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	**Client:**	TMAC Resources Inc.
From:	Maritz Rykaart, PhD, PEng	**Project No:**	1CT022.002
Reviewed By:	Sarah Portelance, PEng	**Date:**	December 2, 2015
Subject:	Responses to IR: AANDC NIRB #11, #12, #27, KIA #30 - Environmental Stressors to the Marine Outfall Pipeline		

1 Issue

The intervenors asked what the environmental stressors are that the marine outfall system has been designed for. The relevant information requests (IR's) are repeated below.

1.1 AANDC NIRB #11 – Marine Water Quality – Diffuser HAZID (Hazard Identification)

1.1.1 Issue

The hazards and risks associated with construction and operation of a marine outfall do not appear to be addressed.

1.1.2 Reference

Package 4 Identification of Potential Environmental Effects & Proposed Mitigation, Section 4.5.2 Water Quality pages 4-49; Package 6 Engineering and Design Docs, pages 6-10, Section 6.3.2 Roberts Bay Outfall.

1.1.3 Concern

There are potential hazards associated with the construction of a marine outfall pipe, an assessment of which has not been provided. The hydraulics of the diffuser, the delivery pipe and the de-aeration tank in the plant are crucial to meeting the stated performance of the marine outfall, and to its continuous operation as designed. There is insufficient information in the documents provided to conduct a technical appraisal of the proposed system.

1.1.4 Information Request

Was a HAZID (hazard identification) conducted for the outfall system? If the answer is "yes", please provide the report or relevant documents, and any follow-up material. If the answer is "no", provide justification for why this step was excluded from the assessment. If there is supplementary information that fulfills a similar goal, please provide that documentation.

1.1.5 Importance of Issue

Any failure in the outfall system would have operational consequences for the Project and could change current environmental impact predictions. This additional information will assist AANDC in the subsequent technical review of this component of the Project, and should help to address any ongoing public concerns with marine discharge of the TIA and groundwater effluent into Roberts Bay.

1.2 AANDC NIRB #12 – Marine Water Quality – Outfall System Hydraulics

1.2.1 Issue

A number of marine outfall system design considerations do not appear to be addressed.

1.2.2 Reference

Package 6 Engineering and Design Docs, pages 6-10, Section 6.3.2 Roberts Bay Outfall.

1.2.3 Concern

The hydraulics of the diffuser, the delivery pipe and the de-aeration tank in the plant are crucial to meeting the stated performance of the marine outfall, and to its continuous operation as designed. There is insufficient information in the documents provided to conduct a technical appraisal of the proposed system.

1.2.4 Information Request

Please provide the design report for the outfall hydraulics. Specific questions are:

a) Of concern is the manner in which the system was designed to operate over a wide range of flow rates, and maintain full-pipe conditions. AANDC requests the Proponent provide information supporting how the discharge system was designed to operate over a range of flow rates and maintain full-pipe conditions.

b) What are the head requirements of the diffuser and outfall pipe?

c) How was the surface area of the de-aeration tank determined?

d) Will the mixture of the TIA supernatant and the mine groundwater lead to either generation of gas bubbles when combined, or scaling in the pipe?

e) Is there provision for potential scaling in the pipe, or other processes that would increase its roughness?

f) How will planned and emergency shut-downs be handled, especially to avoid freezing of the pipe when flow is not maintained?

1.2.5 Importance of Issue

Any failure in the outfall system would have operational consequences for the Project and could change current environmental impact predictions. This additional information will assist AANDC in the subsequent technical review of this component of the Project and should help to address any ongoing public concerns with marine discharge of the TIA and groundwater effluent into Roberts Bay.

1.3 AANDC NIRB #27 – Sea Ice Impacts on the Marine Outfall Pipe

1.3.1 Issue

The Roberts Bay Outfall Pipe must be adequately protected against potential damage from ice impacts to mitigate environmental risks to the marine environment.

1.3.2 Reference

Package 6 - Engineering and Design Docs, pages 6-7, Section 4.6.1, page 6 and RBDS-04.

