Dam 1A Foundation Profile (after Holubec 2004)

5.3 Dam 1B and Dam 1C

Dam 1B was designed as a 2.5 m high saddle dam and Dam 1C was designed as a 2.2 m high saddle dam (Holubec 2005) to prevent the uncontrolled release of water from the TCA. The design is understood to follow the same premise as Dam 1A as shown in Figure 5.

Kinematic surveys of the dam crests were completed in 2000 and the surveyed as-built dam crest elevation for Dam 1B was 485.83 m and Dam 1C was 485.88 m. No design sections, as-built records, or foundation profiles are available for Dams 1B and 1C.

These dams do not retain water on a consistent basis (dependent on the Pond 2 water level), and often at the time of the annual inspections, are generally reported to be in good condition, with occasional need for maintenance of the downstream face.

Dams 1B and 1C do not contain instrumentation (thermistors or piezometers).

5.4 Dam 2

Dam 2 was initially constructed at the same time and under the same premise as Dam 1A. A PVC geomembrane was utilized along the upstream face of the original dam construction, and anchored into permafrost to reduce seepage gradients and allow for the aggradation of permafrost into the dams core. The upstream face was riprapped and a drain was originally specified. Dam 2 was constructed to a crest elevation of approximately 485.5 m in 1981 and raised in 1984 to elevation 486.1 (Geocon 1981, Holubec 2005).

Dam 2 does not have an overflow structure. The original design section for Dam 2 is the same as Dam 1A, as illustrated in Figure 5, while Holubec (2005) provides an updated cross-section in Figure 8 and Figure 9 provides a schematic of the foundation profile. It should be noted that the crest elevations are variable in the design schematics, and a kinematic survey was completed in 2000 (BGC 2000) which indicated the as-built crest elevation was 486.30 m, while the previous as-built crest elevation was 485.6 m. The 2012 digital elevation model (DEM) provided to SRK by LMI generally indicates a variable crest elevation consistent with the kinematic survey and the 1984 as-built elevation reported by Holubec (2005).

Generally, past inspections have indicated that the dam is in good conditions, but have noted erosion along the upstream and downstream faces, and seepage existing downstream of the toe from the right abutment. The seepage has been hypothesized to be seepage generated by thaw from the active layer rather than seepage through the dam, or through the dam foundation (BGC 2004). Maintenance to the upstream face last occurred in 2010.

The dam currently has one active thermistor, D2-00-2n, which is read on an annual basis.

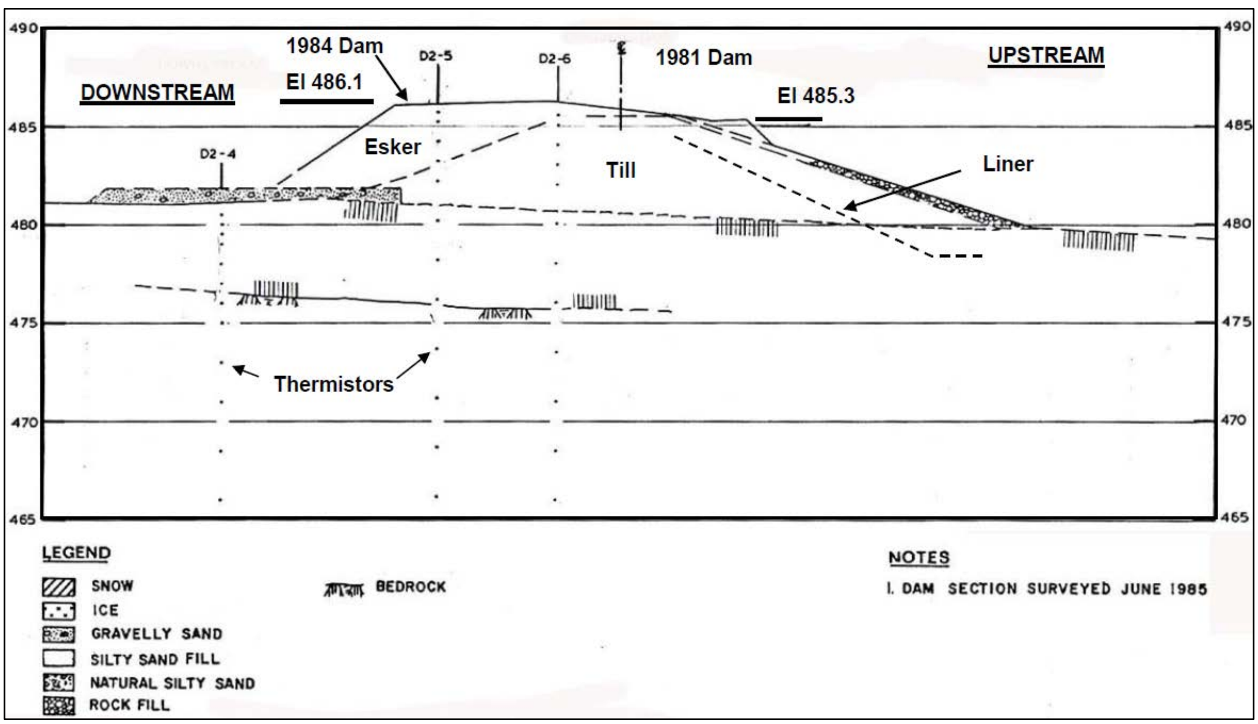

Figure 8: Dam 2 Section (after Holubec 2005)

