2018 Annual Geotechnical Inspection Tailings Impoundment Area Hope Bay Project, Hope Bay, Nunavut

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.028.400
March 2019

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Tailings Impoundment Area
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Executive Summary

Hope Bay Project is a gold mining and milling undertaking of TMAC Resources Inc. The Project comprises three distinct areas of known mineralization, Doris, Madrid (North and South), and Boston. Doris Mine (Phase 1) is currently being operated under Type A Nunavut Water Board (NWB) License 2AM-DOH1323 - Amendment No.1. Phase 2 of the Project is subject to two Water Licenses effective January 2019. TMAC contracted SRK Consulting (Canada) Inc. to conduct an annual geotechnical inspection for the Tailings Impoundment Area (TIA) in accordance with stipulated license conditions. The inspection was completed taking into consideration both the Water License in effect at the time of the inspection, and the new Water License obtained in January 2019.

The TIA consists of a water retaining dam, the North Dam, and two tailings retaining structures, the South Dam and West Dam. Subaerial tailings are retained by the South and West Dam, and the Reclaim Pond is impounded by the North Dam. The North Dam was constructed during the winters of 2011 and 2012, and the South Dam was constructed in one season, during the winter of 2017 and 2018. The Interim Dike is no longer required as part of Phase 2.

Table A provides a summary of inspection components and the primary recommendations stemming from the site inspection, and subsequent review of monitoring data. The North Dam is functioning as designed, and there are no concerns about the ongoing performance of the structure. There are maintenance issues that require attention, and suggestions for improvement of the performance monitoring system. Following construction of the South Dam, there are no concerns about the current state of the physical structure, but the monitoring program for the South Dam still need to be fully implemented.

These items in Table A are considered important and require attention prior to the 2019 annual geotechnical inspection.

Table A: Summary of Recommendations

Inspection Item	2017 Recommendations	2018 Recommendations
Third Party Dam Safety Review	• The North Dam hazard classification was revisited and is considered HIGH. This requires an independent third-party Dam Safety Review by 2024.	• Conduct an independent third-party Dam Safety Review for both the North and South Dams in the summer of 2021.
Tailings Operating, Maintenance and Surveillance (OMS) Manual	• Ensure all staff are aware of the OMS Manual and are familiar with its contents. • Review and revise the OMS manual to ensure consistency with the recently amended Water License. • Provide necessary training in accordance with the OMS Manual.	• An update to the Operations, Maintenance and Surveillance (OMS) Manual is required to reflect the operational, personnel and monitoring changes that are in effect. This update should build on the 2017 edition of the OMS Manual which considers the Phase 2 project as opposed to the Phase 1 project. As part of the update attention needs to be paid to defining Quantifiable Performance Objectives (QPOs) and including Trigger Action Response Plans (TARPs). • TMAC should ensure all staff are properly informed and trained on the contents of the OMS Manual.

Inspection Item	2017 Recommendations	2018 Recommendations
TIA Responsible Parties	• NA	• TMAC must agree on the lines of responsibility of the TIA, document that in the OMS Manual, train and inform personnel of their duties, and operate the facility accordingly.
Monitoring Standard Operating Procedures (SOPs)	• To avoid confusion update SOPs to reflect changes that has been agreed to since the original SOP was developed.	• Update the Monitoring SOP to include South Dam monitoring requirements.
Compliance with Monitoring Requirements	• Improve efforts to conduct monitoring at the frequency described in the SOPs.	• Conduct monitoring in accordance with the Monitoring SOP, paying attention to those areas where conformance is not consistently met.
North Dam Inspection and Monitoring		
Ground Temperature Cables (GTCs)	• In accordance with manufacturers recommendations, the dataloggers must be recalibrated as it has been in operation for more than five years. Internal batteries on the dataloggers must also be replaced. • A monitoring well near ND-VTS-130-DS is no longer required. See "Physical Inspection of North Dam".	• None.
Thermosyphons	• AFI or another qualified contractor must physically inspect thermosyphon North 2 and determine why it is not working. Appropriate repairs must be conducted. • While the contractor is on-site, have them inspect all thermosyphons, and carry out any additional maintenance they recommend.	• TMAC should measure the temperature of each thermosyphon riser pipe directly below the radiator fins using a contact thermometer or thermal camera. This measurement should be completed in early winter when the differential between the ground temperature and air temperature is the greatest. This will identify discrepancies between thermosyphons. • If TMAC's measurement confirms a temperature differential, AFC, or another qualified contractor, must to be contracted to physically inspect thermosyphon North 2, to investigate the cause of the malfunction and conduct any necessary repairs. The inspection must occur in the winter, as early as possible, to ensure adequate ground and air temperature differentials. • If AFC, or another suitable contractor, is on-site have them inspect all other thermosyphons, and carry out any additional maintenance they recommend.
CR1000 Datalogger Battery Voltage	• The external datalogger batteries should be tested and recharged or replaced annually.	• The external CR1000 datalogger batteries should continue to be monitored and recharged annually or replaced as needed.
Inclinometers	• No action required.	• The inclinometer and associated readout device should be recalibrated every 3 years, with the next recalibration due before the spring of 2019.

Inspection Item	2017 Recommendations	2018 Recommendations
Survey Monitoring Points	• Backfill the erosion around ND−DSP−100.	• Backfill the erosion around ND−DSP−100. • Maintain a careful watch on downstream dam shell settlement points ND-SSP-080-3 and ND-SSP-110-3 to determine if thaw settlement of the toe is causing undue deformation.
Creep Displacement	• N/A	• None.
Walkover Surveys	• Improve efforts to conduct walkover surveys in accordance with the frequency prescribed in the SOP.	• The required weekly walkover surveys are not being completed in accordance with the SOP. This is an important surveillance activity as defined in the OMS Manual and needs to be complied with.
North Dam Seepage	• Conduct more rigorous monitoring of the North Dam toe seep in accordance with the recommendations in Appendix J. This includes: • Field measurements of Electrical Conductivity when Surveillance Network Program (SNP) samples are collected at TL-1; • Weekly sampling and geochemical analysis of North Dam toe seepage when present; • Annual review of North Dam toe seepage water chemistry; • Measurement of active layer thaw depth using a frost probe; and • Installation of a V-notch weir (or similar) to improve seepage monitoring.	• Continue water quality monitoring of North Dam seepage according to the methods outlined in SRK (2018b), but include the additional recommendations proposed. • Conduct at least two additional frost probe surveys along the same transects in early summer and early fall, following the same procedure as in 2018.
AGI Physical Inspection	• --	• None.
South Dam Inspection and Monitoring		
Ground Temperature Cables (GTCs) and D405 Dataloggers	• N/A	• Complete troubleshooting and repair damaged, but repairable GTCs in the spring of 2019.
Survey Monitoring Points	• N/A	• Complete installation of survey monitoring points and prepare monitoring database for evaluation.
Physical Inspection of the South Dam	• N/A	• None.
TIA-Wide Monitoring		
Tailings Deposition System	• No action required.	• TMAC needs to install the dedicated mine water discharge pipeline to the TIA as soon as possible to allow tailings deposition to recommence from the South Dam. It is critical that South Dam beaching maintain beach of at least 100 m at all time, for all TIA water levels. • Saline mine water may only be discharged together with tailings from, or within, 300 m of the South Dam provided the freezing point depression is less than

Inspection Item	2017 Recommendations	2018 Recommendations
		0.5ºC. If the freezing point depression exceeds 0.5ºC, saline mine water may be discharged with tailings at other designated tailings discharge points or directly into the Reclaim Pond. The freezing point depression calculation is provided in this AGI and needs to be incorporated into an updated OMS Manual. • Used propylene glycol may be discharged into the Reclaim Pond in accordance with the stipulations provided in this AGI which needs to be incorporated into an updated OMS Manual. • Tailings discharge must be done in accordance with the designated tailings discharge plan, which provides designated tailings discharge coordinates, including elevation. • Areas along the western shoreline of the TIA where tailings discharge has occurred at elevations above 36.5 m needs to be carefully monitored to determine if permafrost damage is occurring due to vegetation dieback. Should any damage be noted, appropriate proactive mitigation may be required.
Emergency Dump Catch Basins	• N/A	• Completely reconstruct the Western Emergency Dump Catch Basin as the earliest opportunity. TMAC has agreed to complete this work in the summer of 2019.
Pipelines (Reclaim, Tailings Deposition and TIA Discharge)	• N/A	• TMAC must carefully inspect all pipelines placed directly on the tundra for signs of vegetation dieback and associated flow path challenging. Where this is occurring, the pipeline must be relocated to follow existing all-weather road shoulders, and appropriate remediation needs to be put in place where damage has occurred. Going forward TMAC should consider abandoning the practice of placing pipelines directly on tundra. • The thermal erosion feature that has developed along the northern shore of the TIA needs to be backfilled. The ideal backfill method should be hydraulic placement of a slurry as that would minimize tundra damage during the activity. The use of tailings slurry for this would be a good practice, however it should ideally be cooled to avoid further thermal erosion. • TMAC should ensure that under no circumstances water be discharged directly onto the tundra adjacent to the

Inspection Item	2017 Recommendations	2018 Recommendations
		TIA, Water should be discharged directly into the TIA Reclaim Pond.
Shoreline Erosion	• N/A	• None.
TIA Water Balance	• N/A	• It is of paramount importance that the Roberts Bay Discharge System Pipeline be completed during the summer of 2019. Further delay of this may result in reduced operations.
Climate Data	• N/A	• None.
TIA Water Quality	• N/A	• TMAC must action the water treatment plant for TIA discharge water to ensure that once the Roberts Bay Discharge System Pipeline is operational in the summer of 2019, water can be treated and discharged.

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1 Introduction

1.1 General

Hope Bay 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 comprises three distinct areas of known mineralization, Doris, Madrid (North and South), and Boston.

The Project is being executed in Phases; Phase 1 is currently carried out under an existing Type A Water Licence (Figure 2), while Phase 2 will be carried out under two new Water Licences approved in January 2019. Phase 1 includes mining and infrastructure at Doris, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km south from Doris, respectively. The Doris Tailings Impoundment Area (TIA) (Figure 3) will ultimately contain both Phase 1 and 2 tailings.

Construction of Phase 1 infrastructure started in 2007, and underground development commenced in 2010. The North Dam which provides containment for the TIA at its northern perimeter was constructed over two winter seasons, 2011 and 2012 (Figure 3). In the Fall of 2012, the Project was placed into Care and Maintenance prior to complete infrastructure development to allow commercial production. Following an ownership change, Phase 1 was taken out of Care and Maintenance in 2015 and transitioned into commercial production in 2017. Construction of the South Dam, providing southern TIA containment was carried out between January and June of 2018 (Figure 3).

To fulfill regulatory compliance requirements for an annual geotechnical inspection (AGI) for the TIA containment dams as well as any supplementary infrastructure pertaining to the TIA operations such as pipelines and emergency catch basins, TMAC contracted SRK Consulting (Canada) Inc. to conduct the 2018 inspection. This report provides a summary of the conditions observed, a review of monitoring data, and recommendations to ensure ongoing successful performance of the system. This is the eighth formal AGI of the TIA, with SRK having performed all previous inspections (SRK 2012a, 2013a, 2014a, 2014b, 2016a, 2017a, 2018a).

Maritz Rykaart, PhD, PEng, the Engineer-of-Record (EOR) for the North and South Dams, and a Principal Consultant with SRK, conducted the on-site geotechnical inspection between August 3 and 5, 2018. Weather conditions during the inspection were rainy on August 3 becoming sunny on August 4 and 5. The detailed inspection of the dams and supporting infrastructure was carried out on foot, followed by an aerial survey of the TIA using a low altitude helicopter flyover. Kyle Conway, On-Site Environmental Coordinator with TMAC, accompanied Maritz during the walkover inspections. Photos detailing the inspection conditions are included as Photologs, and comprehensive monitoring data analysis are provided in Appendixes. A post inspection meeting was held on site with key personnel from relevant departments, where SRK presented the preliminary inspection findings. A copy of this presentation is included as Appendix L.

