Appendix V3-3F

Doris Tailings Management System Phase 2 Design, Hope Bay Project

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Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
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Prepared for

TMAC Resources Inc.
PO Box 44
Suite 1010-95 Wellington St. W
Toronto, ON M5J 2N7

Tel: +1 416 628 0216
Web: www.tmacresources.com

Prepared by

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2

Tel: +1 604 681 4196
Web: www.srk.com

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1 Introduction

1.1 Background

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet (Figure 1). The Project is comprised of three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas hosting known mineral resources are Doris, Madrid, and Boston (Figure 2).

The Project consists of two phases; Phase 1 (Doris deposit) with an estimated ore reserve of 2.5 million tonnes (Mt), and Phase 2 (Madrid and Boston deposits), which includes an additional ore reserve of approximately 18.7 Mt. The total ore reserve for the combined Phases is 21.2 Mt, which is approximately equal to the total amount of tailings that will be produced. Of this, approximately 18 Mt of tailings will be contained within the Doris tailings impoundment area (TIA), with the remaining tailings being deposited in a dedicated Boston tailings management area (TMA) (SRK 2016a).

Ore processing includes cyanidation and flotation methods, with two separate streams of tailings being produced, both captured under the tailings management system (TMS). The cyanidation tailings will be detoxified (cyanide destruction) then filtered and blended with waste rock to be returned underground as backfill. At the Doris and Madrid processing facilities, the flotation tailings will be deposited in the Doris TIA, and at the Boston processing facility, the flotation tailings will be filtered and deposited in the Boston TMA.

The currently licensed Phase 1 TMS (SRK 2015a) was designed for subaerial deposition of about 2.5 Mt of tailings into the designated Doris TIA. This TIA is a former natural lake (Tail Lake), which has been listed on Schedule 2 of the Metal Mining Effluent Regulations (MMER). Phase 2 development will see the expansion of the TIA to accommodate the increased volume of tailings (Figure 3).

To ensure environmental containment, the TIA would be impounded through three dams: the North, South, and West dams (Figure 3). The North Dam, unchanged from the Phase 1 design, will function as a water retaining dam, while the South and West dams will have tailings deposited against their upstream face keeping the Reclaim Pond away from these structures (Figure 3). The North Dam was constructed in 2012 (SRK 2012) as a water retaining frozen core dam, while the South and West dams are designed as frozen foundation rock fill dams incorporating a geosynthetic clay liner (GCL). The South Dam is part of Phase 1 and will be raised as part of the Phase 2 development. The West Dam is a new structure.

Tailings will be spigotted from a number of points along the eastern perimeter of the TIA, and from the South and West dams, creating a landscape that drains towards the North Dam at an average slope of about 1%.

The TIA will be closed through application of a 0.3 m thick quarry rock isolation cover intended to mitigate tailings dust issues and prevent direct contact of tailings with terrestrial wildlife. Water quality modeling (SRK 2016b) confirms once the cover has been applied, water discharge from the TIA will meet environmental discharge criteria. Once that has been demonstrated to occur, the North Dam will be breached as originally intended, returning the natural outflow to the pre-mining elevation of 28.3 m.

This report documents TMAC's proposed changes to the currently permitted TMS to accommodate the additional volume of tailings produced as part of Phase 2 development.

1.2 Scope of Work

SRK Consulting (Canada) Inc. was retained by TMAC to carry out the preliminary design of the revised TMS for the Phase 2 Project. The design and related information provided in this report has been prepared in accordance with industry best practice, which includes, but is not limited to the Canadian Dam Safety Guidelines, as documented by the Canadian Dam Association (CDA) (CDA 2007, 2013), the Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014), various Mining Association of Canada guidelines (MAC 2011a, b, c) and publications and bulletins published by the International Commission of Large Dams (ICOLD).

In addition, in response to the 2014 Mount Polley tailings dam failure in British Columbia, and the 2015 Samarco tailings dam failure in Brazil, the design takes into consideration the key recommendations as outlined in the subsequent Independent Expert Engineering Investigation and Review Panel Report (IEEIRP 2015), as well as the recent BC Dam Safety Regulations (B.C. Reg. 40/2016)

1.3 Report Structure

Section 2 provides a summary of the TMS concept including a comparison of the existing licenced TMS with the proposed revised TMS and a brief discussion of the tailings alternatives evaluation. The TMS design criteria are presented in Section 3, and summary details of the new containment structure design analysis are provided in Section 4. Section 5 list the TMS construction details, including construction material take-off quantities. The TMS operational plan, which includes the deposition plan, is described in Section 6. TMS closure concludes the report in Section 7 and includes a description of monitoring and maintenance activities.

A comprehensive set of appendices, providing details pertaining to the TMS options analysis, tailings deposition plan, hydro-technical design and engineering analysis (seepage, stability, thermal and consolidation) are included at the end of the report. Supporting figures for the new containment structures are also included.

1.4 Reliance on Previous Reports

This report is considered complimentary to reports that have been filed on the public registries as part of the original TMS regulatory approval process, and subsequent compliance reporting. Since much of this information remains valid, the reader is referred to these reports for background information such as general site characterization data which remains unchanged. Table 1 summarizes the key previous reports referred to in this context.

Table 1. Pertinent Previous Reports Relied upon for the Revised TMS Design

Reference	Report Function
SRK Consulting (Canada) Inc. (2005a). *Preliminary Tailings Dam Design, Doris North Project, Hope Bay, Nunavut, Canada*. Report prepared for Miramar Mining Corporation, Project number 1CM014.006, October.	This report was submitted as part of the Final Environmental Impact Assessment for the Doris North Project (MHBL 2005), which ultimately led to issuance of the Project Certificate.
SRK Consulting (Canada) Inc. (2007a). *Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada*. Report Prepared for Miramar Hope Bay Limited. Project number 1CM014.008.165, March.	This report was submitted as part of the Water Licence Application for the Doris North Project (MHBL 2007), which ultimately led to issuance of the Original Water Licence (2AM-DOH0713).
SRK Consulting (Canada) Inc. (2012). *Hope Bay Project, North Dam As-Built Report*. Report Prepared for Hope Bay Mining Limited. Project number 1CH008.058, October	This report was submitted to the NWB in fulfillment of a Licence Condition after completion of construction of the North Dam.
SRK Consulting (Canada) Inc. (2015a). Doris North Project Tailings Management System Design. Report prepared for TMAC Resources Inc. Project Number 1CT022.002.200.560, May 2015.	This Report was submitted to the NWB as part of the application package for an amendment of the Water License (2AM-DOH1323).

2 Tailings Management System Concept

2.1 Current Licensed Tailings Management System

The current licensed TMS for the Doris deposit entails subaerial tailings deposition within the designated TIA (SRK 2015a). This TIA was a natural lake, Tail Lake, and was listed on Schedule 2 of the Metal Mining Effluent Regulations (MMER) specifically for use as a tailings facility.

Under the current licence, environmental containment for the TIA is provided through the construction of two dams: a water retaining frozen core dam, the North Dam, and a frozen foundation dam, the South Dam, retaining tailings solids. A third structure, the Interim Dike, is internal to the TIA with the purpose of retaining the tailings solids while allowing tailings water to drain into the Reclaim Pond. About 2.5 Mt (about 2.0 million m^3) of low solids content slurry tailings (49% solids content) will be deposited subaerially between the South Dam and the Interim Dike. The tailings production rate is 1,000 tpd for the first two years, after which it increases to 2,000 tpd for the remainder of Phase 1.

At closure, once environmental discharge criteria have been met, the North Dam will have been breached, allowing the Reclaim Pond to return to its pre-mining elevation of 28.3 m, while the subaerial tailings are to be covered with an isolation cover of a nominal thickness of 0.3 m.

2.2 Phase 2 Tailings Storage Requirements

Mine planning for Phase 2 has resulted in an overall revised mine plan for the Project with a targeted ore production of about 18.7 Mt, of which 15.5 Mt (about 12.0 million m^3) will be deposited in the TIA. This is in addition to the production accounted for under Phase 1, resulting in a total storage requirement in the TIA for Phase 2 of about 18.0 Mt (14.0 million m^3).

About 8% of the tailings are comprised of detoxified cyanide leach tailings, and this tailings stream will be sent underground where it will be mixed with underground waste rock for use as structural mine backfill. The volume of detoxified tailings is small, and therefore storage requirement planning was completed considering the overall total volume without this reduction.

2.3 Selection of Preferred Revised Tailings Management System

Over the life of the Project, several tailings alternatives evaluations were completed at various stages of planning and development (SRK 2005b, 2009a, 2015a). The alternatives evaluation considered different tailings production technologies, different containment system designs, as well as different tailings containment locations.

With respect to tailings containment locations, all previous alternatives evaluations have identified the former Tail Lake basin, now called the Doris TIA, as the preferred tailings disposal location. The physical setting of this basin makes it ideally suited to provide superior environmental containment, and its ability to accommodate substantially greater volumes of tailings than currently planned, including the proposed Phase 2 tailings, provides a strong case for continued use of this facility through an expansion design. Finally, since this facility is currently a licenced

TIA with an approved MMER Schedule II designation, the decision was reached to retain the Doris TIA as the preferred tailings disposal location.