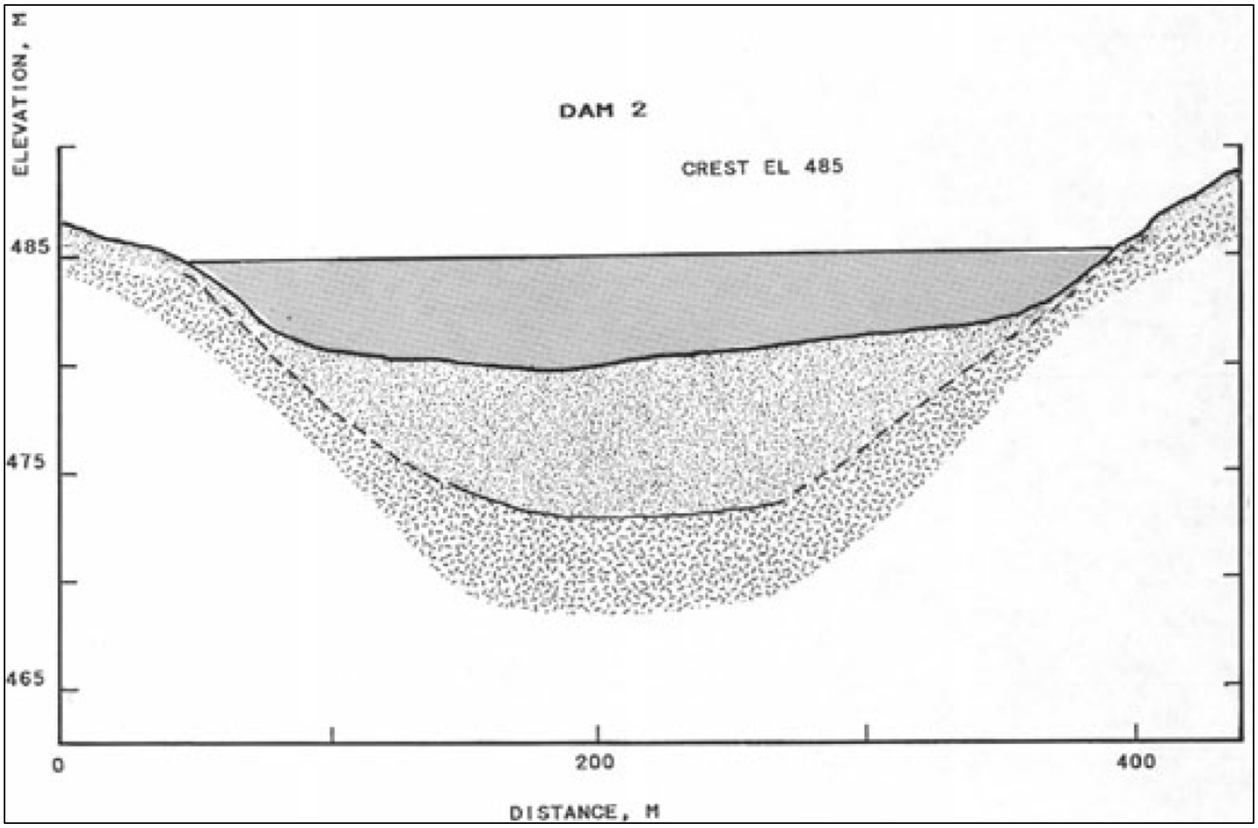

Figure 9: Dam 2 Foundation Profile (after Holubec 2005)

5.5 Dam 3

No original design documents were provided for Dam 3; however, Holubec (2005) indicates the dam was constructed in 1983 to reduce the main watershed area of the TCA, and to facilitate tailings deposition into Cell 1a. Because Boomerang Lake historically drained towards the TCA, and to reduce the potential for water to be impounded on the downstream side of the dam (Holubec 2005), a 1 m deep drainage channel was constructed at the eastern edge to provide an outlet for the lake. Holubec (2005) indicates that the design cross-section for Dam 3 was the same as for Dams 1A, 1B, 1C, and 2, as illustrated in Figure 5. Cell 1a is covered with experimental vegetation trials occurring directly upstream of the crest. The dam does not retain water; closure of the cell began in approximately 1995.

The as-built elevation of Dam 3 has been reported as 488.4 m, and it was noted that no kinematic survey was completed to confirm the elevation (BGC 2000). The 2012 digital elevation model (DEM) provided to SRK by LMI generally indicates that the crest elevation is variable, but consistently above elevation 490 m.

Generally, past inspections have indicated that there has been maintenance required along the surface water conveyance ditch. The ditch was relocated in 2010 (TBT, 2011). Recent maintenance of the dam occurred in 2012 (SRK, 2012) and again in 2015 (SRK, 2015).

Dam 3 does not contain any active thermistors.

5.6 Dams 3C and 3E

No original design documents are available for Dams 3C and 3E; however, these dams were used as internal structures for the management of tailings and supernatant water. Dam 3C separates Cell 1a from Cell 1 and Dam 3E separates Cell 1 from Cell 2. Both dams have covered tailings placed near the crest elevation on both the upstream and downstream sides, and do not retain water. Therefore, consistent with the conclusions made in 1991 (Golder 1991a), these are no longer considered dams.

5.7 Dam 3D

Dam 3D was constructed to separate Cells 1 and 2 from Pond 1 such that Pond 1 could provide longer retention of water prior to treatment / discharge into Pond 2. No design or as-built documents are available for this dam; however, Holubec (2005) reported the dam was constructed in 1986 to a maximum height of 9.5 m from a gravelly sand esker material to form a homogeneous cross-section.

During an inspection in 1991 (Golder, 1991a), Golder found that no riprap was present on the downstream face (Pond 1 side) and there was lateral cracking parallel with the crest on the downstream crest at the south end of the dam due wave action eroding the dam toe, and possibly also due to a high phreatic surface. Golder also noted some diagonal cracking near the mid-point of the dam, and attributed it to foundation settlement.

Holubec (2005) reports that seepage occurred through the dam during operations and the downstream face was buttressed with about 10 m of mine rock on the downstream side, and additional esker material on top of the dam to raise its final elevation to 490.4 m. Dam 3D is shown in section in Figure 10.

Dam 3D has not otherwise generally been included in the annual geotechnical inspections, but was included in 2015 where minor surface and crest erosion was noted, and general maintenance was recommended. SRK's 2015 inspection report also recommended that additional evaluation be completed to determine the depth of tailings within Cells 1 and 2 to determine if Dam 3D could be considered a closed embankment rather than a dam under the CDA guidelines (CDA 2014). A discussion of the Cell 1 thermistor data is provided in Section 7.1.