1.3.3 Concern

The Roberts Bay Outfall Berm only provides protection to the outfall pipe to a water depth of 3.0 m. It is typical in arctic marine environments that ice can move during the winter and also during breakup, often generating pressure ridges that can have keels that will penetrate below the ice surface elevation more than the typical ice thickness. If this occurs in Roberts Bay, it is possible that the keels could impact the pipe if they are deeper than 3.0 m. In addition, there can be wind driven ice pile up in coastal areas that could also potentially lead to ice impacting the pipe at the end of the berm. Thus a 1.0 m allowance to protect against impact by sea ice may not provide sufficient protection.

1.3.4 Information Request

Provide data on the typical characteristics of the sea ice (including thickness, presence of pressure ridges) and its movement in Roberts Bay during the winter and at breakup. Provide rationale for choosing a 1.0 m allowance to protect against impact by sea ice on the outfall pipe.

1.3.5 Importance of Issue

This information is needed to ensure that the potential impacts of ice scouring have been adequately considered in the design of the marine outfall pipe and help ensure that unpredicted impacts are not encountered for this component of the Project.

1.4 KIA #30 – Robustness of discharge infrastructure

1.4.1 Issue/Concern

TMAC states: "A critical component of the outfall involves the crossing of the foreshore zone adjacent to Roberts Bay to a point below the expected depth of freezing (approximately the 4 m bathymetric contour). The pipeline will thus consist of both armoured and exposed sections.

Construction of the marine outfall berm to the 4 m bathymetric contour protects the pipeline from ice scouring and displacement."

We accept that armouring will extend below the level of ice cover (up to 2 m), but are concerned with the capacity of the discharge infrastructure to withstand damage from environmental factors such as the storm that damaged the Roberts Bay Jetty.

1.4.2 Reference

Package 2, Section 3.6.3, Package 6-7; Package 6-8.

1.4.3 Information Request

Please provide an evaluation of the discharge infrastructure's capacity to withstand a range of environmental stressors. This should be accompanied with evidence such as side-scan sonar surveys demonstrating ice scouring is not an issue of concern below 4 m in the vicinity of the discharge infrastructure.

In the event of extended (longer than for standard maintenance) infrastructure failure, please provide the framework for an emergency response plan and contingency for storage of effluent. If this discussion requires consideration of alternate discharge locations (e.g.: those presented in Package 6-7), it should be accompanied with:

- An assessment of the mixing zone;
- The dilution ratio of effluent to receiving environment water needed to meet CCME guidelines at the edge of the required mixing zone; and
- The sensitivity of the receiving environment within the mixing zone.

The mixing zone under failure of the discharge system will vary based upon the season (ice free versus ice cover) and the location of the failure (shoreline versus subsurface) and will be dissimilar to that of the planned mixing zone due to the shallow depth and the absence of a diffusor. Explain in the emergency response plan how this type of failure will be managed and mitigated.

2 TMAC Response

2.1 Context

This technical memo provides additional information pertaining to the environmental stressors for which the marine outfall system has been designed to withstand. A hazard identification is also provided in Section 2.4 within the context of the marine outfall system.

The marine outfall system design essentially comprises two distinct elements as defined below with the relevant design detail reference as it appears in the Amendment application.

- The marine outfall berm (pages 6-7, Roberts Bay Discharge System: Surface Infrastructure); and
- The marine outfall pipeline and diffuser (pages 6-7, Roberts Bay Discharge System: Surface Infrastructure and pages 6-8, Roberts Bay Discharge System: Pump and Pipe Requirements).

2.2 Marine Outfall Berm

The marine outfall berm serves to protect the pipeline as it transitions from an on-land pipeline to a subsea pipeline. Sea-ice in Roberts Bay is single year ice and average ice thickness is approximately 1.7 m (1.65 m recorded in 2009 and 1.69 m recorded in 2010, Rescan (2010, 2011). Given the landfast nature of the ice sheet, pressure ridges are not present in the bay and on-site experience over the past 20 plus years at the site show only small deformities in the ice. This experience has been gained from frequent travel across the bay sea-ice as supplies were transported from the old barge laydown area along the northwest shore of the bay, as well as from Cambridge Bay, which requires travel along the entire length of the bay (Buchan, 2015). The ice-off period normally takes about 1 to 2 weeks and occurs in late June and early July (Rescan 2010, 2011).