The licenced Phase 1 tailings deposition strategy is subaerial hydraulic tailings deposition of a low solids content (49% solids) slurry (SRK 2015a). That tailings technology was adopted as it was demonstrated to be environmentally protective, and economically feasible. For Phase 2, the selected tailings technology was revisited to confirm whether it remained the Best Available Technology (BAT) for the Project.

The first component of that evaluation pertains to the geochemistry of the tailings. Tailings geochemical characterization confirms that the characteristics of the tailings have not changed from what has been evaluated for Phase 1 (SRK 2015b, 2016c). The detoxified tailings are potentially acid generating (PAG), but the flotation tailings are not. Therefore, to ensure environmental protection associated with both short and long-term exposure of the flotation tailings, provided these tailings streams are kept separate, there is no benefit in preventing tailings oxidation. As a result, tailings disposal technologies requiring full saturation is not necessary. Therefore, it was deemed appropriate to continue to separate these streams and deposit only non-PAG flotation tailings in the TIA.

Fresh make-up water for processing, needs to be minimized as far as practical, since the water draws from available lakes, are close to the maximum draw threshold where significant environmental impact might be experienced. As a result, tailings technologies minimizing water loss, maximizing recovery and recycling is encouraged. The TIA is located in an isolated headwater catchment which exceeds the TIA footprint by a factor of 3. Diversion of non-contact water is not practical and as a result, although the climatic water balance at the site is near neutral, the TIA water balance is slightly positive which provides the opportunity for maximizing processing make-up water. This however requires the TIA to have the ability to store contact water, reducing the potential benefits of tailings technologies requiring substantive dewatering.

Tailings containment within the TIA requires the use of containment structures. The height and length of these structures are defined by the assumed design value for tailings density, which will vary in accordance with the adopted deposition technology. Tailings technologies that entail substantive dewatering will result in the need for smaller containment structures which would be advantageous from an overall risk management perspective. However, these risks can also be managed through adopting suitable tailings deposition strategies.

In order to minimize risk to the environment as a result of designing the TIA to contain slurry tailings, the containment structures need to be designed to retain all of the TIA content with a high degree of safety. An evaluation of different tailings deposition strategies to best achieve this was completed (Appendix A), and it was concluded that the preferred deposition strategy entailed developing substantive tailings beaches against the South and West dams, making them solids-retaining structures only (no pond near the dams). There will be no tailings deposition against the North Dam making it a water retaining structure only. This deposition strategy will result in the least amount of environmental risk as tailings discharging from the facility will be prevented. The only environmental release, in case of a containment structure breach, will be supernatant water. This risk is temporary as it will only exist during the operational life of the facility, and can only be eliminated by increasing the fresh water make-up demand from surrounding lakes. Therefore, the best available and preferred tailings technology for Phase 2 is subaerial deposition of 49% solids tailings in the Doris TIA.

2.4 Existing/Unchanged Tailings Management System Infrastructure

2.4.1 North Dam

The North Dam was completed in 2012 (SRK 2012) following a two-season construction period. This structure is a water retaining frozen core dam (Figures 4 and 5), with an original design life of 20 years. Additional stability analysis (Appendix B), thermal analyses (Appendix C), and creep deformation analysis (Appendix D) were completed to support extending the design life of the North Dam to satisfy the needs of Phase 2, additional year to consider decommissioning and closure. These analyses confirmed that operational life can be extended with no changes to the dam geometry to about 30 years (additional 10 years on original design life).

In accordance with the currently permitted tailings management plan, the Reclaim Pond elevation will typically vary between 27.3 m and the full supply level (FSL) of 33.5 m under normal operating conditions as predicted by the site wide water and load balance (SRK 2016b).

Since its construction, the North Dam has been subjected to annual geotechnical inspections by a professional geotechnical engineer licensed to practice in Nunavut in accordance with the stipulated Water Licence conditions (SRK 2013, 2014a, 2014b, 2016d). The inspection reports include a comprehensive analysis of the rigorous dam instrumentation confirming the dam is functioning as designed.

2.4.2 North Dam Spillway

The water level in the TIA will be actively managed through annual discharges to Roberts Bay. Because the North Dam is a frozen core dam, its design requires a substantive thermal freeboard which far exceeds the hydraulic freeboard requirement. As a result, there are no plausible scenarios where the TIA will ever exceed the North Dam hydraulic freeboard level, and therefore an outflow spillway will not be required.

However, as a matter of best practice, an operational spillway has been designed for the TIA at the North Dam at a FSL of 33.5 m. This side-spillway will be 18 m wide and about 180 m long along its centerline with an average gradient of about 0.8%. At the time of its design, the inflow design flood (IDF) was calculated as 3.3 m^3/sec, meaning that flood passing through the spillway would have a maximum flow depth of about 0.2 m at a sub-critical flow velocity of about 1.1 m/sec (SRK 2007a).

As part of Phase 2, the freeboard assessment has been revisited (Appendix E) to allow containment of the probable maximum flood (PMF) such that construction of the spillway will no longer be required.

2.5 Tailings Management System Changes

Table 2 summarizes the proposed changes to the TMS presented in this report and is compared against the existing licensed TMS.

Table 2. Summary of Proposed TMS Changes

Component	Existing Licensed TMS (Phase 1)	Proposed Revised TMS (Phase 2)
Tailings Volume (tonnes)	2.5 million	Additional 15.5 million, for a total of 18.0 million
Tailings Production Rate	1,000 tpd for first two years, ramping up to 2,000 tpd for remaining mine life	1,200 tpd for first year; 2,400 tpd for next 2 years; 3,600 tpd for remaining mine life except last year of mining when production rate drops to 2,400 tpd
Tailings Make-up	Only flotation tailings; detoxified cyanide leach tailings is deposited underground	No change
Deposition Method	Subaerial (single point discharge; multiple locations)	No change (actual spigot locations does differ)
North Dam	Frozen core dam with secondary GCL, construction completed in 2012; FSL at 33.5 m	No change to dam structure; At later stages of the project life when the Reclaim Pond reduces in size the FSL will be lowered to accommodate the IDF
North Dam Spillway	Invert at 33.5 m; designed to pass 1:500 years; 24 hour flood	Not required. Freeboard adjusted to allow containment of IDF of PMF
South Dam	Frozen foundation with GCL liner; Crest elevation 38.0 m	Dam raised by 8 m (downstream method) to a crest elevation of 46.0 m
Interim Dike	New containment structure	Superseded; will be buried by tailings as deposition progresses
West Dam	Did not exist	Frozen foundation with GCL liner; crest elevation of 46.0 m
TIA Discharge Strategy	Seasonal discharge to Roberts Bay; Fixed constant discharge rate; CCME guidelines for the protection of aquatic life (marine) to be met beyond mixing zone in Roberts Bay	No change, with exception of possible year-round discharge at later stages of the project life
Closure Strategy	Breach North Dam; 0.3 m thick dry cover over tailings	No change

The access road to the South Dam will have to be completed in Phase 1 prior to construction of the dam. While not affecting the TIA design directly, the alignment of the road will have to be changed in due time as tailings deposition in Phase 2 will result in sections of the current alignment being submerged in tailings.

3 Tailings Management System Design Criteria

3.1 Dam Hazard Classification

The design, construction, operation and monitoring of dams in Canada have to be completed in accordance with appropriate territorial, provincial, and federal regulations and industry Best Management Practices. The foremost guidance documents are the Canadian Dam Safety Guidelines (CDA 2007, 2013) and the Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014) published by the CDA.

A key component of the guidelines is classifying the dams into hazard categories (dam class) and establishing appropriate geotechnical and hydro-technical design criteria. Table 3 is a reproduction of the recommended dam classifications as presented in CDA (2013). This classification is based on the incremental consequence of a dam failure (as opposed to total consequence). The incremental consequences of failure are defined as the total damage from an event with dam failure, less the damage that would have resulted from the same event (e.g., a large earthquake or a large flood event) had the dam not failed.

Table 3. Dam Hazard Classification

Dam Class	Population at Risk[1]	Incremental Losses		
		Loss of Life[2]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary Only	Unspecified	No significant loss 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 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)

[1] Definitions for population at risk:
None – There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseen misadventure.
Temporary – People are only temporarily in the dam-breach inundation zone (e.g. seasonal cottage use, passing through on transportation routes, participating in recreational activities).
Permanent – The population at risk is ordinarily located in the dam-breach inundation zone (e.g. as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

[2] Implication of loss of life:
Unspecified – The Appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Determination of the appropriate hazard rating is often subjective and is dependent on site-specific circumstances that may require an agreement between the proponent, regulators, and stakeholders. During the dam classification process, each of the four hazard rating components in Table 3 (i.e., population at risk, loss of life, environmental and cultural values, and infrastructure and economics) is considered individually and the overall dam hazard rating is defined by the component with the highest (i.e., most severe) rating. It is important to note that the hazard rating refers to the downstream consequences in the inundation zone of a dam breach.

