Baffinland

TECHNICAL SUPPORTING DOCUMENT

Mary River Project | Phase 2 Proposal | FEIS Addendum | August 2018

TSD 22

Ship Wake and Propeller Wash Assessment

SHIP WAKE AND PROPELLER WASH ASSESSMENT TECHNICAL SUPPORTING DOCUMENT SUMMARY

The Ship Wake and Propeller Wash Assessment Technical Supporting Document provides an assessment of the potential effects of ship wake and propeller wash from shipping activities related to the Phase 2 Proposal and includes new information collected or published since submission of materials for the Approved Project. The Phase 2 Proposal builds on the extensive baseline studies and assessments carried out since 2011 for the larger Approved Project and is thus closely linked to the FEIS and previous addendums. This document is used as input to the assessment of effects on the marine environment.

Ship-generated waves may cause effects on shorelines along the shipping route and potential sediment disturbance effects from propeller generated velocities (propeller wash) in the vicinity of Milne Port. Waves generated by the increased Project-related ship traffic may cause changes in the coastal profile.

To assess potential shoreline effects in terms of erosion and sediment transport potential, the estimates of ship wake energy were compared to wind-generated waves along the shipping route. Results show that ship generated waves (wake) are expected to be minimal along the Northern Shipping Route with maximum wave heights of 0.12 m near the sailing line and less than 0.05 m at distances greater than 1 km from the sailing line. Ship wakes, predicted to be less than 0.05 cm when reaching the shoreline, are expected to have negligible effect on the rocky and coarse-grained shorelines along the shipping route.

Propeller generated velocities were estimated for the representative ore carriers and tugboat. Velocities in the berthing area of the ore docks at Milne Port are expected to range from 0.4 m/s for a tug to 2.3 m/s for a capesize vessel near the seabed for the shallowest potential water depth (21 m) and lowest clearance from seabed to propeller. The estimated velocities near the bed have the potential to cause scour and turbidity in the berthing area for all the vessels; however, disturbed sediment is not expected to remain in suspension beyond the timeframe of one berthing and loading event.

RÉSUMÉ DE LA DOCUMENTATION TECHNIQUE COMPLÉMENTAIRE SUR L'ÉVALUATION DES EAUX DE SILLAGE ET DES REMOUS D'HÉLICES DES NAVIRES

La documentation technique complémentaire sur l'évaluation des eaux de sillages et des remous d'hélices des navires comporte une évaluation des impacts potentiels des sillages de navires et des remous d'hélices liés aux activités d'expédition en vertu de la proposition de la phase 2 et comprend de nouveaux renseignements recueillis ou publiés depuis la soumission des documents pour le projet approuvé. La proposition de la phase 2 est fondée sur les études préliminaires et les évaluations complètes réalisées depuis 2011 pour l'ensemble du projet approuvé et est donc étroitement liée à l'énoncé des incidences environnementales (EIE) et aux addendas précédents. Ce document est utilisé pour l'évaluation des impacts sur le milieu marin.

Les vagues générées par les navires peuvent avoir des effets sur les berges le long du trajet navigable et des impacts potentiels sur les sédiments causés à cause des courants générés par les hélices (remous d'hélices) dans les environs du port de Milne. Les vagues générées par l'augmentation du trafic maritime lié au Projet peuvent entraîner des changements dans le profil côtier.

Pour évaluer les impacts potentiels sur le littoral, en termes de potentiel d'érosion et de transport des sédiments, les estimations de l'énergie dégagée dans le sillage des navires ont été comparées aux vagues générées par le vent le long de la route de navigation. Les résultats montrent que les vagues générées par les navires (sillage) devraient être minimes le long de la route maritime du Nord, avec des hauteurs maximales de 0,12 m près de la ligne de navigation et de moins de 0,05 m à plus de 1 km de la ligne. Les sillages des navires, qui devraient être inférieurs à 0,05 cm en atteignant le rivage, devraient avoir un effet négligeable sur les rivages rocheux et à grain grossier retrouvés le long de la route de navigation.

Les courants générés par les hélices ont été estimés pour des transporteurs de minerai et des remorqueurs représentatifs. Les courants générés dans la zone d'accostage des quais du port de Milne devraient avoir une vitesse variant de 0,4 m/s pour un remorqueur à 2,3 m/s pour un navire Capesize près du fond marin pour la profondeur d'eau potentielle la moins profonde (21 m) et le plus faible dégagement entre le fond marin et l'hélice. Les courants estimés près du lit marin peuvent causer de l'affouillement et de la turbidité dans la zone d'accostage de tous les navires; les sédiments perturbés ne devraient cependant pas rester en suspension au-delà de la durée d'un événement d'accostage et de chargement.

ᐅᒥᐊᕐᔪᐊᑉ ᒪᓕᖓ ᐸᐅᕋᔫᑕᓗ ᑲᐃᕙᑕᖕᒋᑦ ᕿᒥᕐᕈᔾᔪᑎᑦ ᐱᔭᕆᐊᑐᔪᑦ ᐃᑲᔪᐃᔾᔪᑎᑦ ᑎᑎᖅᑲᑦ ᐅᓂᒃᑳᓕᐊᑦ

ᐅᓇ ᐅᒥᐊᕐᔪᐊᑉ ᒪᓕᖓ ᐸᐅᕋᔫᑕᓗ ᑲᐃᕙᑕᖕᒋᑦ ᕿᒥᕐᕈᔾᔪᑎᑦ ᐱᔭᕆᐊᑐᔪᑦ ᐃᑲᔪᐃᔾᔪᑎᑦ ᑎᑎᖅᑲᑦ ᐅᓂᒃᑳᓕᐊᑦ ᐱᑕᖅᑲᖅᑎᑦᑎᕗᖅ ᕿᒥᕐᕈᐃᓂᕐᒥᒃ ᓴᖅᑭᑐᐃᓐᓇᕆᐊᓕᖓᓂᒃ ᐊᒃᑐᐃᓂᐅᓲᓂᒃ ᐅᒥᐊᕐᔪᐊᑉ ᒪᓕᖕᒋᓄᑦ ᐸᐅᕋᔫᑕᓗ ᑲᐃᕙᑕᖕᒋᓄᑦ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐱᓕᕆᑎᑦᑎᓂᖕᒋᓄᑦ ᐊᒃᑐᐊᓂᖅᑲᖅᑐᑦ ᑖᔅᓯᒧᖓ ᐱᓕᕆᐊᑉ ᒪᕐᑭᓕᖅᑕᖓ ᐅᒃᑑᑎᖓᑕ ᐊᒻᒪᓗ ᐃᓚᕐᑲᖅᓱᓂᓗ ᓄᑖᓂᒃ ᑐᑭᓯᐅᒪᔾᔪᑎᒃᓴᓂᒃ ᑲᑎᖅᓯᒐᑦ ᑎᑎᕋᐅᓯᐅᔪᓪᓗᐊᓐᓃᑦ ᑕᐃᒃᑲᓂᑦ ᑎᑎᕋᐅᓯᑦ ᓯᕗᓪᓕᖅᐹᑦ ᑐᓐᓂᕆᔭᐅᓚᐅᖅᑎᓪᓗᒋᑦ ᐊᖏᖅᓯᒪᔭᒧᑦ ᐅᔭᕋᓐᓂᐊᕐᓂᕐᒧᑦ. ᐱᓕᕆᐊᑉ ᒪᕐᑭᓕᖅᑕᖓ ᐅᒃᑑᑎᖓ ᐃᓚᒋᐊᕆᓴᖅᑲᖅᑐᖅ ᖄᖓᒍᑦ ᐊᖏᔫᔪᑦ ᑐᙵᕕᑦ ᖃᐅᔨᓴᕝᕕᓃᑦ ᐊᕙᑖᓄᑦ ᑕᒪᓐᓇ ᕿᒥᕐᕈᐃᓂᖅ ᑕᐃᑲᙶᑦ 2011–ᒥ ᑖᔅᓯᒧᖓ ᐃᓗᐃᑦᑑᔪᒧᑦ ᐊᖏᖅᓯᒪᔭᒧᑦ ᐅᔭᕋᓐᓂᐊᕐᓂᕐᒧᑦ ᑕᐃᓖᓪᓗ ᓂᑉᓯᑉᓯᒪᓂᕐᑲᖅᐳᖅ ᑭᖑᓪᓕᖅᑳᑉ ᐅᓂᒃᑳᖓᓄᑦ FEIS ᓯᕗᓂᐊᒍᓪᓗ ᐅᐃᒍᕆᐊᖅᑕᐅᓂᑰᔭᒃᑯᑦ. ᐅᓇ ᑎᑎᕋᖅᓯᒪᔪᖅ ᐊᑐᖅᑐᖅ ᐃᓕᔭᐅᓪᓗᓂ ᕿᒥᕐᕈᐃᓂᖕᒋᓄᑦ ᐊᒃᑐᐃᓂᕐᑲᕐᓂᐊᑕ ᑕᕆᐅᑉ ᐊᕙᑕᓄᑦ.

ᐅᒥᐊᕐᔪᐊᕐᒧᑦ ᓴᖅᑭᑕᑦ ᒪᓖᑦ ᓴᖅᑮᔪᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᓐᓂᒃ ᓯᓪᓴᖕᒋᒍᑦ ᐊᕙᑖᑕ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑎᒋᔭᖕᒋᑕ ᐊᒻᒪᓗ ᓯᓪᓴᖕᒋᑕ ᓯᐅᕋᖕᒋᑦ ᓅᑕᖅᑕᐅᓂᖕᒋᓄᑦ ᐸᐅᕋᔫᑕ ᑲᐃᕙᑎᑕᖕᒋᓄᑦ (ᐸᐅᕋᐅᔭᐅᑉ ᐊᐅᓚᑎᑖ) ᖃᓂᒋᔫᒧᑦ ᕿᙳᒧᐊᑕ ᐅᒥᐊᕐᔪᐊᓕᕆᕝᕕᐊᑕ. ᒪᓕᖕᒋᑦ ᓴᖅᑭᑦᑐᑦ ᐅᓄᖅᓯᒋᐊᕐᓂᖕᒋᓐᓄᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᓯᔾᔩᑐᐃᓐᓇᓇᓕᐊᑦ ᐊᕙᑖᑕ ᓯᓪᓴᖕᒋᑦ ᑕᐅᑦᑐᕆᓴᖕᒋᓐᓇᒃ.

ᕿᒥᕐᕈᔭᐅᓇᓱᒃᑐᑎᒃ ᓴᖅᑭᑐᐃᓐᓇᕆᐊᓖᑦ ᓯᓪᓴᖕᒋᑕ ᐊᒃᑐᖅᑕᐅᓂᖕᒋᑦ ᑕᑯᓇᒃᑐᒋᑦ ᓄᖑᓴᖅᑕᐅᓂᖕᒋᑦ ᓯᐅᖅᑲᖕᒋᑕᒧ ᓅᑕᖅᑕᐅᓂᖕᒋᑦ ᓴᖅᑭᑦᑐᓇᓲᑦ, ᓇᓚᐅᑦᑖᕆᓴᐅᓪᓗᑎᒃ ᐅᒥᐊᕐᔪᐊᑉ ᒪᓕᖕᒋᑕ ᓴᙱᓂᖕᒋᑦ ᓴᓂᕌᒍᑦ ᐊᓄᕌᖅᑐᒧᑦ ᒪᓕᓕᐊᖑᔪᑦ ᐊᑭᑦᑐᒧᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑖᑕ ᐃᓂᐊᒍᑦ. ᓴᖅᑭᑎᖅᑐᑦ ᑕᑯᔅᓴᕈᐃᓪᓗᑎᒃ ᐅᒥᐊᕐᔪᐊᒧᑦ ᓴᖅᑭᑕᑦ ᒪᓕᖕᒋᑦ (ᒪᓕᖓ) ᐊᖏᓗᐊᕐᔫᖕᒋᑦᑐᑦ ᐊᕙᑖᒍᑦ ᐅᐊᖕᓇᐅᑉ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑖᑕ ᖁᑦᑎᓛᖑᔪᑦ ᐅᒥᐊᕐᔪᐊᑉ ᒪᓕᖕᒋᑦ ᑎᑭᐅᒪᓪᓗᑎᒃ 0.12 ᒦᑕᒧᑦ ᐅᒥᐊᑉ ᐃᒫᖓᓂᐊᑕ ᐊᒻᒪᓗ ᑐᖓᔪᑦ 0.05 ᒦᑕ ᐅᖓᓯᓐᓂᖅᐳᑎᒃ ᐅᖓᑖᓄᑦ 1 ᑭᓛᒦᑕ ᐅᒥᐊᕐᔪᐊᑉ ᐊᖅᑯᑖᓂᒃ. ᐅᒥᐊᕐᔪᐊᑦ ᒪᓕᖕᒋᑦ, ᓇᓚᐅᑦᑖᖅᓯᒪᔪᑦ ᑐᖔᓂ 0.05 ᓴᓐᑕᒦᑕ ᓯᓪᓴᖓᓄᑦ ᑎᑭᑦᑕᕌᖓᑦ, ᐊᖏᓗᐊᖏᑦᑐᒥᒃ ᐊᒃᑐᐃᒐᔭᖅᑐᑦ ᐅᔭᕋᒃᑐᒧᑦ ᐅᖁᒪᐃᑦᑐᓂᓪᓗ ᓯᐅᕋᖕᒋᑦ ᓯᓪᓴᖕᒋᑦ ᐅᒥᐊᕐᔪᐊᑉ ᐊᖅᑯᑖᑕ.

ᐸᐅᕋᔭᒧᑦ ᓴᖅᑭᑕᐅᔪᑦ ᓴᔪᐱᓪᓚᖓᓂᐊᓄᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᓪᓗᑎᒃ ᐊᔾᔨᒌᖕᒋᑦᑐᑦ ᐊᒃᑎᒌᒃᑯᑦ ᐅᒥᐊᕐᔪᐊᕐᒥᓄᑦ ᐅᓯᒃᑕᖅᑐᑦ ᓴᕕᕋᔭᒃᓴᒥᒃ ᐊᔭᐅᕆᔾᔪᑎᒋᓪᓗ ᓄᓇᖅᐸᓯᒃᑐᒥ. ᐊᐅᓚᓂᖕᒋᑦ ᐃᐱᖅᓯᒪᕝᕕᖕᒋᓐᓂᒃ ᓴᕕᕋᔭᒃᓴᑦ ᐅᓯᓕᖅᓯᐃᕝᕕᓂᒃ ᕿᙳᒧᐊᑕ ᐅᒥᐊᕐᔪᐊᓕᕆᕝᕕᐊᓂ ᓂᕆᐅᒋᔭᑦ ᐊᐅᓚᓂᖕᒋᑦ 0.4 ᒦᑕ/ᓴᒃᑲᓐ ᐊᔭᐅᖅᑎᒧᑦ ᑎᑭᓪᓗᒍ 2.3 ᒦᑕ/ᓴᒃᑲᓐ ᐊᖕᒋᓛᑉ ᐅᒥᐊᕐᔪᐊᑉ ᐅᓯᒃᑕᐃᔭᐅᑉ ᖃᓂᓛᖑᔪᖅ ᐃᖅᑲᖓᓄᑦ ᐃᒃᑲᓛᖑᔪᒃᑯᑦ (21 ᒦᑕ) ᐊᒻᒪᓗ ᖃᓂᓛᖑᔪᖅ ᐃᖅᑲᖓᓂ ᐸᐅᕋᔭᖓᓄᑦ. ᓇᓚᐅᑦᑖᖅᑕᖅ ᐃᖅᑲᖓᑕ ᖃᓂᒋᔭᒧᑦ ᐃᓗᑦᑐᐃᓇᔭᖅᑐᖅ ᐃᓯᓕᖅᑎᑦᑎᓗᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓂᒋᔭᓕᒫᖕᒋᑦ; ᑭᓯᐊᓂᓕ, ᐃᖅᑲᖓᓄᑦ ᑲᑖᒐᑲᐅᑎᒋᓇᔭᖅᑐᖅ ᓯᐅᕋᖓ ᐊᑯᓐᓂᐊᒍᑦ ᐃᐱᖅᑕᐅᒋᐊᕐᓂᐊᑕ ᐅᓯᓕᖅᓯᓈᖅᑕᐅᓂᐊᑕᓗ ᐅᒥᐊᕐᔪᐊᑉ.

