Volume 1 Annex V1-7 Type A Water Licence Applications

Package P4-10

Hope Bay Project Boston Tailings Impoundment Area
Operations, Maintenance, and Surveillance Manual

Hope Bay Project, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual

Hope Bay, Nunavut

December 2017

Hope Bay Project, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual

Plain Language Overview:

This Tailings Management Area (TMA) Operation, Maintenance and Surveillance Manual (OMS Manual) is also known as the Boston Tailings Management Plan. This OMS Manual describes how TMAC will manage and monitor the tailings management area. The Management of TMA related to tailings material itself is included in this manual. The dry stack, contact water berms, and water pump and pipeline systems is covered in the Boston Water Management Plan. This document describes how tailings stacking will be carried out and demonstrates how TMAC will ensure the TMA remains safe. The Boston TMA is a dry stack tailings facility, not a dam. However, for the purposes of surveillance, the TMA is treated as a dam.

Hope Bay, Nunavut

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Hope Bay Project
c/o #18 Yellowknife Airport
100 McMillan Drive
Yellowknife, NT X1A 3T2
Phone: 867-873-4767
Fax: 867-766-8667

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Contents

1 Introduction 1

1.1 Purpose of OMS Manual 1

1.2 Objectives 1

1.3 Change Management and OMS Manual Updates 2

1.4 Relevant Legislation and Guidance 3

1.5 Related Documents 4

2 Roles and Responsibilities 5

2.1 Organization and Individual Responsibilities 5

2.2 Competency and Training 7

3 Facility Overview 8

3.1 Project Description 8

3.2 Project History 8

3.3 Site Conditions 9

3.3.1 Climate 9

3.3.2 Permafrost 9

3.3.3 Regional Geology 10

3.3.4 Hydrology 10

3.3.5 Hydrogeology 10

3.4 Facility Components 10

3.4.1 Dry Stack Facility 10

3.4.2 Underdrain 11

3.4.3 Seepage Collection 11

3.4.4 Operational Erosion Protection 11

3.4.5 Closure Components 12

3.4.6 Underperformance of Tailings Filter Press Systems 12

3.5 Tailings Properties 13

3.5.1 Tailings Geotechnical Characteristics 13

3.5.2 Tailings Geochemistry 13

3.6 Dry Stack Hazard Classification 13

3.7 Overall TMA Design Criteria and Parameters 14

3.8 Construction Timing 15
3.8.1 Construction Materials 15
3.8.2 Construction Quality Control and Quality Assurance 15
3.8.3 Material Quantities 15
3.9 Dry Stack Stability Analysis 16
3.9.1 Stability Criteria 16
3.9.2 Foundation and Slope Stability Analysis 16
3.9.3 Liquefaction Analysis 17
3.9.4 Deformation Analysis 18
3.9.5 Seepage Analysis 18
3.10 Water Management 18
3.10.1 Conveyance Channels 18
3.10.2 Contact Water Ponds 19
3.10.3 Discharge Criteria 19
4 Operation 20
4.1 Objective 20
4.2 Operating Criteria and Constraints 20
4.3 Dry Stack Tailings Placement Plan 20
4.4 Winter Operations 21
4.5 Dust Management 21
4.6 Water Management 21
4.7 Off-Specification Tailings Management 21
4.8 Freeboard Requirements 22
4.9 Concurrent Closure 22
4.10 Safety and Security 23
5 Maintenance 23
5.1 Objective 23
5.2 Maintenance Parameters 23
5.3 Maintenance Procedures 23
5.3.1 Routine and Preventative Maintenance 23
5.3.2 Event Driven Maintenance 24
5.4 Documenting and Reporting 24

6 Surveillance 25

6.1 Objective 25

6.2 Frequency and Responsibility 25

6.3 Monitoring Data Management Protocols 25

6.4 Surveillance Components 26

6.5 Surveillance Parameters 26

6.6 Surveillance Procedures 26

6.6.1 Visual Inspections 26

6.6.2 Instrumentation 27

6.6.3 Water Quality Monitoring 27

6.6.4 Tailings Geochemical Monitoring 27

6.7 Documenting and Reporting 27

7 References 28

Tables

Table 1.1: Physical Distribution of OMS Manual 2

Table 1.2. List of federal and territorial regulations governing the Hope Bay, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual 3

Table 1.3. List of documents related to the Hope Bay, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual 4

Table 2.1: TMA Responsible persons 5

Table 3.1: Summarized tailings geotechnical properties 13

Table 3.2: TMA Design Criteria and Design Parameters 14

Table 3.3: Summary of Material Quantities 16

Table 3.4: Operating Constraints 17

Table 4.1: Operating Constraints 20

Figures

Figure 1: Organization Chart

Figure 2: Site Location Plan

Figure 3: General Site Layout Plan

Figure 4: TMA Site Plan

Figure 5: Boston Dry Stack Facility - Plan

Figure 6: Boston Dry Stack Facility -Sections

Figure 7: Contact Water Berm & Dry Stack Cover – Details

Figure 8: Contact Water Berms - Profiles

Glossary

Term	Definition
CDA	Canadian Dam Association
DSI	Dam safety inspection
DSR	Dam safety review
EOR	Engineer of Record
HDPE	High density polyethylene
IDF	Inflow design flood
INAC	Indigenous and Northern Affairs Canada
KIA	Kitikmeot Inuit Association
MAP	Mean annual precipitation
MMER	Metal Mining Effluent Regulations
NIRB	Nunavut Impact Review Board
NWB	Nunavut Water Board
OMS	Operations, maintenance and surveillance
ROQ	Run of quarry
SOP	Standard operating procedures
SRK	SRK Consulting (Canada) Inc.
TBD	To be determined
TMA	Tailings management area
TMAC	TMAC Resources Inc.
WMMP	Wildlife Monitoring and Management Plan

1 Introduction

This Hope Bay Project, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual (the Manual) has been prepared by TMAC Resources Inc. (TMAC) in accordance with various water licences held by TMAC and associated with developments throughout the Hope Bay region, or which are being currenlty applied for (see Table 1.2).

This Manual is intended primarily for use by TMAC and its contractors to ensure that best practices for minimizing potential environmental impacts and potential environmental liabilities, with respect to the Boston Tailings Management Area (TMA), and to ensure that conditions for the water licences will be met.

This Plan is structured in a manner such that one document pertaining to the Boston TMA can be approved and implemented to address the site- and licence-specific needs. In the event of a new water licence, or an in place licence is amended, then only the specific portions of this manual pertaining to that licence will need to be revised in this TMA OMS Manual.

1.1 Purpose of OMS Manual

This *Boston Tailings Management Area Operations, Maintenance and Surveillance (OMS) Manual* (OMS Manual) has been prepared by SRK Consulting (Canada) Inc. (SRK) on behalf of TMAC Resources Inc. (TMAC). The OMS Manual outlines the framework and procedures that TMAC and its contractors will use to ensure safe design, construction, operation, maintenance, surveillance and closure of the Boston Tailings Management Area (TMA).

1.2 Objectives

The OMS Manual defines and describes:

- Roles and responsibilities of personnel assigned to the TMA;
- Procedures and processes for managing change;
- Key components of the TMA;
- Procedures required to operate, monitor the performance of, and maintain the TMA to ensure that it functions in accordance to its design, meets regulatory and corporate policy obligations, and links to emergency planning and response; and
- Requirements for analysis and documentation of the performance of the TMA.

1.3 Change Management and OMS Manual Updates

The procedures required to operate and maintain the TMA can change, and since this OMS Manual is a controlled document, it is revised or updated when necessary.

Revisions to the OMS Manual can be triggered by activities such as changes in dry stack classification, operational performance, personnel or organizational structure, mine ownership, regulatory or social considerations, and life cycle or design philosophy. The OMS Manual will be formally reviewed as part of the annual Engineer of Record's (EOR) Dam Safety Inspection (DSI), and by third parties during Dam Safety Reviews (DSR). These inspections and reviews may lead to recommendations for OMS Manual updates.

OMS Manual updates will be the responsibility of TMAC, specifically the Mill Manager, and will be executed in the following manner:

- Proposed changes will be submitted to the Mine General Manager for review and authorization;
- If changes are related to design elements (as stipulated in Section 3.7 of this document) of the TMA, authorized changes will be submitted to the EOR for review and approval; and
- Implement and document the authorized and approved changes by revising the OMS Manual.

A printed copy of this OMS Manual is available at each of the locations listed in Table 1.1. Printed copies of the OMS Manual found at other locations will be considered uncontrolled versions.

Table 1.1: Physical Distribution of OMS Manual

Location	Responsible Parties
Site Main Office	Mine General Manager
Environmental Department	Environmental Coordinator
Mill	Mill Manager
	Mill General Foreman
External	Engineer of Record

1.4 Relevant Legislation and Guidance

The Project falls under the jurisdiction of both the Government of Canada, and the Kitikmeot Inuit Association (KIA). Authorities involved with permitting and regulating the design, construction, operation, maintenance, surveillance and closure of the TMA include:

- KIA;
- Indigenous and Northern Affairs Canada (INAC);
- Nunavut Water Board (NWB);
- Nunavut Impact Review Board (NIRB); and
- Workers Safety and Compensation Commission Chief Mines Inspector as per Mine Health and Safety Act, and its associated Regulations (Government of Nunavut, 1995).

The TMA authorization is currently in the environmental assessment and regulatory stage. Table 1.2 provides a list of licence requirements and guidelines that govern the structure and content of this OMS Manual.

Table 1.2. List of federal and territorial regulations governing the Hope Bay Project, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual

Regulation	Year	Governing Body	Relevance
Water License No: TBD	TBD	Nunavut Water Board	License to operate. Expires TBD
A Guide to the Management of Tailings Facilities, Third Edition	2017	Mining Association of Canada (MAC)	Guidance related to the management of Tailings Facilities
Dam Safety Guidelines	2013	Canadian Dam Association (CDA)	Guidance related to design and operation of dams
Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams	2014	Canadian Dam Association	Guidance related to design, operation and closure of tailings dams
Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities	2011	Mining Association of Canada	Guidance for structure and content of tailings OMS manuals
Audit and assessment of tailings facilities	2011	Mining Association of Canada	Guidance for audit and inspection of tailings facilities
Management of tailings facilities	2011	Mining Association of Canada	Guidance for management and operation of tailings facilities
Mined Rock and Overburden Piles – Investigation and Design Manual	1991	British Columbia Mine Waste Rock Pile Research Committee	Guidance (interim guidelines) for minimum design factory of safety (stability) considerations.

1.5 Related Documents

The documents listed in Table 1.3 are expected to be referenced and utilized in conjunction with the OMS Manual.

Table 1.3. List of documents related to the Hope Bay Project, Phase 2, Boston Tailings Management Area - Operations, Maintenance and Surveillance Manual

Document Title	Year	Relevance
Emergency Response Plan	2016	Describes Incident Command System and actions relating to all surface emergencies. (TMAC 2016)
Boston Tailings Management Area Preliminary Design	2017	Report presents a description of the TMA concept, TMA design criteria, details of the TMA design, detailed descriptions of the supporting analyses, TMA construction details, TMA operational plan, TMA closure, and includes a brief discussion on monitoring and maintenance. (SRK 2017a)
Site-Wide Water and Load Balance	2017	Water and load balance to evaluate water management needs and predict water quality at the Project and downstream receptors (SRK 2017b)
Boston Water Management Engineering Report	2017	Describes the water management procedures for the Boston site. (SRK 2017c)

2 Roles and Responsibilities

2.1 Organization and Individual Responsibilities

The site management structure is outlined in Figure 1. Individuals (including external advisors and service providers) having responsibilities for operation, maintenance, surveillance, or emergency preparedness and response of the TMA are highlighted in Figure 1 and are listed in Table 2.1 below.