Dam 3D maintains one thermistor, D3D-1 which is monitored on an annual basis.

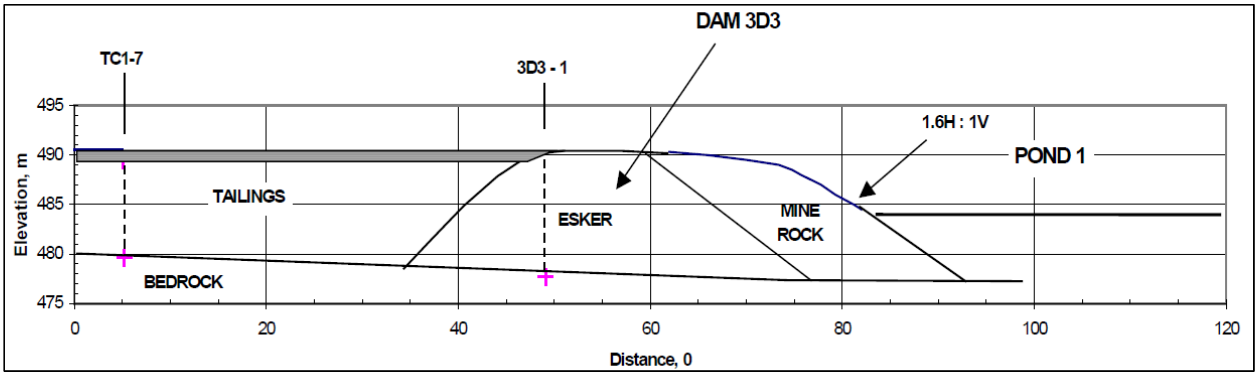

Figure 10: Dam 3D Section (after Holubec, 2005)

5.8 Dam 4

Dam 4 was originally constructed as two separate, low head dams. Dam 4A was intended to separate the TCA from Ferguson Lake, and Dam 4B was intended to separate the TCA from Long Lake. These dams were originally designed by Geocon (1984) and constructed using a cofferdam on the downstream side to prevent the flow from these lakes from flooding the construction area. The dams were constructed with a crest elevation of approximately 485 m (Golder, 1992).

The original alignment of Dam 4B crossed bedrock outcrops and felsenmeer, while many of the bedrock blocks were frost jacked from outcrops as much as 1m with very little overburden observed in the area (Geocon 1984).The original Dam 4B designs included the design of a 30 m long impervious upstream blanket and a keytrench cut-off, intended to penetrate all fractured rocks. The weathered zone in the bedrock varied between 1.5 and 3 m deep. To limit seepage through the fractured bedrock, a long upstream blanket was proposed as well as a key trench. No discussion was provided on the foundation conditions of Dam 4A. The original design section for Dam 4B is provided in Figure 11.

The design section of Geocon (1984) indicates the dams were designed with a liner, and Holubec (2005) indicates that the original dams were constructed using a homogeneous silty sand design due to the small amount of water that was anticipated to be retained with the TCA. Golder (1992) encountered geotextile during their site investigation approximately 1 m below the crest.

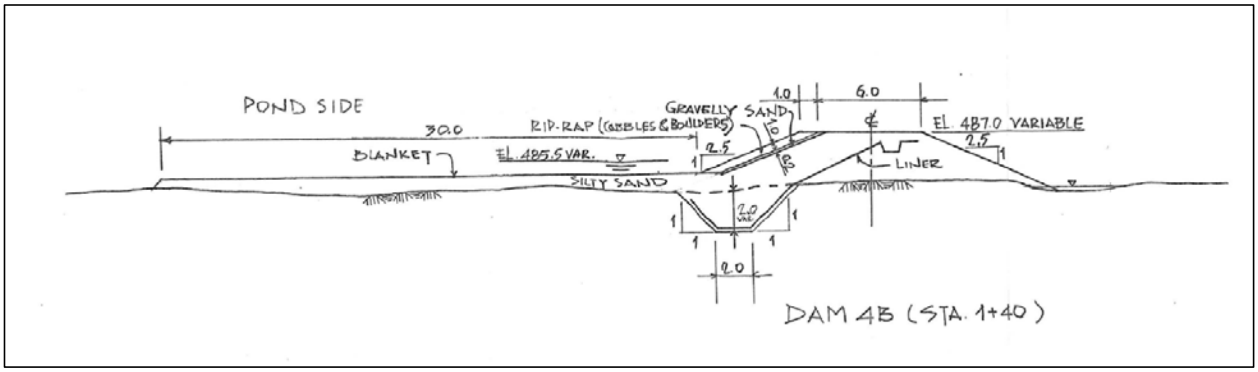

Figure 11: Design Section – Dam 4B (after Geocon, 1984)

Dam 4 was designed in 1992 as a 930 m long, 5 m high dam (Golder, 1992), as illustrated on Figure 12. The 2000 kinematic survey (BGC, 2000) indicated the crest elevation was constructed to EL. 489.59 m.

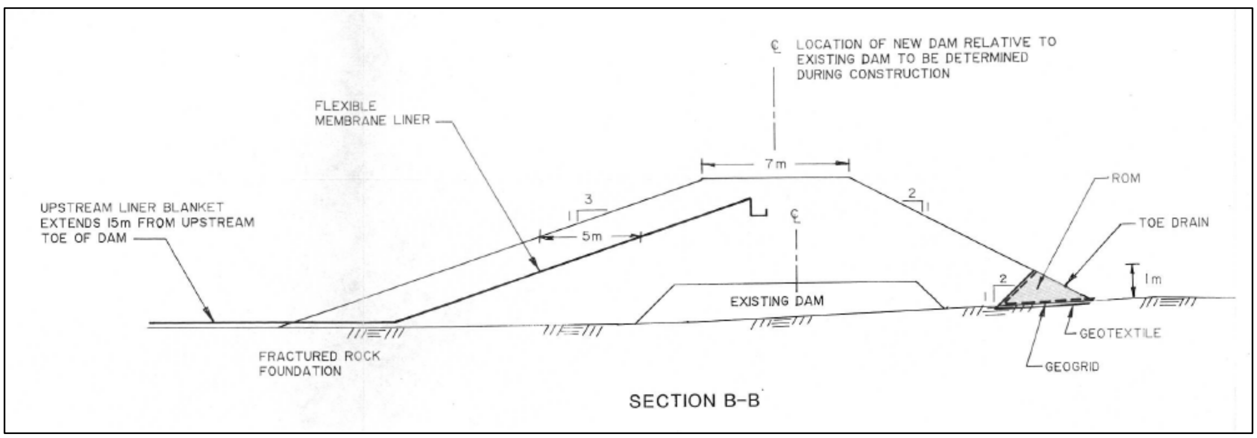

Figure 12: Dam 4 Raise Design Section (after Golder, 1992)