For all three dams, the "*Population at Risk*" has been generously selected as "*Temporary Only*" due to the very infrequent need for personnel to monitor the dams and areas in the likely dam breach inundation zone. The "*Loss of Life*" has again conservatively been selected as "Unspecified" to reflect that there will be short and infrequent periods of time where people will be present in the in the likely inundation zone.

The "*Environment and Cultural*" impacts associated with a breach of the North Dam will be associated with release of supernatant water (not solids) to Doris Lake and subsequently Doris Creek, which will exceed CCME guidelines for protection of aquatic life (fresh water). A breach of the South Dam could result in release of tailings solids and supernatant water into Ogama Lake, and subsequently supernatant water into Doris Lake. A breach of West Dam could result in release of tailings solids and supernatant water into Doris Lake. Ogama Lake and Doris Lake are considered significant habitat, but restoration of this habitat would be highly possible.

"*Economic*" consequences of a breach of any of the three structures could be significant in terms of direct costs to the proponent, including reputational loss, but would be very minimal in terms of losses to infrastructure or services that might affect other parties.

Based on these factors, the three containment structures are assigned a dam hazard classification as summarized in Table 4.

Table 4. Dam Hazard Classification of TIA Containment Structures

Dam Class	Population at Risk	Loss of Life	Environmental and Cultural Values	Infrastructure and Economics	Overall Hazard Classification
North Dam	SIGNIFICANT	SIGNIFICANT	HIGH	LOW	HIGH
South Dam	SIGNIFICANT	SIGNIFICANT	HIGH	LOW	HIGH
West Dam	SIGNIFICANT	SIGNIFICANT	HIGH	LOW	HIGH

3.2 Design Life

Mining and ore processing for Phases 1 and 2 of the Project is expected to be completed in about 17 years, which is 11 years longer than Phase 1. Once tailings deposition ceases, the North Dam is expected to remain operational for approximately 0.5 years, after which it will be breached. Therefore, the TIA operational life (i.e. the period prior to final closure) is 18 years.

The ultimate design life of the North Dam was set to 22 years, to account for the time passed since the dam was constructed. At closure, the West and South dams will continue to be required to contain tailings solids (but no water). These structures must therefore remain in perpetuity.

The North Dam, which was completed in 2012 (SRK 2012), had an original design life of 20 years as a water retaining structure, assuming it was operating 100% of the time at FSL (33.5 m). Since its completion, the normal water level in the TIA has been about 28.5 m, with a peak of 29.3 m. The most up to date monitoring confirms that the structure is performing in accordance with the design (SRK 2016d), and therefore it is reasonable to conclude the structure still has a useable design life of at least 22 years. Additional stability, thermal and creep deformation analysis confirms the expected dam performance can be maintained for a period well over the 22 years of the design life.

3.3 Tailings Physical Properties

Physical properties of the tailings were determined based on three separate geotechnical test campaigns carried out between 2003 and 2009 (Appendix F) and summarized in Table 5.

Table 5. Summarized Tailings Geotechnical Properties

Parameter	Value
Specific gravity	2.85
% Fines (<0.075 mm)	65%
% Silt	52%
% Clay	13%
Void ratio (e) for slurried tailings	1.2
Deposited dry density (Tonnes/m^3) for slurried tailings	1.30
Internal angle of friction (degrees)	40
Cohesion (kPa)	0
Gravimetric Moisture Content (%)	42.6
Hydraulic Conductivity (m/s)	$1.3x10^{-7}$

3.4 Tailings Beach Slope

Subaerial tailings placement will result in beach development (Figures 9 and 12). Specific tailings characterization has not been carried out to confirm the expected tailings beach slope angle for the Project; however, typical gold tailings deposited sub-aerially are known to have beach slope angles that range between 0.5 and 2% (Vick 1990). Where the tailings beach transitions to a pond, the slope angle can increase to between 5 and 7%. An overall beach slope angle of 1% has conservatively been assumed for the purposes of tailings deposition modeling for the Project (Appendix A). Should the actual slope be substantially different, additional deposition points will be added into the overall tailings deposition plan to ensure that the final landform can still be developed.

3.5 Tailings Storage Requirement

The revised mine plan for Phase 2 has a targeted ore production of about 18.7 Mt, over and above the 2.5 Mt of Phase 1 ore. 18 Mt or this total ore will be deposited in the Doris TIA, with the remaining ore being placed in the Boston TMA (SRK 2016a).

For the selected TIA tailings deposition strategy the tailings dry density is about 1.3 tonnes/m^3 (SRK 2016e). This results in an ultimate tailings volume of about 14.0 Mm^3 deposited at a production rate that ranges between 1,200 and 4,800 tpd.

About 8% of the tailings are comprised of detoxified cyanide leach tailings. These tailings will be sent underground where it will be mixed with underground waste rock for use as structural mine backfill. For the purpose of design, this reduction in volume is not considered material and was not subtracted from the total volume. Ice entrainment during subaerial tailings deposition is a common problem for arctic projects (BGC 2003). An allowance of 20% has been accounted for in the TIA design. Complete Project tailings storage requirements are summarized in Table 6.

Table 6. Tailings Storage Requirements

Component	Value	Source
Tailings storage requirement (Phase 2 only)	12.0 Mm^3 (15.5 Mt)	Quantity based on the mine plan (TMAC 2016a); volume conversion based on dry density listed below in this table. Quantity does not include Phase 1 tailings at 2.5 Mt. Value has been rounded up to nearest million.
Tailings production	1,200 tpd for first year; 2,400 tpd for next 2 years; 3,600 tpd for remaining mine life except last year of mining when production rate drops to 2,400 tpd	Supplied by TMAC.
Tailings production period (Phase 2 only)	17 years	Based on the mine plan (TMAC 2016a).
Ice entrainment allowance	2.4 Mm^3 (20% by volume)	Contingency allowance based on engineering judgement and case studies reported by BGC (2003).
TIA storage requirement (Phase 2 only)	14.4 Mm^3	Sum of tailings storage requirement and ice entrainment allowance.
Run-off and contact water allowance	Not required	Additional storage capacity not required as water will be directed towards the Reclaim Pond. Overall water management will be via the Reclaim Pond.
Deposited tailings dry density	1.3 t/m^3	See Appendix F.

3.6 Stability Criteria

The minimum factors of safety (FOS) that are required to be achieved for the raised South and West dams are defined by CDA (2014) and are reproduced in Table 7.

Table 7: Minimum Required Factors of Safety

Stability Condition	Minimum Factor of Safety	Slope
Static Assessment		
During, or at end of construction	Greater than 1.3 depending on risks assessed during construction	Typically downstream
Long-term (steady-state seepage, normal reservoir level)	1.5	Downstream
Full or partial rapid drawdown	1.2 to 1.3	Upstream slope where applicable
Seismic Assessment		
Pseudo-static	1.0	Downstream
Post-earthquake	1.2	Downstream

Note: This table is summarized from Tables 3-4 and 3-5 in CDA (2014)

3.7 Design Earthquake

Based on the dam hazard classification of HIGH assigned to the South and West dams the annual exceedance probability (AEP) earthquake design ground motion will be 1:2,475 using both the risk-informed and standards based approaches (CDA 2014). A detailed analysis of the site specific seismic factors was completed (SRK 2016f) with resultant peak ground acceleration (PGA) of 0.021 g and 0.025 g for the South and West dams, respectively.

CDA (2014) specifies for long-term scenarios, i.e. operations and post-closure, the seismic event for a dam with the hazard classification of HIGH must be increased to halfway between the 1:2,475 and 1:10,000-year event. The PGA associated with this condition is 0.036 g and 0.043 g for the South and West dams, respectively. These higher values were used in the pseudo-static analysis.

3.8 Inflow Design Flood

For dams with a HIGH hazard classification, the inflow design flood (IDF) is defined to be 1/3 between the 1,000-year event and the PMF (CDA 2014). The TIA was however designed without a spillway, thus requiring the retention of the full PMF event. The IDF was therefore increased to account for the PMF corresponding to a dam with an EXTREME hazard classification.

A detailed assessment of the inflows was completed (Appendix E) and took into account the local and regional climate models (SRK 2016g), and the critical (i.e. most conservative) case was determined to be the snowmelt-dominated spring PMF (i.e. probable maximum snow accumulation + 1:100 year 24 hour rain storm). This translates to a volume of 915,382 m^3 related to snowmelt and 178,718 m^3 related to rainfall for a total IDF volume of 1,094,000 m^3.

3.9 Design Freeboard

The South and West dams are not water retaining structures. Tailings beaches will be developed along the upstream slope of these dams to create a final topography free-draining towards the Reclaim Pond ensuring no water will pond adjacent to these structures. The GCL in both of these dams will terminate at elevation 45.0 m, 11.5 m above the TIA FSL. Tailings deposition will commence from discharge points located near the dam crest at elevation 44.5 m for both the South and West dams, leaving a freeboard of 1.5 m.