Table 2.1: TMA Responsible persons

Personnel and Contact Information	Position	TMA Responsibilities
Gil Lawson, P.Eng 416-561-0363 gill.lawson@tmacresources.com	Chief Operating Officer	Corporate overall operational lead for ensuring that the TMA construction, operation, maintenance, surveillance and closure are carried out in accordance with this OMS Manual.
John Roberts, PEng (416) 628-0216 john.roberts@tmacresources.com	Vice President Environmental Affairs	Corporate overall regulatory lead for ensuring that the TMA construction, operation, maintenance, surveillance and closure are carried out in accordance with approved licenses and permits.
Jason McKenzie (867) 988-6882 ext. 100 Jason.mckenzie@tmacresources.com	Mine Manager	Functional site based discipline leads for assigning and applying appropriate resources to execute TMA construction, operation, maintenance, surveillance and closure in accordance with this OMS Manual.
Dan Gagnon (867) 998-6882 ext. 104 dan.gagnon@tmacresources.com	Mine General Manager	
Chad Parent (867) 988-6882 ext. 141 chad.parent@tmacresources.com	Mill (Process) Manager	
Kelly Schwenning (867) 988-6882 ext. 106 kelly.schwenning@tmacresources.com Ron Bertrand (867) 988-6882 ext. 101 Ron.bertrand@tmacresources.com	Surface Manager	
Sarah Warnock Kyle Conway (867) 988-6882 ext. 102 enviro@tmacresouces.com	Environmental Site Coordinator	Day-to-Day execution of environmental monitoring and compliance activities pertaining to TMA construction, operation, maintenance, surveillance and closure in accordance with approved licenses and permits.
Vince Kapinus (867) 988-6882 ext. 155 vince.kapinus@tmacresources.com	Mine Operations Superintendent	Day-to-day execution of discipline based activities and inspections Pertaining to TMA operation, maintenance and

Personnel and Contact Information	Position	TMA Responsibilities
Dave Archibald dave.archibald@tmacresources.com Brad Starcheski brad.starcheski@tmacresources.com (867) 988-6882 ext. 145	Mill (Process) Operations Superintendent	surveillance as it relates to tailings deposition and water management in accordance with this OMS Manual.
Jason Lanoue jason.lanoue@tmacresources.com Murray Weddell murray.weddell@tmacresources.com (867) 988-6882 ext. 131	Surface Operations Superintendent	
Doug Brown (867) 988-6882 ext. 138 doug.brown@tmacresouces.com	Health and Safety Manager	Functional site based lead for assigning and applying appropriate resources towards health and safety procedures for the TMA construction, operation, maintenance, surveillance and closure.
Ken Cook (867) 988-6882 ext. 138 ken.cook@tmacresources.com	Health and Safety Superintendent	Day-to-Day execution of site health and safety procedures related to TMA construction, operation, maintenance, surveillance and closure activities as outlined in all appropriate site health and safety procedures.
Maritz Rykaart, PhD, PEng (SRK) (604) 601-8426 mrykaart@srk.com	Facility Designer and Engineer of Record	Detailed design of TMA components in accordance with industry best practice; Construction quality assurance and associated as-built reporting; Conduct annual DSI, including a review of the OMS Manual.

2.2 Competency and Training

Specific procedures will be adopted to ensure that all persons associated with the TMA activities (as per Table 2.1) are familiar with the contents of this OMS Manual. This will include receiving appropriate training, and having a clear understanding of, and adequate competency for their roles and responsibilities. Procedures for competency and training for TMA personnel will include:

- Requiring previous tailings management experience for specific job descriptions prior to appointing persons in that role;
- If a person's general tailings management experience is deemed insufficient relevant to his/her appointed responsibilities, he/she will be required to complete formal, external training such as on-line tailings management courses offered by Edu-Mine;
- TMAC will develop, and require persons to annually attend a detailed site-specific TMA orientation and training module based on this OMS Manual;
- On-the-job training to persons for specific tasks, such as those outlined in appropriate Standard Operating Procedures (SOPs); and
- Annually, as part of the EOR's DSI, the EOR, if requested, will conduct a workshop for site staff based on the OMS Manual, but focussed on the review findings.

Notwithstanding the specific procedures outlined above, focussed on persons associated with the TMA activities, TMAC will also ensure that all site personnel are familiar with the general TMA management principles, and understand the need to be continually aware of visual indications of the TMA performance. This will be achieved through inclusion of information in the general site orientation.

3 Facility Overview

3.1 Project Description

The Hope Bay Project (the Project) consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 (Madrid-Boston project) which is in the environmental assessment and regulatory stage. 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 due south from Doris respectively.

The Project is a gold mining and milling undertaking of TMAC Resources Inc. that is located 705 km northeast of Yellowknife, 153 km southwest of Cambridge Bay in Nunavut, and is situated east of Bathurst Inlet (Figure 2). The Project comprises three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston (Figure 3).

Ore processing includes cyanidation and flotation methods, with two separate streams of tailings being produced, both captured under the tailings management systems (TMS). The cyanidation tailings will be detoxified (cyanide destruction) to produce detox tailings. The detox tailings are then filtered and blended with waste rock to be returned underground as backfill. At Boston, the flotation tailings will be filtered (to reduce water content) and then deposited in the Boston TMA. The Boston ore reserve is 5.1 Mt, and thus this is also the design capacity of the Boston TMA; not considering that detoxified tailings of about 6 to 8% of this total will be deposited underground.

Environmental containment for the Boston TMA is limited to a series of contact water ponds to collect surface runoff from the facility. At closure, the TMA will be covered with a low infiltration cover consisting of a geosynthetic liner with a protective quarry rock cover.

3.2 Project History

Work at the Project site date back to 1964 when the first exploration was carried out in the area focusing on showings at Ida Point, Ida Bay and Roberts Lake to the north. Three different exploration companies continued exploration through the 1970s and 1980s, but the first exploration drilling only started in 1992. This exploration drilling led to the first site infrastructure at Boston, in the form of an exploration camp on the northeastern shores of Aimaokatalok Lake in 1993. Subsequently, underground development was carried out at Boston in 1996 and 1997 to extract a bulk sample. Exploration drilling expanded to Madrid and Doris in 1999, and a new exploration camp was constructed on the eastern shore of Windy Lake. In 2006, a Project Certificate (NIRB No. 003) was obtained to start a mine at Doris, and the associated Water Licence (2AM-DOH0713) was issued in 2007 (and an amendment issued in 2016).

Construction at commenced in 2007 at the Doris area. Construction was slowed down as the Project transitioned in ownership in 2008, but resumed in 2010. In 2012 the Project was placed in care and maintenance prior to starting commercial production. Another ownership change in 2013 resulted in recommencement of construction, and commercial production started in 2017. TMAC resources is currently applying for a water license for Phase 2 which will also cover the license to operate at the Boston Site. Boston will be a standalone self-contained mining complex complete with all surface infrastructure to support mining and ore processing required to produce gold doré.

3.3 Site Conditions

3.3.1 Climate

The mean annual air temperature (MAAT) at Boston is estimated to be -11.7°C at Boston.

Boston has predominant wind directions west-northwest. The highest wind speeds are recorded from December to April, as is predominantly westerly. During May to October, there is a reduction in wind velocities, with no predominant direction exhibited; however, there is a tendency to be on the East-West axis. Lastly, in November and December, the winds are predominantly westerly.

Precipitation occurs as rainfall and snowfall. The mean annual rainfall for Boston is approximately 89 mm. The mean annual snowfall is 120 mm snow water equivalent. The estimated mean annual precipitation (MAP), water equivalent, is 210 mm.

The overall lake evaporation has been estimated to be 291 mm/year at Boston (SRK 2017h).

3.3.2 Permafrost

The Project is in the region of the Canadian Arctic that is underlain by continuous permafrost. Project-wide overburden consists of permafrost soils which are mainly marine clays, silty clay, and clayey silt, with pockets of moraine till underlying these deposits. The marine silts and clays contain ground ice ranging from 10 to 30% by volume on average, but occasionally as high as 50%. The till typically contains low to moderate ice contents ranging from 5 to 25%. Overburden soil pore water is typically saline due to past inundation of the land by seawater following deglaciation of the Project area. Salinity measurements in the EBA (1996) investigation ranged from 3 to 48 parts per thousand, which depresses the freezing point and contributes to higher unfrozen water content at below freezing temperatures. (SRK 2017a).

Permafrost at the Project area extends to depths of about 565 m, with an average geothermal gradient of 0.021°C/m. Active layer depth in overburden soil averages 0.9 m, with a range from 0.5 to 1.4 m (SRK 2009, SRK 2017a).

3.3.3 Regional Geology

The Project area is in the faulted Bathurst Block, forming the northeast portion of the Slave Structural Province, a geological sub-province of the Canadian Shield. The region is underlain by the late Archean Hope Bay Greenstone belt, which is 7-20 km wide and more than 80 km long in a north-south direction. The belt is mainly comprised of mafic meta-volcanic (mainly meta-basalts) and meta-sedimentary rocks that are bound by Archean granite intrusives and gneisses. The Greenstone package has been deformed during multiple events, and is transected by major north-south trending shear zones that appear to exert a significant control on the occurrence of mineralization, particularly where major flexures are apparent and coincident with anti-forms (SRK 2015).

The Boston deposit is located near the south end of the belt and is associated with a flexure in the Hope Bay regional structure (TMAC 2017a).

3.3.4 Hydrology

The Boston deposit is in a separate watershed to the Doris deposit. The subcatchment around the TMA site naturally drained towards the east-northeast towards Aimaokatalok Lake. As discussed in Section 3.4.5, Contact Water Ponds will be constructed around the dry stack facility and all will collect the contact water until it can be treated and discharged. Additional details on site water and load balances for the Project can be found in the site-wide water and load balance (SRK 2017b). The rainfall depths for the 24-hour, 100 year return period rainfall event are 55 mm and the maximum daily snowmelt is 18 mm at the Boston area (SRK 2017c).

3.3.5 Hydrogeology

Groundwater flow in a continuous permafrost environment is limited to shallow (seasonal) and deep groundwater flow. Shallow seasonal groundwater flow takes place within the active layer. Deep groundwater flow, on the other hand, takes place below the permafrost and in taliks (permafrost free zones) under larger water bodies. Deep groundwater has elevated salinity since the groundwater is ancient trapped seawater (connate water).

The Boston mine will be encapsulated by permafrost and will not intercept and open talik or sub-permafrost area. Therefore, there is not expected to be any groundwater (i.e. mine water) at the Boston site (SRK 2009, TMAC 2017a).

3.4 Facility Components

3.4.1 Dry Stack Facility

The dry stack facility will occupy a flat area just east of the Aimaokatalok Lake extension, south of the proposed new Boston airstrip. This area is separated from the mining infrastructure (SRK 2017e) by the extension of the Aimokatalok Lake and the outflow creek from Stickleback Lake (Figure 4).

The footprint of the dry stack facility is in the shape of an irregular heptagon, with a footprint of about 19.8 hectares (about 410 m in east-west direction and 530 m in north-south direction) and a final height of 26 m. The final height of the facility is governed by the proximity to the airstrip to avoid encroachment into the airstrip exclusion zone (SRK 2017g).

The dry stack facility will be built entirely of filtered tailings. The facility will be constructed in thin lifts of 0.3 m, spread and compacted successively over the life of the mine in 5 m high intermediate benches with side slopes of 3H:1V. Setback benches of 5 m will result in an overall slope configuration of about 3.9H:1V. The top of any given lift will be graded at 2% toward the perimeter of the facility, to promote run-off towards the three contact water ponds.

Access to the facility will be gained via the Madrid-Boston all weather road, then following the Airstrip access road which doubles as the contact water pond berms in select locations (Figure 5). An access ramp with a nominal grade of about 8% will provide continuous access to the rising dry stack.

Additional details for the Dry Stack Facility are presented in SRK (2017a).