Generally, Dam 4 has been observed to be in good condition with the exception of noted erosional gullies developing on the downstream side near the left abutment, and seepage noted at the right abutment. Maintenance to the downstream face occurred in 2010 to stop the observed seepage; this involved infilling the area between the right abutment of Dam 4 (former Dam 4A) and the former cofferdam (TBT, 2010). No seepage has been observed at this location since the repair work completed in 2010.

Dam 4 maintains three active thermistors, D4-1, D4-3, and D4-4.

5.9 Dam 5

Dam 5 was designed in 1992 (Golder) with a height of 1.5 m, a crest length of approximately 250 m and was designed with a geomembrane liner to reduce seepage. The dam served to infill an area between two small knolls to maintain containment within Cell 3. Test-pits completed during the site investigation encountered moist silty sand and gravel till thawed to a depth of approximately 1.3 m. Dam 5 does not retain water, or tailings.

Based on the 2000 Kinematic survey (BGC 2000), the crest elevation was constructed to EL. 491.54 m, which is in general agreement with the 2012 DEM. There are no active thermistors within the dam alignment.

Past inspections have generally found the dam to be in good condition.

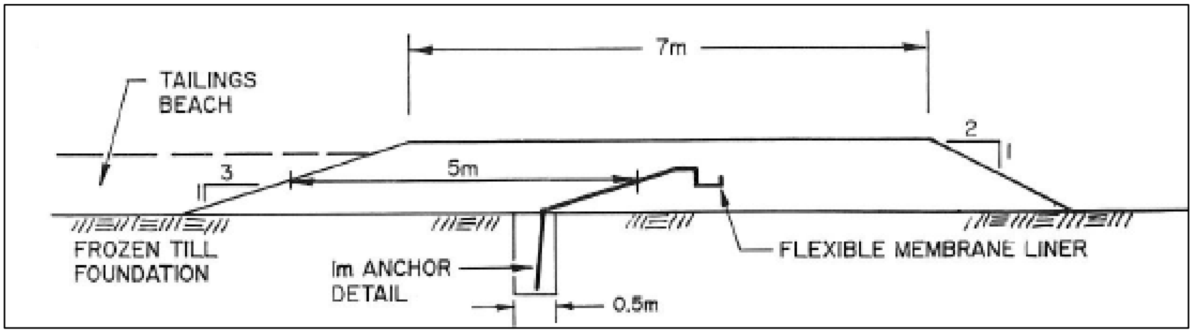

Figure 13: Dam 5 Typical Design Section (after Golder 1992)

5.10 Dam 6

Dam 6 was designed in 1992 by Golder (Golder 1992) with a height of 3 m and a length of approximately 325 m. Foundation conditions consisted of moist silty sand and gravel till (with a higher degree of gravel / boulders than Dam 5) to a depth of 1.3 m, which was the maximum extent of the test pits before permafrost was encountered. The dam served to maintain containment of Cell 3.

The 2000 kinematic survey (BGC 2000) indicated the dam crest was constructed to elevation 490.25 m. Based on past inspections, the dam has been reported to be in good condition, with the exception of the development of erosional gullies on the downstream face.

A design was completed to raise Dam 6 in 2003 (BGC, 2003); however, this raise was never constructed. There are no active thermistors within Dam 6.

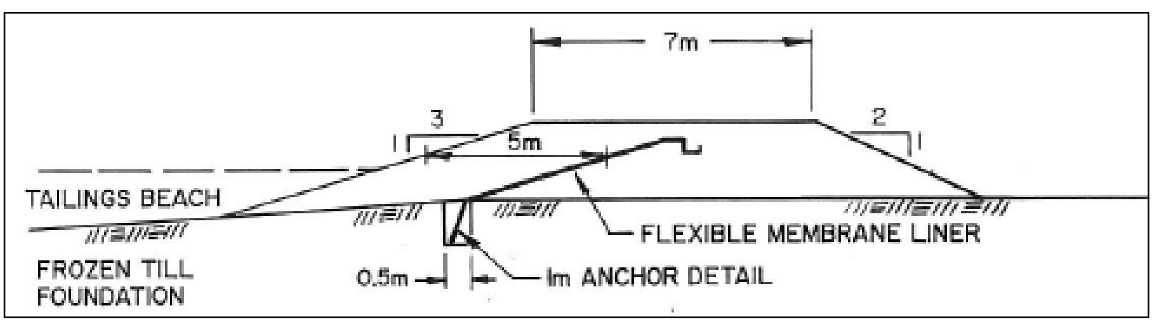

Figure 14: Dam 6 Typical Section (after Golder 1992)

5.11 J Dam

J Dam was designed in 1985 by Golder (Golder, 1985) with a length of approximately 1,200 m and a maximum height of 12 m (to El. 490). The foundation conditions were anticipated to consist of little or no tailings over the natural ground, although it was anticipated that in some areas there may be a thin veneer of sedimented fines where the dam would cross the two areas between the two pre-development natural lakes. A thin veneer of tailings was expected to underlie the eastern arm of the dam, which now forms the limit of Cell 5. The natural condition of the permafrost was anticipated to already have been altered because of the altered water levels imposed due to the presence of Dams 1A and 2, and the tailings discharge point at the north of the TCA. In general, it was expected that the summer period thawed zone would be somewhat deeper than typical, and that areas under water would be thawed to significant depth.