The North Dam is a water detaining structure and is subject to wind a wave action. The hydraulic freeboard is the more critical (CDA 2013) of the following two cases:

- Normal freeboard: no overtopping by 95% of the waves caused by the most critical wind with a frequency of 1 in 1,000-year when the reservoir is at its maximum normal elevation; and
- Minimum freeboard: no overtopping by 95% of the waves caused by the most critical wind associated with the AEP event, when the reservoir is at its maximum extreme level immediately following the inflow design flood.

However, the possibility of the extreme high water levels occurring at the same time as the high wind event must also be considered for mining dams (CDA 2014). This was assessed by evaluating a combined freeboard considering the pond elevation following the IDF event as well as 1:1,000-year wind. The calculated values for the combined freeboard were adopted as the design criteria for the TIA.

The increase in the Reclaim Pond elevation at the end of mine life, when the Reclaim Pond is at its smallest, associated with the IDF is about 2.1 m (Appendix E). Therefore, if the Reclaim Pond has a FSL of 33.5, the water level during the IDF will be at elevation 35.6 m.

Consequently the design freeboard is the sum of the wind setup (0.06 m), the wave run-up (1.16 m), and the rise due to the IDF (2.1 m). This equates to 3.3 m of freeboard required above the FSL level of 33.5 m, or an equivalent elevation of 36.8 m. The crest of the North Dam is at a minimum elevation of 37.5 m which exceeds the required freeboard by about 0.7 m.

Based on the current conservative design assumptions, when the Reclaim Pond is at its minimum capacity at the end of the 17 year mine life, the rise in pond elevation required to store the IDF will result in the pond water level exceeding the top elevation of the water retaining component (frozen core) of the North Dam by about 0.3 m. The actual pond stage storage curve will be monitored during operations to update this analyses and if required the FSL will be lowered to accommodate the IDF storage volume below the frozen core elevation in the final years of operations.

3.10 Summary of TMS Design Criteria

A complete summary of the TMS containment dam design criteria are listed below (Table 8), and are consistent with Best Management Practices, including the CDA (2013, 2014) guidelines.

Table 8. Summary of TMS Containment Dam Design Criteria

Component	Criteria
Dam Hazard Classification	North Dam (HIGH) South Dam (HIGH) West Dam (HIGH)
Design Life • Active use period as water retaining structure • Design basis as active water retaining structure • Active use period as solids retaining structure • Design basis as solids retaining structure • Total life until breach	 North Dam (17 years) North Dam (22 years) South Dam (17 years); West Dam (17 years) South Dam (25 years); West Dam (25 years) North Dam (22 years)
Dam staging	North Dam (none, construction completed in 2012) South Dam (single downstream raise planned increasing crest from 38 m to 46 m) West Dam (none)
Tailings production rate	1,200 tpd for first year; 2,400 tpd for next 2 years; 3,600 tpd for remaining mine life except last year of mining when production rate drops to 2,400 tpd
Tailing slurry solids content	37.5% solids (by weight)
Tailings solids specific gravity	2.85
Tailings settled density	1.3 t/m^3
Tailings storage requirement (Phase 2 only) • By mass • By volume	 12.0 Mt 15.5 Mm^3
Ice entrainment allowance • Percentage of tailings capacity • By volume	 20% 2.4 Mm^3
Tailings beach slope • Subaerial tailings • Sub-aqueous tailings	 1% 1%
Tailings deposition method	Single point spigot subaerial discharge (eight locations over the life of mine)
Maximum design earthquake	Halfway between 1:2,475 and 1:10,000 AEP; PGA of 0.036 g (South Dam) and 0.043 g (west Dam)
Inflow design flood	PMF; approximately 1,094,000 m^3
Freeboard requirement	North Dam (1.0 m normal, 3.3 m total) South Dam (0.5 m normal, 1.5 m total) West Dam (0.5 m normal, 1.5 m total)
Stability FOS (Static)	1.3 during construction 1.5 during operation and closure 1.2 to 1.3 partial or rapid drawdown
Stability FOS (Pseudo-Static)	1.0 during earthquake 1.2 post earthquake

4 South Dam and West Dam Design

4.1 Foundation Conditions

4.1.1 South Dam

Rigorous foundation characterizations have been carried out at the proposed South Dam alignment (SRK 2003b, 2005a, 2007a) and are summarized in SRK (2016f). The foundation conditions are variable with the overburden thickness thinning significantly towards the abutments (Figures 6 and 7). Towards the center of the proposed alignment, the overburden profile is at its maximum thickness. The upper approximately 5.5 m of the profile consists of marine silt, which transitions to marine silt and clay to a depth of about 24 m below ground surface (i.e. about 18.5 m thick). Beneath these sediments is a layer of gravelly till of about 10 m thickness overlying the host basalt bedrock. The entire profile is cold permafrost (-8ºC surface temperature), with an active layer thickness of about 1 m. The marine silts and clays are ice rich with clear ice lenses present. Salinity results from samples collected in the footprint of the South Dam foundation indicate salinity ranges from 6 to 86 parts per thousand, with an average of about 47 parts per thousand. This results in a depressed freezing point of about -2.6ºC in accordance with Velli and Grishin's empirical formulation (Andersland and Ladanyi 2004).

No subsurface investigations were carried out to date to characterize the foundation conditions downstream of the starter dam. For design purposes it was assumed that the stratigraphy described above extends southward to underlay the footprint of the South Dam raise. Detailed confirmation geotechnical investigations will be required prior to the detailed design stage for the South Dam raise.

4.1.2 West Dam

Minimal subsurface investigations were completed within the footprint of the West Dam, consisting of a single borehole. The borehole log indicates that overburden is consisting of silty clay to a depth of 7 m (Appendix G). Geophysical investigations including ground penetrating radar (GPR) were carried out around the perimeter of Tail Lake (SRK 2006). The nearest GPR line is located about 200 m to the east of the proposed West Dam and indicates depth to bedrock between 3 and 5 m, which is consistent with the thickness indicated in the borehole log.

Regarding the thickness of the overburden profile in the longitudinal direction of the West Dam (parallel to the dam centerline), it was assumed that the overburden thins out gradually and tapers off at the abutments where bedrock is outcropping. The gentle surface topography and the saddle-type topography are a good indicator of the overburden thickness.

4.2 Functionality and Design Parameters

4.2.1 South Dam

The South Dam was originally designed as a frozen core dam (Figures 6 and 7) and was intended to retain water for a period of up to 20 years (SRK 2005a, 2007a). With the revised TMS for Phase 1 (SRK 2015a), the South Dam is not required to retain water since the tailings will be deposited as a beach from the face of the dam early on during the tailings deposition plan. As a result the South Dam design for Phase 1 has been changed to a frozen foundation dam consisting of a compacted rock fill dam with a GCL keyed into the permafrost overburden foundation. To accommodate the increased tailings quantities in Phase 2, the South Dam will be raised by 8 m in a downstream configuration to reach a crest elevation of 46.0 m.

The South Dam has been designed with a crest width of 10 m and an upstream slope of 4H:1V and downstream slope of 2H:1V. The dam raise will retain the original design parameters for slope grades and crest width. The Phase 1 dam crest elevation is 38.0 m resulting in a maximum dam height of 6 m. The dam raise will increase the maximum height to 14 m (crest elevation 46.0 m).

The key trench configuration and geometry of Phase 1 will be retained in Phase 2 with additional sections to be excavated near the two abutments (Figure 6). The key trench will be about 4 m deep and will have a base width of 4 m with 2H:1V, and 1H:1V upstream and downstream slopes respectively (Figure 7). The GCL will be placed along the entire base of the key trench, along the upstream face of the key trench and then slope back within the center of the dam at a slope of 3H:1V (Figure 8). The dam raise will also include tying into and raising the GCL liner. The slope of the liner on the raised portion of the dam was however changed to 4H:1V to accommodate geometric constraints of the raise.

4.2.2 West Dam

The frozen foundation West Dam will be built with the same dam cross section as the Phase 1 South Dam, with a key trench and a GCL liner keyed into permafrost. This dam will be constructed in a single raise, and will be about 470 m long with a maximum height of 5 m (crest elevation 46.0 m).

The key design parameters of the TMS containment structures are summarized in Table 9.

Table 9. Summary of Phase 2 TMS New Containment Structure Design Parameters

Parameter	South Dam Raise	West Dam
Structure type	Downstream raise of the frozen foundation rock fill dam with geomembrane	Frozen foundation rock fill dam with geomembrane
Geomembrane type	GCL	GCL
Geomembrane deployment slope	3H:1V (4H:1V for the raise)	3H:1V
Structure crest centerline length	515 m	470 m
Structure maximum height	14.0 m	5.0 m
Structure crest elevation	46.0 masl	46.0 masl
Full supply level (FSL) (i.e. maximum elevation of tailings)	44.5 masl	44.5 masl
Total freeboard	1.5 m	1.5 m

Parameter	South Dam Raise	West Dam
Spillway	None	None
Structure crest width	10 m	10 m
Upstream structure slope	4H:1V	4H:1V
Downstream structure slope	2H:1V	2H:1V
Key trench depth	4.0 m	4.0 m
Key trench upstream slope	2H:1V	2H:1V
Key trench downstream slope	1H:1V	1H:1V

4.3 South Dam Components

4.3.1 Phase 1 Dam

The Phase 1 dam, approved under the existing Water Licence, has a crest elevation of 38.0 m and incorporates a GCL liner as the seepage control element.