1.2 Inspection Requirements

Phase 1, including the TIA, is licensed by the Nunavut Water Board (NWB) under Type A License 2AM-DOH1323 - Amendment No. 1, dated November 4, 2016. This licence which was in effect at the time of the AGI entitles TMAC to use water and dispose of waste associated with their operation. The following specific inspection requirements, relevant to the TIA, are stated in Part J, items 16 and 17 of the license:

16. The Licensee shall undertake a geotechnical inspection annually between July and September, by a Geotechnical Engineer. The inspection shall be conducted in accordance with the Canadian Dam Safety Guidelines where applicable and take into account all major earthworks, including the following:

a. Tailings Impoundment Area North Dam, Interim Dike and South Dam;
b. Geotechnical instrumentation and associated monitoring data;
…
d. Tailings Impoundment Area shoreline and erosion strip survey monitoring results;
…

17. The Licensee shall submit to the Board for review, within ninety (90) days of completion of the geotechnical inspection, the Geotechnical Engineer's inspection report. The report shall include a cover letter from the Licensee outlining an implementation plan addressing each of the Geotechnical Engineer's recommendations and shall include the following:

a. All quantities in cubic meters of dike seepage from the North and South Dams pumped back into the Tailings Impoundment Area;
b. As-built drawings and a summary of the mitigation works undertaken along the shoreline of the Tailings Impoundment Area in response to erosion, as stipulated in the Shoreline Adaptive Management Plan; and
c. All data and information generated from the monitoring of all project geotechnical instrumentation.

Additional inspection requirements for other components of Phase 1 are listed within the water license; these conditions are addressed in separate inspection reports which are submitted to the NWB under different covers.

Phase 2 of the Project is subject to two Water Licences effective January 2019. Since the TIA operational strategy changes to some extent between Phase 1 and Phase 2, the 2018 AGI was completed taking into consideration both the Water Licence in effect at the time of the inspection, and the new Water Licence obtained in January 2019.

2 Site Conditions

2.1 Tailings Impoundment Area History

A summary of the TIA permitting, construction, and operations history is provided in Table 1.

Table 1: Summary of TIA Development History

Period	Comments
2003	Doris North Project preliminary economic assessment is completed with Tail Lake designated as the TIA, assuming subaqueous deposition and a maximum tailings quantity of about 0.4 Mt (SRK 2002a).
2002 - 2005	Geotechnical, geophysical, geohydrological and permafrost investigations of dam foundations (North, South and alternate internal locations), TIA shoreline perimeter, and TIA talik (SRK 2002b, 2003 and 2005a, 2005b and 2005c).
2005	Environmental Assessment for the Doris North Project is completed which includes rigorous alternatives assessment confirming Tail Lake as the preferred TIA.
2006	Project Certificate is issued for the Doris North Project.
2006	Application for Schedule 2 listing of Tail Lake as TIA in accordance with the Metal Mining Effluent Regulations (MMER).
2008	Tail Lake MMER Schedule 2 listing obtained.
Winter 2011 and Winter 2012	North Dam constructed (SRK 2012b).
Fall 2012	Project placed into Care and Maintenance before any tailings was ever produced.
2012 – 2015	Project in Care and Maintenance. Water within the TIA is managed in accordance with the Interim Water Management Plan (SRK 2012c) which includes pumping water from the Pollution Control Pond (PCP) to the TIA and discharging TIA water to Doris Creek.
2015 – 2016	TMAC submits application to amend the Water Licence and Project Certificate which amongst other things will result in a change to sub-aerial tailings deposition, increase the TIA capacity to 2.5 Mt, change of the South Dam design to a frozen foundation dam, and construction of an Interim Dike. This amendment was approved November 4, 2016.
2017 – 2019	TMAC submits application to amend the Doris Water Licence and Project Certificate, and to obtain a new Water Licence in support Phase 2 of the Hope Bay Project. Amongst other things this will result in increasing the TIA capacity to 18 Mt, constructing a South Dam raise, and the Interim Dike would no longer be required. The updated Project Certificate was issued in October 2018, and the amended and new Water Licence issued January 2019.
January 2017	Start of tailings deposition in TIA.
January – June 2018	Completion of Phase 1 South Dam construction.
August 2018	Installation of South Dam instrumentation and data loggers.

2.2 Tailings Management Strategy

2.2.1 Phase 1

Phase 1 tailings are subaerially deposited in the TIA (formerly Tail Lake), which was listed on Schedule 2 of the Metal Mining Effluent Regulations (MMER) specifically for use as a tailings facility. The TIA is located south-east of the Doris mill and mine (Figure 2). Containment for the TIA is provided through a water retaining frozen core dam (North Dam), and a geosynthetic clay liner (GCL) lined frozen foundation tailings dam (South Dam). An Interim Dike near the mid-point of the TIA provide solids containment (Figure 3). Phase 1 tailings solids containment capacity is limited to 2.5 Mt.

2.2.2 Phase 2

Phase 2 tailings management increases the overall tailings solids containment capacity to 18 Mt. The North Dam remain unchanged, but the South Dam gets raised and a new West Dam (also a frozen foundation GCL lined dam) is constructed (Figure 3). Tailings deposition completely covers the Interim Dike if it has been constructed; however, there is no need to construct the Interim Dike to accommodate Phase 2 tailings.

2.3 Tailings Storage Requirements

Planned tailings production rates and associated tailings storage requirements for the Doris TIA is summarized in Table 2.

Table 2: TIA Containment Volume Design Criteria

Description	Value
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; 2,400 tpd for final year
Production Life	17 years
Tailings Specific Gravity	2.85
Deposited Tailings Dry Density	1.3 t/m^3
Tailings Solids Content	35% solids (by weight) initially, increasing to 65%
Phase 1 Tailings Storage Requirement: By Mass By Volume	 2.5 Mt 1.9 Mm^3
Phase 2 Tailings Storage Requirement: By Mass By Volume	 15.5 Mt 11.9 Mm^3
Total Tailings Storage Requirement: By Mass By Volume	 18.0 Mt 13.8 Mm^3
Ice Entrainment Allowance: Percentage of tailings capacity By volume	 20% 2.4 Mm^3
Tailings Beach Slope: Subaerial tailings Sub-aqueous tailings	 1.0% 1.0%

2.4 Tailings Impoundment Area Infrastructure

2.4.1 North Dam

The North Dam forms the northern boundary of the Doris TIA, within a narrow natural valley blocking the original Tail Lake outlet to Doris Lake (Figure 3). Complete North Dam geometric design parameters and design criteria are summarized in Table 3 and Table 4 respectively. Figure 4 though Figure 6 depicts pertinent details of the North Dam and its instrumentation. Photolog 1, Photolog 2 and Photolog 3 show photos of the upstream and downstream faces, and the installed instrumentation.

The North Dam impounds the Reclaim Pond and was designed as a water retaining structure. The dam has a central frozen core with a secondary upstream GCL. The dam is constructed from local quarry rock and consists of processed fines for the core, 150 mm nominal sized transition material, and a run of quarry (ROQ) outer shell. To ensure maintenance of frozen foundation conditions, the key trench of the dam is equipped with 12 horizontal thermosyphon evaporators (SRK 2007, 2012a, 2013a, 2015a).

Construction of the North Dam started in February 2011 and was completed in April 2012, over two distinct winter seasons. Complete as-built details are provided in SRK (2012b).

2.4.2 South Dam

The South Dam is located at the southern end of the former Tail Lake, on the watershed to Ogama Lake (Figure 3). The South Dam is designed as a frozen foundation dam consisting of a compacted rock fill dam (sourced from a local quarry) with a GCL keyed into the permafrost overburden foundation for seepage control. Complete geometric design parameters and design criteria are summarized in Table 3 and Table 4 respectively, with Figure 7 through Figure 9 presenting pertinent details. The dam is designed to retain beached tailings as opposed to water. The dam is to be constructed in two phases, incorporating a single downstream raise.

South Dam construction began in January 2018 and Phase 1 construction was completed in June 2018. The South Dam instrumentation was mostly completed in August 2018. Photolog 4 shows the South Dam Inspection photos.

2.4.3 Interim Dike

The interim Dike is required as part of Phase 1 and consist of a homogeneous ROQ rock fill dike, with an upstream filter zone. This was planned to be constructed within the confines of the TIA, directly on the existing lake bed sediment, without dewatering the TIA (Figure 3). The Interim Dike was originally intended to retain tailings solids while allowing for tailings supernatant water to pass unhindered to the Reclaim Pond (SRK 2016). The Interim Dike is however not required as part of the Phase 2 tailings deposition plan, and since it has not been constructed, it will not be constructed now that the Phase 2 Water Licence has been issued.

2.4.4 West Dam

The West Dam is a frozen foundation dam with a key trench and a GCL liner keyed into permafrost, similar in design to the South Dam. It is intended to retain beached tailings along low-lying ground on the western perimeter of the TIA (Figure 3). Complete geometric design parameters and design criteria are provided in Table 3 and Table 4. This dam will be constructed in a single stage using local quarry rock. This dam has not yet been constructed.

Table 3: TIA Containment Dams Geometric Design Parameters

Description	North Dam	South Dam	West Dam
Structure Type	Frozen core rock fill dam with geomembrane	Frozen foundation rock fill dam with geomembrane	Frozen foundation rock fill dam with geomembrane
Secondary Seepage Barrier	GCL		
GCL Deployment Slope	2.5H:1V	Phase 1 – 3H:1V Phase 2 – 4H:1V	3H:1V
Thermosyphons	12 sloped	None	None
Crest Centerline Length	220 m	515 m	470 m
Maximum Height	11.0 m	Phase 1 – 6.0 m Phase 2 – 14.0 m	5.0 m
Crest Elevation	37.5 masl	Phase 1 – 38.0 masl Phase 2 – 46.0 masl	46.0 masl
Core/GCL Elevation	35.0 masl	Phase 1 – 37.0 masl Phase 2 – 45.0 masl	45.0 masl
Full Supply Level (FSL)	33.5 masl	Phase 1: Water – 33.5 masl Tailings – 36.5 masl Phase 2: Water – 33.5 masl Tailings – 44.5 masl	Water – 33.5 masl Tailings – 44.5 masl
Original Tail Lake Water Level	28.3 masl		
Total Actual Freeboard (Crest to FSL)	4.0 m	Phase 1: Water – 4.5 m Tailings – 1.5 m Phase 2: Water – 12.5 m Tailings – 1.5 m	Water – 12.5 m Tailings – 1.5 m
Total Actual Minimum Freeboard (Core/GCL to FSL)	1.5 m	Phase 1: Water – 3.5 m Tailings – 0.5 m Phase 2: Water – 11.5 m Tailings – 0.5 m	Water – 11.5 m Tailings – 0.5 m
Required Normal Freeboard (CDA 2013)	Wind setup (0.07 m) + Wave runup (1.06 m) = 1.13 m		

Description	North Dam	South Dam	West Dam
Required Minimum Freeboard (CDA 2013)	Wind setup (0.06 m) + Wave runup (1.16 m) = 1.22 m Inflow Design Flood = 2.1 m (at end of mine life when Reclaim Pond is at its minimum size)		
Thermal Protection above Frozen Core	2.5 m	n/a	n/a
Crest Width	13 m	10 m	10 m
Upstream Structure Slope	6H:1V	4H:1V	4H:1V
Downstream Structure Slope	4H:1V	2H:1V	2H:1V
Key Trench Depth	Varies (2.0 – 5.0 m)	Varies (2.0 – 4.0 m)	4.0 m
Key Trench Upstream Slope	0.5H:1V	2H:1V	2H:1V
Key Trench Downstream Slope	0.5H:1V	1H:1V	1H:1V