Although altered permafrost conditions were anticipated, it was not anticipated that the foundation would adversely affect the stability of the structure, given the types of natural material present (bedrock, sand and gravel, broadly graded glacial till) in the foundation. However, it was expected that there would be some tendency for seepage through the unfrozen foundation zone and some differential settlement of the dyke foundation. It was not anticipated that the seepage volumes would be large (approximately 5 to 10 m^3/day), or settlements would be in excess of 0.5 m. It was proposed that investigation of the foundation conditions would occur during stripping of the dam footprint. (Golder 1985).

The dam was recommended to be constructed to an ultimate crest elevation of 486 m (originally intended to be constructed to 490 m); however, it was constructed to 485.6 m (which is consistent with the 2012 DEM), with a crest width of at least 6 m. The sideslopes were not specified, but anticipated to be a function of the construction materials, between 1.5 and 2 H:1V for rockfill and between 2 and 4 H:1V for sand and gravel. The sand and gravel was intended to act as a filter, and was specified to be a minimum 4 m wide. Riprap was recommended for the upstream face. No formal stability analysis was completed. (Golder 1985).

Where the alignment crossed the water limits at the time of construction, it was proposed that waste rock would be advanced by dumping and dozing at a level above the water level, and that the same method would be employed for the sand and gravel filter, and the glacial till. Figure 15 illustrates the proposed marine construction methodology.

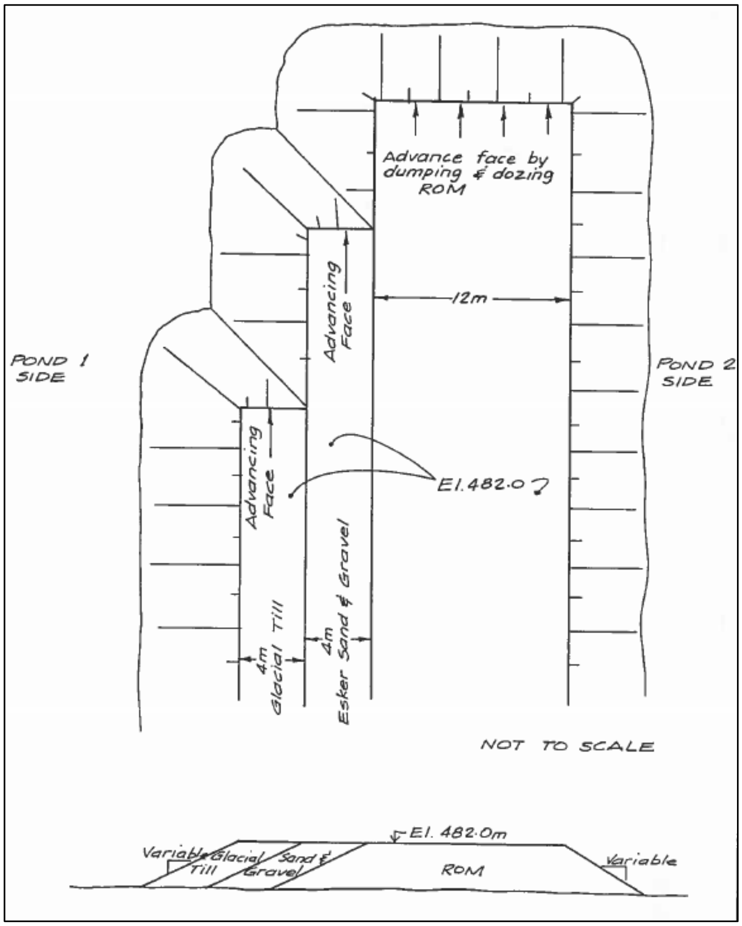

Figure 15: Construction of J Dam within the Marine Section (after Golder 1985)

The Golder 1987 inspection report of J Dam (Golder, 1987) indicated there was a leak in the dam somewhere, and divers were retained to complete inspections of the upstream and downstream sides of the dam. The investigation resulted in no evidence of flow and no fine material deposits suggestive of material-laden flows entering still water were located; however, a sinkhole was noted on the upstream side of the dam. A face armouring design was prepared and implemented on the upstream face to elevation 483.6 m which consisted of crushed Run of Mine (ROM) faced with a zone of esker sand and gravel which was faced with a thickness of tailings material. Whereas the function of the tailings was to reduce seepage, the underlying zones were to function as filter layers to bridge the gradation of the course, open voided ROM section to the new zone of tailings material. Figure 16 provides a schematic of the proposed repair.

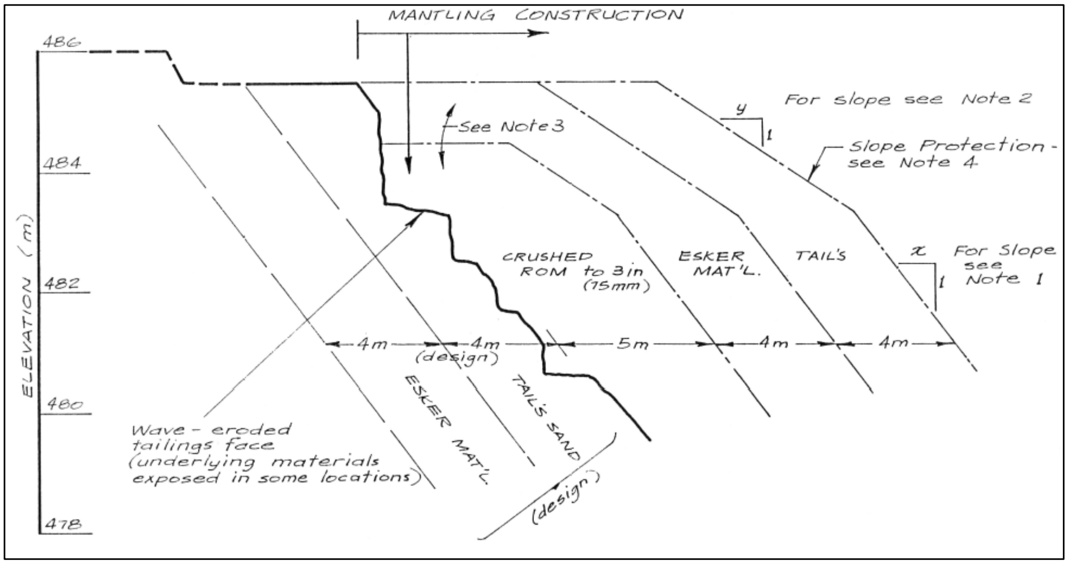

Figure 16: J Dam Repair (after Golder 1987)

J Dam includes four overflow pipes (approximately 6 inch diameter) that are located approximately 0.3 m below the crest elevation. The maximum operating level of Pond 1 is therefore assumed to be 0.3 m below the crest elevation.