3.4.2 Underdrain

The Boston dry stack is founded on permafrost soils, and complete freeze-back of the tailings is expected within the first winter season following deposition (SRK 2017a). Correspondingly, any underdrain will freeze and remain frozen indefinitely once the tailings thickness exceeds the active zone depth. It is therefore not practical or necessary to construct an underdrain for the Boston dry stack facility.

3.4.3 Seepage Collection

The dry stack foundation is frozen, and the tailings will freeze back soon after placement (SRK 2016d), save for the active layer. There is therefore no concern related to potential deep groundwater seepage. Shallow groundwater seepage emerging from the active layer will be collected in the contact water ponds. Post-closure seepage through the active layer will be limited to what may infiltrate through the low permeability cover. This volume of flow is considered negligible, and water quality modeling has confirmed there will be no environmental impact. As a result, no post-closure seepage collection is planned or required (SRK 2017b.

3.4.4 Operational Erosion Protection

As far as practical progressive reclamation of the dry stack facility will be completed; however, at any given time there will be exposed tailings that might be susceptible to overland runoff erosion. Should this occur all eroded sediments will end up in the contact water ponds, with no risk of an uncontrolled environmental discharge. The volume of sediment trapped in the contact water ponds will be monitored and if it compromises the pond design capacity, the sediment will be removed, or the contact water ponds capacity will be increased.Contact Water Ponds

The catchment area, which includes the dry stack facility that drains towards the three contact water ponds is about 28.0 ha. The Contact Water Pond (CWP) berms has a crest width of 8 m with side slopes of 2H:1V (26.5°). Water retention of these contact water ponds are provided by a geosynthetic high density polyethylene (HDPE) liner tied into permafrost, i.e. a frozen foundation dam design. A 2.5 m minimum fill thickness will be placed to construct these berms to provide thermal insulation to ensure the contact between the geomembrane and permafrost soils remain frozen.

Design criteria and design details for the contact water ponds are provide in the Boston Water Management Report (SRK 2017c) and the Contact Water Pond Berm Design Report (SRK 2017j).

3.4.5 Closure Components

The tailings facility will be built in 5 m high benches. The inter-bench slope of 3H:1V and bench width of 5 m results in an overall slope of 3.9H:1V. This slope configuration will be created during active deposition, and no re-sloping is anticipated to be required at closure.

At closure, a low permeability cover will be constructed to reduce the amount of seepage expected. The geomembrane will be placed in direct contact with the tailings and will be protected by a granular cover consisting of 0.3 m of crushed rock and 0.7 m of run of quarry (ROQ). Construction of the cover will be done in stages or at the end of active stacking.

The contact water containment berms will be breached and the liner will be cut to prevent ponding. Several breaches may be required and will be done at topographic lows. The balance of the berms will be left in place.

3.4.6 Underperformance of Tailings Filter Press Systems

It is prudent design to consider the need for occasional storage of non-spec tailings if the tailings filter press systems underperform. If for any reason the filtered tailings cannot achieve the specified minimum density, those tailings will be recycled to the mill and temporarily stored in dedicated tanks until adequate filtration can be resumed. Alternatively, the non-spec tailings will be spread in a lift as thin as possible and allowed to dry before final compaction is completed.

3.5 Tailings Properties

3.5.1 Tailings Geotechnical Characteristics

Physical properties of the tailings were determined based on three separate geotechnical test campaigns carried out between 2003 and 2009 (SRK 2017k) and are summarized in Table 3.1:

Table 3.1: Summarized tailings geotechnical properties

Parameter	Value
Specific gravity	2.85
% Fines (<0.075 mm)	65%
% Silt	52%
% Clay	13%
Void ratio (e) for filtered tailings	0.6
Deposited dry density (tonnes/m^3) for filtered tailings	1.8
Internal angle of friction (degrees)	40
Cohesion (kPa)	0
Gravimetric moisture content (%)	20.5
Hydraulic conductivity (m/s)	1.3×10^{-7}

3.5.2 Tailings Geochemistry

Detailed geochemical characterization of the Boston flotation tailings (SRK 2017i) confirms that the tailings are not potentially acid generating but have the potential for neutral metal leaching, particularly for arsenic.

Collection and treatment of contact water is planned. Collection and treatment will be modified / updated as needed based on the operational monitoring of the contact water ponds.

3.6 Dry Stack Hazard Classification

Although the Boston TMA contains tailings, the dry stack is not a dam, but more closely represents a waste rock dump. The most notable design guidelines for waste rock dumps are those published by the British Columbia Mine Waste Rock Pile Research Committee (BCMWRPRC, 1991). For the purposes of surveillance, the TMA is however treated as a dam, and inspections will be undertaken as per Canadian Dam Association (CDA 2013, 2014) guidelines.

3.7 Overall TMA Design Criteria and Parameters

A complete summary of the TMA design criteria is listed below (Table 3.2), and is consistent with Best Management Practices, including the Canadian Dam Association (CDA 2013, 2014) guidelines.

Table 3.2: TMA Design Criteria and Design Parameters

Component	Criteria
Hazard Classification	SIGNIFICANT
Design Life • Active deposition period • Assumed Post-closure monitoring period • Long-term design basis	 • 7 years • 10 years • Up to year 2100
Tailings Production Rate	400 tonnes per day for first year ramping up to 2,400 tonnes per day for remaining mine life
Tailings Moisture Content	20.5% (by weight)
Tailings Dry Density	1.8 t/m^3
Tailings Storage Requirements • By mass • By volume	 • 5.1 Mt • 2.8 Mm^3
Tailings Deposition Method	Load, haul, dump, place, and compact filtered tailings
Maximum Design Earthquake	1:2,475 seismic event; peak ground acceleration of 0.018 g
Contact Water Pond(s) Inflow Design Flood	1:100 year return period, 24 hour duration storm event (55 mm) plus maximum daily snowmelt of 18 mm, for a total of 73 mm
Contact Water Pond(s) Storage Requirement	North-east Pond – 9,957 m^3 North-west Pond – 1,984 m^3 South-west Pond – 8,762 m^3 Total – 20,703 m^3
Contact Water Pond(s) Freeboard	1.3 m normal
Stability Factors of Safety (Static)	1.3 during construction 1.5 during operation and closure
Stability Factors of Safety (Pseudo-Static)	during earthquake 1.2 post earthquake

3.8 Construction Timing

Construction of the dry stack will be done year-round. The dry stack tailings material will be placed directly on the tundra, with no removal of vegetation or excavation of overburden prior to tailings stacking. To ensure the permafrost foundations remain frozen, the first lift of filtered tailings should, if practical, be placed in the winter when the ground is frozen. If tailings placement must start when the ground is thawed, a layer of ROQ may be required for trafficability.

The closure cover should ideally be constructed during the warmer seasons to facilitate geomembrane seaming and welding. The gravel bedding layer protecting the integrity of the geomembrane must be constructed immediately after geomembrane installation is complete. The final ROQ cover can be placed any time of the year.

Construction of the containment berms of the contact water ponds must be done in the winter to eliminate potential issues caused by thawing of the soft overburden soils as well as to ensure that a thermal blanket is completed to protect the permafrost in the foundation.

3.8.1 Construction Materials

The dry stack facility will be built entirely of filtered tailings.

Construction material for the closure cover and contact water ponds consist of crushed rock (bedding), and run of quarry (ROQ) material. The granular fill will be produced on site from one of the local approved quarries. Geological, mineralogical and geochemical details on these quarry sites are documented in SRK 2017d.

Other materials that will be used to construct these facilities include HDPE liner and geotextile. Complete details of all these materials are provided in the Technical Specifications (SRK 2011).

3.8.2 Construction Quality Control and Quality Assurance

Complete details of the Quality Assurance and Quality Control (QA/QC) procedures to be followed for the contact water berm and closure construction activities are provided in the Technical Specifications (SRK 2011). QA/QC procedures for the tailings deposition will be developed prior to initial deposition. Quality Control will be the responsibility of the Contractor, and/or the equipment and materials manufacturer. The Engineer of Record, which will be a Registered Professional Engineer in the Nunavut Territory, will carry out Quality Assurance. Complete documentation of all QA/QC data will be provided in the relevant As-Built Reports.

3.8.3 Material Quantities

Material quantities for the construction of the TMA are summarized in Table 3.2 (as reported in SRK 2017a). All fill and excavation volumes represent neat volumes, i.e. “in place”, with no allowance for swelling and compaction. The liner quantities are neat quantities, with no allowance for seams and waste.

Table 3.3: Summary of Material Quantities

Materials	Quantity
Closure Cover	
Liner Bedding Material(m^3)	60,850
Geomembrane (m^2)	202,800
Geotextile (m^2)	202,800
ROQ Fill (m^3)	142,000
Contact Water Pond Containment Berms	
Liner Bedding Material (m^3)	16,495
Geomembrane (m^2)	32,700
Geotextile (m^2)	60,095
ROQ Fill (m^3)	71,750
Transition Fill (m^3)	33,660
Key Trench Excavation (m^3)	5,580

3.9 Dry Stack Stability Analysis

3.9.1 Stability Criteria

The minimum factors of safety (FOS) that are applicable to, and required to be achieved for the TMA, are defined by the Canadian Dam Safety Guidelines applied specifically to tailings dams (CDA 2014), and are provided in Table 3.4.

3.9.2 Foundation and Slope Stability Analysis

A comprehensive stability analysis was carried out to confirm whether the dry stack meets the appropriate design requirements as stipulated in Table 3.2. Complete details of the analysis are presented in SRK (2017a) and the results are summarized in Table 3.4. The analysis considered staged construction of the facility according to the five bench heights, and the ultimate long-term stability was assessed at the end of construction, i.e., the full height of the facility.

Table 3.4: Operating Constraints

Analysis Method	Construction Stage	Short-term FOS (Undrained Loading Conditions)	Long-term FOS (Drained Loading Conditions)	Pseudo-Static FOS
Minimum Required FOS		**1.3**	**1.5**	**1.1**
PLAXIS (FE)	1st Stage (Height 6 m)	1.4	1.8	1.3
	2nd Stage (Height 5 m)	1.4	1.9	1.3
	3rd Stage (Height 5 m)	1.4	1.9	1.3
	4th Stage (Height 5 m)	1.4	1.9	1.3
	5th Stage (Height 5 m)	1.4	1.9	1.3
SLOPE/W (LE)	1st Stage (Height 6 m)	1.4	2.5	1.3
	5th Stage (Height 5m)	1.4		1.3

The dry stack meets all the required minimum slope stability FOS as prescribed by CDA (2014).

Given the low seismicity of the Project area and the results of the pseudo-static analysis, deformation of the dry stack during the design earthquake is expected to be negligible. As a result, further numerical analysis of the dry stack facility post-earthquake was not deemed necessary.

Additional analyses with SLOPE/W were completed to assess the long-term creep effects on the stability of the dry stack. The procedure consisted in back-calculating the friction angle of the frozen marine silt and clay required to meet the stability criterion for the long-term condition (i.e., FOS=1.5). It was found that a maximum friction angle of 20° is required to meet the long-term stability criterion, compared to the 26° friction angle observed in these soils (SRK 2017f) and it was therefore concluded that creep is unlikely to compromise the stability of the dry stack.

3.9.3 Liquefaction Analysis

Liquefaction is a process by which all strength is temporarily lost from a saturated soil, and the soil behaves like a fluid. Liquefaction is normally associated with loose sandy soils, as suggested by the process commonly being referred to as "quicksand". Liquefaction is triggered by a sudden increase in pore pressure, which cannot dissipate fast enough and results in the effective stress becoming near-zero (Holtz and Kovacs 1981). In the context of the Boston TMA, liquefaction could theoretically affect the foundation and the tailings deposit; however, it is extremely unlikely to occur for the reasons described below.