4.3.2 Dam Raise Method

The dam raise will be constructed as part of Phase 2 development and will bring the crest elevation to 46.0 m. The raise must be done in one single step as the tailings deposition strategy requires tailings discharge to be started from the crest of the completed raise.

Dam raises are typically constructed in one of three ways: upstream, downstream, or centerline. The construction method for the upstream and centerline methods require most (upstream), or a part of (centerline) the dam wall to be constructed on previously deposited tailings. In contrast, a downstream configuration requires being built completely outside of the previously deposited tailings footprint.

The upstream configuration is typically the least costly, requiring the least amount of additional fill material; however, a large portion of the raise is founded on the existing tailings. The downstream construction method completely envelops the starter dam (Phase 1 dam) and extends the downstream footprint, requiring the largest amount of dam construction material of the three methods. The centerline method is a compromise between the two previous methods.

It was concluded that founding the dam raise completely or partially onto partially frozen tailings would be a high risk for differential settlement and unacceptable deformation of the dam crest, with possible tear of the GCL liner. Therefore, the downstream configuration is the most appropriate in the case of the South Dam raise.

4.3.3 Key Trench

The seepage control component of the South Dam is the GCL liner, which is keyed into the frozen foundation. The Phase 1 key trench extends to a top elevation of 37.0 m at the abutments and will have to be extended when the dam is raised. This extension cannot be in line with the original key trench, but will turn south towards the abutments of the Phase 2 crest extents. The key trench extension will follow the same design cross section as the Phase 1 dam key trench.

Consistent with the Phase 1 key trench design, the key trench will be excavated in the frozen overburden soils underlying the dam to a depth of about 4 m (Figure 7). The key trench will terminate in frozen soil; however, should any massive ice be encountered, the key trench will be deepened until all massive ice has been removed. The upstream slope of the key trench will be excavated to 2H:1V to accommodate the deployment of the geomembrane. The downstream slope will be excavated to a grade of 1H:1V to minimize the excavation.

Excavation of the key trench must be done in the winter when the ground is completely frozen. This is necessary to ensure that the ground is as cold as possible before backfilling starts to facilitate the bond between the foundation and the geosynthetic liner. Drill and blast methods will be required to excavate the key trench, and due to the possible high ice content and nature of the soils, a tight drill pattern and high blast load factor will be required. The excavated material will have to be hauled away and disposed of in designated overburden dump, most likely at Quarry #3.

4.3.4 Geosynthetic Clay Liner

The GCL will be the water retaining element of the dam and will be frozen into the key trench to provide the necessary seal. The GCL of the Phase 1 dam was deployed in a chevron shape starting at the base of the key trench, along the upstream 2H:1V key trench slope, sweeping back on a 3H:1V slope to an elevation of 37.0 m, 1 m below the Phase 1 dam crest (Figure 7).

In preparation for the dam raise, the top of the existing GCL will be exposed by removing the overlying fill and protective cover material. The new GCL sections will be placed in a manner similar to that used in Phase 1. Where the Phase 1 and Phase 2 junction occurs, GCL panels will overlap at least 1 m wide and will include a bead of granular bentonite. The Phase 2 GCL panels will extend to elevation 45.0 m, 1 m below the ultimate dam crest.

The GCL along the raised portion of the dam will be deployed at a slope of 4H:1V, shallower than the 3H:1V slope of the Phase 1 dam. This change in slope is necessary to accommodate the key trench geometry resulting from the downstream raise. The bedding and protection layers of gravel will be tied-in with the Phase 1 dam zones (Figure 8).

The top edge of the GCL will be terminated in an appropriately sized anchor trench. The GCL will be deployed in vertical strips (the width of the GCL rolls). Overlaps will be at least 0.5 m wide, and all overlaps will have a seal of powdered bentonite.

In the base of the key trench, the GCL will be placed directly onto the prepared and clean foundation with imperfections filled with granular bentonite. In all other areas, the GCL will be sandwiched between two 0.3 m thick compacted layers of crushed gravel (pea gravel size).

4.3.5 Dam Bulk Fill

The bulk fill of the starter dam, including the key trench, consists of geochemically suitable run-of-quarry (ROQ) material. The bulk fill of the dam raise will consist of the same type of material. The quarry rock size will be limited to material with a maximum size of 600 mm and well graded with a good mix of fines. This material must be placed in lifts no greater than 1 m and must be compacted with a 15 tonne vibratory compactor or using wheel traffic from loaded haul trucks.

4.3.6 Transition Zone

In the Phase 1 dam, the GCL is protected using a fine crushed gravel (pea gravel) produced from ROQ material. To minimize losses of this bedding material, a transition zone of 150 mm minus crushed ROQ material was placed between the bedding and dam bulk fill zones. Prior to raising the dam, the top of this transition zone will be exposed and then extended to reach the design elevation of the dam raise.

The material must be well graded with sufficient fines. This bedding layer will be about 1 m thick, will be placed in a single lift, and compacted using the same means as the dam bulk fill.

4.3.7 Bedding Zone

For the dam raise the GCL will be sandwiched between two 0.3 m thick compacted layers of bedding material for protection. The top of the bedding zone will be removed from over the GCL and once the new GCL extension was installed, the bedding material will be replaced to create a continuous protective bedding layer (Figures 7 and 8). This material will be ROQ material crushed to pea gravel size.

4.3.8 Dam Shell

No special dam armouring is required and no special upstream or downstream riprap is required. The dam shell will be constructed using the same ROQ material as the dam bulk fill.

4.3.9 Monitoring Instrumentation

Ground temperature cables installed in the key trench of the Phase 1 dam will be protected during construction and maintained for continuous monitoring of the dam performance. The thermal monitoring will be supplemented by new ground temperature cables located within the dam raise as well as the extended key trench. Some of the survey prisms of the Phase 1 dam will be destroyed during construction, and the overall deformation monitoring will rely on new prisms installed in appropriate locations in the raised portion of the dam.

Vertical ground temperature cables will be installed in boreholes drilled through the dam fill after the completion of the dam raise and the new cables will extend to the original ground level. The portion of the boreholes within the ROQ fill may require temporary casing. Horizontal ground temperature cables will be placed within the liner bedding layer along the upstream side of the key trench.

Survey prisms will be permanently installed in large boulders within the dam shell.

4.4 West Dam Components

4.4.1 Timing

The West Dam was designed using the same typical section as the Phase 1 South Dam. Being a dam with a relatively low height, it will be constructed in a single raise; however, the dam construction could be delayed as it will not become necessary until Year 3 of the Phase 2 tailings deposition. The design elements of the West Dam are detailed below.

4.4.2 Key Trench

Considering the foundation conditions along the proposed alignment of the West Dam, the key trench will be excavated in the frozen overburden soils underlying the dam to a depth of about 4 m (Figures 10 and 11). The key trench will terminate on frozen overburden soil; however, should any massive ice be encountered, the key trench must be deepened until all of the massive ice has been removed. The upstream slope of the key trench will be excavated to 2H:1V to accommodate the deployment of the geomembrane. The downstream slope will be excavated to a grade of 1H:1V to minimize the excavation.

Excavation of the key trench must be completed in the winter when the ground is completely frozen. This is necessary to ensure that the ground is as cold as possible before backfilling starts, facilitating the bond between the foundation and the GCL. Drill and blast methods will be required to excavate the key trench, and due to the possible high ice content and nature of the soils, a tight drill pattern and high blast load factor will be required. The excavated material will have to be hauled away and disposed of in designated overburden dumps, most likely at Quarry #3.

4.4.3 Geosynthetic Clay Liner

The GCL will be the water retaining element of the dam and will be frozen into the key trench to provide the necessary seal. The GCL will be deployed in a chevron shape, starting at the base of the key trench, along the upstream 2H:1V key trench slope, and then sweeping back on a 3H:1V slope to an elevation of 45.0 m, 1 m below the dam crest (Figure 11). The top edge of the GCL will be terminated in an appropriately sized anchor trench. The GCL will be deployed in vertical strips (the width of the GCL rolls). Overlaps will be at least 0.5 m wide, and all overlaps will have a seal of powdered bentonite.

In the base of the key trench, the GCL will be placed directly onto the prepared and clean foundation with imperfections filled with granular bentonite. In all other areas, the GCL will be sandwiched between two 0.3 m thick compacted layers of crushed gravel (pea gravel size).