During the 1991 inspection (Golder 1991a), wave erosion was causing damage to the upstream ROM riprap. This appears to be a continual problem as it was also noted in inspection reports between 2000 and 2003, which also indicated that the water level was high. In 2003 a 0.5 m diameter sinkhole was noted near the upstream side of the crest (which was to be backfilled). Internal dam inspections were either not conducted or reported between 2004 and 2011. Since 2012, annual inspection reports note that the upstream and downstream toes were being adversely affected by wave erosion.

Design recommendations to raise J Dam to EL. 488 or 490 were prepared by Golder (1987), but it does not appear that the dam was ever raised. J Dam does not contain any instrumentation (piezometers or thermistors).

5.12 K Dam

K Dam was designed by Golder in 1990 (Golder 1990) with a total length of approximately 700 m and a maximum height of 10 m dam crest to elevation 490 m (2012 DEM indicates crest elevation of approximately 491 m). The downstream slope was designed at 2H:1V and the upstream slope was designed at 3H:1V. Similar to other dams designed at Lupin, a geomembrane was incorporated into the upstream face of the dam, and extended 15 m upstream to limit the potential for seepage and allow permafrost aggraded into the dam's core. The design concept included a homogeneous embankment constructed of tailings sand, or esker sand and gravel, a toe drain – with the function of controlling the seepage outflow of the water from the dam and the foundation. The design also included an upstream seepage barrier blanket to control the rate of seepage beneath the embankment, which included a geotextile filter placed on the foundation. The typical cross-section for K Dam is shown in Figure 17 and the typical toe drain detail is shown in Figure 18.

The K Dam alignment generally consists of an area of bedrock exposure containing some pockets of organics over rocks. Generally, it was considered that the foundation did not contain glacial till, except at the east (right) abutment, locally at the west (left) abutment and that generally the thickness was not great as bedrock was always encountered at shallow depth (Golder 1990).

Special considerations that affected the design concept of K Dam included: the reduction of seepage, and reducing the piping potential through a heterogeneous foundation and homogeneous embankment; the desire to use the most economically available construction materials; and the need to minimize processing of those materials. (Golder 1990).

A starter beach confinement dyke was recommended as a low dyke south of, and parallel to K Dam to facilitate rapid beach deposition. Seepage and stability analyses were completed as part of the original design (Golder 1990). The recommended 2H:1V slope was steeper than that of other internal dams, but was justified due to the presence of both the geomembrane, the downstream to drain, and the opportunity for later maintenance should local sloughs occur. (Golder 1990).

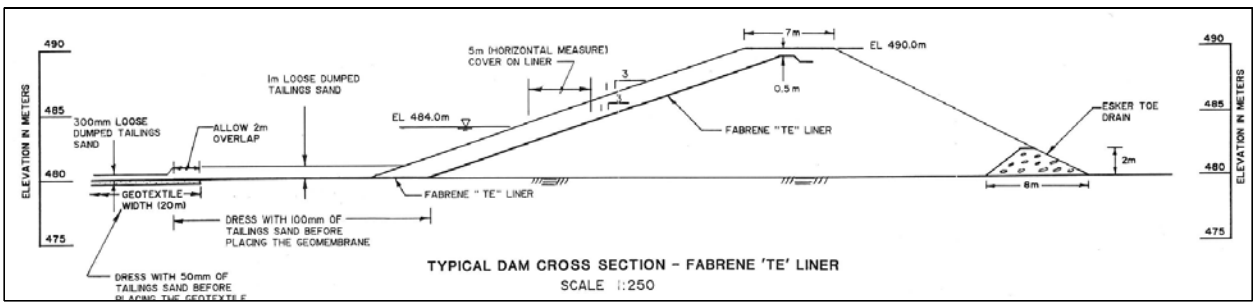

Figure 17: K Dam Typical Section (after Golder 1990)