Table 4: TIA Containment Dams Design Criteria

Description	North Dam	South Dam	West Dam
Settlement Allowance Foundation thaw of 1 m (partial thaw) Foundation thaw of 7 m (full thaw)	1.00 m	 0.47 – 0.67 m 2.45 – 3.85 m	 0.40 – 0.60 m 2.03 – 3.43 m
Deformation Allowance (Total Strain due to Creep)	<2%	n/a	n/a
Design Life: Active use as water retaining structure Design base as water retaining structure Design base until breach Active use as solids retaining structure Design base as solids retaining structure	 17 years 22 years 30 years	 17 years 25 years	 17 years 25 years
Annual Exceedance Probability (AEP) for Inflow Design Flood Risk Based Standards Based	 1/2,475 (0.0004) 1/3 between 1/1,000 and the PMF(1)		
Static Stability Factor of Safety: Long-term (Drained Conditions)	1.3 during construction 1.5 during operation and closure 1.2 to 1.3 partial or rapid drawdown		
Pseudo-Static Stability Factors of Safety	1.0 during earthquake 1.2 post earthquake		
AEP for Earthquake Design Ground Motion	1/2,500 (0.0004)		
Peak Ground Acceleration (PGA)	0.060g(2)	0.036g	0.043g
Mean Annual Air Temperature Climate Change	+6.8°C up to year 2100		
Thermal Design Freezing Point Depression (Normal Conditions) Tailings Overburden Frozen core	 n/a -8°C -2°C	 0 to -1°C -2°C n/a	 0 to -1°C -2°C n/a

Description	North Dam	South Dam	West Dam
Thermal Design Freezing Point Depression (Upset Conditions) Tailings Overburden Frozen core	 n/a -7ºC -1ºC	 0 to -1ºC -2ºC n/a	 0 to -1ºC -2ºC n/a
Seepage Allowance	78 m^3/day	50 m^3/day	<1 m^3/day

Notes:

1. Value based on experiential engineered judgement.
2. A peak ground acceleration for a ½,475 return period was not available at the time of design of the North Dam, and therefore the PGA of 0.06 g was selected based on published data for Kugluktuk. This is further described in SRK (2007).

2.4.5 Spillway

An operational spillway was originally designed for the TIA at the North Dam but is no longer required due to the freeboard of the North Dam being adjusted to contain the IDF as defined in Table 4. This may be revaluated later in the mine life when the Reclaim Pond diminished in size requiring more freeboard to contain the IDF.

2.4.6 Tailings Deposition System

The tailings discharge system is designed as a single heat-traced and insulated pipeline with end-point (i.e. single spigot) discharge at predetermined locations. The tailings deposition pipeline consists of a combination of 6-inch internal diameter steel and High-Density Polyethylene (HDPE) pipelines with no redundancy. There are no double lined pipeline sections for environmental containment. The pipeline is placed directly on the ground, which consist of either engineered rockfill pads, the all-weather road shoulders, or in some areas directly on the tundra.

Actual tailings deposition started in February 2017 and tailings discharge has occurred from 4 locations as illustrated in Figure 10. The different tailings discharge locations were in part because of deferral of South Dam construction which prevented earlier tailings deposition. Photos of the tailings deposition are shown in Photolog 4, 5 and Photolog 6 and the tailings discharge lines in Photolog 8 and Photolog 9.

Table 5 summarizes the deposition status as of November 2018, which confirms that actual tailings deposition is behind what was planned (Table 2) due to commissioning challenges and the tailings solids content has also been different than originally planned (Figure 11 and Figure 12). It should be noted that there is no evidence to suggest that there are any entrained ice within the deposited tailings at this point in time.

Table 5: Actual Tailings Deposition Between Start-up (February 2017) and November 2018

Period	Percent Solids (by Weight)	Tailings Solids (tpd)	Cumulative Tailings Solids (tonnes)	Cumulative Tailings Solids (m^3)
February 2017	39.0	212	5,936	2,120
March 2017	21.7	351	16,814	6,005
April 2017	32.5	635	35,864	12,809
May 2017	23.0	659	56,293	20,105
June 2017	41.7	662	76,153	27,198
July 2017	15.0	569	93,792	33,497
August 2017	20.8	741	116,778	41,706
September 2017	20.5	555	133,431	47,654
October 2017	19.5	733	156,139	55,764
November 2017	17.3	634	175,159	62,557
December 2017	22.0	841	201,234	71,869
January 2018	34.5	814	226,452	80,876
February 2018	33.0	966	253,489	90,532
March 2018	25.2	1,012	284,864	101,737
April 2018	39.2	1,073	317,066	113,238
May 2018	42.0	893	344,758	123,128
June 2018	16.9	818	369,285	131,888
July 2018	28.3	1,027	401,129	143,260
August 2018	44.6	1,386	444,101	158,607
September 2018	45.7	1,614	492,527	175,902
October 2018	48.6	1,851	549,905	196,395
November 2018	48.0	1,842	605,159	216,128

2.4.7 Emergency Dump Catch Basins

Two Emergency Dump Catch Basins (EDCBs) have been constructed on either side of Doris Creek (Photolog 7). The EDCBs are lined cells constructed at a topographic low-point along the tailings and reclaim pipeline routes that allow for the pipelines to be drained during prolonged mill shutdowns or power failures to prevent pipeline freeze-up. They were designed to accommodate at least two consecutive shutdowns plus direct meteoric catchment. The EDCBs were constructed in 2017. Table 6 summarize their design and as-built containment capacities.

Table 6. EDCB Design and As-built Capacities

Component	Western EDCB	Eastern EDCB
Permitted Design Capacity	120 m^3	120 m^3
Required Design Capacity	97 m^3	85 m^3
As-Built Design Capacity	124 m^3	85 m^3

2.4.8 Reclaim Water System

Reclaim water is drawn from the TIA Reclaim Pond for re-use in the Process Plant. Reclaim water is drawn from a submerged suction line feeding a low suction head pump installed in an on-shore enclosure located at the Reclaim Pond (Figure 3). This heat-traced and insulated pipeline follow the TIA Access Road (*aka* Secondary Road) from the Reclaim Pond to the Doris mill and is placed directly on the ground which consist of either tundra, all-weather road shoulder, or the engineered rockfill pads. There are no double-lined sections of this pipeline and there is no redundant pipeline (Photolog 5, Photolog 8, Photolog 9).

Table 7 provides a summary of reclaim water volumes drawn from the TIA since tailings production started.

Table 7: Reclaim Water Volumes Between Start-up (February 2017) and November 2018

Date	Reclaim Volume (m^3/month)	Cumulative Reclaim Volume (m^3)
February 2017	94,080	94,080
March 2017	107,880	201,960
April 2017	100,800	302,760
May 2017	104,160	406,920
June 2017	100,800	507,720
July 2017	81,721	589,441
August 2017	96,586	686,027
September 2017	92,016	778,043
October 2017	92,181	870,224
November 2017	93,088	963,312
December 2017	93,900	1,057,212
January 2018	82,577	1,139,789
February 2018	69,744	1,209,533
March 2018	78,864	1,288,397
April 2018	74,638	1,363,035
May 2018	76,444	1,439,479
June 2018	69,120	1,508,599
July 2018	66,699	1,575,298
August 2018	71,186	1,646,484
September 2018	65,833	1,712,317
October 2018	64,395	1,776,712
November 2018	66,962	1,843,674

2.4.9 TIA Water Discharge System

TIA water will be discharged during the open water season to Roberts Bay once the Roberts Bay Ocean Discharge System is operational. The discharge pump will be located adjacent to the reclaim pump and will pump water along a pipeline following the same route as the reclaim water pipeline. This system has not yet been installed and no Roberts Bay discharge has occurred. Historically, prior to tailings deposition, TIA water was discharged to Doris Creek (compliance monitoring station TL-2) during the open water seasons of 2014 and 2015, as summarized in Table 8.

Table 8: Historic TIA Discharge Water Volumes to Doris Creek (TL-2)

Date	Discharge to TL-2 (m^3/month)	Cumulative Discharge to TL-2 (m^3)
June 2014	104,634	104,634
July 2014	257,778	362,411
August 2014	194,405	556,816
September 2014	118,218	675,034
June 2015	3,095	678,129
July 2015	230,460	908,589
August 2015	233,603	1,142,192
September 2015	164,260	1,306,452

2.4.10 Shoreline Erosion Protection

As part of the original subaqueous tailings deposition plan, six shoreline erosion transects was identified to be monitored. The Phase 1 Amendment approved November 4, 2016 retained four of these transects, as other transects were within the area that would be completely covered by tailings and therefore no longer require shoreline monitoring or protection. Similarly, as part of the Phase 2 tailings deposition plan, shoreline erosion is no longer a concern, and therefore no shoreline erosion monitoring is required. To date there has been no monitoring of any of the shoreline erosion transects.

2.5 Tailings Impoundment Area Instrumentation

2.5.1 North Dam

Permanent performance monitoring instrumentation for the North Dam consists of:

- 11 vertical ground temperature cables (GTCs);
- 13 horizontal GTCs;
- 18 surficial survey monitoring points located throughout the downstream face;
- 14 crest survey monitoring points located along the upstream and downstream crest of the dam;
- 3 deep settlement points;
- 6 inclinometers located within the downstream face; and
- 12 single bead thermistors, measuring thermosyphon contact temperatures.

Figure 4 through Figure 6 illustrates the location of North Dam instrumentation. All GTCs are connected to dataloggers allowing continuous data collection. Slope inclinometers are recorded manually using a slope inclinometer instrument owned by TMAC. Settlement monitoring is done manually by ground survey. The North Dam Standard Operating Procedure (SOP) provides comprehensive details pertaining to this instrumentation (SRK 2018b).

2.5.2 South Dam

The South Dam permanent monitoring instrumentation consists of:

- 11 horizontal GTCs;
- 16 vertical GTCs;
- 26 surficial survey monitoring points;
- 12 crest survey monitoring points; and
- 3 deep settlement points.

The monitoring instrument locations are shown on Figure 7 through Figure 9. Prior to the end of the monitoring period covered in this 2018 AGI, the South Dam instrumentation system had not been fully implemented and therefore monitoring data is not presented in this report.

2.5.3 Interim Dike

Since this structure is no longer required, no monitoring will be undertaken.

2.5.4 West Dam

This structure will, once constructed have a similar monitoring plan to that of the South Dam.

2.5.5 Other TIA Instrumentation and Monitoring

Additional monitoring data collected for the TIA are summarized below:

- The water level in the TIA Reclaim Pond is monitored by an automated pressure transducer-datalogger installed at monitoring point TIA-2. The data is then transmitted by a solar-powered iridium satellite transceiver to and online portal where it can be accessed. There is also a back-up datalogger installed to record data should a problem occur with the primary data collection system. The secondary datalogger also records water temperature which is beneficial from a thermal review perspective.

  The datalogger is configured to collect a reading every 15 minutes in the summer (every 60 minutes during the winter) and the data is transmitted to an online portal daily. Additional detail of the installation is described by ERM (2017) and SRK (2018b);

- Tailings deposition is a continuous operation and the volumes are monitored with a flowmeter and an automated data collection system;

- Reclaim water is measured using a flowmeter with an automated data collection system;
- Mine water is measured by means of a totalizer instrument, recorded manually twice daily; and
- Climate data most directly related to the TIA monitoring includes temperature and precipitation (Appendix J). The ambient air temperature shown is collected at the crest of the North Dam as part of the thermal monitoring system. Precipitation data has historically been collected from several sources including on-site meteorological stations. For the indicative use in this report, the precipitation data shown in Appendix J is based on precipitation data from Cambridge Bay, adjusted for under catch.