In the case of the foundation, the soils are mostly comprised of marine-type silty clay deposits, with traces of sand. These types of soils are finer than the particle size distribution commonly associated with liquefaction, and are thus not susceptible to liquefaction. In addition, the foundation soils are frozen and will remain frozen indefinitely. In the worst-case scenario of the foundation becoming unfrozen, any thawing would be progressing slowly from the outside of the facility toward the middle and thus would allow timely dissipation of any excess porewater pressures. The dry stack facility will be built gradually with an average rate of rise of about 3.7 m/year (SRK 2017a). The tailings will be laid out in thin lifts and compacted, thus eliminating the loose state required for liquefaction. In addition, the tailings deposited in previous years will freeze over the subsequent winter, eliminating any possibility of pore pressure fluctuations except for the top 2.5 m representing the active layer thickness in exposed tailings (SRK 2017a).

3.9.4 Deformation Analysis

Deformation of the dry stack will be due to two mechanisms: consolidation settlement and creep.

Settlement of the dry stack facility is the apparent displacement of the facility as a whole and is limited to consolidation of the foundation soils. The foundation will however remain frozen (SRK 2017a), preventing any settlement due to consolidation.

Tailings are not expected to experience creep since they are not ice-rich materials. For the foundation, long-term ductile behavior is predicted for the frozen marine silt and clay. Creep shear strains in this layer will occur very slowly and remain below the strain rate for brittle failure. SRK (2017a) presents additional details for the deformation analysis completed.

3.9.5 Seepage Analysis

Seepage through the tailings in the TMA is considered negligible due to the high placed density and the fact that tailings will freeze back and remain frozen for the foreseeable future (other than the active layer) (SRK 2017a).

3.10 Water Management

Contact water from the tailings area will be retained by a series of contact water ponds , surrounding the facility on three sides. The eastern contact water pond containment berm will double as the access road to the proposed airstrip (Figure 8).

3.10.1 Conveyance Channels

The top surface of the dry stack will be graded to shed water and the final cover will assume the same configuration. This water will be collected and conveyed off the top of the dry stack by appropriately designed conveyance channels. Detailed hydraulic and geotechnical design of these channels will be completed at later stages in the project planning (i.e. closure stage). As the final cover layer is ROQ which is not prone to erosion, no intermediate channels are required.

3.10.2 Contact Water Ponds

The contact water ponds are required to temporarily detain the contact run-off water from the dry stack. Once the closure cover is constructed, there will no longer be any contact water; therefore, the contact water ponds will be decommissioned.

3.10.3 Discharge Criteria

Water quality from the tailings pore water will not meet discharge criteria; therefore, the low permeability cover will be constructed to minimize as much as possible any seepage from the tailings. This mitigation has been shown to allow discharge criteria to be met (2017b).

4 Operation

4.1 Objective

This is a standalone Operations, Maintenance and Surveillance (OMS) Manual for the Boston TMA. This OMS Manual is to be compliant with the mine's Water License, the Mining Association of Canada's (MAC) guideline (MAC 2011), as well as the Canadian Dam Association's Dam Safety Guideline (CDA 2014). Prior to TMA tailings stacking, this OMS Manual will need to be updated to ensure it is fit for purpose.

4.2 Operating Criteria and Constraints

The operating criteria and constraints for the Boston TMA is presented in Table 4.1.

Table 4.1: Operating Constraints

Concern	Triggers	Operational and Preventative Maintenance Considerations	Mitigation Strategies
Tailings dust	Wind and equipment traffic	• Minimize use of equipment on tailings surface. • Apply water.	• Apply chemical dust suppressants as appropriate.
Animal access	Terrestrial mammals accessing TMA area	• Implement Wildlife Monitoring and Mitigation Plan (WMMP).	• Refer to WMMP.
People safety	Uninformed people accessing TMA area	• Conduct site specific orientation and training.	• Implement access controls through signs and road barricades.

4.3 Dry Stack Tailings Placement Plan

The tailings produced by the Boston process plant will be filtered to a water content amenable to handling by typical earth moving equipment (loaders, trucks, bulldozers) and stockpiled in the mill building. When sufficient tailings accumulated to provide several truckloads, a loader will load the tailings into 40 tonne rock trucks which will then transport the tailings to the dry stack facility. Tailings will be end-dumped by the trucks and spread to a thin lift (about 0.3 m) by a bulldozer dedicated to this operation. Once spread, the tailings will be compacted to achieve the target density. For the purposes of this preliminary design, a target density of 1.8 t/m^3 was selected; however, this may change in the more advanced phases of the design based on specific testing. QA/QC procedures for the tailings stacking will be developed prior to initial placement.

The facility is built up in this fashion to reach a maximum height of about 26 m, with 5 m high intermediate benches and 5 m setbacks (Figure 6). The inter-bench slope will be 3H:1V, with the overall slope of about 3.9H:1V.

The footprint occupied by the tailings facility is about 19.8 hectares, but the location offers the possibility of expanding this area to the north if required in the future.

4.4 Winter Operations

During winter operations, the active stacking surface will be kept clean as much as possible. Any snow blanket exceeding 10 cm in thickness will be removed prior to placement and compaction of a tailings lift. In freezing conditions, the tailings will be spread and compacted immediately after, to prevent the freezing in place of un-compacted tailings.

4.5 Dust Management

A comprehensive assessment of possible dust management practices for the tailings surface is presented in Attachment B. The tailings stacking plan will be developed to, as far as practical, minimize the area of exposed inactive tailings surface that might be prone to dusting. Beyond such mitigation by design, the primary dust control measure of the TMA will be the use of environmentally suitable chemical dust suppressants. The application of these suppressants will be reviewed on an ongoing basis to ensure that any areas that may be at risk will be adequately covered. Generally annual application of chemical suppressants will be applied; however, it is recognized that more frequent applications may be required depending on the stacking sequence.

4.6 Water Management

Contact water will be collected in the contact water ponds and pumped to the Boston process plant as make-up water and / or treated in water treatment plant and discharged. The ponds were sized to retain the inflow design flood (IDF) of 1:100 year rainfall (24hr) plus the maximum daily snowmelt. The ponds will be emptied within two weeks of the storm event and operated normally empty (SRK 2017c).

Post-closure, water quality for combined run-off and seepage from the TMA will meet the discharge criteria (SRK 2017b). Although the thermal model indicates most of the tailings will be perennially frozen, the seepage resulting from the active layer may exceed the water quality guidelines for closure. To mitigate this issue, a low permeability cover will be required to reduce seepage to essentially zero. This is achieved by constructing a very low permeability cover including a geomembrane. The geomembrane will be laid directly onto the tailings surface and covered by a protective non-woven geotextile and a 0.3 m thick crushed gravel layer. The final 0.7 m thick erosion protection layer of the cover will be constructed of ROQ.

4.7 Off-Specification Tailings Management

As discussed in Section 3.4.7, if the tailings filter press system underperforms, the off-specification tailings will be recycled to the mill or plant and temporarily stored in dedicated tanks until adequate filtration can be resumed. Alternatively, the non-spec tailings will be spread in lifts a thin as possible and allowed to dry before final compaction is completed.

4.8 Freeboard Requirements

A freeboard of 1.3 m was adopted for the contact water berms (SRK 2017c), to prevent overflow by wind setup and wave action. This freeboard extends from the full supply level (FSL) to the crest of the berm (Figure 7). The top elevation of the geomembrane in each of the containment berms was determined based on the maximum elevation (FSL) of the water resulting in each of the ponds from the combined IDF with an additional 0.3 m hydraulic freeboard allowed for. This is conservative as the ponds will be operated normally dry.

4.9 Concurrent Closure

The closure objectives for the TMA are:

- Ensure long-term physical stability of tailings;
- Ensure chemical stability by minimizing release of neutral metal leaching to the receiving environment;
- Prevent direct contact between of the tailings by humans and wildlife; and
- Restore natural drainage, to prevent the need for long term water management.

To ensure physical stability during operations, the filtered tailings will be placed and compacted in thin lifts, and benched with a maximum inter-bench slope of 3H:1V, and maximum overall slope of 3.9H:1V. At closure, the top of the facility will be regraded to 2% to ensure drainage, but re-sloping of the sides is not required.

Geochemical characterization of the Boston tailings predicts that the flotation tailings within the TMA will not be acid generating, but will have the potential for neutral metal leaching (SRK 2017i). Additionally, the metal leaching potential of the tailings is expected to result in runoff water exceeding discharge guidelines if mitigation measures are not applied (SRK 2017b, i, TMAC 2017b). Therefore, a low infiltration cover will be placed over the tailings at closure to reduce the amount of seepage expected.

The cover will consist of a geomembrane placed directly on the tailings, covered by a protective non-woven geotextile, overlain by a crushed rock bedding layer cover consisting of 0.3 m crushed rock, with a final erosion protection layer constructed of 0.7 m ROQ.

Construction of the cover will be done in stages or at the end of the active deposition. Both the bedding and shell materials will be sourced from geochemically suitable quarried rock or waste rock.

Once the cover is placed, the contact water pond berms will be breached and the liner will be cut to restore natural drainage and to prevent water collection. Several breaches may be required and will be done at the topographic lows. The remainder of the berms will stay in place to preserve the permafrost, as removal of the ROQ fill could result in localized permafrost degradation. Under the adaptive management approach, water quality in the TMA contact water ponds will be continuously monitored throughout the operations period and predictive models refined. This will allow for refinement of the current closure concept based on updated water quality predictions.

4.10 Safety and Security

The Boston project is accessed by air, with use of an all-weather air strip, and with an annual barge sealift re-supply in Roberts Bay during the open water season. Within the mine site, access to the TMA is restricted to authorized employees, contractors and consultants. All workers accessing or operating the facility are trained and knowledgeable about workplace hazards at and near the TMA.

5 Maintenance

5.1 Objective

The objective of the maintenance program is to ensure all TMA components are operating according to their performance criteria.

5.2 Maintenance Parameters

The Boston TMA components that require maintenance include:

- Contact water berms (during operations); and
- Geomembrane encapsulated in closure cover (post closure).

5.3 Maintenance Procedures

5.3.1 Routine and Preventative Maintenance

The contact water berms will require minimal routine maintenance during operations. Routine maintenance will typically involve minor repair of the driving surface on the berm crest as required. The contact water berms will be decommissioned and not require maintenance post closure.

The geomembrane encapsulated in the closure cover may require maintenance and repairs for a period post closure. For closure cost purposes, this has been assumed to be 10 years. The actual timeframe will be dependent on inspection findings by a qualified geotechnical engineer.

5.3.2 Event Driven Maintenance

In addition to planned inspections and preventative maintenance, the TMA is inspected after any unusual or extreme events such as heavy rainfall, flooding, windstorm, severe icing, rapid snow melt, earthquakes, and exceedance of the maximum water level in contact water ponds. Triggers for such unusual events are to a large extent judgement of the responsible on-site parties.

Event-driven maintenance for the TMA components will be directed by the TMA / Mill Manager and Mine General Manager under the consultation of the EOR.

5.4 Documenting and Reporting

Maintenance records of each component are kept by the Mill Manager and include:

- Up to date logs of in service equipment and facilities;
- Maintenance schedules;
- Maintenance history;
- Inspection logs;
- Repair records;
- Frequency and cause of problems, and planned mitigation;
- Component reliability records;
- Photographic evidence of repairs;
- Inventory of spares, material, tools and equipment; and
- Critical spares list.

6 Surveillance

6.1 Objective

The Boston TMA is a dry stack tailings facility, not a dam. However, for the purposes of surveillance the TMA is treated as a dam and inspections will be undertake as per Canadian Dam Association (CDA 2013, 2014) guidelines. Throughout the operational phase of the Project, the contact water berms and the dry stack will be subject to rigorous monitoring to evaluate their performance. This will include thermal, settlement and deformation monitoring. In addition, thermal monitoring of the tailings dry stack will be carried out to confirm tailings freeze-back assumptions. All the above will be subject to annual inspections by a qualified professional engineer as part of routine annual inspections. The frequency of these inspections may be reduced as time progresses in accordance with the inspection engineer's recommendations.