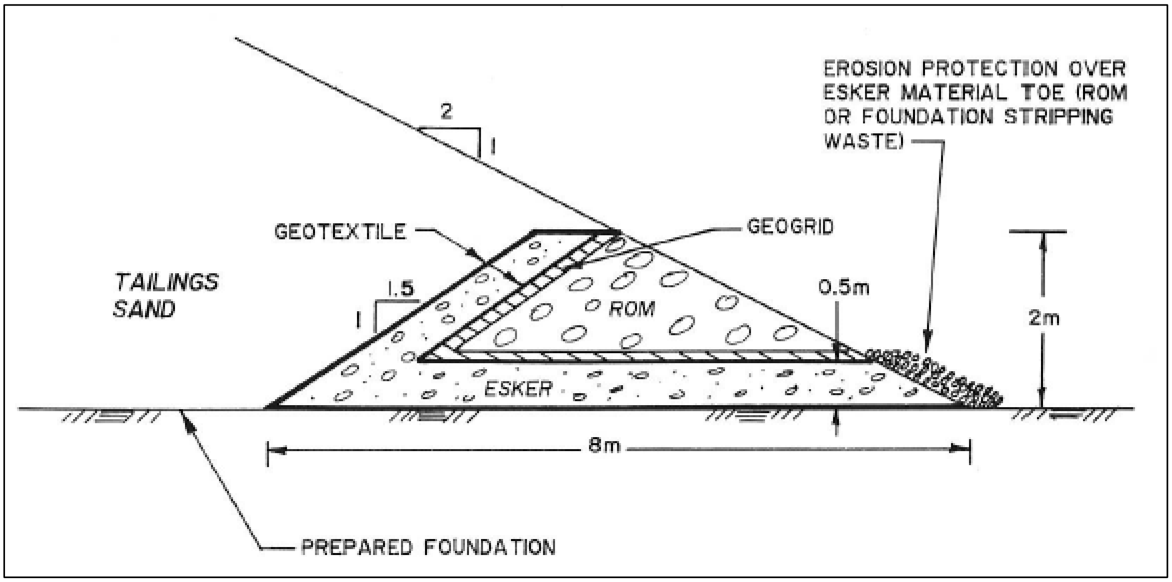

Figure 18: K Dam – Typical Toe Drain Detail (after Golder 1990)

Generally, K Dam is not included in the annual perimeter dam inspections until 2012; however, Golder (1991a), and BGC (2001, 2002, and 2003) provide commentary on the condition of the Dam. Golder (1991a) indicated the crest condition was good, and that no cracking was evident, but that the lower toe drain was constructed without the lower riprap protection. It was noted that Pond 2 would need to rise before this became an issue. BGC (2001, 2002, and 2003) identified significant erosional scarps formed at the toe of the downstream slope due to the water levels of Pond 2. Regrading the eroded toe and/or placement of protective riprap was recommended to prevent further erosion and progressive slumping of the face. There is no mention of repair and K Dam was not included in an annual inspection again until 2012. In 2012, SRK (SRK, 2012) indicated that there was downstream slope surface erosion and some undercutting at the toe from Pond 2 wave action. Subsequent inspections (2013 to 2015) have noted that the erosion has been getting progressively worse.

K Dam maintains one active thermistor, DK-3, and Cell 3, immediately upstream of the dam maintains one thermistor (TC3-1). Both thermistors are read on an annual basis.

5.13 L Dam

No design documents or as-built reports were available for L Dam. However, Holubec (2005) indicates that the Dam was constructed in 1992 to contain tailings in Cell 3, and provide an additional water treatment pond (Cell 4). Deposition of tails in Cell 3 commenced in 1990 (Holubec, 2005). Holubec (2005) reports the dam was constructed in two stages from esker material, and that the upstream and downstream slopes of the dam were protected with mine rock riprap. Figure 19 provides a cross-section of the dam.

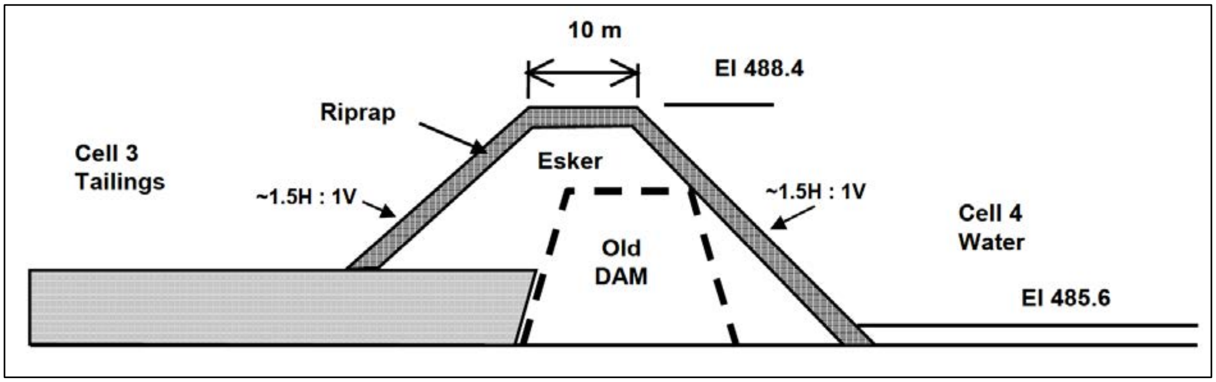

Figure 19: L Dam – Typical Section (after Holubec 2005)

Dam L was included in the 2003 annual inspection report (BGC 2003) which highlighted that three transverse cracks were noted on the crest, and it was recommended that these be backfilled to prevent infiltration of water. It was also noted that numerous sloughs and settled areas were occurring on the downstream face, generally due to scarps formed at the toe and that a significant crack was noted to have formed in the northern portion of the crest, directly proximal to the tailings line. It was recommended that the slope be flattened to prevent further movement, but no record of maintenance or further inspections was provided until 2012 (SRK). In 2012, SRK noted that there was minor slope erosion and some minor undercutting at the toe, and that there was a breach of the dam in the southern section (likely between the Pond in Cell 3 and Cell 4). The dam breach was repaired in 2015 (SRK, 2015).

L Dam does not contain any instrumentation (thermistors or piezometers).

5.14 M Dam

No design records are available for M Dam; however, an as-built plan and sections are presented in EBM 2001. Holubec (2005) indicates that the dam was constructed in 1992 from gravelly sand esker material and the downstream slope was covered with a thick layer of mine rock riprap. EBM (2001) reported that a “second lift” was constructed on the dam in 2000 to increase the height of the dam by approximately two metres. The as-built plans (EBM 2001) indicate the dam is founded on tailings.

M Dam was inspected in 2002 and 2003 (BGC), and the inspection reports indicated that the outer portion of the upstream face of the dam has observed significant cracking and settlement, and that there was a recommendation that the upstream slope be flattened so that the cracking did not progress further. The condition of M Dam was again discussed in 2012 by SRK which observed slope surface erosion, and a major tension crack observed over a 15 m section south of Dam N, with cracks up to 6 m long, and deeper than 30 cm. Recommendations to mitigate the failure were provided by SRK which included the construction of a buttress at the toe of the dam. This repair has not been completed, and the dam continues to exhibit tension cracks along the downstream crest and the progression of a circular failure has further increased (SRK 2015).