2.6 Water Management

2.6.1 Water Management Plan

The TIA is used as the overall collector for all site contact water, which are either pumped or trucked to the TIA. Saline underground water (i.e., mine water) may also be pumped to the TIA if it is not discharged directly to Roberts Bay. TIA water is stored in the Reclaim Pond which is recycled for processing make-up to the extent possible. During the open water season, any excess water in the TIA will be discharged to Roberts Bay for ocean discharge. Prior to discharge to Roberts Bay, all water must meet MMER limits (SRK 2017b, TMAC 2017).

There are no non-contact surface water diversions upstream of the TIA. The TIA is in an isolated catchment measuring 461 ha, and the benefits of any diversions are outweighed by the relative cost and complexity of constructing them. A schematic of the TIA water management plan is presented in Figure 15.

2.6.2 Water Balance

A site wide water and load balance, including the TIA, has been developed for the Project (SRK 2017b) and forms the basis for the Water Management Plan (TMAC 2017). A detailed operational TIA water balance has also been developed considering the relevant TIA inflows and outflows. This is used by TMAC to make day-to-day operational decisions pertaining to the TIA. This operational water balance incorporates the most recent available site measurements and then uses historical measurements and direct user inputs to predict future TIA water levels. The direct user-inputs allow for the modelling of various scenarios to test future “what if cases”. The cases all start with a base case prediction defined as the most likely outcome based on the information known today and the base case prediction is presented in Figure 16. Several assumptions feed into the prediction including:

- All measured data to date (in this case, end of 2018);
- A production rate of 2,000 tpd for the remainder of the model;
- Doris Underground mine water was pumped to the Doris TIA at a rate ramping up from measured flows to the FEIS water load balance values up until March 2022;

- All process water (including freshwater inputs) are sourced from the Doris TIA and are based on historical usage rates (m^3 water/ tonnes ore processed);
- SCP water is pumped to the Doris TIA based on historical rates;
- Discharge to Robert's Bay from the Doris TIA commences in October 2019 until January 2020 and occurs each year from June to September (inclusive) at a rate of 6,650 m^3/day (after pump availability considerations);
- Sewage treatment plant effluent is directed to the Doris TIA starting in September 2019 based on an average camp size of 300 people at historical usage rates (0.16 m^3/person/day);
- No water make-up or losses occurring in the mill, and;
- Average climatic conditions.

2.7 Dam Hazard Classification

Dam hazard classifications for the TIA containment dams were made in accordance with the Canadian Dam Safety Guidelines (CDA 2013), as well as the CDA Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014), as summarized in Table 9. The designated dam hazard classifications assigned to each structure is listed in Table 10 (SRK 2015, 2016b).

Table 9: Dam Hazard Classification (as defined in CDA 2013)

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 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 highly possible	High economic losses affection 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] 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 unforeseeable 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] Implications for 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.

Table 10: 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
Interim Dike	LOW	LOW	LOW	LOW	LOW
West Dam	SIGNIFICANT	SIGNIFICANT	HIGH	LOW	HIGH

3 TIA Inspection and Monitoring Instrumentation Findings

3.1 Third Party Dam Safety Review

In accordance with the Dam Safety Guidelines (CDA 2013, 2014), including the CDA Technical Bulletin on Dam Safety Reviews (CDA 2016), independent third-party Dam Safety Reviews (DSRs) should be conducted in accordance with a frequency informed by the hazard classification of the structures. This frequency typically ranges between 5 and 10 years. It is recommended a dam with a HIGH hazard classification, such as the North Dam and South Dam, undergo a Dam Safety Review every seven years. This hazard classification needs to be reviewed periodically to ensure that conditions remain valid.

SRK reviewed the hazard rating as part of the 2018 inspection, and considering tailings deposition has started, SRK agrees that a hazard rating of HIGH is appropriate for the constructed North and South Dams.

Therefore, in accordance with CDA guidelines, the North and South Dams should have independent Dam Safety Reviews (DSR) every seven years. The North Dam started impounding water in 2011, which means that a DSR should have been completed in 2018. As is illustrated in Figure 16, the North Dam generally retained about 0.7 m head of water (average water level of 29.0 m) until the summer of 2016. This is about 13% of the full supply level (FSL) head based on the original Tail Lake water level of 28.3 m. After that time the water level has been consistently rising to its current elevation in 2018 of 30.7 m, which constitutes a head of 2.4 m, or 46% of the FSL head of 5.2 m. Considering the dam performance to date, as well as the fact that considerable technical reanalysis of the dam was done in 2017 as part of the Phase 2 design, SRK is comfortable at this time, to defer completion of a DSR to 2021, which is 10 years after initial impoundment started.

South Dam construction was completed in 2018, which means a DSR for that structure is due in 2025; however, since a DSR is needed for the North Dam in 2021, it is recommended that the South Dam DSR be completed at the same time.

Recommendations:

- Conduct an independent third-party Dam Safety Review for both the North and South Dams in the summer of 2021.

3.2 Tailings Operating, Maintenance and Surveillance Manual

Phase 1 tailings management is carried out under a Tailings Operating, Maintenance and Surveillance (OMS) Manual prepared in 2016 (TMAC 2016). Because tailings deposition in 2017 was inconsistent and less than planned due to mill commissioning challenges, a thorough review of OMS Manual procedures was not undertaken. There were however substantive operational changes in 2018, including significant personnel changes and as a result the OMS Manual is substantially outdated. Although the OMS Manual was updated in 2017 (TMAC 2017), that update was centered around changes associated with the Phase 2 project, and the necessary operational and personnel changes has not been adequately captured. Furthermore, an updated North Dam Monitoring SOP has been issued (SRK 2018b), the changes of which are not captured in the current OMS Manual. With completion of the construction of the South Dam, a South Dam Monitoring SOP need to be completed, and that information should be captured in an updated OMS Manual.

The current OMS Manual does not adequately define Quantifiable Performance Objectives (QPOs) for the Dams, and there are no Trigger Action Response Plans (TARPs).

Based on SRKs site inspection, as well as ongoing interactions throughout the year between the EOR and site personnel, it is evident that the relevant on-site responsible parties associated with the TIA operations are not familiar with the contents of the OMS Manual. Additional training and familiarization of the documents is therefore required.

Recommendation:

- An update to the OMS Manual is required to reflect the operational, personnel and monitoring changes that are in effect. This update should build on the 2017 edition of the OMS Manual and consider the Phase 2 project as opposed to the Phase 1 project. As part of the update attention needs to be paid to defining Quantifiable Performance Objectives (QPOs) and including Trigger Action Response Plans (TARPs).

- TMAC should ensure all staff are properly informed and trained on the contents of the OMS Manual.

3.3 TIA Responsible Parties

Responsible parties for the TIA are defined in the OMS Manual. However due to operational challenges associated with an extended commissioning period, and the fact that South Dam construction was being carried out, the transition period was not an effective time to capture all required changes to the OMS . It is however understood that the primary responsible party should be the mill, and TMAC is working towards implementing measures to ensure the requirements are understood.

Maritz Rykaart, PhD, PEng, a licenced professional engineer in Nunavut Territory, and a Principal consultant with SRK has been the EOR for the North Dam since its construction, and is also the EOR for the South Dam, and this remains the status at the time of completing this report. All monitoring data for the North Dam is submitted to the EOR monthly, and the EOR remains in constant communication with site staff regarding the overall TIA operations. TMAC has allowed free access to information and resources to allow the EOR to fulfill his duties.

Recommendation:

- TMAC must agree on the lines of responsibility of the TIA, document that in the OMS Manual, train and inform personnel of their duties, and operate the facility accordingly.

3.4 Compliance with Monitoring Requirements

The North Dam monitoring frequency requirements were first outlined in the North Dam As-built Report (SRK 2012b) and subsequently finalized in the North Dam Monitoring Standard Operating Procedures (Monitoring SOP) which was updated in 2018 (SRK 2013b, 2018b). The South Dam monitoring requirements are similar to the North Dam, where applicable, and need to be included in a revised Monitoring SOP that includes both dams.

Since transitioning to tailings production in 2017, the monitoring frequency requirements and actual monitoring frequency for the 2017/2018 monitoring period are summarized in Table 11 for the established instrumentation on the North Dam, and within the TIA. The South Dam monitoring program has not yet been fully established as it was still under development at the time of the inspection; however preliminary monitoring since construction is summarized in Table 12.

Table 11: North Dam Monitoring Requirements for the 2017 to 2018 Monitoring Year(1)

Element	Item	Method	Resp.	Required Frequency	Conformance with SOP (SRK 2018b)(1)(2)	Comments
Thermal	Ground Temperature Cables	Datalogger	TMAC	Daily (automated)	Yes	• Record four times daily • No readings Jan. and Feb. 2018 due to datalogger recalibration
	Thermo-syphons				Yes	• Record four times daily • No readings Jan. and Feb. 2018 due to datalogger recalibration
	Datalogger downloads	Manual		Monthly	Yes	• No downloads Jan. and Feb. 2018 due to datalogger recalibration
Deformation	Downstream Surface Settlement	Manual	TMAC	Monthly (May to Nov.)	No	• Surveys received for Sep. 2017, May to Oct. 2018 • No surveys received for Oct. or Nov. 2017
	Downstream Deep Settlement				No	

Element	Item	Method	Resp.	Required Frequency	Conformance with SOP (SRK 2018b)(1)(2)	Comments
	Crest Settlement				No	
	Depressions				Yes	• No changes observed
	Inclinometers			Monthly	Yes	• Data collected monthly
Water Balance	Water Level	Datalogger Station	TMAC	Daily (automated)	Yes	• Readings every 15 min and uploaded daily
	Water Level	Manual		Monthly	No (Acceptable)	• Water Level surveyed during installation of datalogger and must be surveyed once during open water season (2019)
	Seepage			Weekly when seepage is observed	Yes	• Seepage documented at the toe of North Dam during spring 2018
Visual	Walkover Survey	Manual	TMAC	Weekly (below FSL(3)) Daily (at or above FSL)	No	• 12 inspections conducted between Aug. 2017 and Oct. 2018
	Annual Geotechnical Inspection		Independent Qualified Licensed Geotechnical Engineer	Annually	Yes	• Jul. 2017 (SRK 2018) • Aug. 2018 (This report)
Maintenance						
North Dam Thermal Datalogger	Datalogger Primary Batteries	Manually recharge	TMAC	Annually	Yes	• Recharged Jun. 2018
	Datalogger Backup Batteries	Manually replace		5-year cycle	Yes	• Replaced during datalogger recalibration
	Datalogger Recalibration	Manual			Yes	• Completed Jan. 2018
	Desiccant Packs	Manually replace		As required	Not required	• No action required
Water Level Datalogger Station (TIA-2)	Datalogger Transmission Subscription	Online		Annually	Yes	• 22% of the data service plan remains
	Physical Datalogger Station	Manually recalibrate or replace		As required	Not required	• No action required

Note(s):

(1) Data reporting period included in this report was September 1, 2017 to October 31, 2018 which is a continuation of data from the last AGI (SRK 2018a)
(2) This column lists if the monitoring frequency is compliant with the monitoring frequency requirements since the last AGI (SRK 2018a)
(3) FSL: Full Supply Level

Table 12: South Dam Preliminary Monitoring Following Construction(1)

Element	Item	Method	Resp.	Required Frequency	Conformance with Preliminary Needs	Comments
Thermal	Ground Temperature Cables	Datalogger	TMAC	Daily (automated)	No (Acceptable during transition period)	• Datalogger systems were not fully established prior to the end of the monitoring period
	Datalogger downloads	Manual		Monthly		
Deformation	Downstream Surface Settlement	Manual	TMAC	Monthly (May – Nov.)		• Survey monitoring points were not fully established prior to the end of the monitoring period.
	Downstream Deep Settlement					
	Crest Settlement					
	Depressions					• No issues observed
Water Balance	Seepage	Manual	TMAC	Weekly when seepage is observed	Yes	• No seepage observed
Visual	Walkover Survey	Manual	TMAC	Weekly (below FSL(2)) Daily (at or above FSL)	No (Acceptable during transition period)	• Formal documentation of the South Dam inspections should commence in a similar fashion to the North Dam
	Annual Geotechnical Inspection		Independent Qualified Licensed Geotechnical Engineer	Annually	Yes	• August 2018 (This report)
Maintenance						
South Dam Thermal Datalogger	Datalogger Primary Batteries	Manually recharge	TMAC	Not yet established	Not applicable during transition period	• The maintenance requirements will be provided in the updated TIA monitoring SOP
	Datalogger Backup Batteries	Manually replace				
	Datalogger Recalibration	Manual				
	Desiccant Packs	Manually replace				

Note(s):

(1) The monitoring period following construction was July 2018 to October 31, 2018.