REPORT

Baffinland Iron Mines Corporation, Mary River Project - Phase 2 Proposal

TSD #22: Ship Wake and Propeller Wash Assessment

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LIST OF ACRONYMS

Term	Abbreviation
Baffinland Iron Mines Corporation	Baffinland
Block coeffficent	Cb
Deadweight tonnage	DWT
Golder Associates Ltd.	Golder
Median diameter	D_{50}
Lower low water tide	LLWT
Propeller shaft centerline distance above bed	Zp
Technical Support Document	TSD
Velocity behind the propeller	Up

1.0 INTRODUCTION

The Mary River Project (the Project) is an operating iron ore mine located in the Qikiqtani Region of Nunavut. Baffinland Iron Mines Corporation (Baffinland; the Proponent) is the owner and operator of the Project. As part of the regulatory approval process, Baffinland submitted a Final Environmental Impact Statement (FEIS) to the Nunavut Impact Review Board (NIRB), which presented in-depth analyses and evaluation of potential environmental and socioeconomic effects associated with the Project.

In 2012, NIRB issued Project Certificate No 005 which provided approval for Baffinland to mine 18 million tonnes per annum (Mtpa) of iron ore, construct a railway to transport the ore south to a port at Steensby Inlet which operates year-round, and to ship the ore to market. The Project Certificate was subsequently amended to include the mining of an additional 4.2 Mtpa of ore, trucking this amount of ore by an existing road (the Tote Road) north to an existing port at Milne Inlet, and shipping the ore to market during the open water season. The total approved iron ore production was increased to 22.2 Mtpa (4.2 Mtpa transported by road to Milne Port, and 18 Mtpa transported by rail to Steensby Port). This is now considered the Approved Project. The 18 Mtpa Steensby rail project has not yet been constructed, however 4.2 Mtpa of iron ore is being transported north by road to Milne Port currently. Baffinland recently submitted a request for a second amendment to Project Certificate No.005 to allow for a short-term increase in production and transport of ore via road through Milne Port from the current 4.2 Mtpa to 6.0 Mtpa.

1.1 Phase 2 Proposal Overview

The Phase 2 Proposal (the third project certificate amendment request) involves increasing the quantity of ore shipped through Milne Port to 12 Mtpa, via the construction of a new railway running parallel to the existing Tote Road (called the North Railway). The total mine production will increase to 30 Mtpa with 12 Mtpa being transported via the North Railway to Milne Port and 18 Mtpa transported via the South Railway to Steensby Port. Construction on the North Railway is planned to begin in late 2019. Completion of construction of the North Railway is expected by 2020 with transportation of ore to Milne Port by trucks and railway ramping up as mine production increases to 12 Mtpa by 2020. Shipping from Milne Port will also increase to 12 Mtpa by 2020. Construction of the South Railway and Steensby Port will commence in 2021 with commissioning and a gradual increase in mine production to 30 Mtpa by 2024. Shipping of 18 Mtpa from Steensby Port will begin in 2025.

Phase 2 also involves the development of additional marine infrastructure at Milne Port, including a second ore dock. Shipping at Milne Port will continue to occur during the open water season, and may extend into the shoulder periods when the landfast ice is not being used to support travel and harvesting by Inuit. Various upgrades and additional infrastructure will also be required at the Mine Site and along both the north and south transportation corridors to support the increase in production and construction of the two rail lines.

In order to account for the increased tonnage of ore being transported under the Phase 2 Proposal, an increase in total vessel traffic serving Milne Port is proposed. Vessels ranging in size from Supramax to Cape Size will be retained by Baffinland depending on availability. An estimated 176 round trips (upper range) will occur per season, with an average voyage time per vessel of 26 days. Shipping will occur seasonally over a period of approximately 90 days between 1 July and 15 November, with each chartered vessel making one to three round trips per season.

1.2 Scope of Work and Objectives

Golder Associates Ltd (Golder) was retained by Baffinland to assess the potential effects of the Phase 2 Proposal on the marine environment. This Technical Support Document (TSD) specifically addresses the following Project effects on the marine physical environment related to shipping activities:

- Potential effects of ship-generated waves on shorelines along the shipping route; and
- Potential sediment disturbance effects from propeller generated velocities in the vicinity of Milne Port.

Hydrodynamic modeling was performed to evaluate the potential effects of Project shipping on nearshore waves, currents and bottom substrate (seabed), based on shipping operations proposed under the Phase 2 Proposal. The objectives of this work were:

- To characterize waves generated by ore carriers transiting to and from Milne Port along the Northern Shipping Route;
- To compare ship generated waves with natural wind wave energy along the Northern Shipping Route and provide an assessment of potential shoreline effects in terms of erosion and sediment transport; and
- To characterize propeller-generated velocities from tugs and ore carriers in the vicinity of the ore docks at Milne Port and estimate the potential for bed erosion (scour).

1.3 Background Information

1.3.1 Ship Generated Waves

Ship-generated wave (wakewash) effects on the marine environment may result from increased wave action along the shorelines bordering the Northern Shipping Route. Moving ships generate waves as water flows past the hull. Two different types of waves are generated, diverging waves and transverse waves (Figure 1-1). The transverse and diverging waves meet to form cusps located along the cusp locus line; the highest wave heights are found along this line (Sorenson 1997) which are also known as secondary waves. Wave height attenuates exponentially with distance from the sailing line. Wave characteristics will vary depending on vessel speed, vessel characteristics (geometry and operating draft), and water depth. Typical wave heights from container ships or freighters vary between 0.25 and 0.50 m with maximum values up to 1.0 m; wave periods typically vary between 2 and 4 seconds (CIRIA 2007).

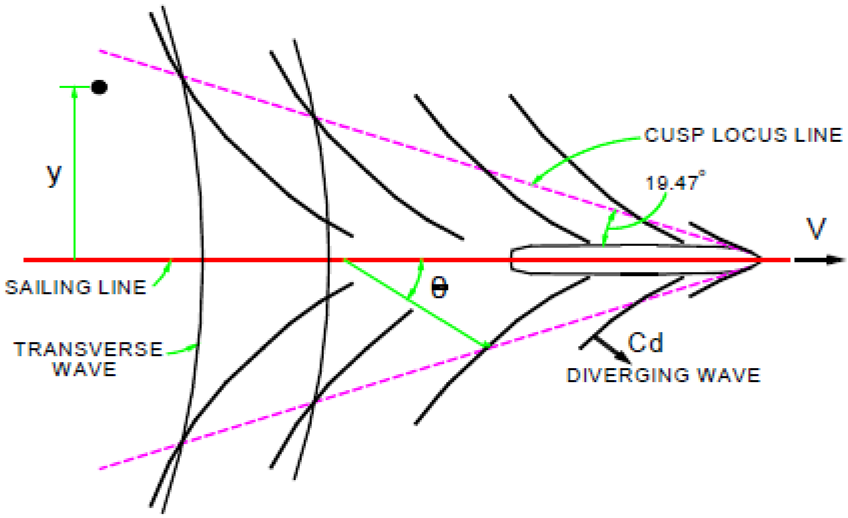


Figure 1-1: Plan-view sketch showing ship-generated waves. Adopted from Kriebel and Seelig (2005)

It is widely accepted that ship traffic has the potential to cause environmental damage in narrow waterways and in the vicinity of sensitive areas such as wetlands or naturally low-energy coasts where waves generated by vessels can cause rapid changes in the coastal profile near the waterline (Kelpsaite et al. 2009; Kofoed-Hansen et al. 1999). Sediment transport rates and patterns can be altered by even a small increase in hydrodynamic loads. Waves of all types can also change the nature of benthic habitats by altering factors such as sediment grain size distribution and nutrient availability (Curtiss et al. 2009). The erosion potential from ship wakes is dependent on shoreline sediment type, energy input from other sources (i.e., wind waves), and sailing line proximity to the shore. Shores with fine-grained sediments and in close proximity to the sailing line are most likely to be affected by ship wakes.

1.3.2 Propeller Generated Velocities (Propeller Wash) and Scour Potential

Propeller generated velocities (propeller wash) has the potential to disturb seabed sediments as a result of increased bottom shear stress. Disturbance of bed sediments may result in potential changes in water quality (e.g., increase in turbidity) and associated impacts on marine benthos. A vessel maneuvering or using its propeller to remain stationary generates a fluid jet (propeller wash) directed opposite to the direction of the vessel travel. As the jet propagates through the water column, it widens and reduces in velocity as a result of turbulence. In free water, the fluid jet dissipates until its velocity is of the order of magnitude of background velocities derived from natural currents and waves. Near-bed velocities generated by propeller jets of a ship's main propulsion system can reach six metres per second (m/s) or higher, and up to three m/s for bow or stern thrusters (CIRIA 2007). Velocities are related to the power applied by the ship and the propeller characteristics. The highest velocities are typically reached during maneuvering and quasi-stationary operations. Velocities while a vessel is in transit in deep water can typically be ignored because the point of generation of the jet is not fixed so the jet is not sustained at a given location for a long enough period of time and the fluid jet dissipates into the surrounding environment faster than one associated with a maneuvering (and quasi-stationary) vessel.

Scour (erosion) caused by propeller wash is the result of increased bottom shear stress induced by the water velocity. The vessel scour depth is a function of the distance between the propeller and the sediment bed, with substantially less scour in deeper water, and the sediment grain size distribution. The potential for scour is highest for large (deep draft) vessels with minimum keel clearance above the bed that maneuver and berth unassisted. Other factors influencing propeller wash scour are propeller angle, thrust, blade configuration, and duration of the high-power event under stationary conditions.

A bathymetric map of Milne Port and the proposed ore dock configuration is shown in Figure 1-2. The map shows potential vessel tracks for accessing and egressing each dock. Water depths in the berthing area range from approximately 21 to 30 m at the proposed dock and from 17.5 to 25 m at the existing dock. The minimum keel clearance is small (less 5 to 10 m) for a Cape size vessel at the proposed dock and is similar in comparison to the clearance for a Supramax or Panamax size vessel at the existing dock. The minimum clearance for a Panamax size vessel at the proposed dock is larger (7 to 15 m). The potential for scour is expected to be greater for the Cape size vessel than the Panamax size vessel at the proposed dock due to the low keel clearance.

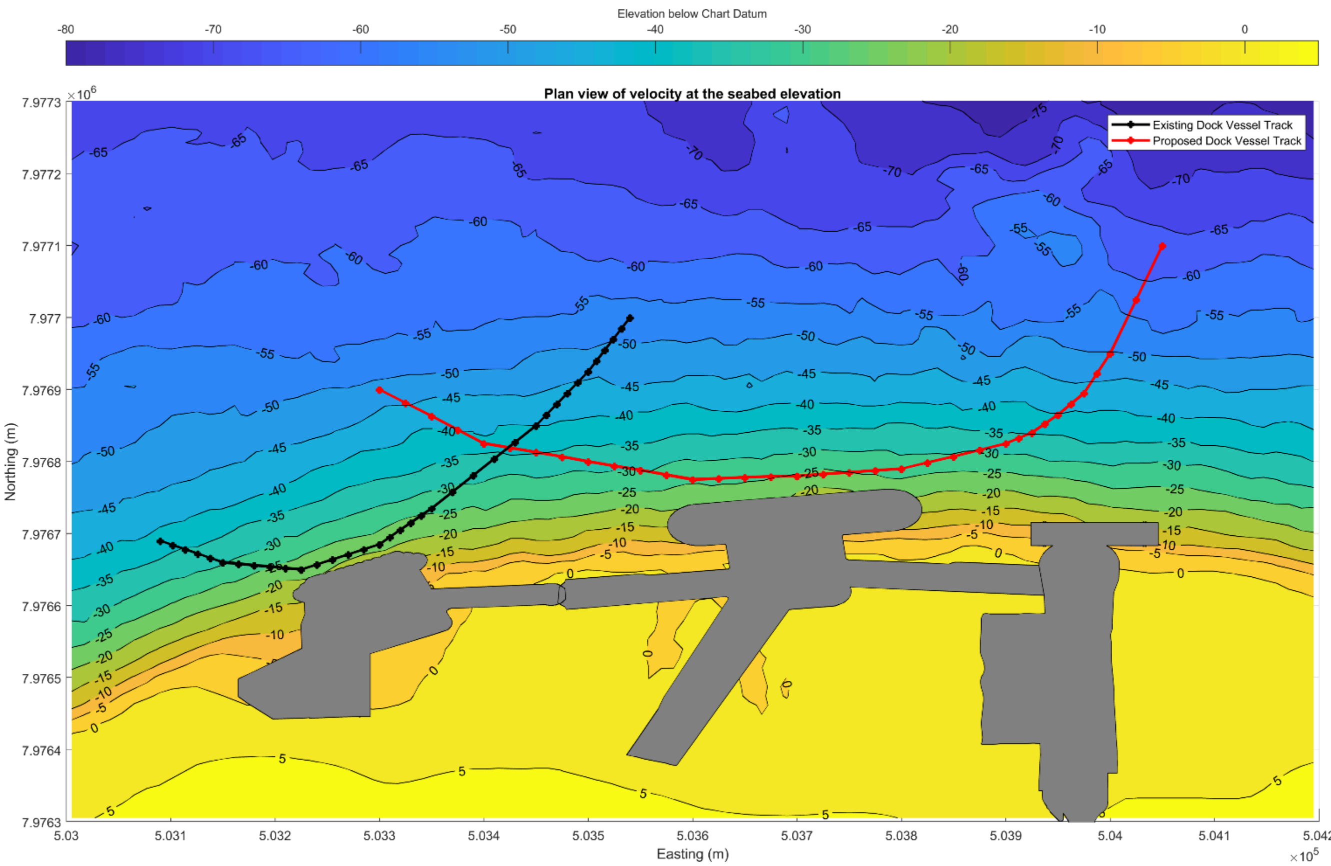


Figure 1-2: Map of existing ore dock (left), proposed ore dock (middle) and freight dock (right) with bathymetry and potential vessel tracks at each ore dock.

2.0 MODEL INPUTS

2.1 Vessel Specifications and Schedule

Based on Baffinland's projected ore shipping (navigation) schedule for the Phase 2 Proposal (Baffinland 2017), peak shipping months are expected to occur during the ice free open water season of July, August and September; with an estimated total of 184 round-trips respectively past Pond Inlet, inclusive of ore carriers, freight and fuel. The optimized ore shipment schedule (Table 2-1) was used as the basis for the present ship generated wake assessment.