6.2 Frequency and Responsibility

The Mill Manager is responsible for ensuring that the ongoing monitoring is completed. An example of the expected level of reporting for ongoing monitoring is documented in the Doris North Dam surveillance SOP (SRK 2013). Once construction of the Boston TMA has begun, and after monitoring instrumentation has been installed, a SOP that is specific to the Boston TMA will be developed. If determined necessary, the Mill Manager may consult with the EOR to complete a safety inspection outside of the routine annual DSI.

Annually, the EOR, or an authorized representative, undertakes a physical inspection of the TMA. This inspection is carried out in the summer and culminates in a detailed DSI report. The report includes findings and recommendations on the TMA performance considering inspection observations, interviews with operations staff responsible for the TMA, as well as a review and analysis of all monitoring data collected. This report is delivered in a timely manner so that, if required, maintenance and mitigation can be carried out to address areas of concern. Should important matters be observed, those will be communicated to TMAC at the time of the DSR.

6.3 Monitoring Data Management Protocols

All monitoring data will be stored electronically with backup. Manual notes are scanned and the raw data saved together with any transposed data. Data is reviewed by qualified staff immediately following collection to confirm integrity of the instrumentation, as well as to ensure that the TMA performance is consistent with expectations and the monitoring guidelines specified in the dry stack surveillance SOP (see SRK (2013) as an example of requirements).

6.4 Surveillance Components

The surveillance elements for the Boston TMA includes:

- Visual observation; and
- Instrumentation (thermal, settlement and deformation).

6.5 Surveillance Parameters

Key parameters of surveillance are identified through identifying and describing potential failure modes of the dry stack.

Visual observations can indicate potential failure modes such as:

- Surface cracking, bulging, depressions, sink holes, etc.;
- Seepage, including quantity and quality paying specific attention to turbid water; and
- Uncontrolled surface runoff and erosion.

Routine monitoring for ensuring facility performance include:

- Checking for holes or settlement on the dry stack surface or benches;
- Measuring foundation and tailings dry stack temperatures;
- Measuring dry stack deformation;
- Water sampling in contact water ponds; and
- Recording weather conditions.

6.6 Surveillance Procedures

6.6.1 Visual Inspections

Plant operations staff carry out daily visual inspections of the TMA structures, taking note of any signs of settlement, signs of seepage, or any signs of damage or vandalism to instrument clusters. Records of these daily inspections are documented in a site diary, completed by the person carrying out the inspection. This inspection may trigger maintenance or operational actions. A monitoring checklist will be presented in the dry stack surveillance SOP.

The EOR is notified immediately after any inspection where notable changes to any of the TMA facilities outside of normal operating constraints are observed. The EOR will, in consultation with operations staff, assess the situation and develop any actions plans if deemed appropriate.

6.6.2 Instrumentation

Ground temperature cables to verify the foundation thermal response will be installed below the contact water pond containment berms, as well as along specific cross-sections of the contact water pond containment berms.

Ground temperature cables will also be installed below the stack and within the dry stack as it is built up. This will confirm that the foundation remains frozen and that tailings freeze back is occurring.

Deformation of the crest and slopes of the dry stack tailings will be monitored during construction and into the initial post-closure period to provide an early indication of possible instability. Monitoring will be performed through a network of survey prisms placed at appropriate intervals along the inter-bench berms and the crest of the facility. The prisms will be installed in large boulders imbedded within the final ROQ cover.

6.6.3 Water Quality Monitoring

Water quality monitoring for the TMA is described in the Water Management Plan (SRK 2017b**)**.

6.6.4 Tailings Geochemical Monitoring

Tailings geochemical monitoring (including confirmatory monitoring and sampling) for the Boston TMA is described in 2017i.

6.7 Documenting and Reporting

Example templates for the daily visual inspection report, and monthly instrumentation report forms are included in the Doris TIA SOP; although these templates were specifically developed for the North Dam at Doris North they give a good example of what would be expected to be done for the Boston dry stack monitoring as well. Once the Boston TMA starts construction then site specific templates will be prepared for the Boston TMA. The surveillance and inspection reporting would be carried out by a qualified person under the supervision of the Mill Manager. These reports are then to be submitted to the EOR on a monthly basis.

The following reports will be prepared in accordance with the relevant water licences and submitted no later than March 31 of the year following monitoring:

- Annual Tailings Geochemical Monitoring Report; and
- Annual Geotechnical Inspection Report.

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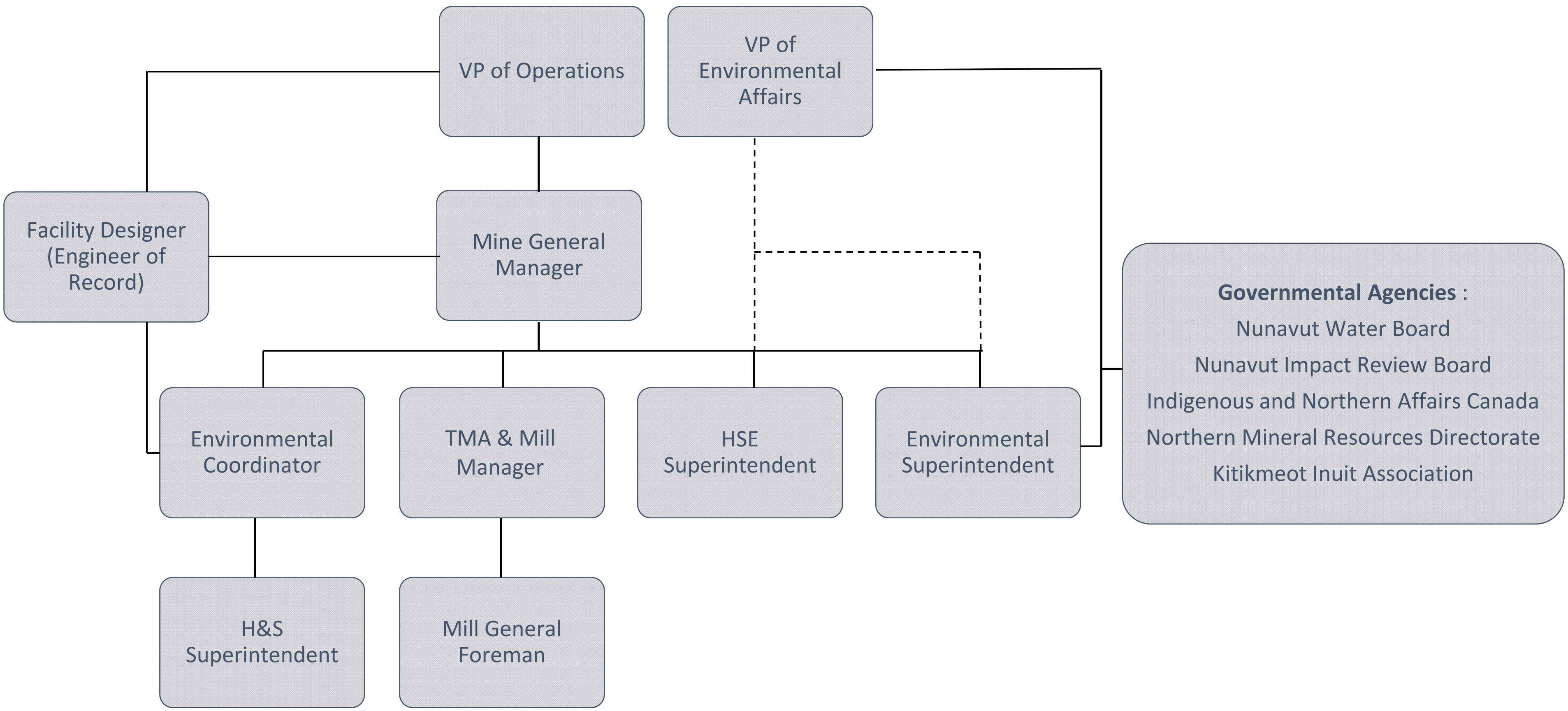
Figures



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TMAC RESOURCES

Boston TMA OMS

Organization Chart

Job No: 1CT022.006.200

Filename: Figure 1_OrgChart_20160527

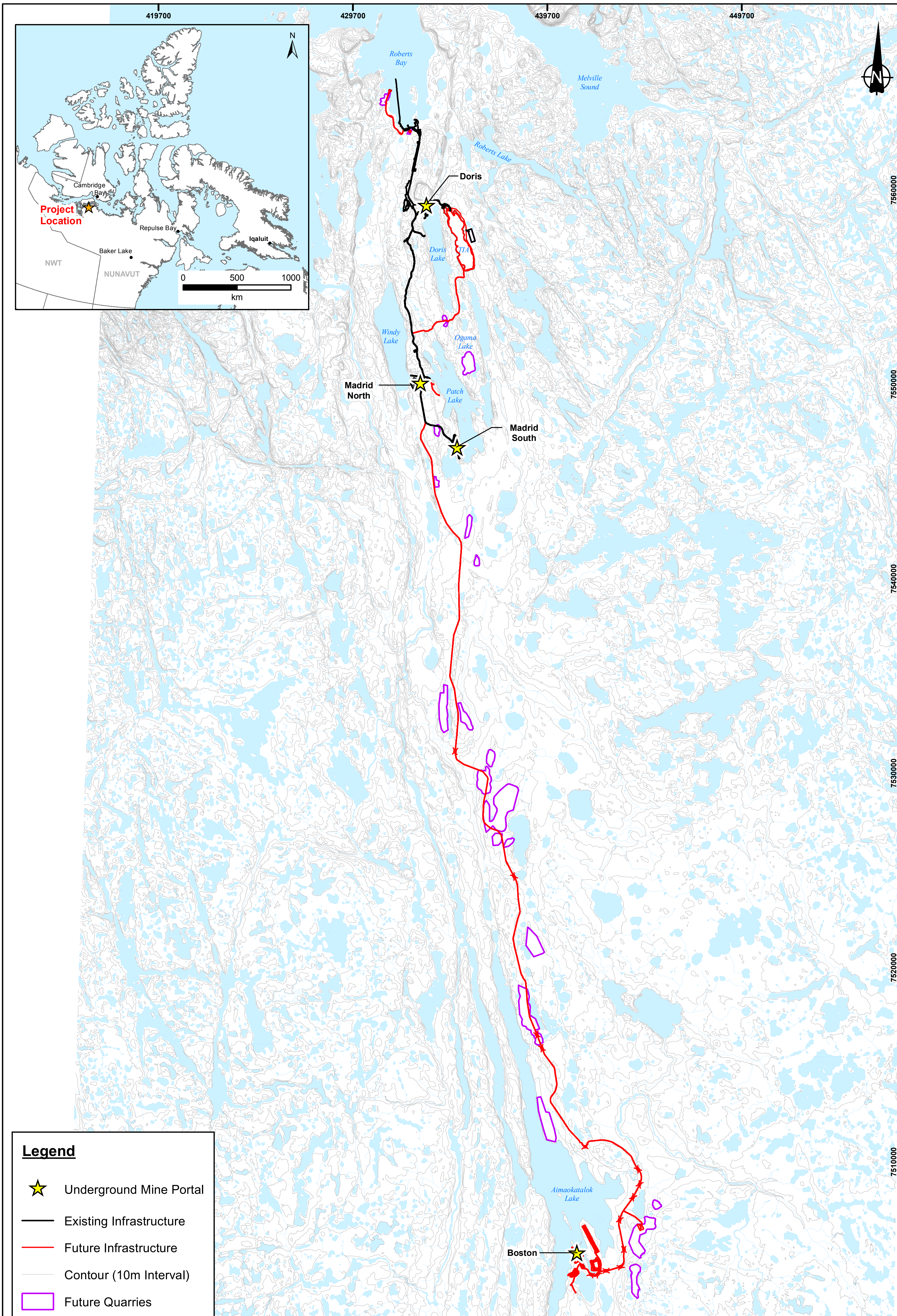
Hope Bay Project

Date: May 2016

Approved: EK

Figure: **1**

srk consulting	TMAC RESOURCES	Boston TMA OMS
		Site Location Plan
SRK JOB NO.: 1CT022.004.600.10	HOPE BAY PROJECT	DATE: May 2016
FILE NAME: 1CT022.004.600.10 - FIGURE 1.dwg		APPROVED: IM
		FIGURE: 02