(2) FSL: Full Supply Level

Recommendations:

- Update the Monitoring SOP to include South Dam monitoring requirements.
- Conduct monitoring in accordance with the Monitoring SOP, paying attention to those areas where conformance is not consistently met.

3.5 North Dam Inspection and Monitoring

3.5.1 Ground Temperature Cables

To monitor long-term temperature of the frozen core and the dam foundation, a total of twenty-four GTCs were installed during the North Dam construction (SRK 2012b). Of the twenty-four installed GTCs, twenty-two are still functional. Since September 2012, GTC data for the North Dam is recorded every six hours by two Campbell Scientific CR1000 dataloggers (Photolog 3). Data is downloaded from the dataloggers by TMAC personnel using compact flash memory cards.

The frequency of datalogger downloads and the recorded temperature data is presented in Appendix B. The only gap in data for the 2017/2018 monitoring period was due to the datalogger system being offline for recalibration between December 31, 2017 and March 3, 2018. Data error for the GTCs was somewhat less than in previous years, which is attributed to the datalogger recalibration. The complete status of all North Dam GTCs is summarized in Table 13.

Table 13: North Dam Ground Temperature Cable Status

GTC ID	Status	Comments
ND-VTS-040-KT	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-040-31.5	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-040-33.5	Active	Cable disconnected from datalogger October 10, 2013 to May 13, 2014
		Connection to datalogger more permanently repaired July 2014
		Disconnected for recalibration January 1 to March 3, 2018
ND-VTS-060-US	Inactive	Irreparably damaged between April 27 and August 8, 2012
ND-VTS-060-DS	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-VTS-060-KT	Active	Spliced during construction. Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-060-28.8	Active	Bead 7 - No readings February 11, 2012 to December 8, 2013
		Bead 7 - No readings since April 21, 2014
		Bead 7 - Readings between November 1, 2014 and April 19, 2015
		Bead 7 - Readings between October 2015 and April 2016
		Bead 7 - Readings between October 2016 and June 2017
		Bead 7 – Readings between September 2017 and May 2018 (excluding recalibration period), resuming at the end of October 2018. Occasional erratic readings continue (since fall 2016) and are attributed to instrument errors.
		Bead 9 - No readings October 10, 2013 to May 20, 2014 and July 2014 onward
		Disconnected for recalibration January 1 to March 3, 2018
ND-HTS-060-31.0	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-060-33.5	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-VTS-085-US	Active	Erratic data at most beads (excluding Beads 3, 6 and 9) between June 2016 and May 2017 with lower amplitude spikes between December 2016 and May 2017
		Erratic data subsided since May 2017

GTC ID	Status	Comments
		Disconnected for recalibration January 1 to March 3, 2018
ND-VTS-085-DS	Active	Erratic data at most beads (excluding Beads 3, 6 and 9) between June 2016 and May 2017 with lower amplitude spikes between December 2016 and May 2017
		Erratic data subsided since May 2017
		Disconnected for recalibration January 1 to March 3, 2018
ND-VTS-085-KT	Active	Erratic data at most beads (excluding Beads 3, 6 and 9) between June 2016 and May 2017 with lower amplitude spikes between December 2016 and May 2017
		Erratic data subsided since May 2017
		Disconnected for recalibration January 1 to March 3, 2018
ND-HTS-085-25.3	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-085-29.4	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-085-33.5	Inactive	Irreparably damaged during construction
ND-VTS-130-US	Active	Bead 9 – Readings erratic for periods since June 2016 (temperature dropping to less than -15ºC)
		Disconnected for recalibration January 1 to March 3, 2018
ND-VTS-130-DS	Active	Small magnitude temperature spikes during summer months between 2013 and 2017 (Bead 3, 7, 8, 9, 11), no spikes observed in 2018
		Beads 3 – 8 were offline after the connector at the datalogger housing was damaged on September 24, 2017. Repaired and reconnected on March 11, 2018 following datalogger recalibration
		Disconnected for recalibration January 1 to March 3, 2018. Beads 3 to 8 were disconnected and repaired between September 24, 2017 and March 3, 2018 (due to damaged cable connection)
ND-VTS-130-KT	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-130-28.8	Active	All beads were offline after the connector at the datalogger housing was damaged on September 24, 2017. Repaired and reconnected on March 4, 2018 following datalogger recalibration
		Disconnected for recalibration January 1 to March 3, 2018
		Low temperature spikes and intermittent logging from Bead 2 in Summer 2018
ND-HTS-130-31.0	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-130-33.5	Active	Fully operational, except for cable repair and recalibration September 24, 2017 to March 3, 2018
ND-VTS-175-KT	Active	Spliced during construction
		Incorrectly connected to datalogger as ND-HTS-175-33.5 from August 9, 2012 to June 16, 2014
		Beads 9, 10 and 11 - No readings August 9, 2012 to June 16, 2014
		Disconnected for recalibration January 1 to March 3, 2018
ND-HTS-175-32.5	Active	Fully operational, except for recalibration January 1 to March 3, 2018
ND-HTS-175-33.5	Active	Spliced during construction
		Incorrectly connected to datalogger as ND-HTS-175-KT, from August 9, 2012 to June 16, 2014
		Disconnected for recalibration January 1 to March 3, 2018

Source: J:\01_SITES\Hope.Bay\!Project_Data (Not Job Specific)\06_NorthDamMonitoringData\[SiteMonitoringSummary.xlsx]ThermisorStatus

The North Dam GTCs were installed to ensure the dam core and key foundation section remain below the design temperatures of −2˚C and −8˚C, respectively under normal operating conditions. Under upset conditions these temperatures increase to −1˚C and −7˚C. In addition, ground temperature data along with thermosyphon monitoring data can be used to determine if the thermosyphons are functioning correctly. Observations related to a review of the data presented in Appendix B are summarized in Table 14.

Table 14: Summary of Core and Key Trench Ground Temperature Cable Observations

Zone	Horizontal GTCs	Vertical GTCs	Observation
Design Temperature	**−2˚C**	**−8˚C**	• **The minimum criteria required to ensure Dam is performing in accordance with design specifications**
Station 0+040	Meets	Meets	• Performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling
Station 0+060	Meets	Meets	• Performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling • Following on from the 2017 seepage review (SRK 2018a), no temperature readings of concerns were noted at this station
Station 0+085	Meets	Meets	• Generally performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling in the core, foundation and downstream portions of the dam • Erratic data spikes previously observed were not observed after May 2017, however, temperatures appear to have risen in the shallowest beads of ND-VTS-085-US. This rise is interpreted to be caused by the rise in TIA water level. Seasonal variability in temperature continues to be observed and the temperatures remain below 0C. Ground warming is expected in this area. • Following on from the 2017 seepage review (SRK 2018a), no temperature readings of concerns were noted at this station
Station 0+130	Meets	Meets	• Generally performing as expected with substantive safety buffer and stable or a slight cooling trend • Short term temperature spikes are noted for all but the uppermost 2 beads of ND−VTS−130−DS in 2017 (and every year prior). In 2018, no temperature spikes were noted. Between 2013 and 2017, the temperature spikes were observed between May and November with the largest amplitudes in 2013 and 2016 (Appendix B.13) • Erratic reading attributed to instrumentation error are noted in both ND-HTS-130-28.8 (Bead 2) and ND-VTS-130-US (Bead 9) in 2018. Previously erratic readings were only observed in ND-VTS-130-US • Following on from the 2017 seepage review (SRK 2018a), no temperature readings of concerns were noted at this station
Station 0+175	Meets	Meets	• Generally performing as expected with substantive safety buffer and stable or a slight cooling trend • The annual maximum of the uppermost two beads remain slightly above the design temperature at -7˚C

Recommendations

- None.

3.5.2 Thermosyphons

Passive thermosyphons assist in cooling the North Dam key trench foundation. They function when the ambient air temperature is colder than the ground temperature where the thermosyphon is located. This happens because of phase change of the carbon dioxide gas with which the thermosyphon is filled. Therefore, during the winter months the cold ambient air temperature is used to draw heat from the foundation, but during the summer period the thermosyphons remain dormant.

Thermosyphon temperature monitoring for the North Dam has been automated. Single bead thermistors connected to the datalogger system are attached to each thermosyphon evaporator pipe below the ground surface, and insulation has been placed around the thermistor beads to ensure the evaporator pipe temperature, and not the ambient air temperature is measured (SRK 2012b). Additionally, air temperatures are recorded at the dataloggers every six hours. This data is downloaded as part of the monthly thermal datalogger downloads.

To monitor the performance of the thermosyphons, thermosyphon evaporator pipe contact temperatures and air temperatures are plotted against time. During the winter months, when the thermosyphons are working, the thermosyphon pipe temperature should be roughly 5˚C warmer than the air temperature. If the thermosyphon pipe temperature during the winter months is approximately the same as the air temperature, it indicates that the thermosyphon is not working correctly.

Thermistor data indicates all the south and north thermosyphons are functioning except for North 2 (Appendix C). Since 2012, the measured pipe temperature of North 2 was only slightly higher than the measured air temperature, which indicates a malfunction. Ground temperature readings near the North 2 thermosyphon pipe support the conclusion that the North 2 thermosyphon is not working correctly.

During the 2014 North Dam AGI, thermosyphon North 2 was inspected in detail to determine the cause of the elevated temperature readings. No damage or reason for the malfunction was observed (SRK 2014b). SRK recommended that Arctic Foundations of Canada Inc. (AFC) be contracted to investigate further and repair the thermosyphon. On April 10 and 11, 2017, AFC travelled to site to inspect the thermosyphons. The report from this inspection (AFC 2018, included as Appendix A) indicates no issues with North 2, however the monitoring data from this period indicates that the inspection was conducted when the thermosyphons were transitioning into the dormant phase and it is unlikely there would have been evidence of a problem with North 2 during this time (Appendix C.2). A comparison of the performance between October 1 and November 30, 2018 indicate the same performance issues remain (Appendix C.3).

The thermosyphon radiator steel foundations are in good condition. The thermosyphons themselves do not show any physical damage; however, there is rust and peeling paint at the weld between the evaporator pipe and the twin radiators on most of the thermosyphons. AFC, during their inspection was not concerned about this surface rust. The granular fill surrounding the thermosyphon pilings are progressively eroding and gullies are increasing in size. Preventative repairs to avoid complete exposure of the foundations are recommended.