Table 2-1: Anticipated Iron Ore Shipping Schedule for the Mary River Project – Phase 2

Period	Dates	Ship type	Ships Loaded Dock # 1	Ships Loaded Dock # 2
Early Season	1 Jul –14 Aug	Ice class	14 x Supramax	24 x Panamax
Mid Season	15 Aug– 20 Sep	Non ice class	22 x Panamax	28 x Cape Size
Late Season	21 Sep – 15 Oct	Ice class	8 x Supramax	24 x Panamax

The schedule calls for 48 Panamax size ships and 28 Cape size ships berthing at the proposed dock. However, Golder understands that in order to maximize the capacity and use of the port, a variety of market vessels will be used depending on the time of year and availability. These may include:

- Supramax ~55,000 deadweight tonnage (DWT);
- Panamax ~75,000 DWT;
- Post Panamax ~90,000 DWT; and
- Cape size vessels ~250,000 DWT.

Table 2-2 provides the vessel specifications that are used in the analysis. The specifications were obtained for "typical" vessels in each size class based on a published literature (PIANC 2014; 2015) and by reviewing vessel fleets likely to operate at the Project. The sources for the assumptions are documented in the table footnotes.

Table 2-2: Vessel Specifications for Milne Port and Northern Shipping Route

Criteria	Standard Tug[1] (Ice-class)	Ore Carrier			
		Supramax[2] (55,000 DWT)	Panamax[3] (75,000 DWT)	Post-Panamax[4] (90,000 DWT)	Cape size[5] (250,000 DWT)
Propeller diameter[9]	2.0 m to 2.5 m	6.0 m-8.5 m	6.0 m-8.5 m	6.0 m – 8.5 m	6.0 m – 8.5 m
Engine Power[10]	3,750 kw	8,750 kW	9,470 kW	10,080 kw	20,500 kW

Criteria	Standard Tug[1] (Ice-class)	Ore Carrier			
		Supramax[2] (55,000 DWT)	Panamax[3] (75,000 DWT)	Post-Panamax[4] (90,000 DWT)	Cape size[5] (250,000 DWT)
Propeller shaft centerline distance above bed (Zp)[11]	17.3 m	12.3 m	11.2 m	11.3 m	4.8 m
Vessel length	29 m	198 m	225 m	240 m	335 m
Vessel draft	5.0 m	13.0 m	14.1 m	14.0 m	20.5 m
Vessel beam	11 m	32 m	32 m	36.5	52.5 m
Block coefficient (Cb)	N/A	0.80	0.84	0.84	0.85
Water depth (docking)	21 m minimum depth at berth[6]				
Water depth (transit)	50 to 800 m minimum depth[7]				
Transit speed	9 knots (4.6 m/s), maximum allowed speed in Milne Inlet[8]				

Notes: m – metre; m/s – metres per second; not applicable
1) Based on the azimuth stern drive (ASD) ice class tugboats Svitzer Nerthus and Njal https://gltugs.wordpress.com/svitzer-nerthus/. Svitzer Canada is currently operating tugboats in Milne Port.
2) Based on PIANC (2015); and representative vessels M/V Arkadia and M/V Kumpula; http://www.eslshipping.com/en/fleet/ships/m-s-kumpula/; and M/V Federal Franklin
3) Based on Table 1.1 PIANC (2014) and PIANC (2015); representative vessel M/V Nordic Odyssey ice class 1A vessel (http://www.nordicbulkcarriers.com/ice-bulk-carriers)
4) Based on PIANC (2015)
5) Based on PIANC (2015)
6) Pre-feasibility study drawings (Hatch 2016)
7) Bathymetry for Milne Inlet compiled by Golder in 2017
8) Based on Standing Instructions (Fednav 2016)
9) Following D_p/Draft < 0.65 with maximum of 9.0 to 10 m (MAN Diesel & Turbo 2011)
10) Propulsion Trends in Bulk Carriers (MAN Diesel & Turbo 2014)
11) Calculated as minimum depth (21 m) minus vessel draft and one half the vessel propeller diameter

2.2 Northern Shipping Route

The navigational corridor for the Northern Shipping Route outlined in the Milne Port Standing Instructions (Fednav 2016) was used as the basis for the ship wake assessment. The route consists of 10 legs defined by nine waypoints and is shown in overview in Figure 2-1 and in detail in Figure 2-2 to Figure 2-4 for Legs 1-3, 4-6, and 7-9, respectively. Milne Inlet is approached through Baffin Bay and Pond Inlet. A description of the route follows:

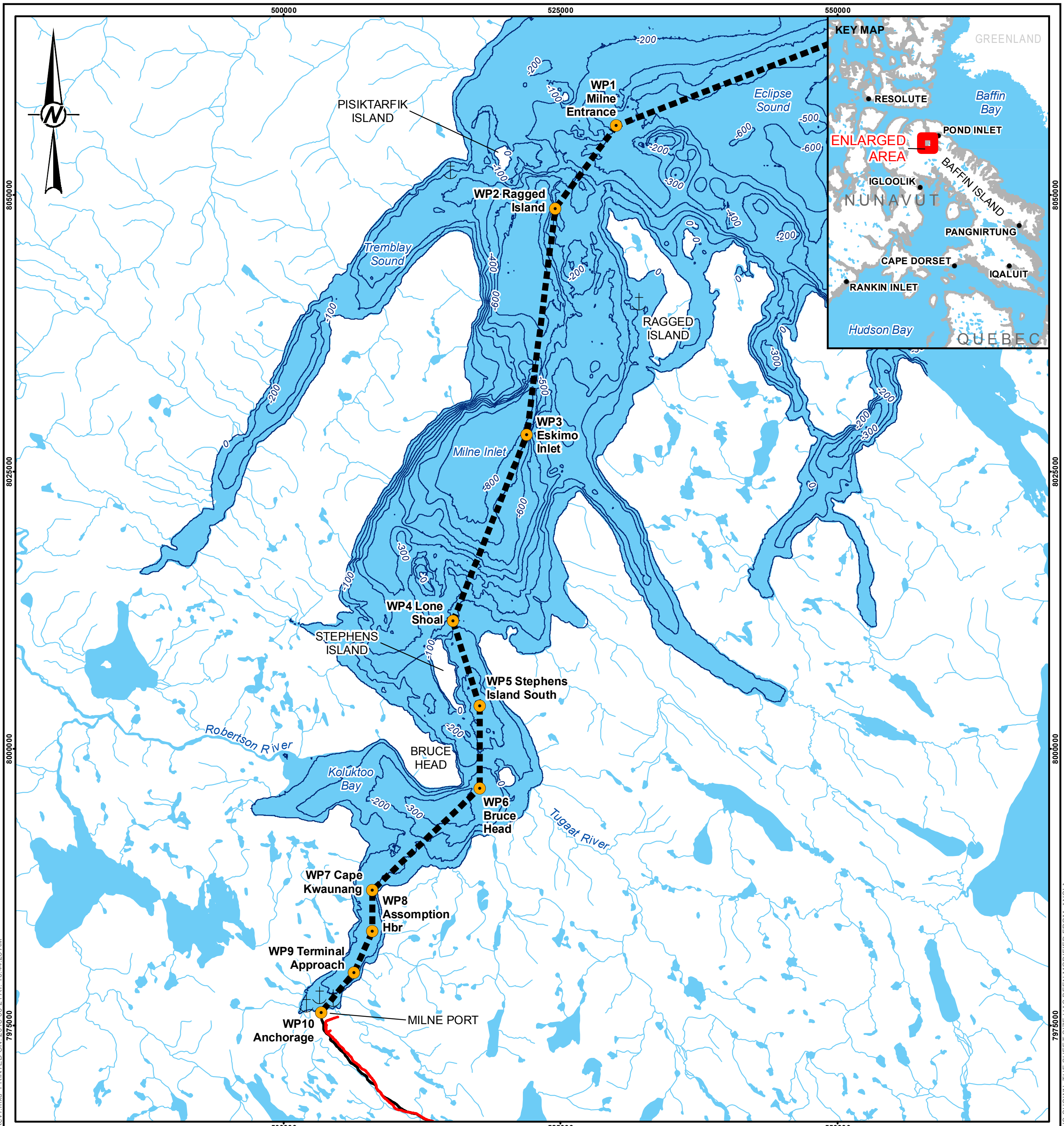
- Legs 1-3 (200 to 800 m water depth). The entrance to Milne Inlet lies midway between two shoals:
  - Leg 1 is approximately 9 km with a heading towards the southwest. Depths along Leg 1 are 200 to 300 m; the nearest shoreline along this route is the northern tip of Ragged Island which is approximately 5 km away;
  - Leg 2 is approximately 20 km with a heading towards the south-southwest. Depths along Leg 2 are 200 to 800 m; the nearest shoreline along this route is approximately 5 km away; and

- Leg 3 is approximately 19 km with a heading towards the southwest. Depths along Leg 3 are up to 700 m, and shallow to 200 m moving towards Leg 4. The nearest shoreline along this leg is approximately 6 km away just south of Eskimo Inlet.

- Legs 4-6 (100 to 300 m water depth). The route along Legs 4-6 narrow substantially from Legs 1-3 as the route passes Stephens Island and Bruce Head:
  - Leg 4 is approximately 9 km with a heading towards the south-southeast. Depths along Leg 4 are 100 to 200 m; the nearest shoreline along this route is eastern Stephens Island approximately 1 km away;
  - Leg 5 is 7 km in length with a heading towards the south-southwest. Depths along Leg 5 are 150 to 200 m; the nearest shoreline along this route is the end of Bruce Head, approximately 1.5 km away; and
  - Leg 6 is approximately 13 km with a heading towards the southwest. Depths along Leg 6 are approximately 100 to 300 m; the nearest shoreline is Cape Kwaunang which is approximately 1 km away.

- Legs 7-9 (50 to 250 m water depth). The final three legs follow the narrow southern end of Milne Inlet, south of Koluktoo Bay:
  - Leg 7 is 2 nautical miles with a heading to the south. Depths along Leg 7 are 100 to 150 m; the nearest shoreline is Cape Kwaunang which is approximately 0.7 km away;
  - Leg 8 is approximately 4 km with a heading towards the south-southwest. Depths along Leg 8 are 100 to 150 m; the nearest shoreline is approximately 0.9 km; and
  - Leg 9 is approximately 5 km in length with a heading toward the southwest. Depths along Leg 9 are 150 to <50 m as the route reaches the anchorage and terminal. The nearest shoreline is 1 km away from the anchorage point to the port shoreline.

It is assumed that all Project-related vessels (i.e., ore carriers, freight vessels and fuel tankers) are required to adhere to a maximum speed limit of 9 knots (16.7 km/hr) while transiting through Eclipse Sound along the Northern Shipping Route.



LEGEND

- ANCHOR LOCATION
- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (100 m INTERVAL)
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- WATERCOURSE
- WATERBODY

0 10 20

1:500,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017.
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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
NORTHERN SHIPPING ROUTE OVERVIEW MAP

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	18000	REV.	FIGURE
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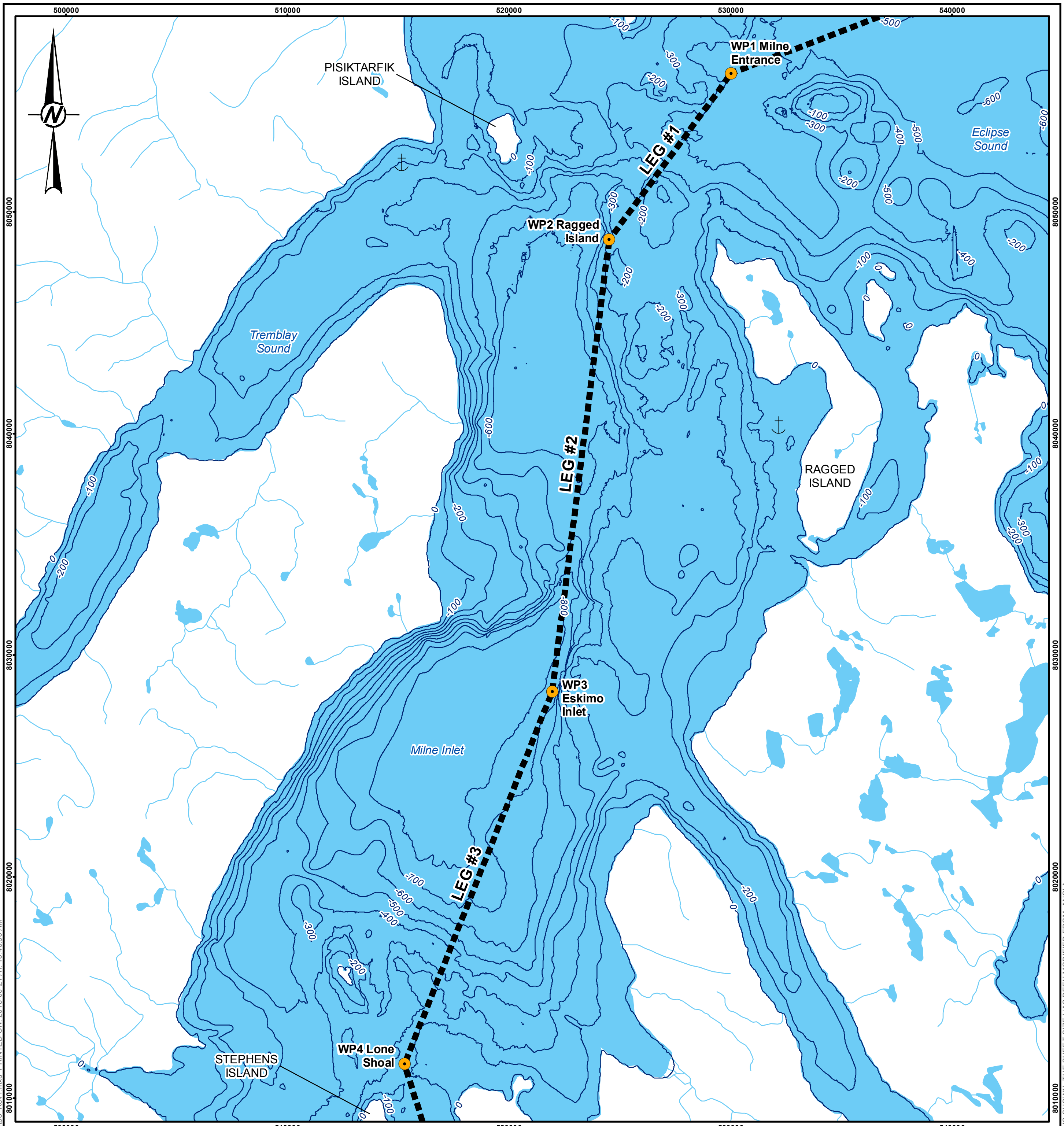

LEGEND

- ANCHOR LOCATION
- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (100 m INTERVAL)
- WATERCOURSE
- WATERBODY

0 5 10
1:250,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
NORTHERN SHIPPING ROUTE LEGS 1-3