0 2 4 6 8 10

Kilometres

Notes:

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

srk consulting

Project No: 1CT022.004.200.10

Filename: 1CT022.004.200.10_Fig_2_TIASiteLocationMap_mzs

TMAC RESOURCES

HOPE BAY PROJECT

Boston TMA OMS

General Site Layout Plan

Date:	Approved:	Figure:
Nov. 2016	MMM	3

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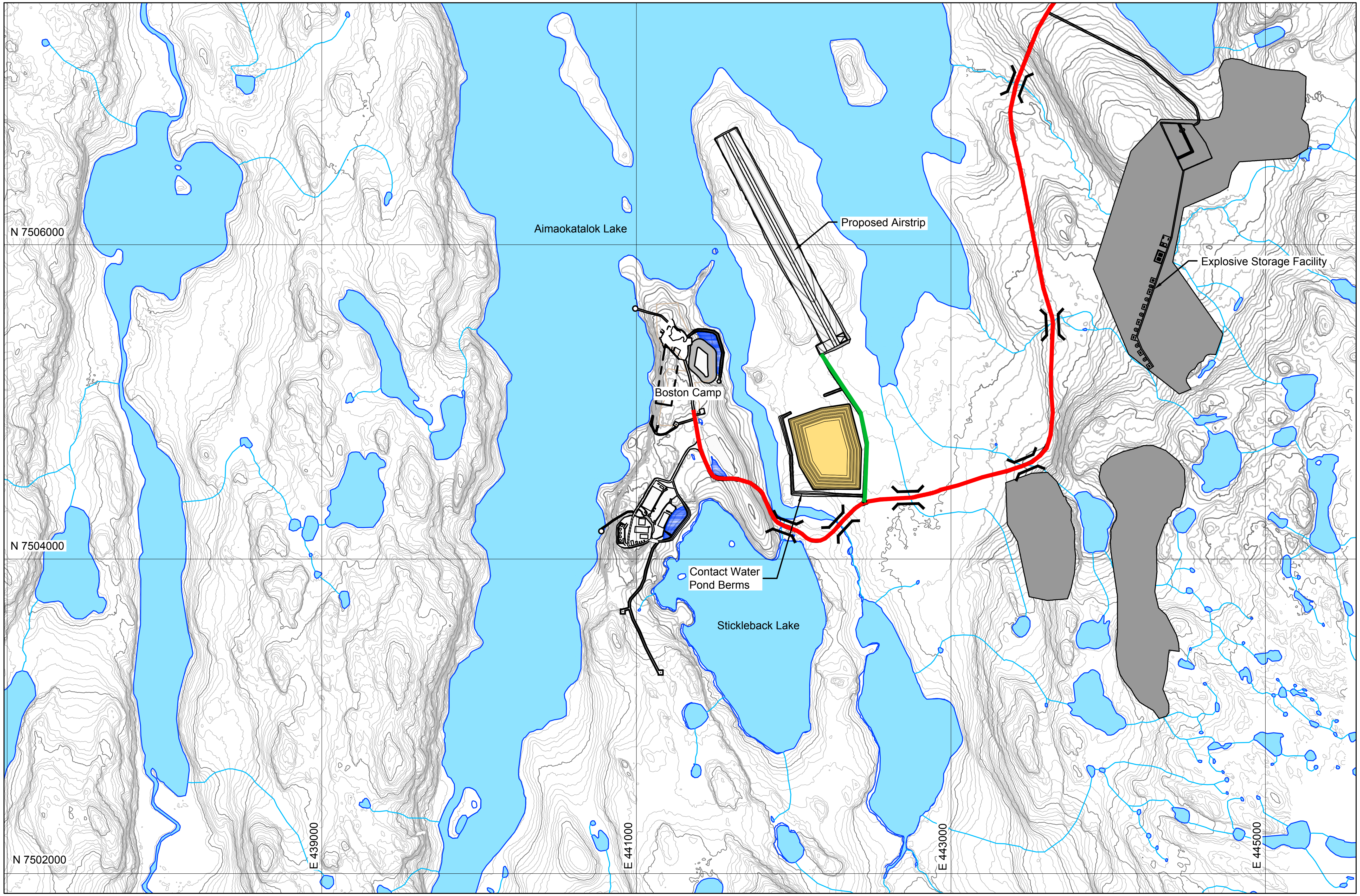

LEGEND

- Lakes
- Tailings Area
- Quarry Footprint
- Creeks and Rivers
- Airstrip Access Road
- Madrid-Boston Road
- Bridge Crossing

NOTES

1. Contours shown at 1.0m Intervals.
2. NAD 83 UTM Zone 13

0m 200 400 600 800 1000

NO.	DESCRIPTION	CHK'D	APP'D	DATE
A	ISSUED FOR DISCUSSION	IM	EMR	17/11/24

DRAWING NO. | DRAWING TITLE — REFERENCE DRAWINGS

REVISIONS

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FILE NAME: 1CT022.013-137_2.dwg

TMAC RESOURCES

HOPE BAY PROJECT

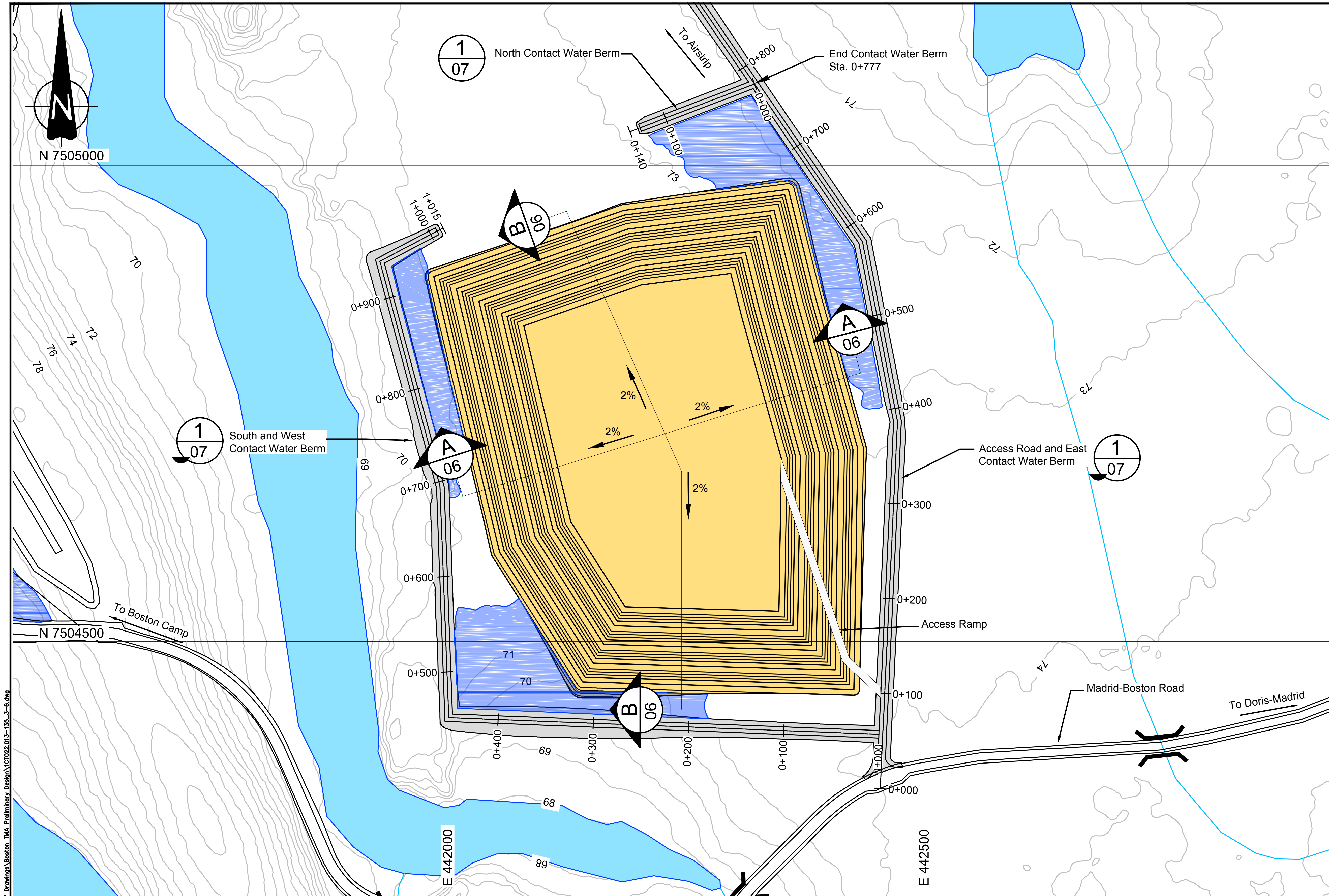
SRK JOB NO.: 1CT022.013-135

Boston TMA OMS

DRAWING TITLE: TMA Site Plan

DRAWING NO.: Figure 4

REVISION NO.: A



LEGEND

- Lakes
- Tailings Area
- Contact Water Pond
- Creeks and Rivers

NOTES

1. Contours shown at 1.0m Intervals.
2. NAD 83 UTM Zone 13

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HOPE BAY PROJECT

SRK JOB NO.: 1CT022.013-135

Boston TMA OMS

DRAWING TITLE

Boston Dry Stack Facility - Plan

DRAWING NO. Figure 5

REVISION NO. A

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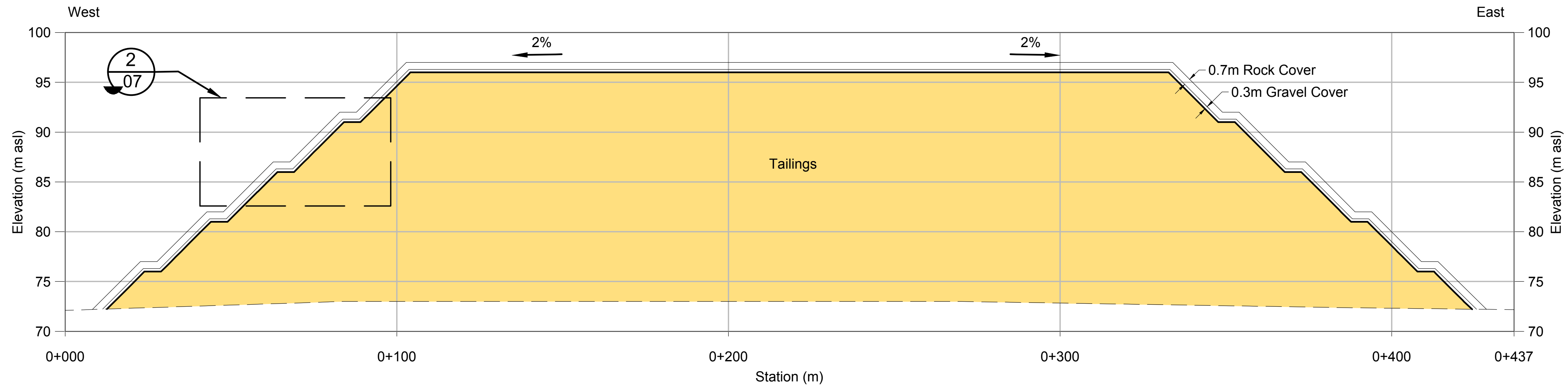