Recommendations:

- TMAC should measure the temperature of each thermosyphon riser pipe directly below the radiator fins using a contact thermometer or thermal camera. This measurement should be completed in early winter when the differential between the ground temperature (warmest) and air temperature (coldest) is the greatest. This will identify substantial discrepancies between thermosyphons (AFC 2018).
- If the measurement confirms a temperature differential between North 2 and the other thermosyphons, AFC, or another qualified contractor, must to be contracted to return to site to inspect thermosyphon North 2, to further investigate the cause of the malfunction and conduct any necessary repairs. The inspection must occur in the winter, as early as possible, otherwise the appropriate testing cannot be done.
- If AFC, or another suitable contractor, is on-site have them inspect all other thermosyphons, and carry out any additional maintenance they recommend.

3.5.3 CR1000 External Datalogger Battery Voltage

Each CR1000 data logger is powered by an external lead acid battery. Battery voltage is an important indicator of datalogger performance. If the battery voltage drops below 12 V, it is operating outside of the optimal range. At or below 9.6 V, voltage is outside of the operating range and the recorded readings could be incorrect, or the datalogger will shut down and readings would not be recorded at all. The dataloggers record the minimum battery voltage four times daily. A graph of battery voltage versus time is provided in Appendix D.

The batteries have been recharged on multiple occasions since the North Dam was commissioned. At no time has the voltage dropped low enough to cause any concerns with data integrity. The batteries should continue to be monitored to ensure they maintain their charge through the winter months.

Recommendations:

- The external CR1000 datalogger batteries should continue to be monitored and recharged annually or replaced as needed.

3.5.4 Inclinometers

Six inclinometers were installed within the downstream face of the North Dam. These inclinometers are used along with the survey monitoring points to monitor deformation within the dam and dam foundation. Inclinometer readings are taken by TMAC site personnel. As discussed in Section 3.1, inclinometer readings were collected intermittently prior to May 2014. Readings were collected monthly during the 2017/2018 monitoring period.

Inclinometer measurements are provided in Appendix E. Data quality for the surveys has generally been good. The inclinometer profiles show only negligible displacements in the dam foundation, and small displacements the portion of the inclinometer above the natural ground surface as summarized in Table 14. Inclinometer ND-IN-120-3 is the only inclinometer that suggests a trend of downslope movement. All other inclinometers are showing virtually no movement, or the movement is oscillating seasonally which likely means there is some movement of the inclinometer tube itself, as opposed to actual deformation of the dam or foundation.

Table 14: Summary of Inclinometer Measurement Observations (Sep. 2012 through Oct. 2018)

Inclinometer	Maximum Overall Deformation			Maximum Foundation Deformation (m)	Observations
	Magnitude (m)	Location – Depth Below Dam Shell (m)	Location – Height Above Foundation (m)		
ND-IN-070-1	0.023	1.0	8.5	0.002	• Deformation essentially constant since 2015
ND-IN-070-2	0.026	2.5	6.5	0.017	• Seasonal oscillation, and overall trend suggest slight increase in deformation over time
ND-IN-070-3	0.013	3.5	4.0	0.002	• Deformation essentially constant since 2015
ND-IN-120-1	0.011	0.5	6.5	0.004	• Deformation essentially constant since May 2016
ND-IN-120-2	0.022	0.5	5.5	0.005	• Deformation below 1.5 m essentially constant since May 2016. Upper deformation oscillating somewhat
ND-IN-120-3	0.017	0.5	2.7	0.002	• General trend of movement towards the south and downstream of the dam

Recommendations:

- The last inclinometer calibration occurred in late 2014 when the system was sent in for repair. Although Durham Geo-Slope Indicator (DGSI) does not stipulate regular intervals for recalibrations of the probe, the instrument and readout device are very sensitive instruments and in SRK's experience should be frequently recalibrated. SRK suggests recalibration every 3 years to limit errors in readings, as it is challenging to determine if the instrument is working well while in the field. It is recommended that the next calibration be done before spring 2019.

3.5.5 Survey Monitoring Points

A series of 14 crest survey monitoring points, 3 deep survey monitoring points, and 18 surficial survey points were installed in the North Dam upon completion. These survey monitoring points were installed to monitor any surface movement of the downstream face and deep settlement of the downstream foundation of the dam.

Survey monitoring of the North Dam occurred for seven of nine occurrences between September 2017 and October 2018. The survey data should be collected monthly between May and November. Complete survey data is presented in Appendix F.

The overall vertical and horizontal displacement since completion of construction based on these readings are summarized in Table 15. Deep settlement and crest displacement have been very small and of similar magnitude, and has been essentially unchanged since September 2013, confirming that the measured displacement to date is all directly related to the period immediately following construction.

Downstream dam shell settlement follows the same general trends as the deep and crest settlement points; however, the total displacement magnitude is about twice as much. There is also an increasing trend in displacement in two points (ND-SSP-155-2 and ND-SSP-110-3) since June 2016. The measured vertical displacement of these points suggests no displacement change, but the horizontal displacement is increasing, which results in the overall increased displacement trend. Both these points are located near the downstream toe of the dam, and this increased displacement is likely a result of increased active layer thaw beneath the shallow rockfill toe of the dam, but it should be carefully monitored go forward.

Table 15. Summary of Survey Monitoring Observations (May 2012 through Oct. 2018)

Location	**No. of Stations**	**Vertical Displacement (m)**			**Horizontal Displacement (m)**		
		Min.	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**
Deep settlement points	3	0.02	0.04	0.03	0.01	0.08	0.05
Crest settlement points	14	0.03	0.08	0.05	0.02	0.07	0.04
Downstream dam shell settlement points	18	0.03	0.21	0.11	0.25	0.25	0.07

There is significant erosion around the deep settlement monitoring point ND−DSP−100 (Photolog 3). This was noted during all inspections since 2013 (SRK 2014a, 2014b, 2016, 2017), yet the recommended remedial action has not been carried out. This needs to be repaired as the instrument’s integrity will be compromised.

Recommendations:

- Backfill the erosion around ND−DSP−100.
- Maintain a careful watch on downstream dam shell settlement points ND-SSP-080-3 and ND-SSP-110-3 to determine if thaw settlement of the toe is causing undue deformation.

3.5.6 Creep Displacement

North Dam displacements as recorded by the inclinometers and survey points are expected to be caused primarily because of creep of the saline ice-rich foundation soils. Table 16 summarize the predicted deformation as determined through rigorous numerical creep deformation modeling (SRK 2017c), as well as the allowable design values. Figure 17 presents a plot comparing predicted vertical displacement against measured vertical displacement along the crest of the dam near Station 1+20. This graph clearly demonstrates that the current displacement is less than predicted.

Table 16. Predicted North Dam Deformation Displacement

Period	Location	Max. Shear Strain Rate (year-1)	Max. Shear Strain (m/m)	Displacement (m)	
				Max. Horizontal	Max. Vertical
Overall allowable design values	**Core**	**3.2E+02**	**2%**	**-**	**1.0**
10 years post construction	Core crest	-	-	-	0.2
	Core	5.0E-08	5.0E-02	0.4	0.6
	Foundation	1.0E-07	~1.0E-01	0.4	0.6
30 years post construction	Core crest	-	-	-	1.0
	Core	2.0E-08	1.0E-01	0.8	1.0
	Foundation	4.0E-08	~2.0E-02	0.6	1.0

Recommendations:

- None.

3.5.7 Walkover Surveys

Walkover surveys of the North Dam are required weekly when tailings deposition is occurring, but the TIA water level is not at the FSL. During the 2017/2018 monitoring period only 12 walkover surveys was completed, and the associated reports and photos are included as Appendix G.

The walkover survey reports and tracks all changes to the dam surface, visible damage to instrumentation, signs of erosion or seepage, or any other surface anomalies. To date, the primary observations of note from the walkover surveys include:

- Surface depressions;
- Minor cracking on the turn-around pad on the upstream side;
- Rust on the thermosyphons (Section 3.5.2);
- Erosion near the thermosyphons (Section 3.5.2); and
- Ponded or flowing water at the downstream toe of the dam (Section 3.5.8).

The surface depressions are located on the upstream and downstream faces of the dam. Six depressions have historically been classified as significant depressions requiring monitoring (D1, D2, D3, U1, U2 and U3), as illustrated in Appendix H. The Monitoring SOP requires a GPS location, photographs and estimated dimensions/extents of these large surface depressions on a continuous basis to track if they are increasing in size. No monitoring of the depressions was completed during this monitoring year. Based on the AGI physical inspection (Photolog 1 and Photolog 2), SRK is however satisfied that there were no substantial changes to these surface depressions since the 2017 AGI, and this observation is confirmed by the settlement data.

Recommendations:

- The required weekly walkover surveys are not being completed in accordance with the SOP. This is an important surveillance activity as defined in the OMS Manual and needs to be complied with.

3.5.8 North Dam Seepage

Since completion of the North Dam there has been evidence of surface water flow along the downstream toe of the North Dam. This flow has historically been reviewed by SRK, and a rigorous thermal assessment and water quality review was conducted in 2017 to establish whether the flow was in any way indicative of North Dam seepage (SRK 2018a). The evaluation concluded that North Dam seepage was unlikely but could not be definitively excluded. It was recommended that flow measurements be obtained, systematic water quality sampling be undertaken, and frost probe data be collected.

A V-notch weir was installed at this location in July 2017, as illustrated in Figure 4 and Photolog 2, and flow and water quality sampling were carried out in accordance with the newly established Monitoring SOP (SRK 2018b). SRK's review of the 2018 seepage water quality data (Appendix K) confirm that currently there is strong evidence to suggest that the origin of the seepage water is not the TIA; however, some additional data collection could allow for a more rigorous determination going forward if things were to change.

As part of the seepage monitoring, flow through the V-notch weir varied between 0 and 0.5 l/s and was only present between late June and early September (approximately 80 days). The flow was variable, and generally correlates with rainfall which suggest that a consistent baseflow seepage from the TIA is unlikely. The total estimated cumulative seepage volume was less than 1,000 m^3 for the entire season which is negligible, and again supports the conclusion that North Dam seepage is unlikely.

Two frost probe surveys were conducted along seven transects downstream of the North Dam. The data collected identifies variation in the seasonal active layer thaw depth between July and November, typically varying by 0.2 – 0.4 m. The greatest variation was observed near the previously identified flow path locations along the NE downstream toe where the maximum thaw depth was 1.0 m. This data is consistent with the settlement data indicating maximum dam deformation at the toe of the dam.

Based on all data reviewed in relation to the North Dam seep, there is currently no anomalous data that suggest that TIA water is seeping from the North Dam.

Recommendations:

- Continue water quality and flow monitoring of North Dam seepage according to the methods outlined in SRK (2018b), but include the additional recommendations proposed.
- Conduct at least two additional frost probe surveys along the same transects in early summer and early fall, following the same procedure as in 2018.

3.5.9 Physical Inspection of the North Dam

As part of the AGI a walkover survey of the North Dam was completed. No general issues of concern were observed. Specific physical issues associated with monitoring components are described above. Photolog 1 and Photolog 2 provides some general pictorial of conditions on the North Dam.

Recommendations:

- None.

3.6 South Dam Inspection and Monitoring

3.6.1 Ground Temperature Cables

To monitor long-term temperature of the frozen foundation dam, a total of twenty-seven GTCs were installed during South Dam construction (SRK 2018c). The GTCs are connected to Beaded Stream Dataloggers (D405) to allow continuous data capture; however, the system was not completely installed at the time of the inspection and therefore data will not be reported in this AGI. Table 17 provides a summary of the GTC status during the 2018 AGI inspection.

The design criteria require maintenance of ground temperature of at least -2°C at the upstream base of the key trench (Figure 9).