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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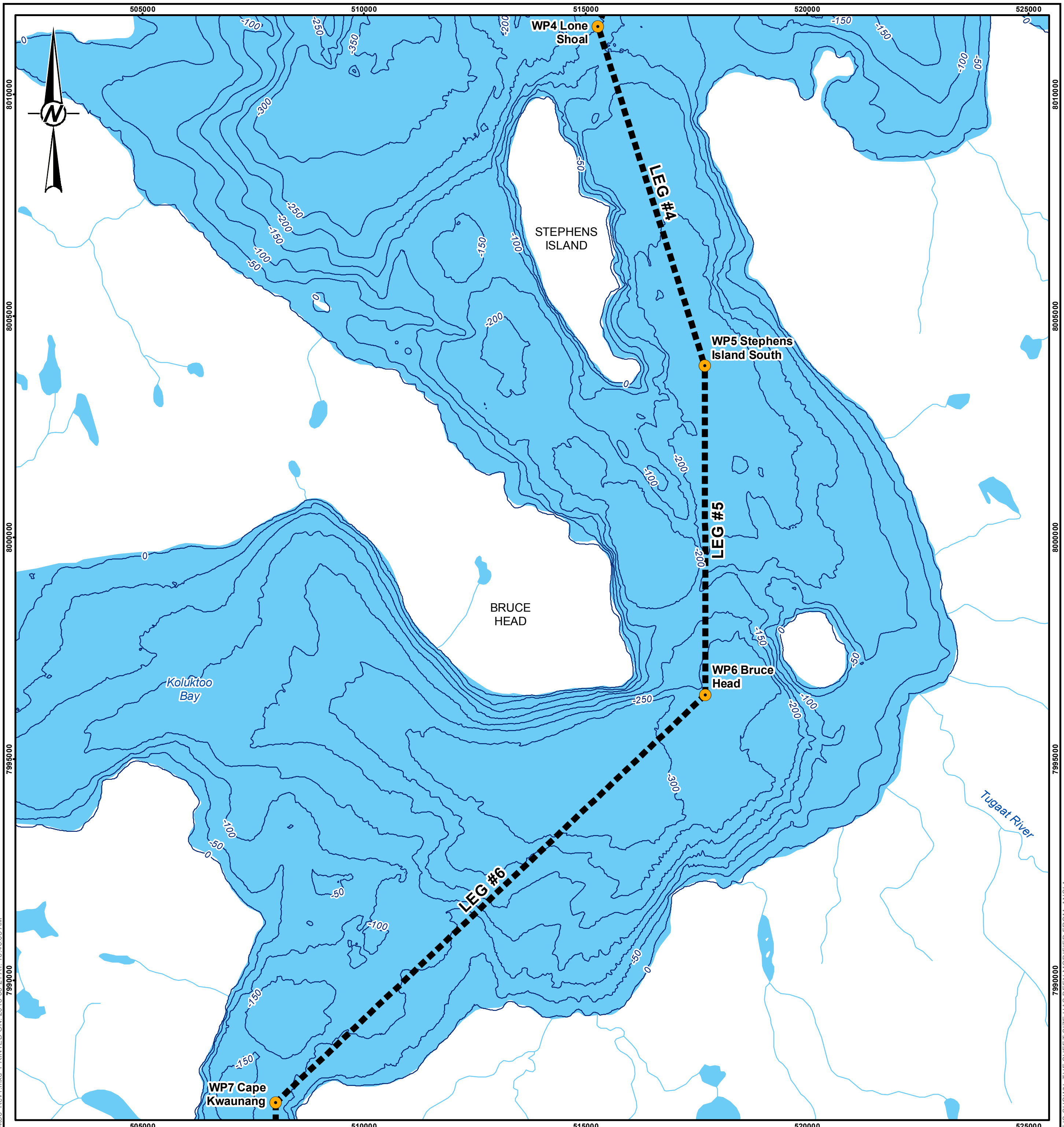

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- WATERCOURSE
- WATERBODY

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
NORTHERN SHIPPING ROUTE LEGS 4-6

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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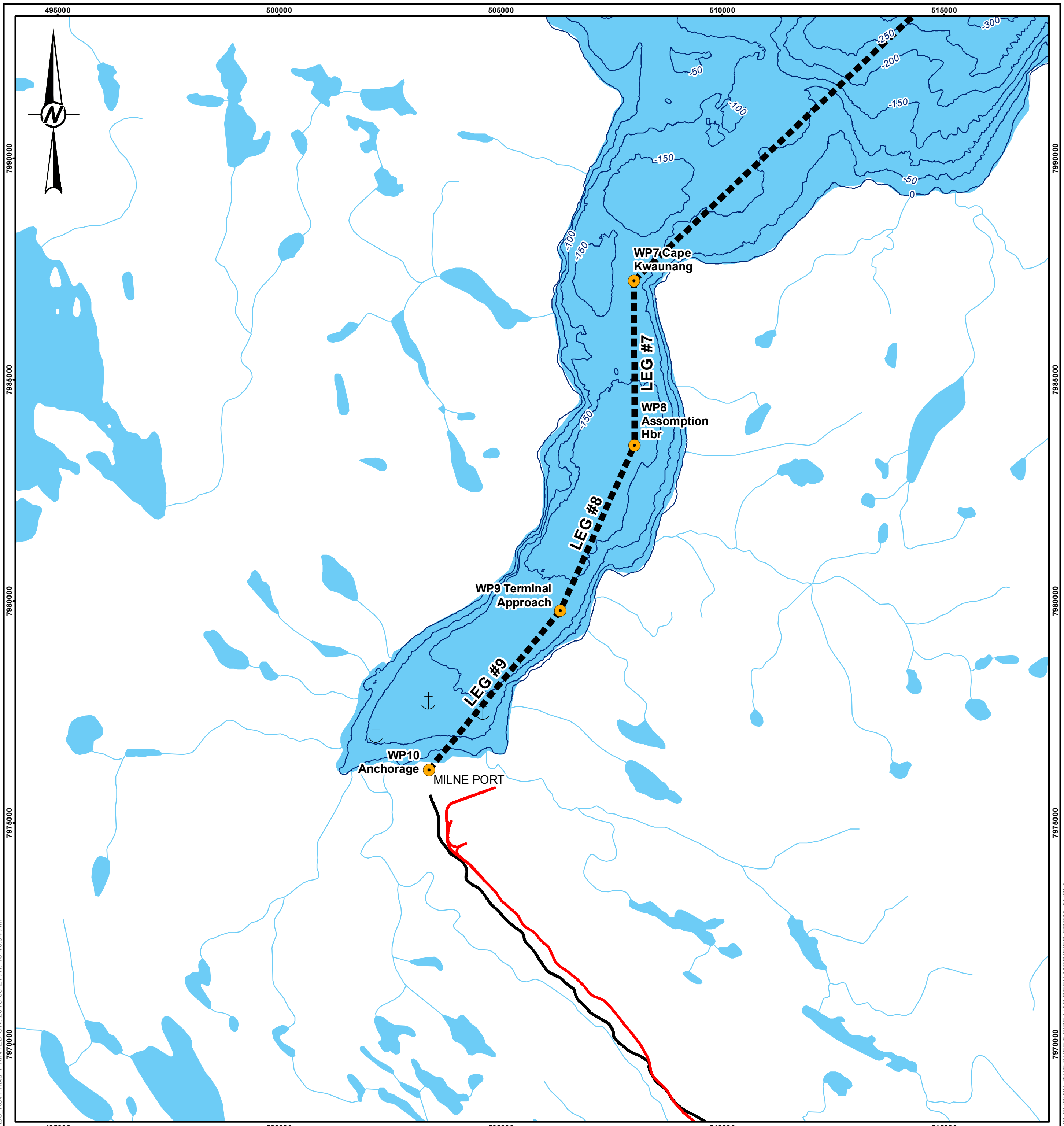

LEGEND

- ANCHOR LOCATION
- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- WATERCOURSE
- WATERBODY

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017.
3. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
NORTHERN SHIPPING ROUTE LEGS 7-9

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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Milne Port is located at the head of Milne Inlet. The current Port Site consists of a sheet pile ore dock and ship loader capable of handling Panamax size vessels (Figure 2-5). The Phase 2 Proposal includes a second ore dock and ship loader to accommodate Cape size vessels at Milne Port (Baffinland 2017). The proposed plan and section view of the proposed new ore dock and ship loader are shown in Figure 2-6, based on BESIX Van Pile (2017) and the pre-feasibility engineering report (Hatch 2016). The proposed ore dock expansion is located along the shoreline to the east of the existing ore dock and will be constructed of a steel cell sheet pile wall with the berth face parallel to the bathymetry contours. To the east of the main dock is a freight dock causeway constructed of rock fill surrounded by rock armouring. At the end of the causeway is a floating dock (spud barge) which will be orientated in either a horizontal or vertical direction. Three spacer barges will be moored along the berth of the new ore dock. Water depths in the ship loading area will be a minimum of 21 m below Lower Low Water Tide (LLWT) to accommodate Cape size vessels. Two to four tugboats will assist ships with maneuvering to the berth at the dock.

Figure 2-5: Existing ore dock and loading facility at Milne Port (Baffinland 2017)

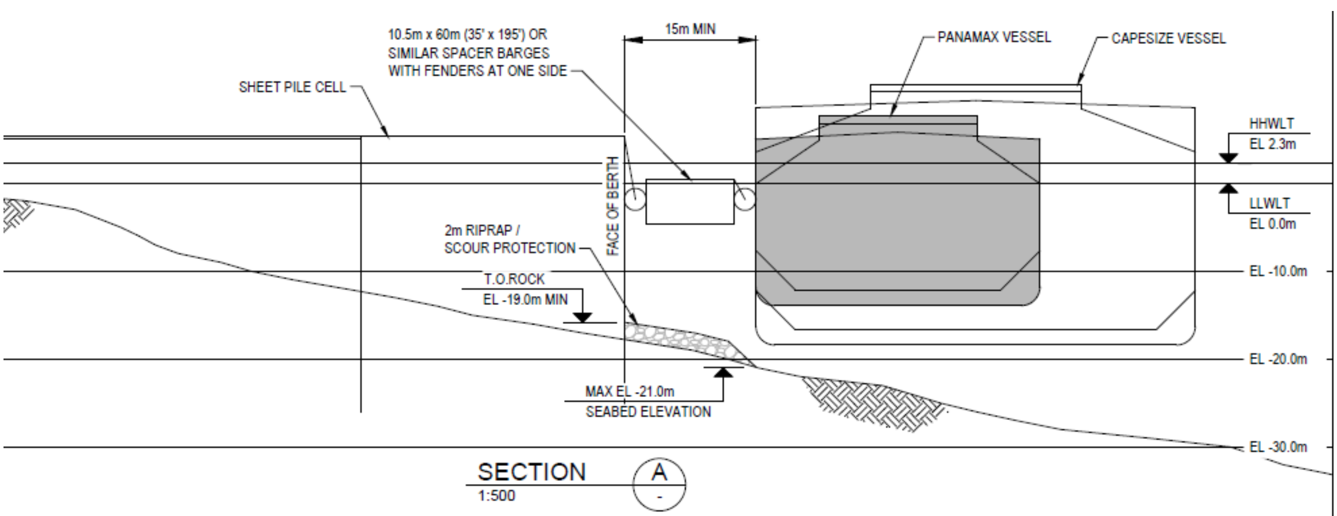

Figure 2-6: Plan view (top; BESIX Van Pile 2017) and section view (bottom; Hatch 2016) of proposed ore dock and ship

2.3 Sediment

Seabed sediment characteristics are summarized in Appendix A of TSD No. 20 (Golder 2017). The sediment at the proposed new ore dock can be classified as fine to medium sand with a median grain size diameter (D_{50}) of 0.20 to 0.25 mm based on Ponar grab samples and geotechnical investigations (Hatch 2017) conducted within the footprints of the existing and proposed ore dock infrastructure, in water depths between 15 and 30 m. The sediment characterization reported by fraction is 20%, 70%, and 10% for the fines (D_{50}=0.064mm), sand (D_{50}=0.2 mm), and gravel (D_{50}=2.0 mm) fraction, respectively.

Shorelines along the Northern Shipping Route from Milne Port to Eclipse Sound are primarily rocky and bedrock, consisting of coarse cobble and boulder-sized material. Near Milne Port, the shoreline is medium fine sand with localized gravel armouring along the intertidal beach. The beaches are gently sloping and cuspate in shape. Fine sand accumulations are focused at the intersections between the shoreline and riprap structures which are part of the sealift supply ramp. Some tidal ripples are present in sand and mud flats. More detailed shoreline descriptions are summarized in Appendix A of TSD No. 20 (Golder 2017).

3.0 METHODS

3.1 Ship Generated Waves from Ore Carriers

The estimation of ship-generated waves (wake) and the potential shoreline effects was completed using several steps:

1) Determine vessel and environmental parameters;
2) Calculate estimates of maximum wave height, period and cumulative wave energy flux (power); and
3) Assess potential for shoreline erosion and compare to one-dimensional (1-D) wind-wave estimates.

Several empirical models were used to calculate wake parameters (characteristic wave height, characteristic wave period, and wave power) from each vessel accessing Milne Port during the open water season. The wake parameters were calculated for three different sections of the shipping route, Legs 1-3, 4-6, and 7-9, based on the approximate water depths described in the assumptions below. The models used to estimate ship wake parameters were:

- The Permanent International Association of Navigation Congresses (PIANC) (1987) model is based on work at Delft by Blaauw et al (1984) for estimating ships wake heights in canals. It is similar to the Kriebel and Seelig (2005) model but makes use of a depth-based Froude number. The method tends to over-predict wave heights (Kriebel and Seelig 2005);
- An empirical model developed by Kriebel and Seelig (2005) is an improved model based on a previous one developed by Weggel and Sorenson (1986). The improved model makes use of a modified Froude number which is dependent on the depth-to-draft ratio and length-based Froude number; and
- CIRIA (2007) provides an approximation for estimating ship wake parameters based on PIANC (1987) and Przedwojski et al. (1995). The approximation uses a depth-based Froude number.

The following assumptions were made when applying each method:

- Vessel parameters were used as described in Table 2-2;
- An entrance length (L_e) equal to one third of the overall vessel length. Entrance length is the length from the ship bow to the start of the parallel middle-body of the ship. This is considered a conservative estimate, since for slender streamlined hulls, L_e can be as much as nearly one-half the overall vessel length, lessening the wave-generating potential;
- Fully loaded draft (conservative assumption);
- A nominal water depth was applied to three sections of the route (Leg 1-3, Leg 4-6, and Leg 7-9) using the minimum (conservative) depth for the respective range:
  - Leg 1-3: 200 m;
  - Leg 4-6: 100 m; and
  - Leg 7-9 50 m.

- Vessel speed: 9 knots (4.6 m/s);
- Wave celerity: Based on empirical equation developed by Weggel and Sorensen (1986) for ship wake celerity;
- For cumulative wave energy flux (power) calculations:
  - The number of vessel trips was assumed based on the schedule specified in Table 2-1 and multiplied by 2 to account for inbound and outbound passes;
  - A 2 minute wake duration per vessel passing was assumed for integrating wave energy flux; and
- Wave transformation due to bathymetric effects was not considered along the shipping route.

Wind-Generated Waves

Wind-wave energy along the Northern Shipping Route varies with exposure to wind events. Fetches along the shipping route vary from approximately 2 to 80 km. Winds from the meteorological station at the Milne Port dock were used as the basis for a 1-D wind-wave hindcast for the range of fetches along the route. The maximum wind speed during the open water season (July through October) in the 9-year record is approximately 25 m/s with an average speed of approximately 5 m/s. Wind-wave estimates were calculated following the method for wind-wave growth estimation from the Coastal Engineering Manual (USACE 2008) and Automated Coastal Engineering System (ACES) software (Leenknecht et al. 1992). Wave parameters along the shipping route were calculated for a range of wind speeds from the average wind speed to the maximum wind speed and a range of fetches (2 to 80 km).

3.2 Propeller generated velocities and scour potential

The estimation of propeller-generated velocities and scour potential at the proposed port was completed using several steps:

1) Determine vessel and environmental parameters;
2) Calculate estimates of maximum bottom velocity resulting from propeller wash; and
3) Calculate estimates of bed shear stress and potential bed scour (entrainment, suspension, and scour depth).