The movement of the ice flow during thawing and freezing is primarily driven by surface winds with ice accumulating in the bay during northern winds and leaving the bay in southern winds. Sustained, high winds from the south can move ice from Roberts Bay in a matter of days (Rescan 2010, 2011). No direct measurement (i.e. using an ice profile) of surface ice movement have been made in Roberts Bay.

Due to the presence of sea-ice the pipeline needs to be suitably protected through the transition zone from the terrestrial environment to the marine environment. Based on the observed ice thickness of 1.7 m (maximum assumed to be 2 m) and ice flow behaviour, the transition zone was deemed to be at least 1 m below the maximum ice thickness, with the transition protection depth being set at 3 m below the Low Water Level (LWL- large tide) in Roberts Bay. This is a conservative estimate given typical ranges in single year ice thickness based on experience and engineering judgement. Accordingly, the options considered for suitably protecting the pipeline through the transition zone are either burying the pipeline or armouring the pipeline.

Burying the pipeline is not a preferred strategy due to the ground conditions in the Roberts Bay foreshore area. Permafrost exists, and extends to subsea permafrost, which has been confirmed to be present up to 60 m from the shoreline along the shallow shelf of southern Roberts Bay. These observations were based on drilling and subsequent ground temperature monitoring at the existing Roberts Bay jetty, located about 400 m east of the proposed marine outfall structure location (SRK, 2014). Excavation into permafrost requires drilling and blasting, both on land and subsea. Drilling and blasting within the marine environment is technically challenging; however, more importantly can have environmental effects on the marine environment (specifically fish and fish habitat), and as such was not selected as the preferred alternative.

The preferred strategy is therefore to armour the pipeline along the transition zone. A number of armouring strategies were considered, including mechanical solutions that would provide a protective sleeve for the pipeline (i.e. pipe-in-pipe), structural civil engineering solutions such as encasing the pipeline in reinforced concrete, and bulk earthworks solutions that require encasing the pipeline with run-of-quarry rock. In each case the most significant environmental stressor that this armouring must withstand is the bending and crushing strength of sea ice as listed in Table 1 below.

Given the remoteness of the site, the cost and constructability of the mechanical and structural civil engineering solutions are disproportionately more challenging. Therefore the preferred armouring methodology is a bulk earthworks solution as the primary armouring method, with a secondary mechanical armouring solution, being pipe in pipe, as presented in the Amendment application (P6-7, Roberts Bay Discharge System: Surface Infrastructure).

The environmental stressors that the marine outfall structure has to be designed for; complete with the rationale and adopted design strategy are provided in Table 1.

Table 1. Environmental Stressors to Account for in the Marine Outfall Structure Design

Environmental Stressor	Magnitude	Rationale	Strategy
Wind	50 year recurrence interval, 44 knots, 5 minute duration	Protect marine outfall structure from wave erosion	Size riprap around outer face of marine outfall structure. This will be done using the same design specifications as adopted for the jetty repairs completed in 2013
Seismic	2% exceedance in 50 years, site class = E, PGS = 0.06 g, S_s = 0.12 and S_1 = 0.023	Protect pipeline embedded in the marine outfall structure from excessive deformation	Encase marine outfall pipeline in a steel pipe sleeve that has sufficient strength against expected deformation
Ice	2 m thick (max.), bending strength = 345 kPa, crushing strength = 1,034 kPa	Protect marine outfall structure and marine outfall pipeline against bending and crushing forces from sea ice	Encase marine outfall pipeline with run-of-quarry rock to an elevation of 1 m below the maximum expected ice thickness. As a contingency encase the marine outfall pipeline in a steel pipe sleeve
Tide	HHW (large tide) = 0.6 m, LLW (large tide) = 0.0 m, HHW (mean tide) = 0.6 m, LLW (mean tide) = 0.2 m	Protect marine outfall structure from wave erosion and sea ice crushing	Use HHW (large tide) and LLW (large tide) to set design elevations

Prior to construction of the marine outfall structure, detailed engineering analysis will be carried out to confirm that the design is an adherence with the environmental stressors listed in Table 1. Following that, detailed Issue-for-Construction (IFC) drawings will be issued complete with engineering specifications. These documents would be submitted to the Nunavut Water Board prior to construction.