The tailings within the foundation may not be providing adequate foundation support; and with water upstream and downstream of the dam, it may not have been possible for permafrost to re-establish in the foundation, or the depth of thaw (the active layer) may be greater than in other areas.

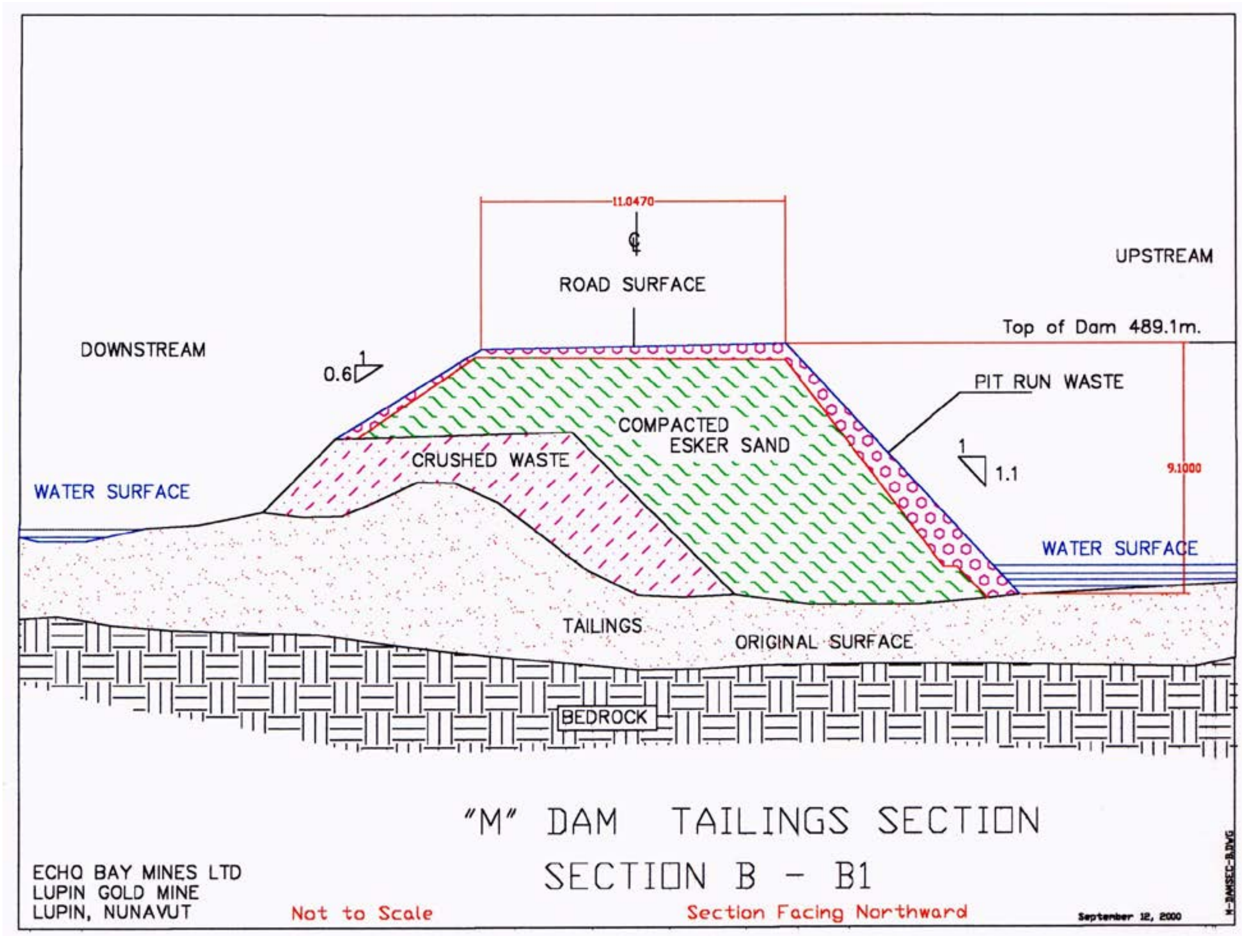

Figure 20: M Dam – Typical Section (EBM 2001)

5.15 N Dam

No design documents are available for N Dam; however, Holubec (2005) indicates that N Dam was constructed to allow the covering of a small area of exposed tailings beyond the M Dam alignment (and outside of Cell 5). It is understood that this dam consists of an esker zone covered with mine rock riprap on the downstream side.

N Dam was not included in the annual inspection reports until 2015, which indicated that the dam was nearly submerged at the time of the inspection. N dam is not included in the 2012 DEM.

5.16 Divider Dyke

The divider dyke design was completed by Golder in 1985 (Golder 1985). The foundation conditions appeared to consist largely of generally vertically bedded, heavily jointed bedrock. A thin layer of glacial till overlaid the bedrock, and it was anticipated that the natural permafrost conditions would still be intact as the area had not yet been inundated with water, and because the area had not yet been inundated, it was considered that the proposed dykes would become frozen before they retained water (Golder 1985).

The dyke was designed with a crest width of 6 m, and local settlements and regular maintenance were anticipated. Armouring of the divider dyke was not considered necessary based on the anticipated pond levels at the time; however, it was noted that later increases in dyke elevation would require face riprapping (Golder 1985). The design did not include discussion of a stability analysis.

The design discussed does not include a gated culvert, and it is not clear at what point the gated culvert was incorporated into the design.

The divider dyke has only been included in one inspection, that of Golder (1991a). At the time, the inspection indicated that the crest was generally in good condition, but exhibited some local cracking parallel to both edges of the crest (assumed to be indicative of minor foundation settlements), and that no riprap had been installed although some run of mine rock had been piled at the north end of the structure. There was no ponded water against the structure at the time of the inspection.

There is no instrumentation in the dyke (thermistors or piezometers).

5.17 Lower Sewage Dam

No design or construction documents were provided with respect to the lower sewage dam. BGC (2003) reported the dam was in good condition in their annual dam inspection report. SRK (2015) indicated that repairs were completed of the surface of the dam, and that the repairs were completed appropriately.

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