4.4.4 Dam Bulk Fill

The bulk fill of the West Dam, including the key trench, will consist of geochemically suitable ROQ material. The quarry rock size will be limited to material with a maximum size of 600 mm and well graded with a good mix of fines. This material must be placed in lifts no greater than 1 m and must be compacted with a 15 tonne vibratory compactor or using wheel traffic from loaded haul trucks.

4.4.5 Transition Zone

The GCL is protected using a fine crushed gravel (pea gravel) produced from ROQ material. To minimize losses of this bedding material, a transition zone of 150 mm minus crushed ROQ material will be placed between the bedding and dam bulk fill zones. The material must be well graded with sufficient fines. This bedding layer will be about 1 m thick, placed in a single lift, and compacted using the same means as the dam bulk fill.

4.4.6 Bedding Zone

The GCL will be sandwiched between two 0.3 m thick compacted layers of bedding material for protection. This material will be ROQ material crushed to pea gravel size.

4.4.7 Dam Shell

No special dam armouring is required, and no special upstream or downstream riprap is required. The dam shell will be constructed using the same ROQ material as the dam bulk fill.

4.4.8 Monitoring Instrumentation

A series of ground temperature cables and survey prisms will be installed at the West Dam to monitor the thermal regime of the foundation and overall deformation performance.

Vertical ground temperature cables will be installed in boreholes drilled through the dam fill after the completion of the dam. The portion of the boreholes within the rock fill may require temporary casing. Horizontal ground temperature cables will be placed within the geomembrane bedding layer along the upstream side of the key trench.

Survey prisms will be permanently installed in large boulders within the dam shell.

4.5 Stability Analysis

A comprehensive stability analysis was carried out to confirm whether the raised South Dam and the West Dam meet the appropriate design requirements as stipulated in Section 3.6. Complete details of the analysis are presented in Appendix B and the results are summarized in Tables 10 and 11.

Table 10. South Dam Minimum Factors of Safety

Stability Condition	Required Minimum Factor of Safety (CDA 2014)	Assessed Minimum Factor of Safety	
		Upstream Face	Downstream Face
Short Term (Construction)	Greater than 1.3	1.6	1.3
Long Term	1.5	1.6	1.6
Full or Partial Rapid Drawdown	1.2 to 1.3	Not applicable	Not applicable
Pseudo-static	1.0	1.4	1.2

Table 11. West Dam Minimum Factors of Safety

Stability Condition	Required Minimum Factor of Safety (CDA 2014)	Assessed Minimum Factor of Safety	
		Upstream Face	Downstream Face
Short Term (Construction)	Greater than 1.3	1.8	1.3
Long Term	1.5	2.3	1.5
Full or Partial Rapid Drawdown	1.2 to 1.3	Not applicable	Not applicable
Pseudo-static	1.0	1.4	1.1

Both the South Dam raise and the West Dam meet all the required minimum slope stability FOS as prescribed by CDA (2014). This applies for the expected most conservative condition of a partially thawed undrained foundation. Detailed site characterization, and associated material property testing have been carried out under the Phase 1 South Dam alignment, and as a result there is a high level of confidence in these results.

4.6 Settlement Analysis

Settlement of the South and West Dams could occur as a result of one of two reasons: dam fill consolidation or foundation consolidation. Since the dam's fill are compacted ROQ material and the total dam height is limited, there is no expectation of any appreciable fill settlement.

Foundation settlement beneath the South and West Dams could occur as a result of thaw consolidation. Normal thaw consolidation can also be exacerbated by thaw of massive ice which may be present in the foundation soils. Thermal analysis (Appendix H) has however demonstrated the foundation beneath both dams will remain frozen for the design life of the structure. As a result, thaw consolidation is not expected to be of concern while this facility is in active operation.

4.7 Deformation (Creep) Analysis

4.7.1 North Dam

Creep deformation analysis was completed as part of the original North Dam design (SRK 2007a, EBA 2006). This analysis considered the original design life of the North Dam of 25 years. Since the Phase 2 Project extends the North Dam design life to 2041 (i.e. 30 years from 2011 when construction started), a reassessment of the creep deformation analysis was undertaken. This new timeline assumes a period of nominal water impoundment prior to start of tailings deposition in 2017, active tailings deposition between 2017 and 2036, and a five-year post closure period prior to breaching the dam in 2041.

The objective of the creep deformation analysis is to anticipate if long-term strains, occurring over the dam design life, can affect the performance or compromise the stability of the North Dam. The analysis also confirms whether the integrity of frozen ice-saturated core and underlying saline foundation will be affected by creep deformations occurring in these two zones, and if the level of the core crest remains above the FSL throughout the dam design life.

The detailed analysis is presented in Appendix D and confirms the following:

- Long-term ductile behavior is predicted for the materials in the ice-saturated frozen core and underlying frozen foundation. Creep shear strains in these zones will occur very slowly and will remain below the strain rate for brittle failure modes.
- Vertical creep displacements will not compromise the long-term integrity of the frozen core and underlying foundation. Shear and deviatoric stresses in these zones caused by creep strains will remain well below the expected peak strengths of the materials. No shear strain localization is predicted within and underneath the frozen core.
- Long-term performance of the frozen core is not expected to be compromised throughout the dam design life. Thirty years after dam construction, the total settlement of the core will be around 1.0 m, i.e., 0.5 m above the FSL.
- Shear strains are predicted to localize at the downstream side of the dam. Thirty years after dam completion, high shear strains (~ 60%) with very low strain rates (~1.0E-08 year-1) can be expected in few points within the localization surface. However, shear stresses and principal stress differences will remain well below the expected peak deviatoric stress of the materials (> 1 MPa).

4.7.2 South Dam and West Dam

The South and West dams will be subject to creep deformation over the very long term. Creep has previously been assessed for the South Dam (SRK 2007a), and no further analysis was completed. Deformation monitoring during the operational phase of the structures will be undertaken, and if required, the downstream dam slopes will be flattened to 4H:1V as was the case for the original South Dam design. However, the revised thermal analysis (Appendix H) suggests this will likely not be required. Notwithstanding this possible mitigation strategy, the South and West dams will not retain saturated tailings, and therefore the structure can tolerate a large amount of long term deformation.

4.8 Thermal Analysis

4.8.1 North Dam

An updated thermal model was completed (Appendix C) to predict the behavior of the North Dam based on the extended design life of the structure. The analysis assumes a very conservative constant water level in equal to the FSL of 33.5 m. The modeling was completed for a 48-year design life (ending in calendar year 2050) which extends well beyond the expected period of mining and subsequent closure. The calibrated model, with consideration for climate change and conservative inputs indicate the frozen core will remain below the required -2°C under normal operating conditions.

Towards the end of the design life, the foundation over a portion of the critical section is expected to be warmer than -8°C beneath the thinnest sections of the dam, i.e. near the abutments. The warmer foundation conditions will result in a higher fraction of unfrozen water and a greater potential for creep deformation. The thermal criteria is met over the actual expected design life for the thickest section of the dam which impounds the greatest head of water, indicating that the dam will perform as intended for the expected life of the facility.

4.8.2 South Dam and West Dam

Rigorous thermal modeling was completed to determine whether the foundation of the South and West dams would function as proposed (Appendix H). The modeling confirms, using conservative assumptions, the GCL would remain frozen into the underlying foundation for the required mine life, and if fact perpetuity. The analysis was completed taking into account the freezing point depression as a result of overburden soil pore water salinity.

4.8.3 Tailings

Freeze-back of the placed tailings was assessed as part of the South and West dams thermal models. Tailings freeze-back was predicted to range from 13 years near the South Dam to 2 years near the West Dam, depending on the thickness of the tailings layer. This assessment is however based on the conservative assumption that the entire volume of tailings and the associated thermal forcing is applied instantaneously at the beginning of tailings deposition and lasts for the entire duration of the deposition. In reality successive thin layers of tailings will be deposited throughout the year, with some of the layers being frozen and some thawed depending on timing of deposition, therefore complete freeze-back is expected to occur much earlier.

The active layer within the tailings is predicted to be just under 1.5 m for the active design life of the dams. Considering climate change, the active layer is predicted to increase to about 2.1 m by the year 2,100.

4.9 Tailings Consolidation Analysis

Tailings consolidation will result in a change of storage capacity over the life of the facility, as well as create a change in landform post closure. A rigorous assessment of the consolidation characteristics of the tailings surface was undertaken (Appendix I) to assess the possible range of settlement, assuming thaw of foundation soils to a depth of 7 m.

These results confirmed that consolidation will be about 1.6 m at the expected maximum thickness of tailings of about 20 m. In addition, assuming fully thawed conditions beneath the tailings, an additional settlement of 1.0 to 2.6 m might be experienced as a result of settlement of the underlying foundation soils due to loading of the tailings.

The tailings thermal analysis associated with the South and West dams (appendix H) indicated freeze back of the individual tailings layers will occur relatively quickly, and therefore the expected settlement in the tailings is not likely to materialize.

4.10 Dam Break Analysis

In accordance with CDA (2013), a dam break analysis may be required when a dam has a hazard rating of HIGH or greater. The purpose of a dam break analysis is to determine the inundation zone downstream of the dam in question should a catastrophic breach occur.