2.3 Subsea Pipeline

The subsea pipeline is subject to two primary risk factors; (1) damage due to shipping traffic, especially anchors, and (2) damage due to ice scour. To mitigate the risk against shipping traffic the subsea pipeline location was moved 400 m west, away from the jetty where watercraft normally operate.

To mitigate against ice scour, three primary strategies can be adopted; (1) structural armouring of the pipeline, (2) burial of the pipeline, and (3) managing ice. These strategies are all technically and logistically challenging, especially given the remote site conditions.

In order to develop the appropriate strategy a consideration of the likelihood of ice scour was completed. As noted in Section 2.2 there is no multi-year ice in Roberts Bay and the ice is generally flat with minimal deformation and pressure ridge formation. In the history of the Project there has never been any evidence of icebergs in the bay and none of the bathymetric surveys carried out in the bay has picked up any evidence of ice scour gorges in the seabed. Based on this evidence it was concluded ice scour was unlikely to occur in the Roberts Bay and therefore it was decided that no specific mitigation strategies would be adopted to protect the subsea pipeline against ice scour.

Should for any reason the subsea pipeline is damaged, ocean discharge would cease until remedial action has been taken as previously described in TMACs response to IR’s.

2.4 Hazard Identification

Table 2 summarizes a hazard identification completed for the marine outfall system. The objective of this hazard identification was to establish major external hazards and associated environmental consequences such that appropriate design criteria for the system could be developed. There are other operational hazards such as power or pump failures which would not result in consequences related to environmental stressors. The mitigation strategy against those failures is to provide backup systems; however, TMAC has the ability to retain water in the TIA or mine under such circumstances and as a result redundant backup systems are not provided.

Table 2. Roberts Bay Discharge System Environmental Hazard Identification System

Area	Hazard	Failure	Consequence	Mitigation Strategy
Roberts Bay discharge pipeline	Freezing	Pipe rupture	Uncontrolled discharge to tundra	Heat tracing and insulation; Remote pressure monitoring; Routine visual inspections; Drain pipeline when not in use
		Flow blockage	Inability to discharge	Heat tracing and insulation; Remote pressure monitoring; Drain pipeline when not in use
	Traffic impact	Pipe rupture	Uncontrolled discharge to tundra	Bury pipeline at crossings; Provide physical barrier where appropriate separation distances are not available
	Permafrost degradation	None	Permafrost damage	Ensure pipeline is appropriately insulated

Area	Hazard	Failure	Consequence	Mitigation Strategy
Marine outfall berm	Wave erosion (wind and tides combined)	Eroding of armoring protecting pipe against sea ice, which could ultimately lead to pipe rupture	Release of Total Suspended Solids during erosion and uncontrolled discharge to marine environment as result of pipe rupture	Appropriate sizing and placement of Riprap; use and placement of run of quarry materials in accordance with 2AM-DOH1323; Secondary armouring of subsea pipe in structural steel pipe
	Ice crushing			
	Seismic	Deformation of structure leading to pipe rupture	Uncontrolled discharge to marine environment	Secondary armouring of subsea pipe in structural steel pipe
	Subsea permafrost degradation	Settlement of marine outfall structure leading to pipeline deformation which could lead to pipeline rupture		
Marine outfall pipeline	Freezing	Pipe rupture	Uncontrolled discharge to marine environment	Heat tracing and insulation (only to end of marine outfall structure); Remote pressure monitoring; Drain pipeline when not in use
		Flow blockage	Inability to discharge	
	Ice scour	Pipe rupture	Uncontrolled discharge to marine environment	Remote pressure monitoring
	Shipping impact			Clearly identify subsea pipeline on navigation chart; Remote pressure monitoring
	Anchoring			
Diffuser	Freezing	Pipe rupture	Larger and less effective mixing zone	Remote pressure monitoring
		Flow blockage	Inability to discharge	
	Marine organisms and growth	Flow blockage	Inability to discharge	Remote pressure monitoring
	Irregular pressure	Poor mixing	Less effective mixing zone	Remote pressure monitoring; Pump at constant rates (3,000 m^3/day for mine water and 4,000 m^3/day for TIA discharge)[1]

[1] Pressure heads, flow rates and velocities for the marine outfall pipeline are presented in Figure 2 of P6-8 Roberts Bay Discharge System: Pump and Pipe Requirements.

3 References

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