The vessel propeller-generated velocities were estimated using the method outlined in the CIRIA Rock Manual (CIRIA 2007) for estimating the time-averaged velocities in propeller jets caused by main propellers. Velocities were estimated for each typical bulk ore carrier operating at 25% power and for a tugboat operating at full (100%) power at low tide. The equation uses the vessel draft, propeller dimensions, and installed engine power to estimate velocity behind the propeller, $U_{p,}$ as shown in the schematic in Figure 3-1. Velocity estimates for bow and stern thrusters were not completed because propeller velocities are expected to be higher and thus a more conservative constraint for bed disturbances. Velocity estimates were also not completed for vessels in transit because these can be ignored (CIRIA 2007) for the range of water depths along the majority of the shipping route outside the Port.

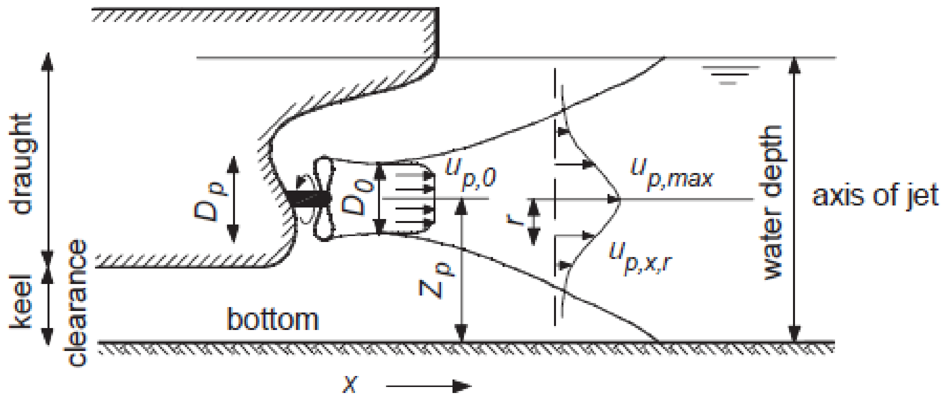

Figure 3-1: Vessel propeller wash due to a main propeller (CIRIA 2007)

Velocity estimates were completed for the vessel while stationary at a minimum water depth (21 m) at the landward boundary of the berthing area to provide an upper limit for the velocities while stationary in the berthing area. Velocity estimates and sediment mobility were also estimated and mapped to show the magnitude and extent of scour potential with actual depth (bathymetry) around the Port area using an assumed vessel path (as shown in Figure 1-2) for access and egress to and from the proposed ore dock. The vessel track is from west to east per the Milne Port Standing Instructions for the starboard side to be along the berthing area (Fednav 2016). For comparison purposes, a similar map was also completed for an assumed vessel track at the existing dock for a Panamax size vessel.

The estimates are expected to be conservative because the analysis assumes low tide (giving the lowest possible clearance from the bed) and the largest propeller diameter for a given vessel class. The area calculations also do not account for rock armour beneath the proposed spacer barges. Additionally, tugs are expected to be primarily responsible for berthing operations and the ship propeller will only be used intermittently.

Sediment mobility was estimated by calculating the bed shear stress for the velocity at each grid point in the contour map using the method of Soulsby (1997) which assumes a steady state flow. The bed shear stress was used to calculate the Shields parameter for the seabed assuming a median (D_{50}) sand diameter of 0.25 mm. The Shields parameter was compared to the critical Shields parameter for the corresponding grain size to determine if the shear stress exceeded the threshold of sediment motion for the sediment bed. Similarly, the skin friction velocity was calculated and compared to the theoretical settling velocity for the D_{50} sand diameter and fine fraction (D_{50} equal to 0.064 mm) to determine if sediment suspension will occur.

A nominal bed scour depth was estimated using the method of Hamill et al. (1999) scaled to the water depth and the Shields parameter. The empirical method was developed for prediction of maximum depth of scour for a given exposure period for both free expanding jets and those in close proximity to harbor structures. The method is based on laboratory experiments using four different propellers over a bed of fine to coarse sand. It is limited, however, to depths where the clearance from the tip of the propeller to the seabed is greater than the half the propeller diameter and less than 2.5 times the propeller diameter.

4.0 SHIP WAKE AND PROPELLER EFFECTS

4.1 Ship generated wave estimates

Estimates of the ship wake parameters were calculated using the three different methods described in Section **Error! Reference source not found.**. The wake heights estimated by all three methods were small, primarily due to the low vessel speed (9 knots) relative to the water depths along the shipping route. Results from the most conservative method, PIANC (1987), are summarized in Table 4-1 for wake heights relative to distance from the sailing line for the four classes of ore carriers. The wake heights range from 0.12 to 0.01 m across a range of distances from 50 m to 10 km from the sailing line, decreasing as they attenuate with distance from the sailing line. There is almost no noticeable difference in wake height predicted for the various vessel size classes; the prediction methods appear to be most sensitive to vessel speed followed by water depth and are less sensitive to ship dimensions. Contour maps illustrating the estimated wake height with distance from the shoreline are shown by shipping route leg in Appendix A. In all cases, wake heights attenuate to less than 0.05 m by the time they reach the shoreline along the shipping route. The potential for erosion, disturbance to habitat or traditional hunting and gathering activities from waves of this size is negligible for the coarse-grained and rocky shore types along the route.

Wave energy flux (power) is reported by vessel class for each class of ore carrier in Table 4-2 based on the expected number of trips for each size vessel during one season. The wave energy flux varies along the shipping route with water depth and distance from the sailing line. At a distance of 1 km from the sailing line (also the shortest distance along the shipping route to the shoreline – e.g., near Cape Kwaunang and Stephens Island) the estimated wave energy flux ranges from 5 to 69 kilowatts per metre per year (kW/m/year).

Table 4-1: Wake heights relative to distance from sailing line for four classes of ore bulk carriers using the PIANC (1987) method

Water Depth	Shipping Route Legs	Wake Height (m)					
Distance from Sailing Line:		50 m	100 m	500 m	1,000 m	5,000 m	10,000 m
Vessel Size Class: Supramax (55,000 DWT)							
200 m	Legs 1 to 3	0.04	0.03	0.02	0.01	0.01	0.01
100 m	Legs 4 to 6	0.07	0.05	0.03	0.02	0.01	0.01
50 m	Legs 7 to 9	0.11	0.08	0.04	0.04	0.02	0.02
Vessel Size Class: Panamax (75,000 DWT)							
200 m	Legs 1 to 3	0.04	0.03	0.02	0.01	0.01	0.01
100 m	Legs 4 to 6	0.07	0.05	0.03	0.02	0.01	0.01
50 m	Legs 7 to 9	0.11	0.08	0.04	0.04	0.02	0.02
Vessel Size Class: Post Panamax (90,000 DWT)							
200 m	Legs 1 to 3	0.04	0.03	0.02	0.01	0.01	0.01
100 m	Legs 4 to 6	0.07	0.05	0.03	0.02	0.01	0.01

Water Depth	Shipping Route Legs	Wake Height (m)					
50 m	Legs 7 to 9	0.11	0.08	0.04	0.04	0.02	0.02
Vessel Size Class: Cape size (250,000 DWT)							
200 m	Legs 1 to 3	0.05	0.03	0.02	0.01	0.01	0.01
100 m	Legs 4 to 6	0.08	0.05	0.03	0.02	0.01	0.01
50 m	Legs 7 to 9	0.12	0.08	0.05	0.04	0.02	0.02

Table 4-2: Wake energy flux (power) relative to distance from sailing line for four classes of ore bulk carriers

Water Depth	Shipping Route Legs	Wave Energy Flux (kW/m/year)					
Distance from sailing line:		50 m	100 m	500 m	1,000 m	5,000 m	10,000 m
Vessel Size Class: Supramax (55,000 DWT)							
200 m	Legs 1 to 3	47.0	25.7	8.0	5.0	1.7	1.1
100 m	Legs 4 to 6	118.4	64.8	20.1	12.6	4.3	2.7
50 m	Legs 7 to 9	298.2	163.2	50.8	31.6	10.7	6.8
Vessel Size Class: Panamax (75,000 DWT)							
200 m	Legs 1 to 3	102.5	56.1	17.4	10.9	3.7	2.3
100 m	Legs 4 to 6	258.2	141.3	44.0	27.4	9.3	5.8
50 m	Legs 7 to 9	650.7	356.0	110.8	69.0	23.4	14.7
Vessel Size Class: Post Panamax (90,000 DWT)							
200 m	Legs 1 to 3	49.2	26.2	8.0	5.0	1.7	1.1
100 m	Legs 4 to 6	123.9	65.9	20.2	12.6	4.3	2.7
50 m	Legs 7 to 9	312.2	166.2	50.9	31.7	10.7	6.8
Vessel Size Class: Capesize (250,000 DWT)							
200 m	Legs 1 to 3	75.9	35.7	10.3	6.4	2.2	2.4
100 m	Legs 4 to 6	191.3	89.9	26.0	16.1	5.4	6.1
50 m	Legs 7 to 9	482.1	226.5	65.6	40.5	13.7	15.4

4.2 Propeller Generated Velocities and Scour Potential

Propeller generated velocities were estimated for the representative ore carriers and tugboat. Figure 4-1 and Figure 4-2 show contour maps of propeller generated velocities for the Panamax and Cape size carriers at the seabed relative to longitudinal and latitudinal distance behind the propeller for a water depth of 21 m (the minimum possible depth within the berthing area). Additional figures for the tug, Supramax, and Post-Panamax size vessels are shown in Appendix B for all results in this section. Maximum seabed velocity estimates were found to range from 0.40 m/s for the tug to 2.3 m/s for the Cape size vessel. Velocities are greatest for the Cape size vessel due to the small clearance between the propeller and the seabed whereas the tug has the most clearance, the smallest propeller, and thus lowest estimated bed velocity. The maximum velocities for each size vessel class are located in an area on the seabed approximately 50 to 100 m in length and 10 to 50 m wide. Velocities decrease with longitudinal and latitudinal distance from the propeller as the fluid jet dissipates.

Contour maps of maximum velocities at the seabed and sediment mobility are shown in Figure 4-3 to Figure 4-5 for a Panamax and Cape size vessels. The maps show the variation in velocity and scour potential with actual depth (bathymetry) around the berthing area using an assumed paths for access/egress to the proposed ore dock. Areas where entrainment of sand-size sediment is possible are shown in blue and areas where suspension of sand-sized sediment is possible are shown in yellow. The highest potential for scour is where velocities are highest and water depths are the shallowest, particularly shoreward of the berthing area. In these areas, the threshold of motion is exceeded by approximately a factor of 2 to 3 for all the vessel types. The area of potential sediment motion encompasses most of the berthing area along the vessel track and is largest for the Cape size vessel. The area of potential suspension is less than one fourth the area of potential sediment motion for the Cape size vessel. For the Panamax vessel the predicted area of suspension is minimal (~315 m^2).

The areas for sediment motion and suspension were calculated assuming the sediment D_{50} value, fine fractions (in this case 20% of the grain size distribution) may be mobilized and suspended over a larger area. The sand fraction, based on the predicted settling velocity, can be expected to settle out within approximately 5 to 15 minutes for the depths in the berthing area; whereas the fine fraction would settle out on the order of 1 to 3 hours (assuming no background currents or waves).

Contour maps of predicted scour depth are shown in Figure 4-6 and Figure 4-7 for a Panamax and Cape size vessels. Scour is predicted to occur over most of the berthing area for both classes of vessels. A small localized area of scour is predicted to exceed 0.5 m in depth for the Cape size ore carrier and 0.2 m depth for the Panamax ore carrier. Scour from the tug is expected to be minimal and only occur when on the egress portion of the vessel track when the propeller is facing the shoreline.

Table 4-3 provides a summary of maximum velocities for each type of vessel at a water depth of 21 m in the berth and across the entire mapped area. The table also provides the approximate area of seabed where there is potential for entrainment and suspension to occur. Maximum seabed velocities based on the vessel tracks at the proposed dock range from 0.6 to 1.5 m/s. The maximum velocities based on the vessel tracks vary from the calculation at 21 m water depth because of the variation in water depth along the vessel track. The area where sediment is potentially entrained along the vessel track ranges from 8,100 m^2 for a single tug to 39,900 m^2 for the Cape size bulk carrier. The area of suspension is smaller, ranging from a few hundred square metres to 7,000 m^2 for the Cape size bulk carrier.

In comparison, at the existing dock a Panamax bulk carrier (Figure 4-9 to Figure 4-11) is estimated to have a maximum seabed velocity of 1.1 m/s and entrain sediment in an area of approximately 20,600 m^2. Potential for scour (up to 0.5 m) is predicted along the entire length of the berthing area. The estimates do not account for potential increases in scour due to confinement from the sheet pile wall.

Table 4-3: Vessel propeller wash summary by dock and vessel class

	Proposed Dock					Existing Dock
	Standard Tug (Ice-class)	Supramax (55,000 DWT)	Panamax (75,000 DWT)	Post-Panamax (90,000 DWT)	Cape size (250,000 DWT)	Panamax (75,000 DWT)
Maximum velocity - seabed elevation (assuming 21 m)	0.38 m/s	0.66 m/s	0.73 m/s	0.74 m/s	2.26 m/s	1.07 m/s (at 17.5 m water depth)
Maximum velocity – seabed elevation (based on vessel track)	0.57 m/s	0.68 m/s	0.73 m/s	0.75 m/s	1.51 m/s	0.97 m/s
Area of sediment motion potential (m^2)	8,100 m^2	18,500 m^2	20,800 m^2	22,600 m^2	39,900 m^2	20,600 m^2
Area of sediment suspension potential (m^2)	N/A	115 m^2	275 m^2	315 m^2	7,000 m^2	1,700 m^2

Notes: m – metre; m/s – metres per second; m^2 – metres squared; N/A – not applicable

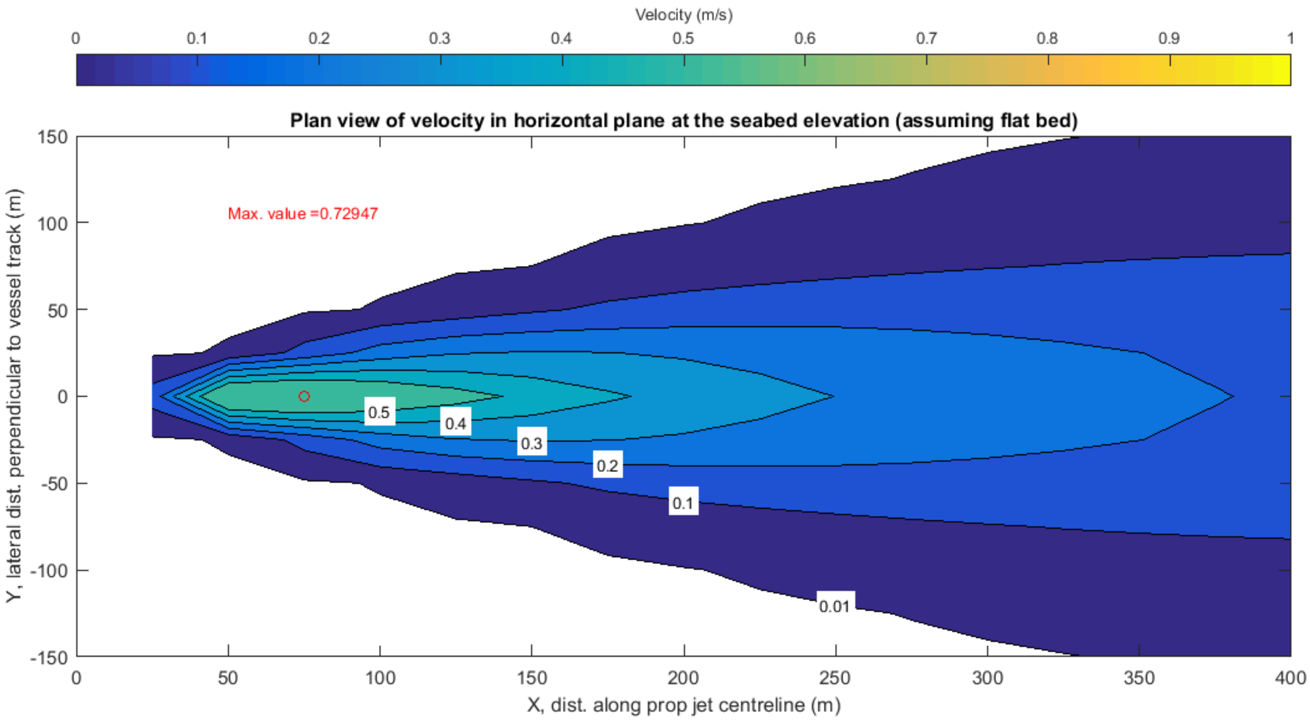

Figure 4-1: Plan view of vessel propeller generated velocities behind the main propeller for a Panamax ore carrier at the seabed elevation. Labels have units of m/s