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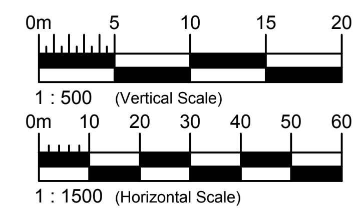
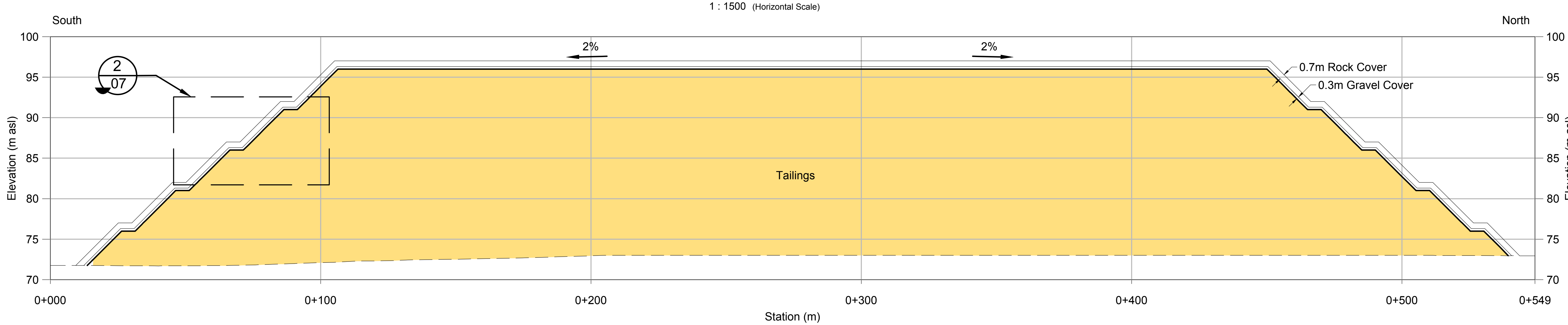
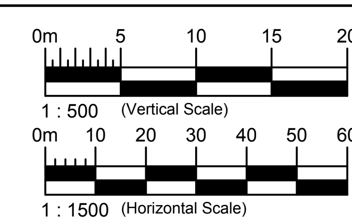




BB
05
SECTION



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HOPE BAY PROJECT

SRK JOB NO.: 1CT022.013-135

Boston TMA OMS

DRAWING TITLE

Boston Dry Stack Facility - Sections

DRAWING NO. Figure 6

REVISION NO. A

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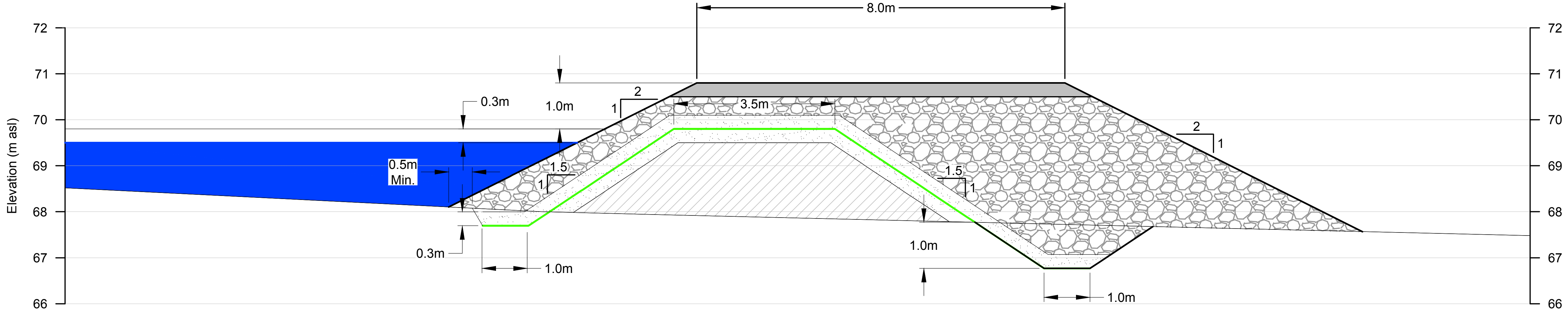
LEGEND

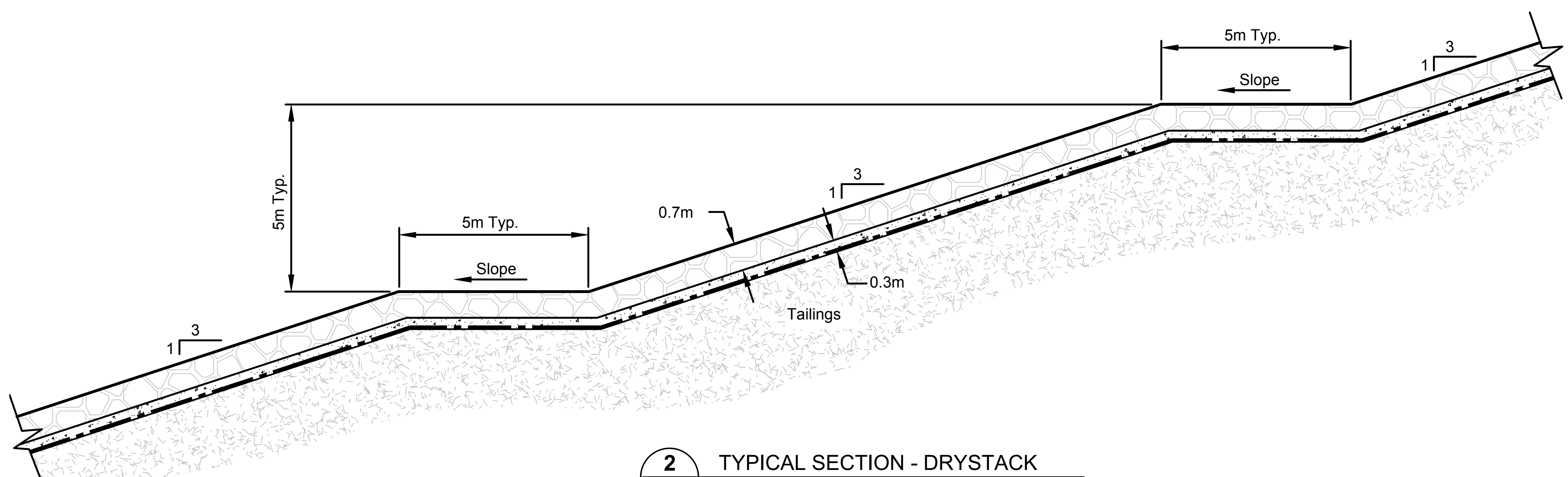
- Surfacing Material
- Bedding Material
- Run of Quarry Material
- Crushed Rock Protection Layer
- Transition Material
- Tailings
- HDPE Liner
- Liner System



1 / 05 Typical Section - Contact Water Berm

0m 0.5 1.0 1.5 2.0 2.5 3.0
1 : 75 (Vertical Scale)

0m 1 2 3 4 5 6
1 : 150 (Horizontal Scale)



2 / 06 TYPICAL SECTION - DRYSTACK

0m 1 2 3 4 5 6
1 : 150

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HOPE BAY PROJECT

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Boston TMA OMS

DRAWING TITLE: Contact Water Berm & Dry Stack Cover - Details

DRAWING NO.: Figure 7

REVISION NO.: A

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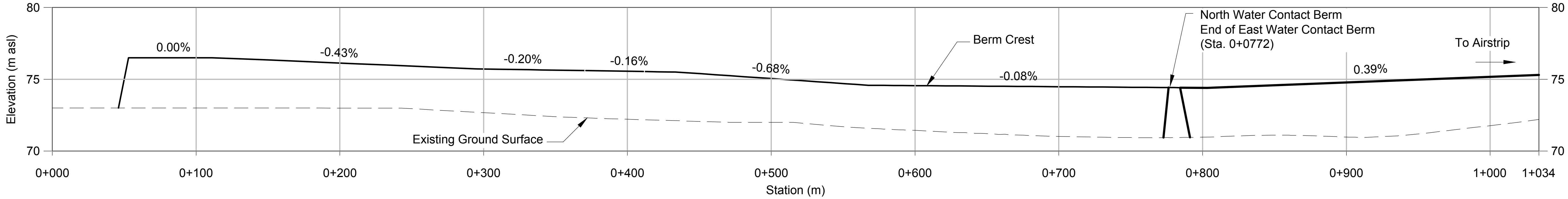
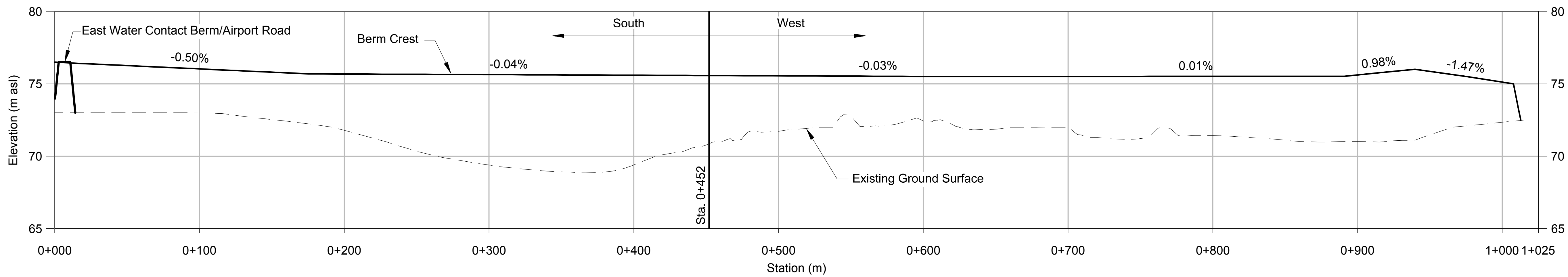
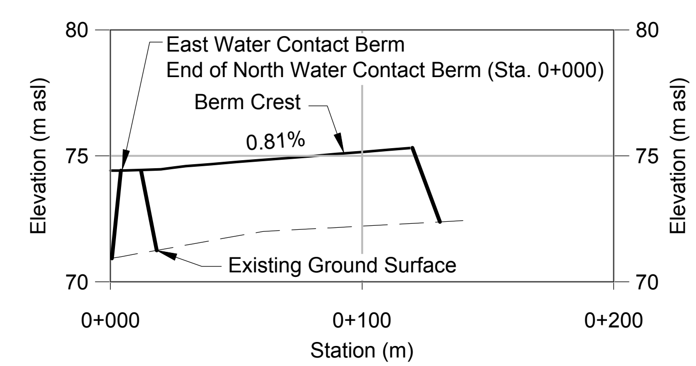


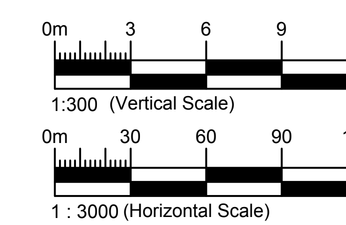
CENTRELINE PROFILE EAST CONTACT WATER BERM



CENTRELINE PROFILE SOUTH AND WEST CONTACT WATER BERM



CENTRELINE PROFILE NORTH CONTACT WATER BERM



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TMAC RESOURCES

HOPE BAY PROJECT

SRK JOB NO.: 1CT022.013.135

Boston TMA OMS

DRAWING TITLE

Contact Water Berms - Profiles

DRAWING NO. Figure 8

REVISION NO. A

HOPE BAY PROJECT, PHASE 2, BOSTON TAILINGS MANAGEMENT AREA - OPERATIONS, MAINTENANCE AND SURVEILLANCE MANUAL

HOPE BAY, NUNAVUT

Attachment A: Tailings Area Dust Control Strategy for Boston TMA

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

T: +1.604.681.4196
F: +1.604.687.5532

vancouver@srk.com
www.srk.com

Memo

To:	John Roberts, PEng, Vice President Environment Oliver Curran, MSc, Director Environmental Affairs	**Client:**	TMAC Resources Inc.
From:	Iozsef Miskolczi, PEng,	**Project No:**	1CT022.013
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	December 6, 2017
Subject:	Hope Bay Project: Tailings Area Dust Control Strategy for Boston TMA		

1 Introduction

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

The Project consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 (Madrid-Boston project) which is in the environmental assessment and regulatory stage. 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 due south from Doris, respectively.