In determining the dam hazard classification, consideration was given to tailings supernatant water and tailings solids reaching the receiving environment. The North Dam will include Tail Lake outflow, Doris Lake, Doris Creek and further downstream Little Roberts Lake. The South Dam will include Ogama Lake, Ogama Lake outflow and subsequently Doris Lake, while tailings breaching the West Dam will reach Doris Lake.

As previously explained, there is no conceivable chance of tailings solids being released as a result of a breach of the North Dam. Supernatant water; however, could conceivably reach the entire downstream catchment all the way to Roberts Bay.

A breach of the South Dam could result in release of tailings solids into Ogama Lake. There is a remote chance that some solids may find their way into the Ogama Lake outflow, and ultimately Doris Lake. The tailings solids will not be transported any further. Supernatant water will; however, progress all the way along the drainage network to Roberts Bay.

Tailings solids from a breach of the West Dam could reach Doris Lake, but at a location about 3.5 km away from the Doris Lake outflow, it is not expected the solids would migrate any further. Supernatant water could progress all the way along the drainage network to Roberts Bay.

The breach scenarios described above are intuitive, although likely extremely conservative. Nonetheless, these scenarios were adopted in assigning the dam hazard classification for the structures. A rigorous dam breach analysis will not result in a different conclusion, and therefore was not done.

4.11 TSF Water Balance

A site wide water and load balance, including the TIA, has been developed for the Project (SRK 2016b). The TIA is designed to contain site-wide contact water, mill process water as well as treated domestic waste water. Reclaim water will be drawn from the TIA Reclaim Pond for re-use in the Process Plant.

There are no non-contact surface water diversions upstream of the TIA. The TIA is located in an isolated catchment, and the benefits of any diversions are outweighed by the relative cost and complexity of constructing them.

4.12 Seepage Analysis

The purpose of the South and West dams is to retain the tailings and supernatant water. Tailings deposition will be done such that a beach will develop upstream of the dams. This will have the resultant effect of ensuring there will never be any water in close proximity of the dams.

While the tailings beach is being developed, there may be short periods when some water may be in close proximity of these dams. However, as it has been demonstrated by the seepage analysis (Appendix B), the maximum amount of seepage that might occur under the worst case scenario is about 50 m^3/day from the South Dam and less than 1 m^3 per day from the West Dam. This result is only predicted if; the tailings remain fully saturated in perpetuity; the TIA is at its full supply level of 33.5 m; and ignoring the fact that most of the tailings and the foundation soils are frozen in the long term.

4.13 Seepage Collection

No seepage collection is planned for either the North, South or West dams since the design analysis confirm that seepage is not expected (SRK 2007a, 2015a, and Appendix B). Should seepage be identified as part of the routine monitoring, a collection system will be implemented and any seepage collected will be pumped back to the TIA.

5 South Dam and West Dam Construction

5.1 Construction Materials

Construction material for the South Dam raise and West Dam consists of bedding, transition and ROQ material. The granular fill will be produced on site from one of many local approved quarries, with Quarry #3 likely being the primary source. Complete geological, mineralogical and geochemical details of these quarry sites are documented in SRK (2007b, 2008).

Other materials to be used to construct these structures include GCL and geotextile. Complete details of these materials are provided in SRK (2011).

5.2 Construction Equipment

Typical construction equipment will be used at the South Dam raise and West Dam. A contractor fleet consisting of 100 tonne trucks will be used for hauling the excavated overburden and the dam fill, with smaller articulated trucks used in the narrower areas near the top of the dam. Bulldozers and smooth drum vibratory compactors will be used to complete the fill placement. Hydraulic excavators may be used for special tasks as required. Drilling and blasting will be completed using conventional tracked blast hole drills.

5.3 Construction Quality Control and Quality Assurance

Complete details of the Quality Assurance and Quality Control (QA/QC) procedures to be followed for the construction activities are provided in SRK (2011). QC will be the responsibility of the Contractor, and/or the equipment and materials manufacturer. The Engineer of Record, a Registered Professional Engineer in the Nunavut Territory, will carry out the QA. Complete documentation of all QA/QC data will be provided in relevant as-built reports.

5.4 Construction Schedule

Extension of the South Dam key trench excavation and backfill must be completed in the winter to eliminate potential issues caused by thawing of the soft overburden soils, as well as to ensure that a thermal blanket is completed to protect the permafrost in the foundation. The bulk of the fill can be completed during any season. Similarly, excavation of the West Dam key trench must be completed in the winter while the bulk fill can be completed during any season.

5.5 Material Quantities

Material quantities for the construction of the South Dam raise and West Dam are summarized in Table 11. All fill and excavation volumes represent neat volumes, i.e. “in place”, with no allowance for swelling and compaction. It was assumed that the key trench excavation will be completed to the full 4 m depth specified, i.e. no termination on shallow bedrock. The liner quantities are neat quantities, with no allowance for seams and waste.

Table 12. South Dam and West Dam Material Quantities

Material	Quantity	
	South Dam Raise	West Dam
Liner Bedding (m^3)	9,300 m^3	6,100 m^3
GCL (m^2)	14,900 m^2	10,000 m^2
ROQ (m^3)	148,500 m^3	33,300 m^3
Transition Fill (m^3)	32,800 m^3	14,700 m^3
Key Trench Excavation (m^3)	8,000 m^3	17,000 m^3

6 Tailings Management System Operation

6.1 Operations, Maintenance and Surveillance Manual

A standalone Operations, Maintenance and Surveillance (OMS) Manual exists for the Doris TIA (TMAC 2016b). The OMS Manual is compliant with Part G of the mine's current Water Licence, the Mining Association of Canada's (MAC) guideline (MAC 2011), as well as CDA (2014). Prior to Phase 2 tailings deposition, this OMS Manual will require updating.

6.2 Tailings Deposition

Complete details of the tailings deposition plan, including the options evaluated, are described in Appendix A. The preferred tailings deposition plan ensures that the supernatant pond will be located away from the South and West dams (Figures 9 and 12). Deposition will start from the crest of the South and West dams to create beaches that would push the supernatant water away from these structures. Once these beaches were created, the spigot points will be moved to the east flank of the TIA, where deposition will begin from elevation 49.5 m. This will create a long and even tailings surface sloping toward the North Dam, ensuring that the water in the original Tail Lake is displaced towards the north.

6.3 Reclaim Pond Storage Volume

The tailings deposition plan will result in the Reclaim Pond reducing in size over the life of the Project. For all but the last few years of the Project, the Reclaim Pond will have sufficient capacity to allow year-round reclaim water to be drawn from the TIA, including under ice conditions in the winter. However, near the end of the Project life, this condition cannot be satisfied; therefore, increased volumes of fresh make-up water and more TIA discharge will be required, and potentially the FSL may have to be lowered to accommodate the IDF.

6.4 Dust Management

A comprehensive assessment of possible dust management practices for the tailings surface is presented in Appendix J. The tailings deposition plan has been developed, as far as practical, to minimize the area of exposed inactive tailings surface that may be prone to dusting. Beyond such mitigation by design, the primary dust control measure of the Project site TIA will be the use of environmentally suitable chemical dust suppressants. The application of these suppressants will be reviewed on an ongoing basis to ensure any areas that may be at risk will be adequately covered. Generally, annual application of chemical suppressants will be applied; however it is recognized that more frequent applications may be required as discharge locations are changed throughout any year.

In addition to chemical dust suppressants, natural dust control in the form of packed snow when available, will be used as far as practical. Again, the effectiveness will fluctuate on a year by year basis depending on how deposition points vary for any given winter season.

Finally, if for any reason the above dust control methods prove to be temporally ineffective, a suitable water cannon will be available to allow for dust suppression by wetting the areas of concern.

7 Tailings Closure and Reclamation

7.1 Closure Concept

Upon closure, the tailings surface will be covered with a nominal waste rock cover of 0.3 m thickness. The function of the cover is to prevent dust and to minimize direct contact by terrestrial wildlife. Once the water quality in the Reclaim Pond has reached the required discharge criteria, the North Dam will be breached as originally intended for Phase 1.

7.2 Closure Components

7.2.1 Landform Design

The tailings deposition plan has been developed to ensure that a free draining tailings surface remains at closure. This tailings surface will be shaped as part of the regular tailings deposition plan (Appendix A), such that there is a primary drainage channel leading from the South Dam towards the Reclaim Pond. This ensures there is no requirement for construction of diversion structures post-closure.

7.2.2 Cover System

The TIA will only contain flotation tailings which are non-PAG with abundant neutralization potential and thus buffering capacity. Although several metals in the tailings solids occur at concentrations in excess of crustal abundances, many of these metals are associated with sulphides and as such will primarily partition into the detoxified tailings which means they will not be of concern in the TIA. Long-term humidity cell tests indicate that after the initial flushing of the samples, an increased tendency for neutral pH metal leaching may develop, with arsenic being of particular concern.