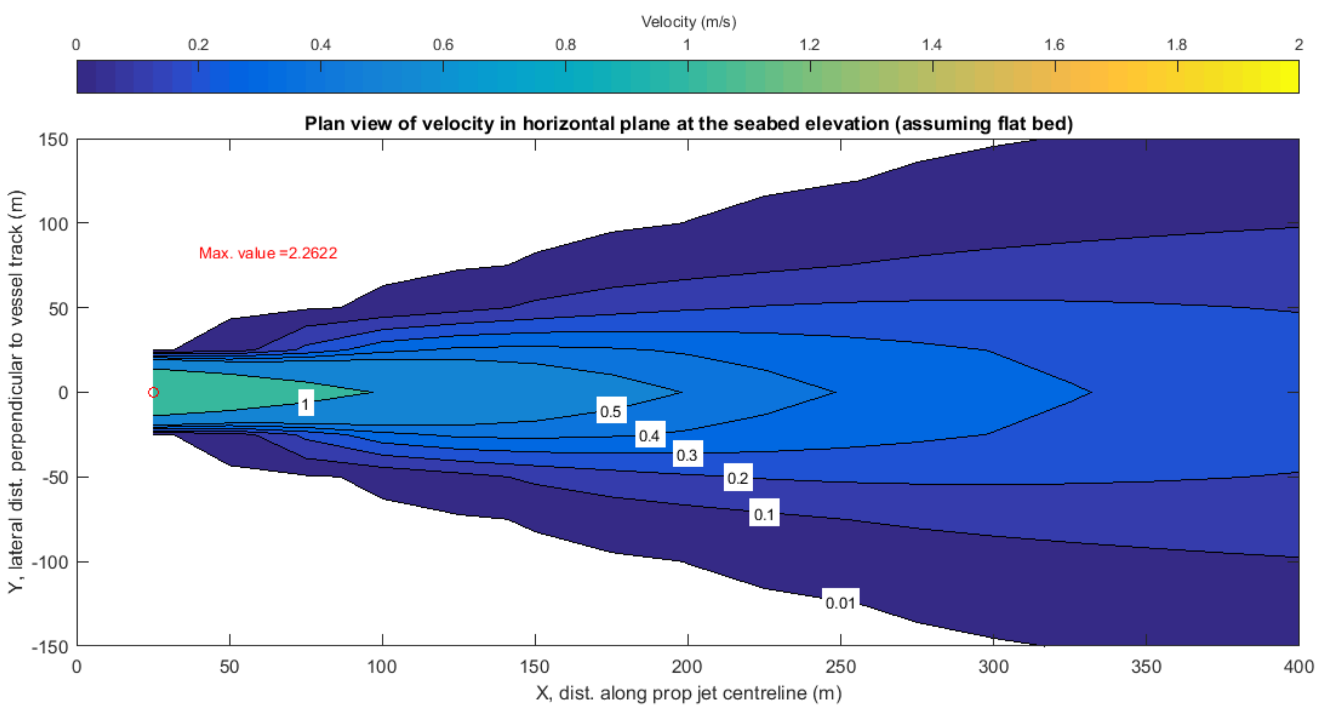

Figure 4-2: Plan view of vessel propeller generated velocities behind the main propeller for a Cape size ore carrier at the seabed elevation. Labels have units of m/s

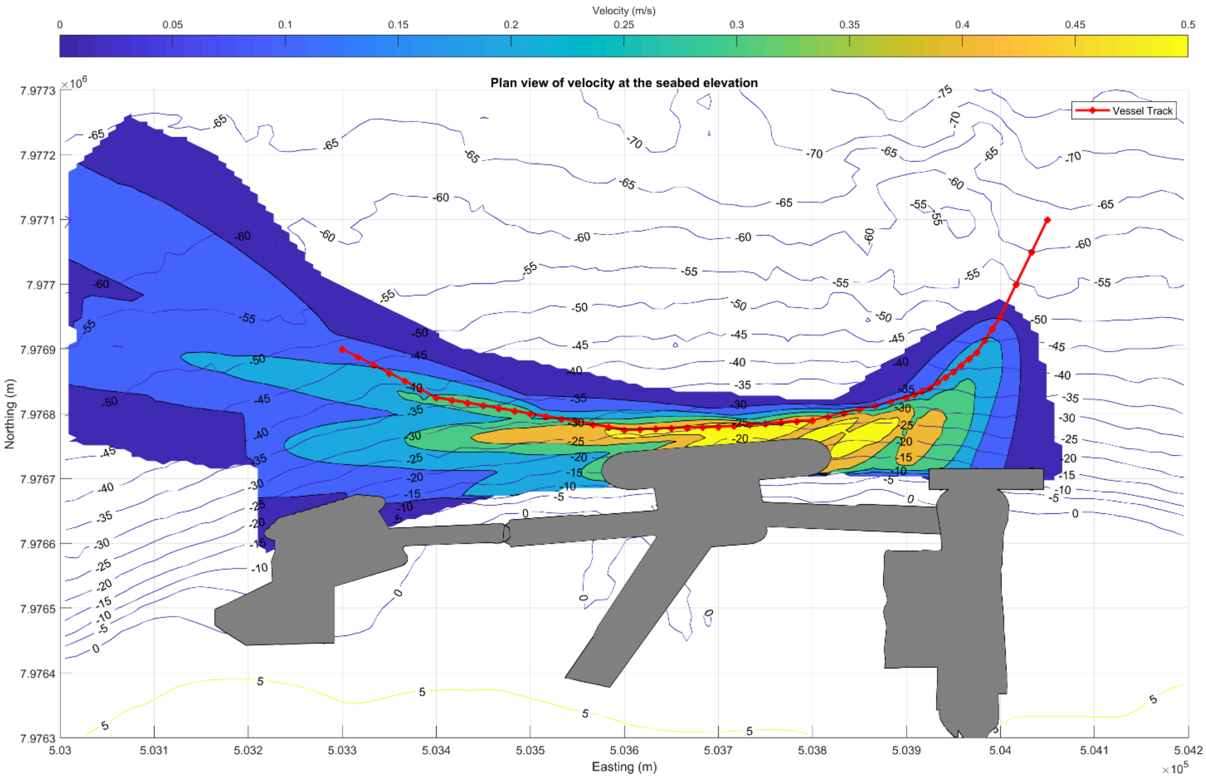

Figure 4-3: Map of maximum seabed velocities behind the main propeller for a Panamax ore carrier along a possible ship track at the berthing area for the proposed ore dock.

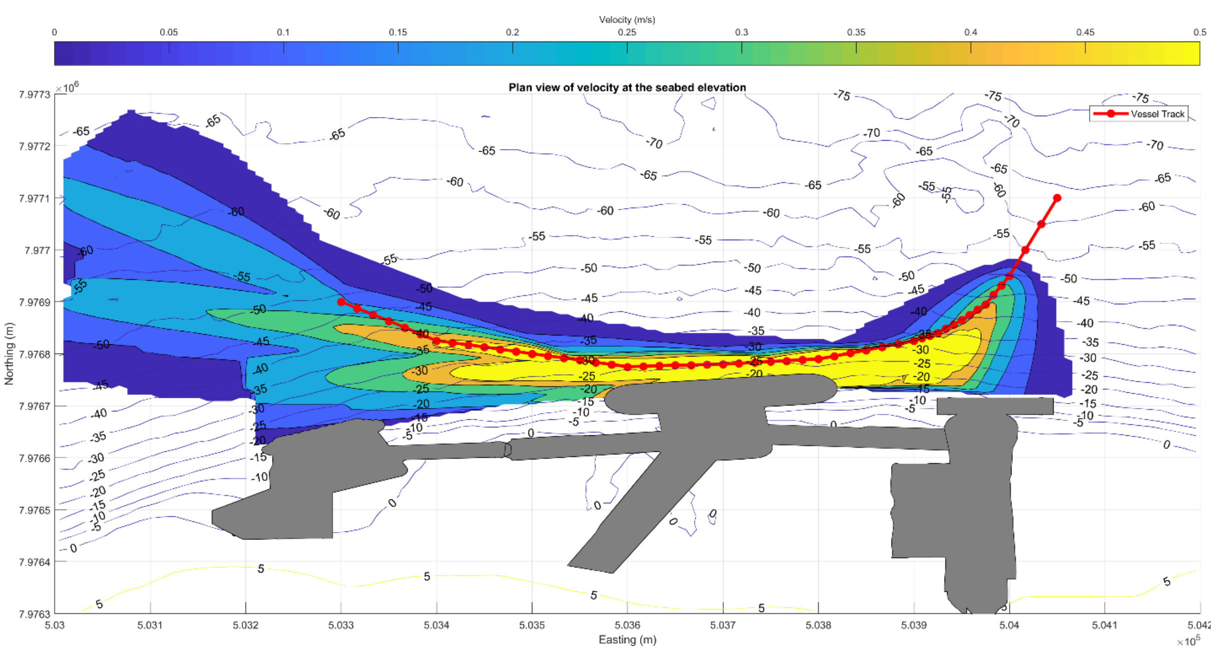

Figure 4-4: Map of maximum seabed velocities behind the main propeller for a Cape size ore carrier along a possible ship track at the berthing area for the proposed ore dock.

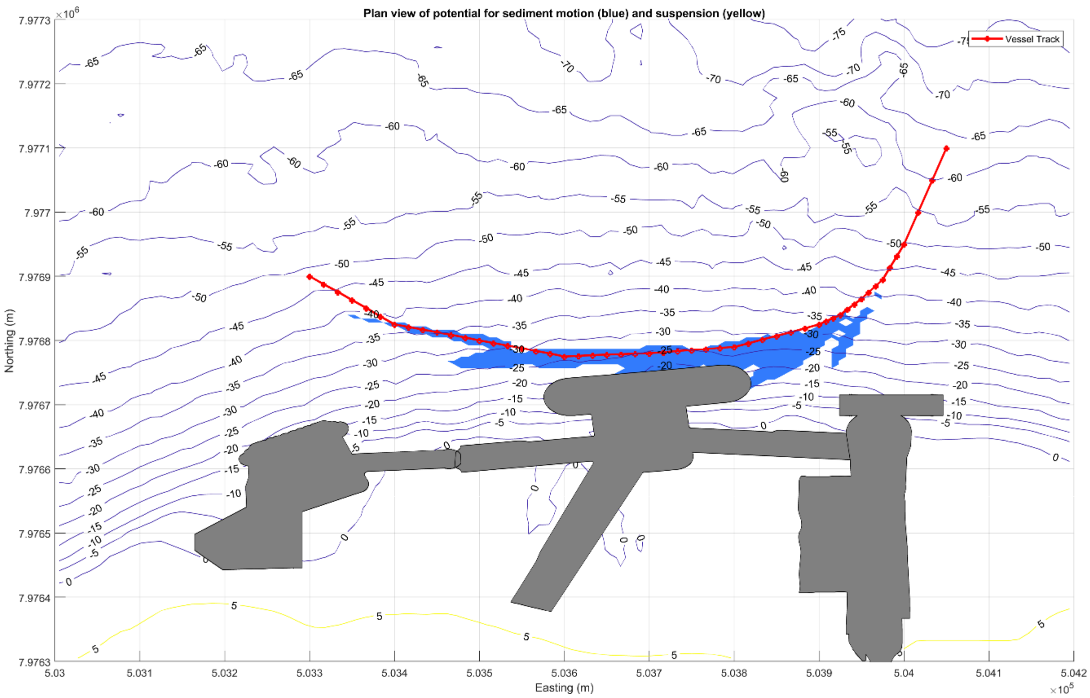

Figure 4-5: Map of sediment motion potential behind the main propeller for a Panamax ore carrier along a possible ship track at the berthing area for the proposed ore dock.

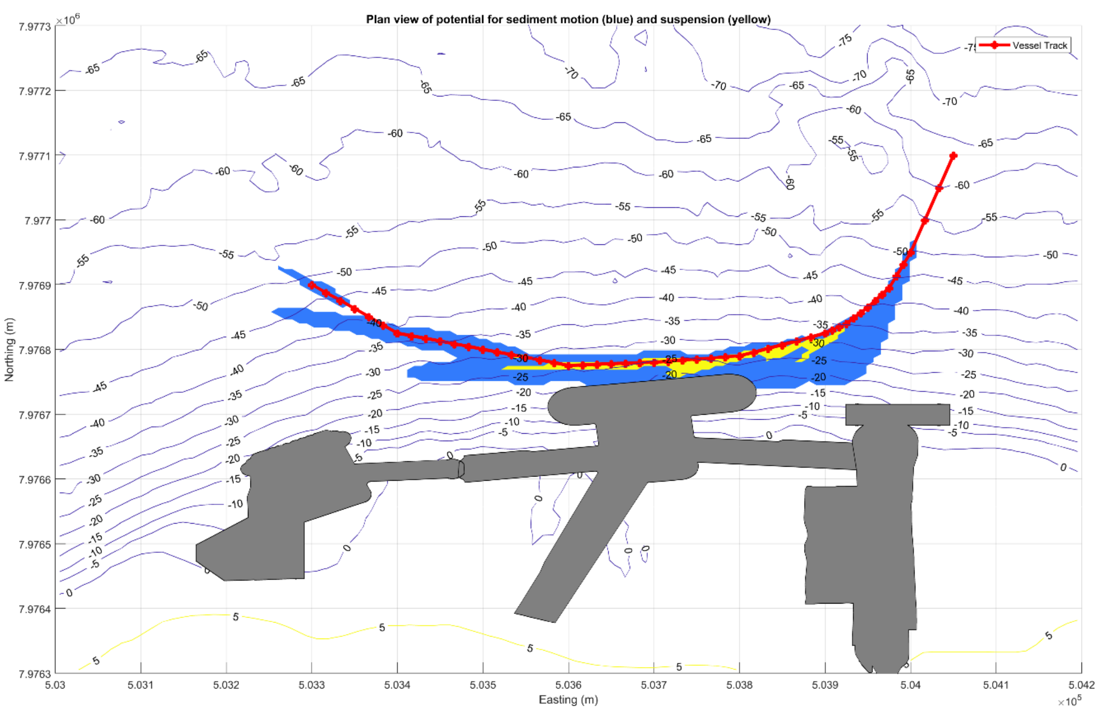

Figure 4-6: Map of sediment motion potential behind the main propeller for a Cape size ore carrier along a possible ship track at the berthing area for the proposed ore dock.