Table 17: South Dam Ground Temperature Cable Status Summary

String #	GTC ID	Station	Status	Comments
2	SD-VTS-65-KTC	0+65	Active	• Cable damaged after construction but repaired
3	SD-HTS-065-US	0+65	Active	• Cable damaged after construction but repaired
4	SD-VTS-155-KTC	1+55	Active	
5	SD-VTS-155-UST	1+55	Active	• Only top bead working
6	SD-VTS-155-DST	1+55	Active	
7	SD-HTS-155-US	1+55	Active	
8	SD-HTS-155-KT	1+55	Inactive	• Cable irreparably damaged during construction
11	SD-VTS-240-KTC	2+40	Active	
12	SD-VTS-240-UST	2+40	Active	
13	SD-VTS-240-DST	2+40	Active	
14	SD-HTS-240-US	2+40	Active	
15	SD-HTS-240-KT	2+40	Active	
16	SD-VTS-365-KTC	3+65	Inactive	• Cable irreparably damaged after construction
17	SD-VTS-365-UST	3+65	Active	• Cable damaged after construction but repaired
18	SD-VTS-365-DST	3+65	Active	
19	SD-HTS-365-US	3+65	Active	

String #	GTC ID	Station	Status	Comments
20	SD-HTS-365-KT	3+65	Active	• Cable damaged after construction but repaired
21	SD-VTS-460-KTC	4+60	Active	
22	SD-VTS-460-UST	4+60	Active	• Cable damaged after construction but repaired
23	SD-VTS-460-DST	4+60	Active	
24	SD-HTS-460-US	4+60	Inactive	• Cable irreparably damaged after construction
25	SD-HTS-460-KT	4+60	Active	
26	SD-VTS-510-KTC	5+10	Active	
27	SD-HTS-510-US	5+10	Active	• Cable damaged after construction but repaired
29	SD-VTS-US1	3+35	Active	• Installed in suspected ground ice wedge near upstream toe • Serial # 3197 corresponds to serial # 2841 on build sheet
30	SD-VTS-US2	3+35	Active	• Installed in suspected ground ice wedge near upstream toe
9	SD-HST-B1-KT	n/a	Active	

Recommendations:

- Conduct final troubleshooting and repair of damaged, but repairable, GTCs in the spring of 2019.

3.6.2 Survey Monitoring Points

A series of 12 crest survey monitoring points, 3 deep settlement points, and 26 surficial survey monitoring points are proposed for the South Dam. Prior to the end of the monitoring period, only the crest survey monitoring points were installed. The surficial survey monitoring points and deep settlement points have not yet been fully implemented. These survey monitoring points were installed to monitor any surface movement of the downstream face and deep settlement of the downstream foundation of the dam.

Recommendation:

- Complete installation of surface survey monitoring points and installation of the deep settlement point instruments.

- Begin the survey of each monitoring points (May to November) once installed and prepare monitoring database for evaluation

3.6.3 Physical Inspection of the South Dam

As part of the AGI a walkover survey of the South Dam was completed. As dam construction had just been completed, there were no issues of concern to note. Photolog 4 provides some general South Dam pictorials.

Recommendations:

- None.

3.7 Tailings Deposition System

Table 5, Figure 10, and Figure 11 provides a summary of tailings deposition in the TIA to date. Up to the end of November 2018, the total amount of tailings deposited in the TIA was about 0.6 Mt, which is about 50% of which was planned. The solids content during this time has been variable, although there has generally been a constant increase from about 15% solids by weight in July 2017 to approximately 48% solids by weight by November 2018. Similarly, the daily tailings production rate has steadily been increasing from about 200 tpd at the start to approximately 1,850 tpd in November 2018.

Tailings deposition has occurred as single point discharge form 4 separate locations; two locations along the eastern shoreline of the TIA, and two locations from the South Dam as shown on Figure 10. At the time of the 2018 AGI tailings discharge from the South Dam had just started. Tailings deposition needs to continue from the South Dam in accordance with the tailings deposition plan (SRK 2017d, and Figure 12 to Figure 14).

In accordance with the site water management plan, saline mine water can be discharged directly to Roberts Bay, or directed to the TIA via a dedicated pipeline. Since the marine outfall pipeline has not been constructed, mine water has been discharged to the TIA, but the dedicated mine water pipeline has also not been constructed and therefore this saline mine water has been discharged with the tailings between February 2018 when it was first encountered and August 2018 when the AGI was conducted. SRK advised that it is not acceptable to discharge saline mine water with tailings, especially when beach development from the South Dam is being done because the entrained saline pore water will depress the freezing point of the tailings which could compromise the performance of the South Dam or the long-term freeze-back of the tailings.

TMAC subsequently redirected saline mine water to the Sedimentation Control Pond (SCP) on August 6, 2018 which allowed this water to be pumped to the TIA Reclaim Pond with PCP water independently of the tailings steam. Tailings beaching was subsequently done from the South Dam until September 17, 2018 when the saline mine water was recombined with the TIA stream as there is no freeze protection of the PCP pipeline. On September 18, the TIA discharge location was relocated to the western shore of the TIA (modified Spigot Point #5) with a discharge elevation of 45 masl.

Going forward the maximum amount of saline mine water that may be discharged with the tailings, when deposition occurs from the South Dam, or within 300 m from the South Dam must not allow the entrained pore water to have a depressed freezing point of more than 0.5^{o}C. This maximum allowable depressed freezing point is a function of the tailings production rate, the tailings solids content, the tailings salinity content, the mine water volume and the mine water salinity content. The freezing point depression as influenced by salinity (normally expressed as a NaCL concentration) was developed by Velli and Grishin (1983) as described by Andersland and Ladany (2004) and reproduced below:

$$T_f = T_k \left(\frac{S_{pw}}{1000+S_{pw}}\right) \quad \text{Eq. 1}$$

Where:

T_f	=	Freezing point depression (°C)
T_k	=	Reference temperature (62°C, assuming primary salt is NaCL)
S_{pw}	=	Salinity of the mixture (g/L, ppt)

The volume of water contained in the slurry mixture is calculated as follows:

$$Q_t = \left(\frac{M_t}{T_{sc}} - M_t\right) \quad \text{Eq. 2}$$

Where:

Q_t	=	Volume of water in the tailings slurry, excluding mine water (m^3/day)
M_t	=	Tailings slurry volume, or production rate (tonnes per day)
T_{sc}	=	Tailings solids content (% by weight)

The total chloride concentration for the tailings pore water after mine water has been added to the tailings sump box is calculated as follows:

$$C_{mix} = \left(\frac{Q_t \times C_t + Q_m \times C_m}{Q_t + Q_m}\right) \quad \text{Eq. 3}$$

Where:

C_{mix}	=	Tailings pore water chloride concentration after mine water mixing (mg/L)
C_t	=	Tailings pore water chloride concentration, excluding mine water (mg/L)
C_m	=	Mine water salinity concentration (mg/L)
Q_m	=	Mine water pumping rate (m^3/day)

Because the primary constituent causing salinity at the project site within the mine water is chloride, the salinity (ppt) is corrected as follows:

$$S_{pw} = 0.0018066 \times C_{mix} \quad \text{Eq. 4}$$

Therefore, solving for all these equations, assuming a maximum freezing point depression of 0.5°C, the maximum amount of saline mine water that can be discharged with the tailings at any given time equates to:

$$Q_m = \frac{Q_t(C_t - 4500)}{(4500 - C_m)} \quad \text{Eq. 5}$$

Table 18 provides a few hypothetical examples of the results that this equitation would yield, illustrating its use. TMAC must conduct this calculation daily to confirm that the entrained pore water does not exceed a salinity concentration that would result in an exceedance of the design freezing point depression. If there is uncertainty, the mine water must be discharged elsewhere, such as the Reclaim Pond, until the Roberts Bay marine outfall pipeline is constructed.

Table 18: Example of Allowable Mine Water Discharge Rates at Different Chloride Concentrations

$M_t(tpd)$	$T_{sc}(\%\ by\ weight)$	$Q_t(m^3/day)$	$C_t(mg/L)$	$C_m(mg/L)$	$Q_m(m^3/day)$
2,000	30%	4,667	1,300	15,000	1,422
2,000	40%	3,000	1,300	15,000	914
2,000	50%	2,000	1,300	15,000	610
1,000	40%	1,500	1,300	15,000	457
2,000	40%	3,000	1,300	10,000	1,745
2,000	40%	3,000	1,300	20,000	619
2,000	30%	4,667	1,300	15,000	1,422
2,000	40%	3,000	1,000	15,000	1,000
2,000	40%	3,000	2,000	15,000	714

The original tailings discharge locations used by TMAC prior to August 2018 was not designated discharge points according to the tailings deposition plan, both from a spatial and an elevation context. Because of the relatively small volume of tailings discharged, the spatial variance is not of concern but the elevation is of concern as it is higher than the final tailings surface proposed during Phase 2. Tailings may not be discharged at elevations above 36.5 masl.

TMAC has advised that they would like to dispose of propylene glycol from aircraft de-icing activities in the TIA on occasion. Small volumes of glycol will not affect the TIA chemistry, but glycol does have a depressed freezing point and therefore discharging glycol with the tailings solids can only be done under the following conditions:

- Glycol must be discharged directly into the Reclaim Pond, at least 300 m away from any dams, and at least 10 m from any exposed shoreline;
- The maximum discharge rate of glycol is 30 m^3 per 6 months;
- All glycol disposal into the TIA must be recorded with the product details, disposal volume, location of discharge and date; and
- The EOR must be informed of all glycol discharges to the TIA.

Recommendations:

- TMAC needs to install their dedicated mine water discharge pipeline to the TIA as soon as possible to allow tailings deposition to recommence from the South Dam. It is critical that South Dam beaching maintain beach of at least 100 m at all time, for all TIA water levels.
- Saline mine water may only be discharged together with tailings from, or within, 300 m of the South Dam provided the freezing point depression is less than 0.5^{o}C. If the freezing point depression exceeds 0.5^{o}C, saline mine water may be discharged with tailings at other designated tailings discharge points or directly into the Reclaim Pond (or other permitted

discharge locations). The freezing point depression calculation is provided in this AGI and needs to be incorporated into an updated OMS Manual.

- Used propylene glycol may be discharged into the Reclaim Pond in accordance with the stipulations provided in this AGI which needs to be incorporated into an updated OMS Manual.

- Tailings discharge must be done in accordance with the designated tailings discharge plan, which provides designated tailings discharge coordinates, including elevation.

- Areas along the eastern shoreline of the TIA where tailings discharge has occurred at elevations above 36.5 m needs to be carefully monitored to determine if permafrost damage is occurring due to vegetation dieback. Should any damage be noted, appropriate proactive mitigation may be required.

3.8 Emergency Dump Catch Basins

The Eastern Dump Catch Basin is in good shape as illustrated in Photolog 7. The Western Dump Catch Basin was however not constructed in accordance with the Design Drawings and Technical Specifications and may not perform as intended. SRK has therefore advised that this structure be reconstructed at the earliest opportunity. TMAC has agreed to do this reconstruction in the summer of 2019.

Recommendations:

- Completely reconstruct the Western Emergency Dump Catch Basin as the earliest opportunity. TMAC has agreed to complete this work in the summer of 2019.

3.9 Pipelines (Reclaim, Tailings Deposition and TIA Discharge)

Pipelines are placed directly on the ground which consists of either rockfill pads, road shoulders or directly on the tundra. There are signs of the start of vegetation dieback because of pipelines placed directly on the tundra along northern shore of the TIA upstream of the Reclaim Pump Station (Photolog 5). This is becoming a preferred flow path for surface runoff which could ultimately lead to rapid surface erosion and subsequent thermal erosion.

The PCP discharge pipeline was terminated on the tundra along the northern shore of the TIA upstream of the Reclaim Pump Station. A large thermal erosion feature has developed here where massive ground ice has melted as illustrated in Photolog 5 and Photolog 8. This erosional feature is expected given the high ice content of the soil, and continued discharge of warm water onto this ice has caused the thermal erosion. This feature will continue to expand in size and must therefore be backfilled.