Two tailings storage areas are planned for Phase 2. The existing Doris tailings impoundment area (TIA) will be expanded, and a new Boston tailings management area (TMA) will be developed comprised of filtered tailings developed as a dry-stack. This memo is addressing dust management strategies for the Boston TMA facility.

Two tailings streams will be produced; flotation tailings, comprising approximately 94% of the overall volume, and detoxified leach tailings (following cyanidation, and subsequent cyanide destruction), comprising about 6% of the overall volume. Only flotation tailings will be deposited in the Boston TMA. The detoxified leach tailings will be filtered, mixed with mine waste rock and used for underground mine backfill.

The dry stack within the Boston TMA will be closed by construction of a low permeability cover incorporating a geosynthetic liner. The liner will be protected by a 0.3 m thick layer of gravel overlain by 0.7 m of ROQ as final erosion layer. The cover could be constructed in stages, as each 5 m high bench is completed, or at the end of the operations. In any case, the top surface of the facility will be exposed throughout operations, being the active stacking site, while the side slopes may be exposed for various time periods depending on the chosen closure schedule.

Throughout the operational phase, portions of the tailings surface will be exposed, and sufficiently inactive such that they would dry out and pose a dusting risk. This memorandum describes alternative dust management strategies that have been considered, and presents the rationale for selection of the preferred strategy.

2 Definition of Dust

2.1 Fugitive Dust

Fugitive dust is particulate matter suspended in air by wind action and human activities. Tailings in the Boston TMA will have relatively low moisture content (but still wet), allowing the surface to dry quickly.

Fugitive dust from the tailings surface could be generated when equipment and personnel operate on, or travel across areas where the surface layer of the deposited tailings has dried out. This activity is expected because of standard operating and maintenance activities, as well as routine safety inspections. Additional fugitive tailings dust will be generated during the period when the tailings closure cover is being constructed.

2.2 Aeolian Dust

Aeolian dust is defined as particles that are transported as suspended load due to wind action on a surface. The Boston facility will be a dry stack so the tailings will be filtered before being stacked at moisture contents near optimal. This means that the surface will under the right conditions rapidly dry. As a result, at any given time, most of the outer Boston tailings surface will be exposed dry tailings. Aeolian tailings dust is therefore expected because the Project site is prone to high winds and the moderate surrounding topography does not offer effective protection from wind.

3 Typical Dust Control Methods

3.1 State of Practice

Dust control from operating and closed tailings impoundments is a significant concern in the mining industry, and as a result, the state of practice is quite advanced. There are three primary dust control strategies for fugitive and aeolian dust from exposed tailings areas: natural dust control, physical dust control and chemical dust control. Natural dust control specifically relies on maximizing the benefits offered by nature in the form of precipitation (rain and snow). While highly effective, these benefits are opportunistic and may not always be available at the times when it may be needed.

Physical dust control is by far the most effective strategy, as it relies on creating a physical barrier, such as a cover, that would preclude dusting. This may however not be a cost-efficient strategy for an operating tailings impoundment, since any interim cover would occupy space within a tailings impoundment that would otherwise be required for tailings.

Chemical dust control relies on modification of the tailings surface that generates the dust. The effectiveness of this method is temporary, but its application is typically simple, making it a very good alternative for managing dust from an operating tailings impoundment.

The sections that follow provide a detailed description of all the dust control methods that are currently being used in the industry, with a specific focus towards their potential applicability for this Project.

3.2 Natural Methods

3.2.1 Snow Cover

If early in the fall season, wet snow falls directly on the exposed tailings surface and subsequently freezes, it will remain in place all winter protecting the tailing surface from dusting. Snow that falls later in the season is typically drier and more powdery and it tends to be subject to wind transport and redistribution (drifting). This means that portions of the tailings surface will become exposed and opportunity for dust release increases. This is exacerbated by the fact that during the winter the tailings surface gets extremely dry because of freezing, making it highly susceptible to dusting.

To maximize the potential benefits offered by snow as a natural dust control method, any snow that does fall on the tailings surface can be track packed by machinery. By mechanically compacting the snow, it will stay in place longer and will melt at a much slower rate in the spring, extending the useful life of the snow as a dust control method.

No tailings should be stacked over any areas of compacted snow. If the compacted snow does not melt during the subsequent summer season due to the insulating blanket of the overlying tailings, then an outer ice lenses may form over the tailings TMA dry stack surface. This may lead to possible instability and settlement issues as well as occupy space that is not accounted for.

There is sufficient snowfall at the Project site that this dust control method could be effectively used. In addition, there is a requirement on site for snow removal in specific areas. Snow that is removed could be hauled to the TMA and used specifically for creating a compacted snow cover over any temporarily inactive tailings surface areas. Due to the temporary nature of this dust control method, it will not be a complete solution, but would be a practical complementary dust control method.

3.2.2 Ice Cover

An ice cover would work for more conventional slurry tailings deposition, but as the dry stack will not have any free water, a full ice cover forming naturally over the TMA surface cannot occur and therefore this strategy is not deemed practical.

3.3 Physical Methods

3.3.1 Water – Surface Wetting

Water is by far the most common temporary dust control measure used in areas where water shortage is not of concern. The exposed surface is wetted up, preventing particles from becoming airborne. Since the water rapidly evaporates (in a matter of hours or days), it needs to be reapplied at a frequent interval to be effective. The surface wetting can be done using a conventional water truck, a water cannon fitted to a water truck, or a stationary sprinkler system. Naturally this dust control method is only applicable during non-freezing periods of the year.

For the Project, water could readily be obtained from the mill or can be hauled via water truck from the site contact water ponds. As a contingency option water could be pumped or trucked from Aimaokatalok Lake. The tailings surface is however too steep for wheeled trucks and the only viable means of frequent tailings wetting would be via a water cannon, or a sprinkler system. While both of these methods are viable, the short useful life of every wetting cycle makes this a very labor-intensive dust control method which is not preferred. This method will however be reserved as a last line of defence should any of the other dust control methods prove to be ineffective.

3.3.2 Water – Flooding

Flooding the tailings surface will naturally preclude any dust concerns. This is however not a viable strategy for the Project since the objective is to place tailings in an unsaturated state in an above-grade dry stack facility.

3.3.3 Permanent Dry Cover

The most effective permanent dust control system is a permanent physical dust cover. Typically, this is in the form of a layer of soil, or other suitable readily available cover material. This is however not practical until the tailings surface has reached its final elevation. To facilitate placement of a final dust cover as expediently as possible, any tailings stacking plan should be designed taking into consideration all opportunities for progressive reclamation.

The Boston TMA will be constructed by placing the tailings in thin layers, i.e. “stacking”. The top surface of any given layer becomes the operational base of the subsequent layer, thus it is not amenable to intermediate dust covers. The side slopes could be covered under a progressive reclamation scenario, but the joining of the subsequent sections of geosynthetic membrane becomes challenging in a staged approach like this.

3.3.4 Sacrificial Dry Cover

In extreme cases, nominal sacrificial covers such as a layer of sand or gravel are used to manage tailings dust when the final tailings surface has not yet been reached, but the period until tailings stacking might resume at any location may be extensive. When tailings stacking eventually returns to the covered area, these materials are not removed and tailings stacking proceeds to overtop the sacrificial cover. This however can be very cost intensive and will take up valuable storage space in the facility.

There are no suitable natural sacrificial cover materials readily available at the Project site. Gravel could be produced from quarry rock; however, at great cost. This is therefore not considered a viable dust control strategy for the Project TMA.

3.3.5 Biodegradable Cover

Biodegradable material such as hay, wood mulch or sewage treatment sludge can be applied over exposed tailings surfaces to mitigate dust for a limited period (i.e. requiring occasional reapplication). Naturally this option is only economically viable if the organic source is readily available. The tailings surface must also be sufficiently trafficable to allow equipment to spread these materials. As these materials biodegrade and dry out, they themselves become prone to being part of the dust hazard.

There is no viable source of biodegradable materials at the Project site and therefore this is not considered a viable dust control strategy for the Hope Bay Project.

3.3.6 Wind Barriers

A wind barrier (aka windbreak or shelterbelt) is a physical structure used to reduce the wind speed, which will reduce tailings from being re-mobilized from the TMA. Typically, a wind barrier consists of one or more rows of trees or shrubs. Trees and shrubs don't grow at the Project site (at least not to the size where they would be effective wind barriers), therefore, any wind barriers would have to be engineered structures. The efficiency of wind barriers is also a function of wind speed, and often, at very high wind speeds, wind barriers can fail since it is simply not cost effective to design and build these structures to withstand large wind velocities. As well, wind barriers only work effectively over a very narrow range of wind directions. Multiple wind barriers would need to be installed to cover all the Project's prevalent wind directions to provide a comprehensive dust management system for the TMA.

Given the very high wind speeds and the multiple wind directions, experienced at the Project's TMA, engineered wind barriers are not be considered a viable dust control strategy for the Project.

3.3.7 Vegetation

Revegetating an exposed tailings surface is a very effective way to mitigate dust. In an arctic setting such as at the Project site, this is not a practical option since the growth season is simply too short to allow for rapid onset of effective vegetation. In addition, the tailings material may not be amenable to supporting vegetation without the addition of supplemental nutrients, which might preclude establishment of natural successional vegetation species. This is therefore not a viable dust control method for the Project.

3.4 Chemical Methods

3.4.1 Salt (Calcium Chloride)

"Salted" sand will not freeze at temperatures above minus 10°C, and can be spread in a thin layer over exposed frozen tailings surfaces during the shoulder seasons. The calcium chloride in the sand acts to melt the frost on the exposed tailing surface and stops the fine particulate dust particles from becoming airborne.

There are no sources of sand at the Project site, requiring that both sand and salt would have to be imported at great cost. As runoff occurs from the tailings surface, the salt will dissolve reducing the efficiency; however, since this mitigation method is best used during freezing conditions this risk is limited. However, during freshet the salt is washed off towards the unlined contact water ponds which may result in vegetation die-back, permafrost degradation, and additional environmental concerns. This is therefore not a viable dust control strategy for the Project TMA.

3.4.2 Chemical Suppressants

There are many environmentally safe commercial chemical dust suppressants on the market. Although originally developed for other forms of fugitive dust management, they are routinely used for dust control on tailings surfaces. These products work in different ways, but principally they all either chemically bind dust, or alternately facilitate towards development of a crust to prevent particles from separating and becoming airborne.

The chemical suppressants are normally supplied in concentrated liquid form in containers of various sizes. They are typically water based and are diluted before application at a ratio of about nine parts water, to one part suppressant. The solution is applied by means of a spray cannon mounted on a modified water truck, but can also be done via hand held sprayers. The application rate is typically about four liters per square metre.

Chemical suppressants have a useful life which is dependent on the concentration applied and local weather conditions. Normally, products are applied at a concentration which would render a useful life of approximately one year.

Of all the dust control methods, chemical suppressants offer the greatest flexibility for application at the Project TMA. The concentrated liquid can be shipped to site on an annual basis and solution can be mixed an applied-on site as required. The relatively long useful life limits the amount of effort that needs to be exerted and therefore makes the dust control method practical.

4 Dust Control Procedures for Boston TMA

The primary dust control measures of the Boston TMA will be the use of environmentally suitable chemical dust suppressants. The application of these suppressants will be reviewed on an ongoing basis to ensure that any areas that may be at risk will be adequately covered. Generally, annual application of chemical suppressants will be applied; however, it is recognized that more frequent applications may be required as dry stack construction progresses throughout any year.

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

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