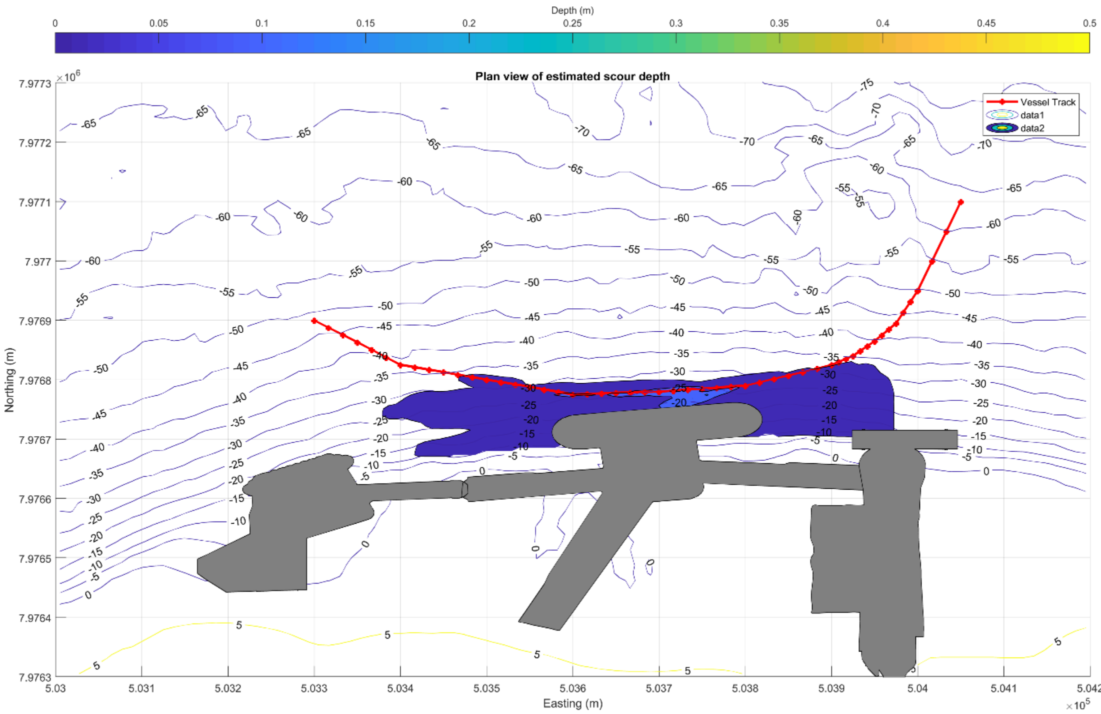

Figure 4-7: Map of estimated vessel propeller scour depth based on bed velocities for a Panamax ore carrier at the proposed ore dock.

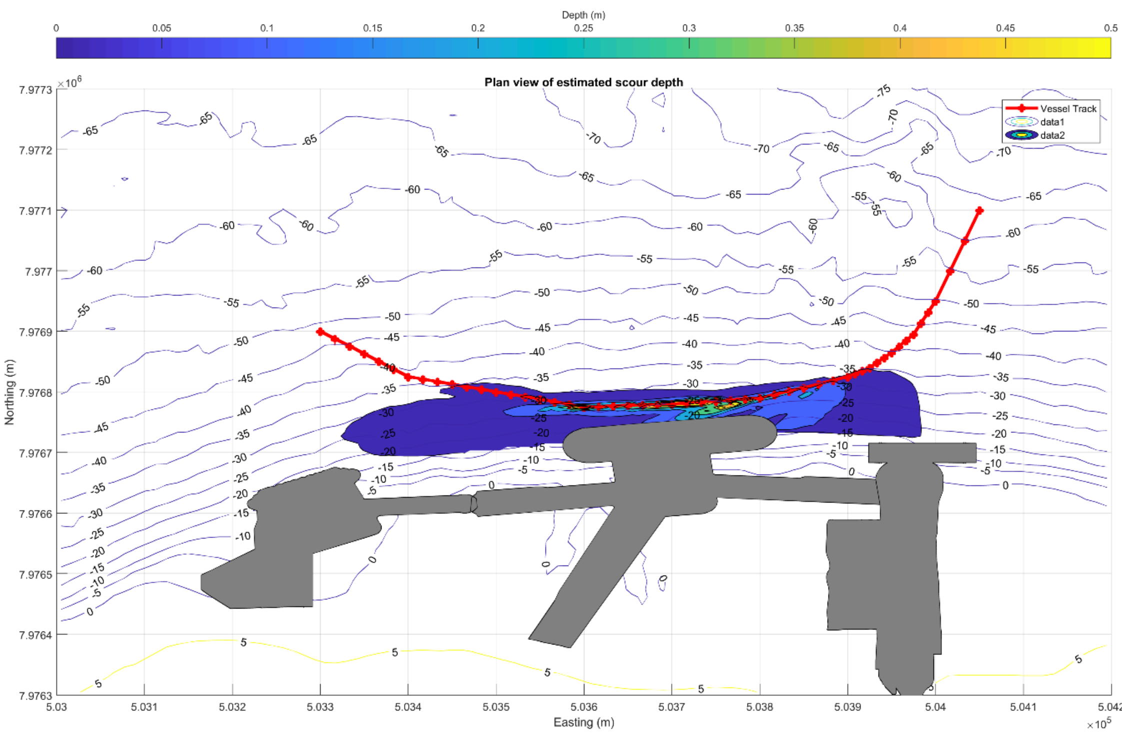

Figure 4-8: Map of estimated vessel propeller scour depth based on bed velocities for a Cape size ore carrier at the proposed ore dock.

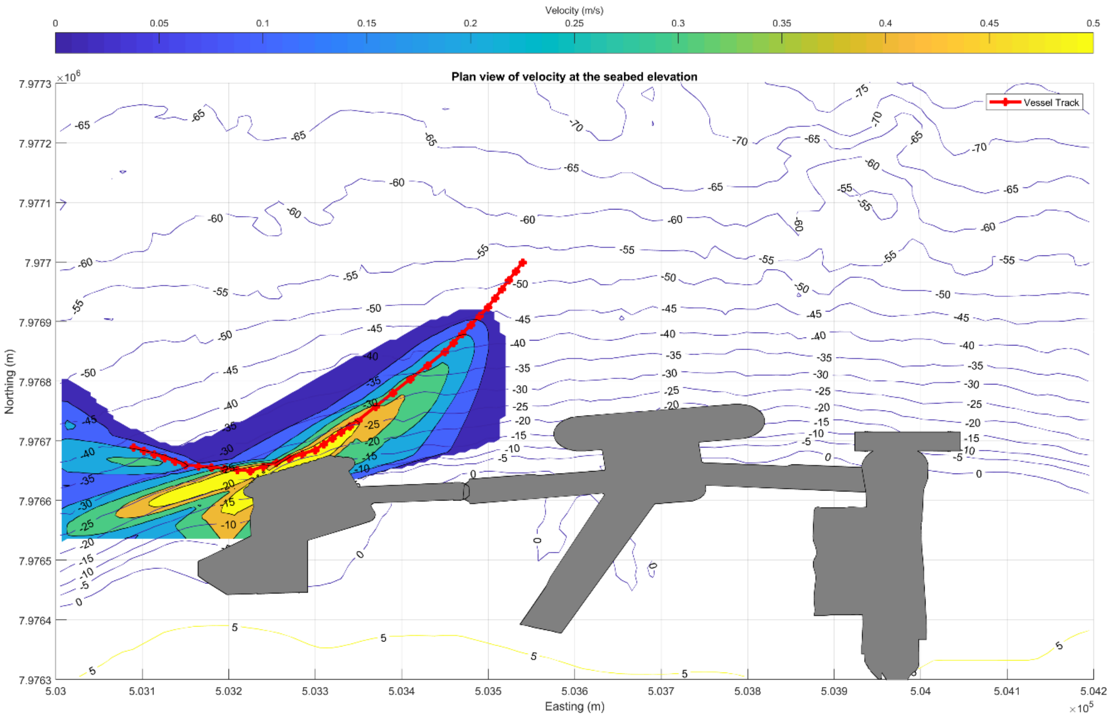

Figure 4-9: Map of maximum seabed velocities behind the main propeller for a Panamax ore carrier along a possible ship track at the berthing area for the existing ore dock.

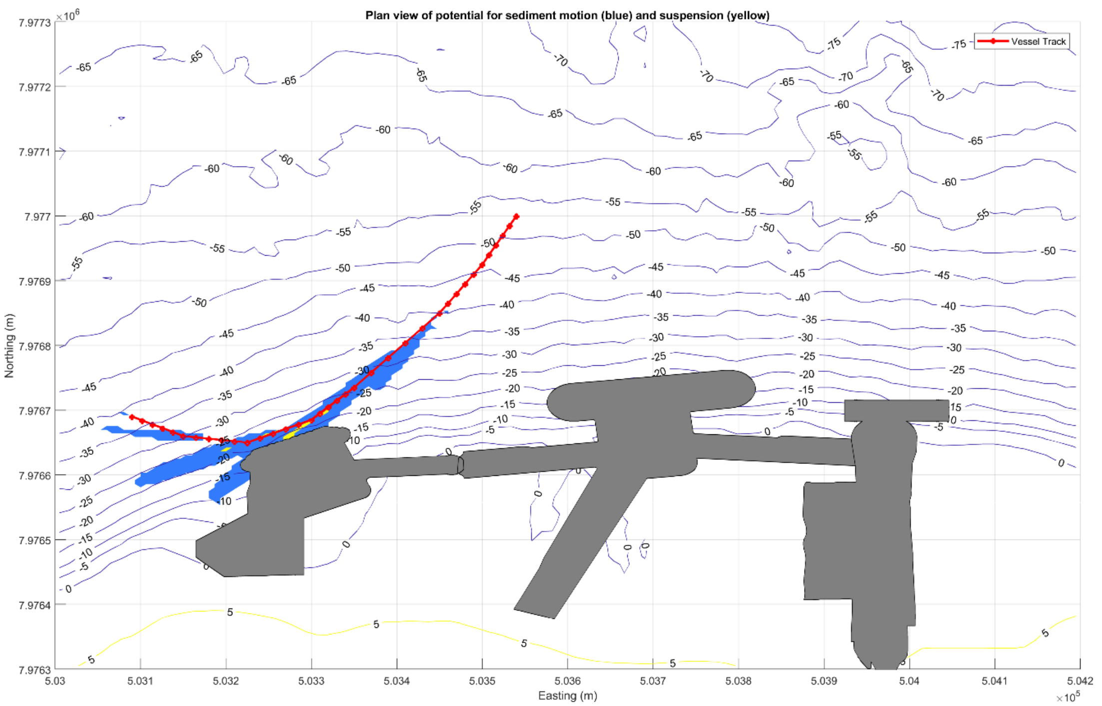

Figure 4-10: Map of sediment motion potential behind the main propeller for a Panamax ore carrier along a possible ship track at the berthing area for the existing ore dock.

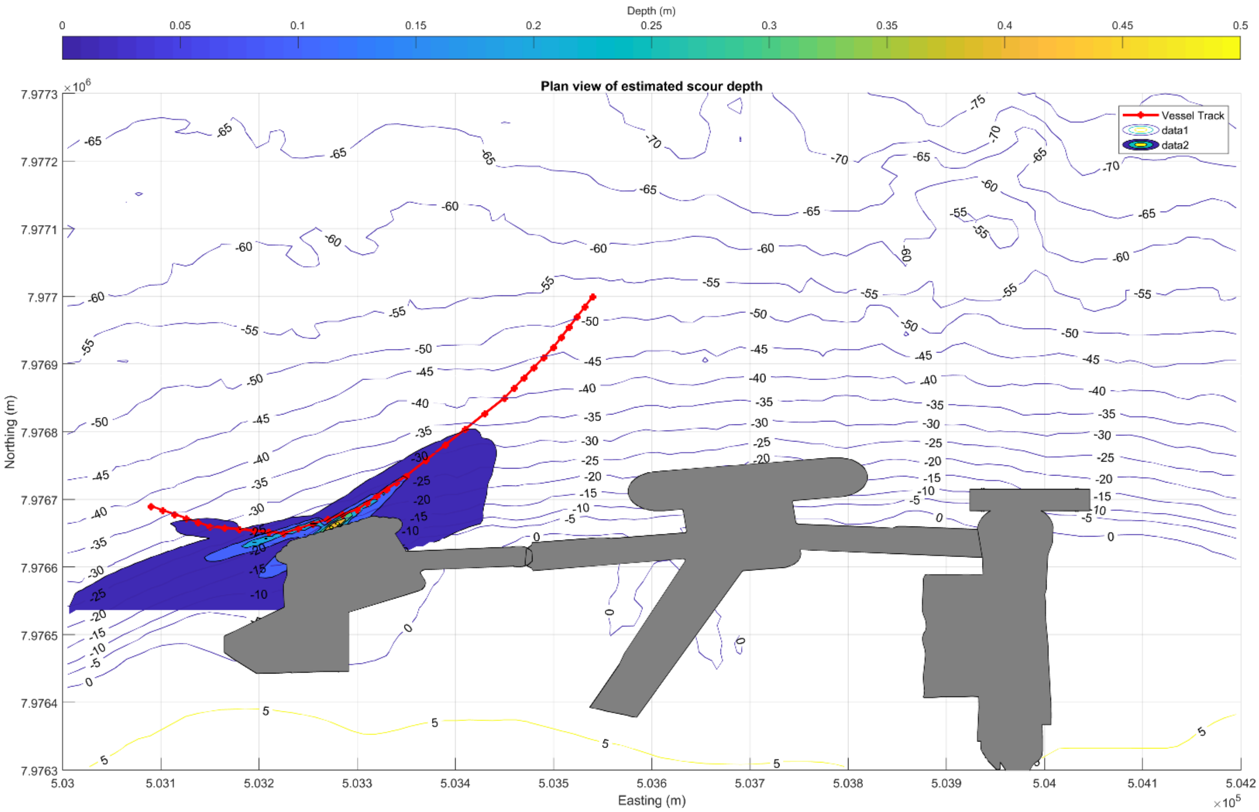

Figure 4-11: Map of estimated vessel propeller scour depth based on bed velocities for a Panamax ore carrier at the existing ore dock.

4.3 Effects on Local Sediment Transport, Scour, and Turbidity

4.3.1 Ship Generated Wave Effects

To assess potential shoreline effects in terms of erosion and sediment transport potential, ship wake energy estimates were compared to wind-generated waves along the shipping route. Wind-wave energy on the shorelines along the shipping route varies with exposure to wind events. Significant wave heights were (Table 4-4) calculated for a range of wind speeds between the average wind speed and maximum wind speed and a range of fetches (2 to 80 km). Estimated significant wave heights range from 0.1 to 5.1 m and peak wave periods range from 1.3 to 8.1 seconds. Significant wave heights from wind-waves are predicted to exceed wake heights at 50 m from the sailing line in all cases except for the average wind speed for the shortest (2 km fetch), and exceed wake heights at 100 m and further from the sailing line in all cases.

On the basis of wave height alone, wind-generated wave energy exceeds that of wake energy. Additionally, wind storm events typically occur over several hours in comparison to a ship wake which lasts a few minutes. Wave energy flux from wind-waves along the shipping route will far exceed that of ship wakes over an open water season by several orders of magnitude and will have a much greater potential for sediment transport along the shorelines than ship wakes. For example, for the shortest wind fetch (2 km), assuming an average wind speed during the open water season, the wave energy flux from ship wakes is less than 2% of the wind-wave total.