Recommendations:

- TMAC must carefully inspect all pipelines placed directly on the tundra for signs of vegetation dieback and associated flow path channeling. Where this is occurring, the pipeline must be relocated to follow existing all-weather road shoulders, and appropriate remediation needs to be put in place where damage has occurred. Although SRK previously approved the placement of insulated pipelines directly on the tundra, inspection observations suggest TMAC should avoid placement of any pipelines on the tundra where possible and relocate any un-insulated pipes on the tundra.

- The thermal erosion feature that has developed along the northern shore of the TIA needs to be backfilled. The ideal backfill method should be hydraulic placement of a slurry as that would minimize tundra damage during the activity. The use of tailings slurry for this would be a good practice, however it needs to be cooled to avoid further thermal erosion.

- TMAC should ensure that under no circumstances water be discharged directly onto the tundra adjacent to the TIA. Water should be discharged directly into the TIA Reclaim Pond.

3.10 Shoreline Erosion

The pre-mining water level in the pond is 28.3 m. Since the start of commercial production, the water level has risen to 30.7 m, which is 2.4 m above the original lake water level. Therefore, a large section of shoreline has been flooded which has resulted in vegetation stress. At this time, there are however no visible signs of shoreline erosion, and therefore no additional monitoring is required.

Recommendations:

- None.

3.11 TIA Water Balance

The TIA operational water balance can be used to predict water levels in the TIA going forward. With the Roberts Bay Discharge System Pipeline not yet constructed, and only expected to be operational by the summer of 2019, the water level in the TIA is expected to continue to rise and if discharge does not start in the summer of 2019, there is a possibility that the TIA may each FSL requiring reduced operations and subsequent increased discharge to Roberts Bay.

Recommendations:

- It is of paramount importance that the Roberts Bay Discharge System Pipeline be completed during the summer of 2019. Further delay of this may result in reduced operations and subsequent increased discharge to Roberts Bay, to maintain the water level within the TIA.

3.12 Climate Data

For reference, precipitation and temperature data, as described in Section 2.5.5, is provided in Appendix J.

Recommendations:

- None.

3.13 TIA Water Quality

TIA Water quality is monitored at compliance station TL-1 at the Reclaim Water pump station. Since no discharge is occurring this water quality has not been critically scrutinized; however, there are no water quality parameters that currently exceed MMER or MDMER limits which would prohibit discharge to Roberts Bay, except for Total Suspended Solids (TSS).

A comprehensive analysis of the reasons for the high TSS concentrations has been completed (SRK 2019) and it has been concluded that a water treatment plant is required to allow for filtering of the TIA discharge to ensure compliance with discharge limits.

Recommendations:

- TMAC must action the water treatment plant for TIA discharge water to ensure that once the Roberts Bay Discharge System Pipeline is operational in the summer of 2019, water can be treated and discharged.

4 Recommendations and Conclusions

The Doris TIA is functioning as designed. Any of the issues observed in the physical inspection and any anomalies observed in the monitoring data can be explained and are not of concern. Table 19 presents a summary of the recommendations listed throughout this report.

Table 19: Summary of Recommendations

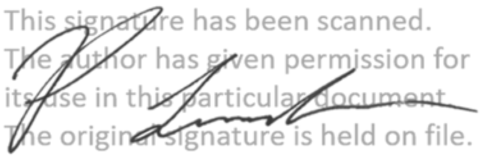
Inspection Item	2017 Recommendations	2018 Recommendations
Third Party Dam Safety Review	• The North Dam hazard classification was revisited and is considered HIGH. This requires an independent third-party Dam Safety Review by 2024.	• Conduct an independent third-party Dam Safety Review for both the North and South Dams in the summer of 2021.
Tailings Operating, Maintenance and Surveillance (OMS) Manual	• Ensure all staff are aware of the OMS Manual and are familiar with its contents. • Review and revise the OMS manual to ensure consistency with the recently amended Water License. • Provide necessary training in accordance with the OMS Manual.	• An update to the Operations, Maintenance and Surveillance (OMS) Manual is required to reflect the operational, personnel and monitoring changes that are in effect. This update should build on the 2017 edition of the OMS Manual which considers the Phase 2 project as opposed to the Phase 1 project. As part of the update attention needs to be paid to defining Quantifiable Performance Objectives (QPOs) and including Trigger Action Response Plans (TARPs). • TMAC should ensure all staff are properly informed and trained on the contents of the OMS Manual.
TIA Responsible Parties	• NA	• TMAC must agree on the lines of responsibility of the TIA, document that in the OMS Manual, train and inform personnel of their duties, and operate the facility accordingly.
Monitoring Standard Operating Procedures (SOPs)	• To avoid confusion update SOPs to reflect changes that has been agreed to since the original SOP was developed.	• Update the Monitoring SOP to include South Dam monitoring requirements.
Compliance with Monitoring Requirements	• Improve efforts to conduct monitoring at the frequency described in the SOPs.	• Conduct monitoring in accordance with the Monitoring SOP, paying attention to those areas where conformance is not consistently met.
North Dam Inspection and Monitoring		
Ground Temperature Cables (GTCs)	• In accordance with manufacturers recommendations, the dataloggers must be recalibrated as it has been in operation for more than five years. Internal batteries on the dataloggers must also be replaced. • A monitoring well near ND-VTS-130-DS is no longer required. See “Physical Inspection of North Dam”.	• None.
Thermosyphons	• AFI or another qualified contractor must physically inspect thermosyphon North 2	• TMAC should measure the temperature of each thermosyphon riser pipe directly

Inspection Item	2017 Recommendations	2018 Recommendations
	and determine why it is not working. Appropriate repairs must be conducted. • While the contractor is on-site, have them inspect all thermosyphons, and carry out any additional maintenance they recommend.	below the radiator fins using a contact thermometer or thermal camera. This measurement should be completed in early winter when the differential between the ground temperature and air temperature is the greatest. This will identify discrepancies between thermosyphons. • If TMAC's measurement confirms a temperature differential, AFC, or another qualified contractor, must to be contracted to physically inspect thermosyphon North 2, to investigate the cause of the malfunction and conduct any necessary repairs. The inspection must occur in the winter, as early as possible, to ensure adequate ground and air temperature differentials. • If AFC, or another suitable contractor, is on-site have them inspect all other thermosyphons, and carry out any additional maintenance they recommend.
CR1000 Datalogger Battery Voltage	• The external datalogger batteries should be tested and recharged or replaced annually.	• The external CR1000 datalogger batteries should continue to be monitored and recharged annually or replaced as needed.
Inclinometers	• No action required.	• The inclinometer and associated readout device should be recalibrated every 3 years, with the next recalibration due before the spring of 2019.
Survey Monitoring Points	• Backfill the erosion around ND−DSP−100.	• Backfill the erosion around ND−DSP−100. • Maintain a careful watch on downstream dam shell settlement points ND-SSP-080-3 and ND-SSP-110-3 to determine if thaw settlement of the toe is causing undue deformation.
Creep Displacement	• N/A	• None.
Walkover Surveys	• Improve efforts to conduct walkover surveys in accordance with the frequency prescribed in the SOP.	• The required weekly walkover surveys are not being completed in accordance with the SOP. This is an important surveillance activity as defined in the OMS Manual and needs to be complied with.
North Dam Seepage	• Conduct more rigorous monitoring of the North Dam toe seep in accordance with the recommendations in Appendix J. This includes: • Field measurements of Electrical Conductivity when Surveillance Network Program (SNP) samples are collected at TL-1;	• Continue water quality monitoring of North Dam seepage according to the methods outlined in SRK (2018b), but include the additional recommendations proposed. • Conduct at least two additional frost probe surveys along the same transects in early summer and early fall, following the same procedure as in 2018.

Inspection Item	2017 Recommendations	2018 Recommendations
	• Weekly sampling and geochemical analysis of North Dam toe seepage when present; • Annual review of North Dam toe seepage water chemistry; • Measurement of active layer thaw depth using a frost probe; and • Installation of a V-notch weir (or similar) to improve seepage monitoring.	
AGI Physical Inspection	• --	• None.
South Dam Inspection and Monitoring		
Ground Temperature Cables (GTCs) and D405 Dataloggers	• N/A	• Complete troubleshooting and repair damaged, but repairable GTCs in the spring of 2019.
Survey Monitoring Points	• N/A	• Complete installation of survey monitoring points and prepare monitoring database for evaluation.
Physical Inspection of the South Dam	• N/A	• None.
TIA-Wide Monitoring		
Tailings Deposition System	• No action required.	• TMAC needs to install the dedicated mine water discharge pipeline to the TIA as soon as possible to allow tailings deposition to recommence from the South Dam. It is critical that South Dam beaching maintain beach of at least 100 m at all time, for all TIA water levels. • Saline mine water may only be discharged together with tailings from, or within, 300 m of the South Dam provided the freezing point depression is less than 0.5ºC. If the freezing point depression exceeds 0.5ºC, saline mine water may be discharged with tailings at other designated tailings discharge points or directly into the Reclaim Pond. The freezing point depression calculation is provided in this AGI and needs to be incorporated into an updated OMS Manual. • Used propylene glycol may be discharged into the Reclaim Pond in accordance with the stipulations provided in this AGI which needs to be incorporated into an updated OMS Manual. • Tailings discharge must be done in accordance with the designated tailings discharge plan, which provides designated tailings discharge coordinates, including elevation.

Inspection Item	2017 Recommendations	2018 Recommendations
		• Areas along the western shoreline of the TIA where tailings discharge has occurred at elevations above 36.5 m needs to be carefully monitored to determine if permafrost damage is occurring due to vegetation dieback. Should any damage be noted, appropriate proactive mitigation may be required.
Emergency Dump Catch Basins	• N/A	• Completely reconstruct the Western Emergency Dump Catch Basin as the earliest opportunity. TMAC has agreed to complete this work in the summer of 2019.
Pipelines (Reclaim, Tailings Deposition and TIA Discharge)	• N/A	• TMAC must carefully inspect all pipelines placed directly on the tundra for signs of vegetation dieback and associated flow path challenging. Where this is occurring, the pipeline must be relocated to follow existing all-weather road shoulders, and appropriate remediation needs to be put in place where damage has occurred. Going forward TMAC should consider abandoning the practice of placing pipelines directly on tundra. • The thermal erosion feature that has developed along the northern shore of the TIA needs to be backfilled. The ideal backfill method should be hydraulic placement of a slurry as that would minimize tundra damage during the activity. The use of tailings slurry for this would be a good practice, however it should ideally be cooled to avoid further thermal erosion. • TMAC should ensure that under no circumstances water be discharged directly onto the tundra adjacent to the TIA, Water should be discharged directly into the TIA Reclaim Pond.
Shoreline Erosion	• N/A	• None.
TIA Water Balance	• M/A	• It is of paramount importance that the Roberts Bay Discharge System Pipeline be completed during the summer of 2019.
Climate Data	• N/A	• None.
TIA Water Quality	• N/A	• TMAC to action water treatment for TIA discharge to ensure once the Roberts Bay Discharge System Pipeline is operational, water can be treated and discharged.

This final report, 2018 Annual Geotechnical Inspection, Tailings Impoundment Area, Hope Bay Project, Hope Bay, Nunavut was prepared by



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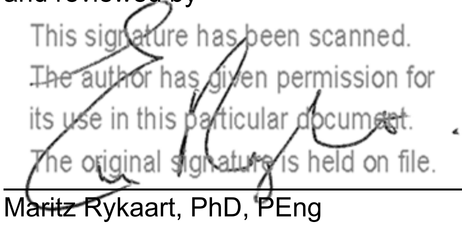

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All data used as source material plus the text, tables, figures, and appendices of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Figures