The TIA water and load balance (SRK 2016b) suggests that possible neutral metal leaching does not pose a limitation in ensuring that the water quality in the TIA meet site specific closure water quality criteria, and therefore no infiltration reduction cover is required on the exposed tailings surface. The tailings surface will however be susceptible to wind erosion with the resultant effect of dust exposure.

Similarly, although the tailings surface is landscaped to allow free drainage, the tailings are susceptible to hydraulic erosion, which will mobilize tailings towards the Reclaim Pond with a resultant increase in total suspended solids.

Therefore, a tailings cover that functions to prevent wind and water erosion will be constructed over the entire tailings surface.

The minimum thickness of cover that can practically be placed over the tailings surface would be about 0.3 m thick, and therefore the cover design has been set at 0.3 m thick ROQ material.

Part of the tailings will not be trafficable for some years following tailings placement. Therefore, in order to place the cover winter construction over a frozen tailings surface will be required in those areas. Although thermal modeling has demonstrated that the bulk of the tailings mass will freeze back in the long term, and remain frozen (Appendix C), consolidation settlement in the active zone (about 2 m thick) can still be expected (Appendix I). In addition, should ice lenses develop within the tailings beach, these ice lenses, if present in the active zone could further contribute towards long term differential settlement of the tailings surface and subsequently any associated cover system. Such differential settlement will not negatively affect the cover performance since localized ponding that might result would not prohibit the cover from ensuring that wind and water erosion is mitigated.

7.2.3 Water Management

Conveyance Channel

Although the tailings will be landscaped to ensure positive drainage of the entire tailings surface area, the resultant effect will be a dedicated primary conveyance channel along the west side of the facility. This channel will be sized and armoured to allow conveyance of the 1 in 500 year, 24-hour duration storm event. Based on the channel geometry, the peak flow is expected to be about 4.3 m^3/second, requiring riprap with a D_{50} of 0.1 m. This rock is similar to the proposed ROQ cover material, and therefore no special requirements for the primary conveyance channel is required other than possible local thickening of the cover. For bonding cost estimates, it has been assumed that this localized cover thickening would occur over a zone about 20 m wide along the entire length of the channel. This section will have an increased cover thickness of 0.6 m.

Discharge Criteria

A key closure objective is to ensure a walk away closure scenario, and therefore the water retaining North Dam must be breached. This can however only occur when the water quality in the Reclaim Pond meets environmental discharge criteria. The TIA, once breached will discharge into Doris Lake which in turn discharges into Doris Creek. The environmental discharge criteria for the TIA is therefore site-specific water quality criteria.

7.2.4 Containment Structures

North Dam

Water in the Reclaim Pond will continue to be managed via active pumping to the Roberts Bay Discharge System until such time as the environmental discharge criteria can be met within the Reclaim Pond. At that time, the water in the Reclaim Pond will be pumped down to its pre-mining elevation of 28.3 m, and the North Dam will be breached. The breach design will consist of a slot cut through the dam down to the pre-construction elevation. The cut will measure about 20 m wide, with 4H:1V side slopes on either side. The cut slopes will be covered with a 2.5 m thick layer of ROQ material to ensure physical and thermal stability (Appendix C).

Tail Lake outflow will be re-established along the base of the cut and suitable bedding material will be put in place to ensure channel stability.

South Dam and West Dam

The South Dam and West Dam will be left in place during closure as they will not be retaining any water. No additional closure activities are required.

7.3 Monitoring and Maintenance

7.3.1 Monitoring

Throughout the operational phase of the Project, the containment structures (North, South and West dams) will be subject to rigorous monitoring to evaluate their performance. This will include thermal, settlement and other general deformation monitoring. In addition, thermal monitoring of the tailings profile will be carried out to confirm tailings freeze-back assumptions. All of the above will be subject to annual inspections by a qualified professional engineer as part of routine annual inspections. The frequency of these inspections may be reduced as time progresses in accordance with the inspection engineer’s recommendations.

Once environmental discharge criteria in the Reclaim Pond has been reached and the North Dam has been breached, it is expected that routine monitoring will proceed for a period of about five years after which it may be demonstrated that the system is stable and no further action is required.

7.3.2 Maintenance

Throughout the active closure period it is conceivable that some tailings differential settlement could occur. Where necessary maintenance in the form of additional cover or fill material will be allowed for to address any areas of concern.

This report, ***"Hope Bay Project Doris Tailings Management System Phase 2 Design"***, was prepared by SRK Consulting (Canada) Inc.

Iozsef Miskolczi, MASc, PEng (BC)
Senior Consultant

and reviewed by

Maritz Rykaart, PhD, PEng (NWT/NT)
Principal Consultant

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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

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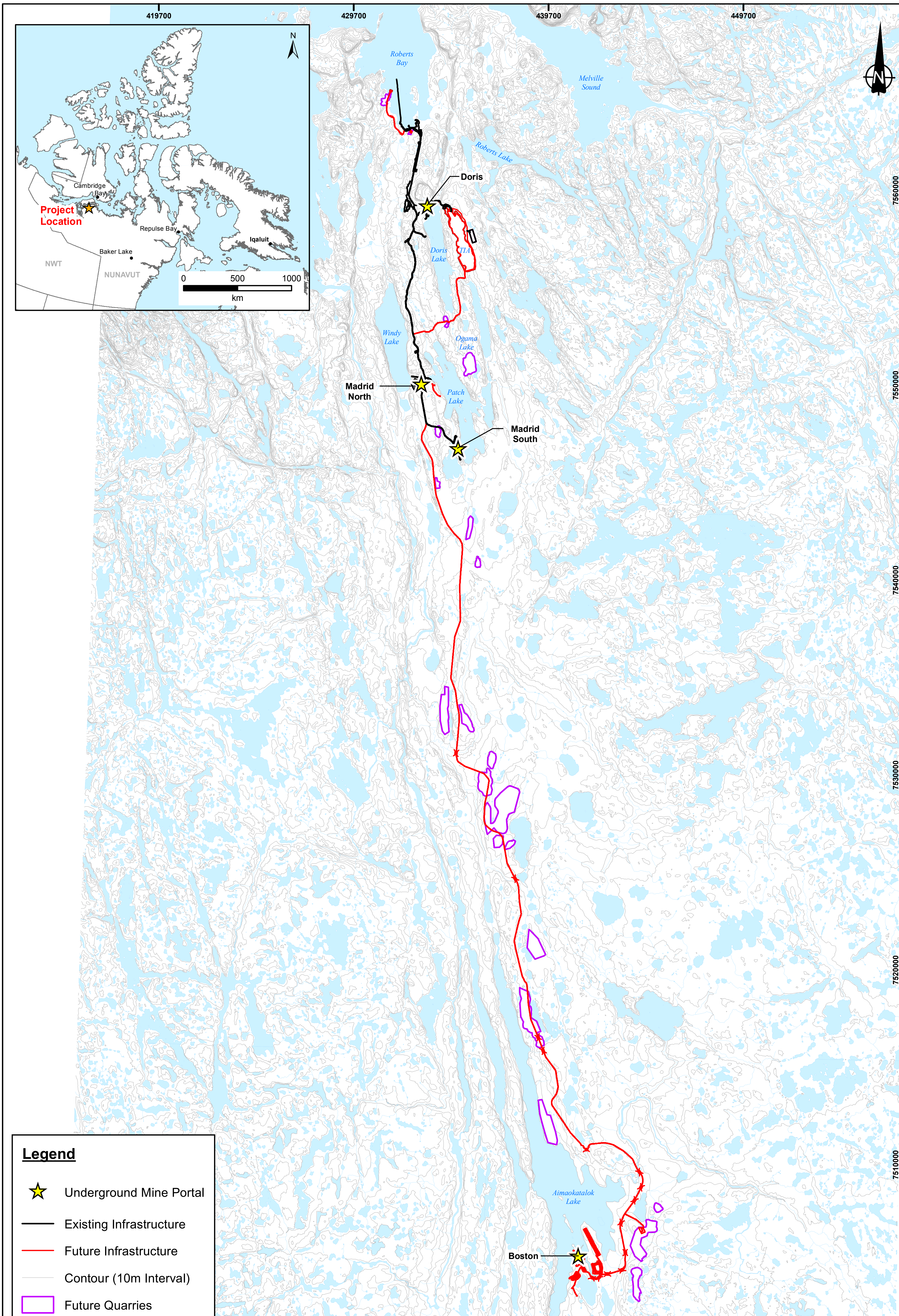
Figures

srk consulting	TMAC RESOURCES	Doris TMS Phase 2 Design Site Location Plan
SRK JOB NO.: 1CT022.004.600.10 FILE NAME: 1CT022.004.600.10 - FIGURE 1.dwg	HOPE BAY PROJECT	DATE: May 2016 / APPROVED: IM / FIGURE: 01



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Kilometres

Notes:
1. Coordinate System: NAD 1983 UTM Zone 13N
2. Base Topo Data: CanVec, Natural Resources Canada

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HOPE BAY PROJECT

Doris TMS Phase 2 Design

Site Location Map

Date:	Approved:	Figure:
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