Table 4-4: Significant wave height and wave period as a function of fetch along the shipping route and wind speed

Fetch (km)	Wind Speed (m/s)	Significant Wave Height (m)	Peak Wave Period (seconds)
2	5	0.1	1.3
	10	0.3	1.7
	15	0.4	2.1
	20	0.6	2.3
	25	0.8	2.6
10	5	0.3	2.3
	10	0.6	3.0
	15	0.9	3.5
	20	1.3	4.0
	25	1.8	4.4
20	5	0.4	2.9
	10	0.9	3.9
	15	1.4	4.6
	20	2.1	5.2
	25	2.8	5.7
80	5	0.8	4.2
	10	1.7	6.1
	15	2.9	7.3
	20	3.9	7.3
	25	5.1	8.1

4.3.2 Propeller Wash Effects

The analysis of propeller generated velocities found near bed velocities in the berthing area are predicted to range from 0.4 m/s for a tug to 2.3 m/s for a Cape size vessel. Bed velocities are largely dependent on the clearance above the bed. Estimates of potential scour (Table 4-3) in the berthing area indicate that Cape size vessels have the potential to entrain and suspend sediment over the largest area. Based on estimates of settling velocity for the fine and sand fractions of the sediment in the Port area, disturbed sediment will remain in suspension for less than one berthing and loading event and therefore a cumulative effect from successive ships would only occur when a vessel exits the dock and is immediately followed by one entering the berthing area. Estimates show that the area of sediment scour for a Cape size vessel at the proposed dock versus a Panamax vessel at the existing dock is approximately 1.9 times greater. Whereas the increase for a Panamax vessel (the most frequent vessel size) at the proposed dock versus the existing dock is approximately equal.

5.0 EFFECTS ASSESSMENT SUMMARY

Following is a summary of Project shipping on nearshore waves, currents and bottom substrate (seabed), based on shipping operations proposed under for the Phase 2 Proposal:

- Ship generated waves (wake) are expected to be minimal along the Northern Shipping Route with maximum wave heights of 0.12 m near the sailing line and less than 0.05 m at distances greater than 1 km from the sailing line. The wake height is primarily constrained by the vessel speed limit of 9 knots along the shipping route;
- Based on a 1-D wind-wave hindcast, significant wave heights from wind-generated waves are estimated to exceed ship generated wave heights during both average and peak wind conditions. The resulting wave energy flux due to wind-waves is expected to exceed wake energy flux by several orders of magnitude over a single open water shipping season and have much greater potential to disturb sediments along the shoreline than those from ship wakes. Ship wakes, predicted to be less than 0.05 cm when reaching the shoreline, are expected to have negligible effect on the rocky and coarse-grained shorelines along the shipping route; and
- Propeller generated velocities in the berthing area of the ore docks at Milne Port are expected to range from 0.4 m/s for a tug to 2.3 m/s for a Cape size vessel near the seabed for the shallowest potential water depth (21 m) and lowest clearance from seabed to propeller. The estimated velocities near the bed have the potential to cause scour and turbidity in the berthing area for all the vessels; however disturbed sediment is not expected to remain in suspension beyond the timeframe of one berthing and loading event. The Cape size vessel has the potential to entrain and suspend sediment over a much larger area than the Panamax (and smaller) size vessels (1.9 times), however, the most frequent size vessel (Panamax) calling to the proposed ore dock is predicted to scour sediment over an area roughly equal to that of a similar size vessel at the existing dock. Additionally, tugs will be primarily responsible berthing activities and the ship propeller will only be used intermittently, so the estimates of vessel generated velocities and scour potential from bulk carriers are likely conservative.

6.0 CLOSURE

We trust that the information contained in this report meets your present requirements. Please contact us if you have any questions or concerns regarding the above.

Golder Associates Ltd.

NON-SIGNING CONTRIBUTING AUTHOR

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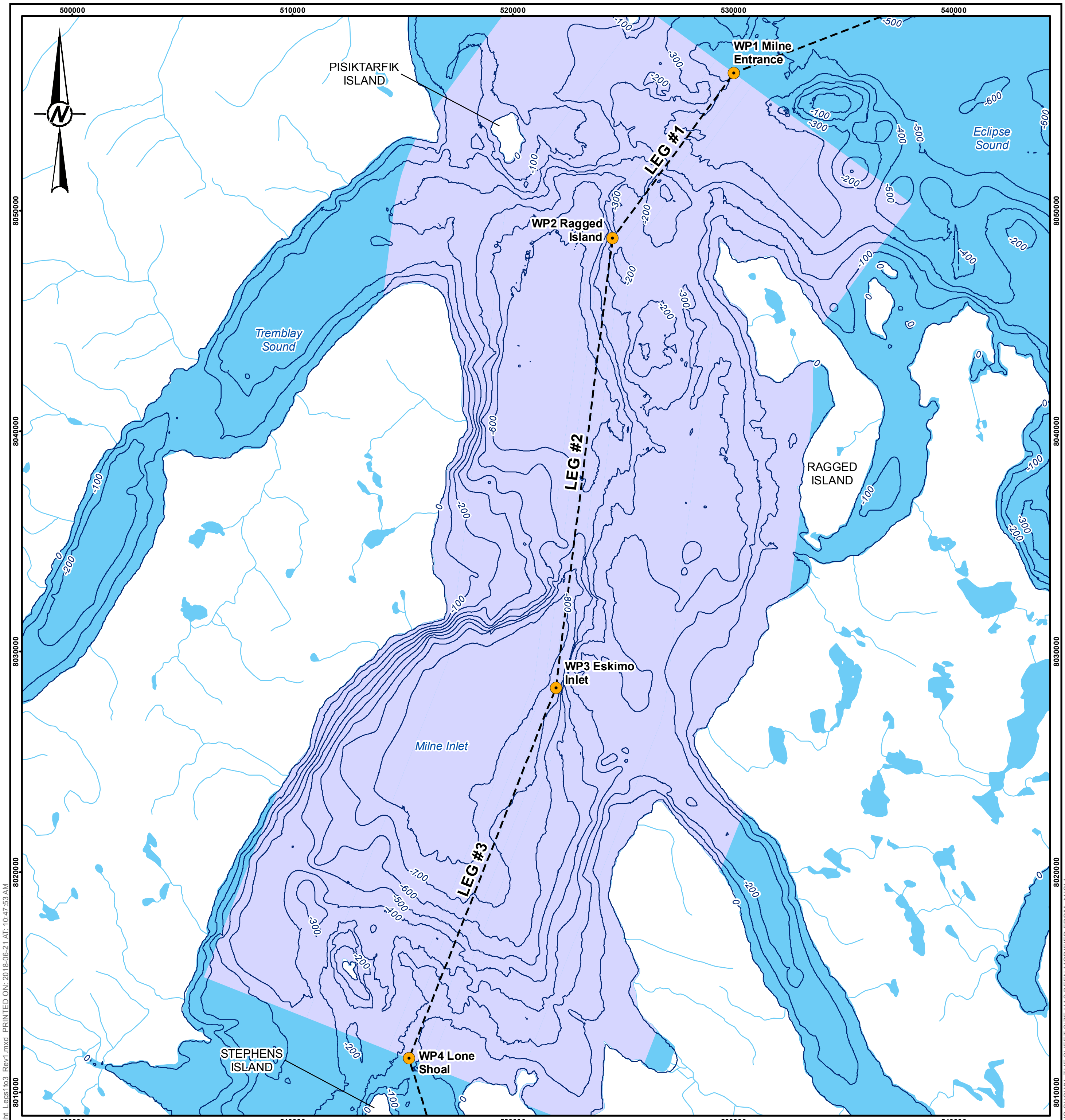
APPENDIX A

Expanded Results



LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (100 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 5 10

1:250,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
SUPRAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 1-3)

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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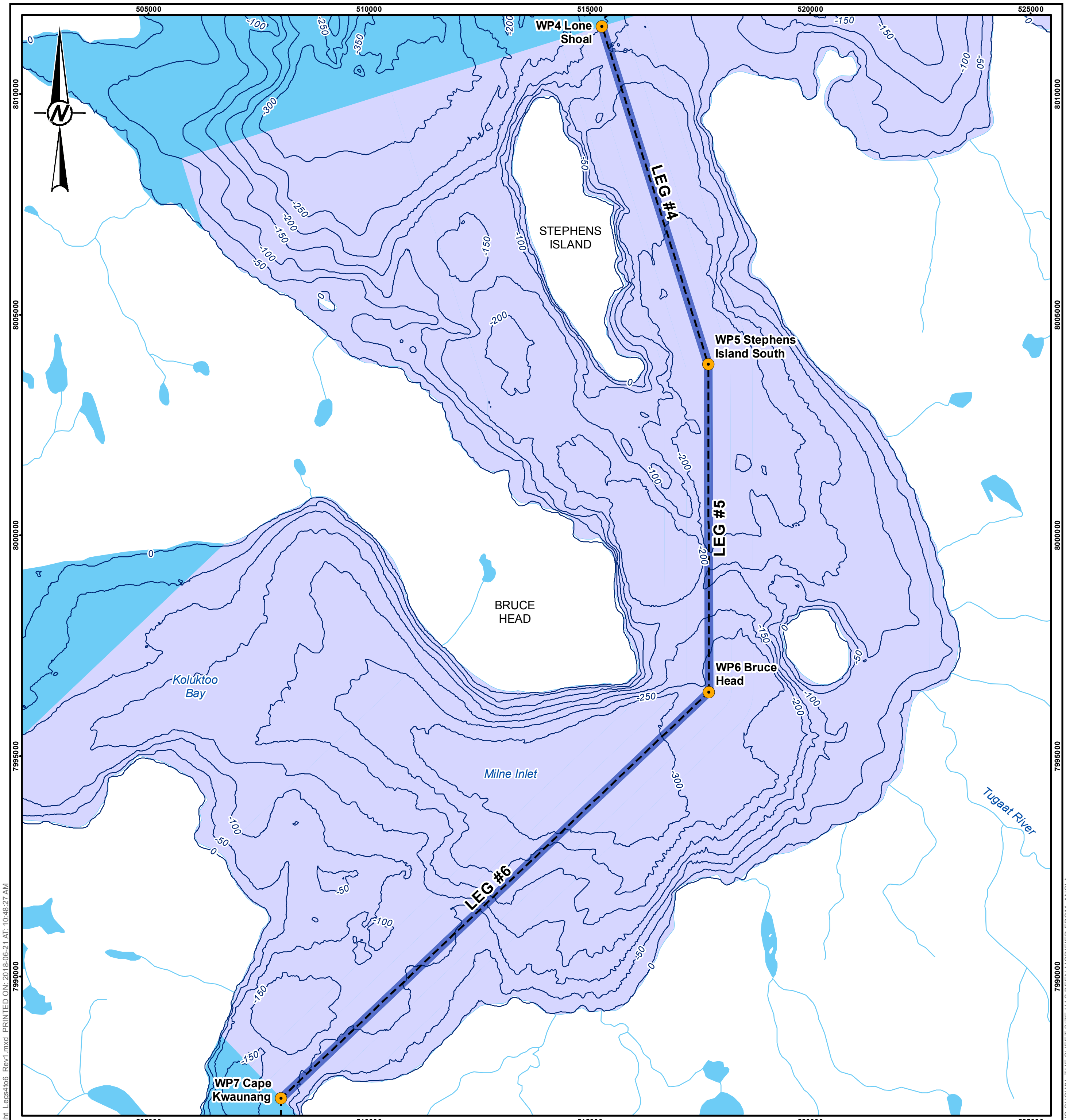

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25mm

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
SUPRAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 4-6)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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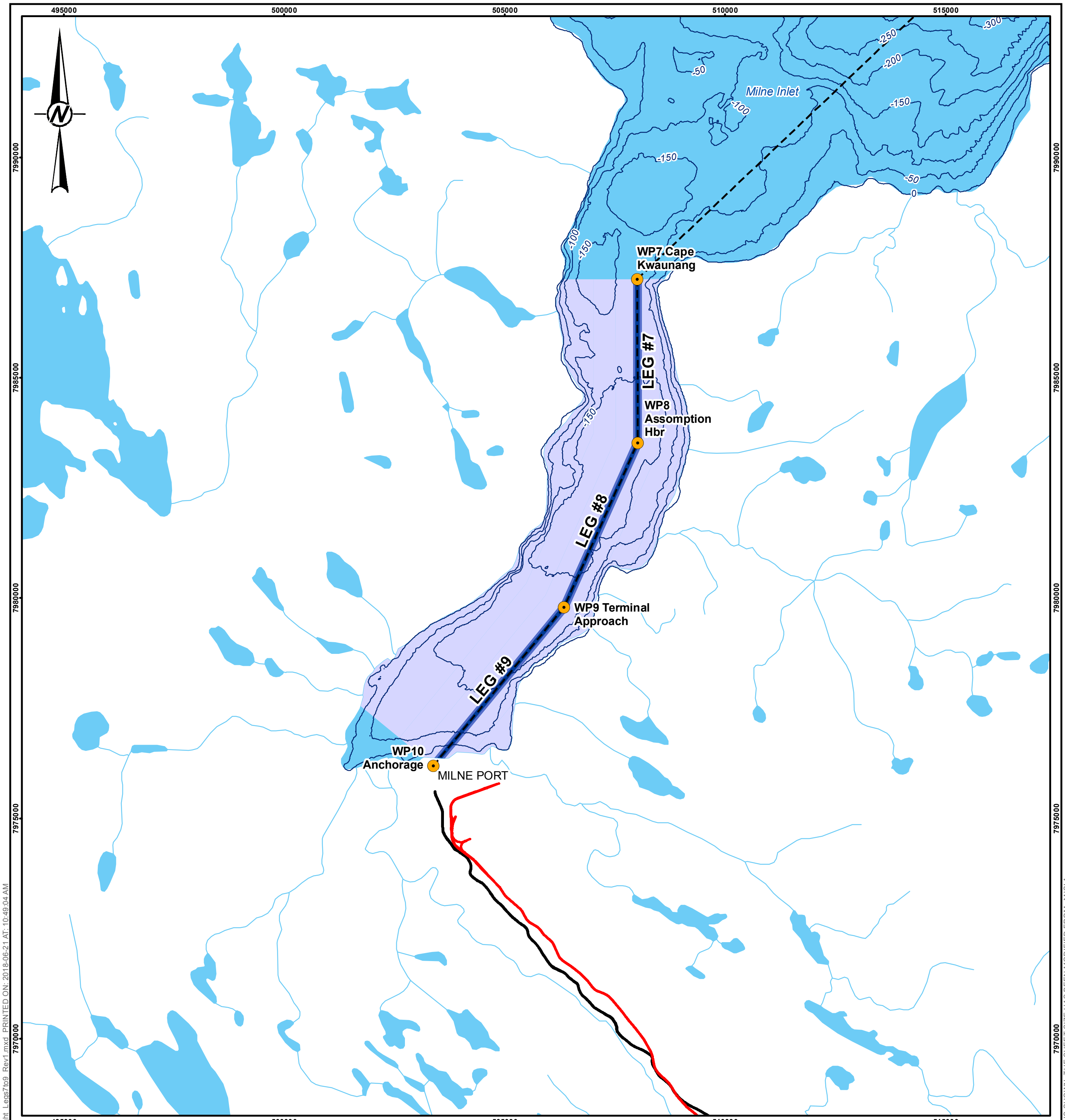

LEGEND

SHIPPING ROUTE WAYPOINT	
SHIPPING ROUTE (APPROXIMATE)	
BATHYMETRIC CONTOUR (50 m INTERVAL)	
MILNE INLET TOTE ROAD	
PROPOSED NORTH RAILWAY	
WATERCOURSE	
WATERBODY	

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017.
3. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
SUPRAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 7-9)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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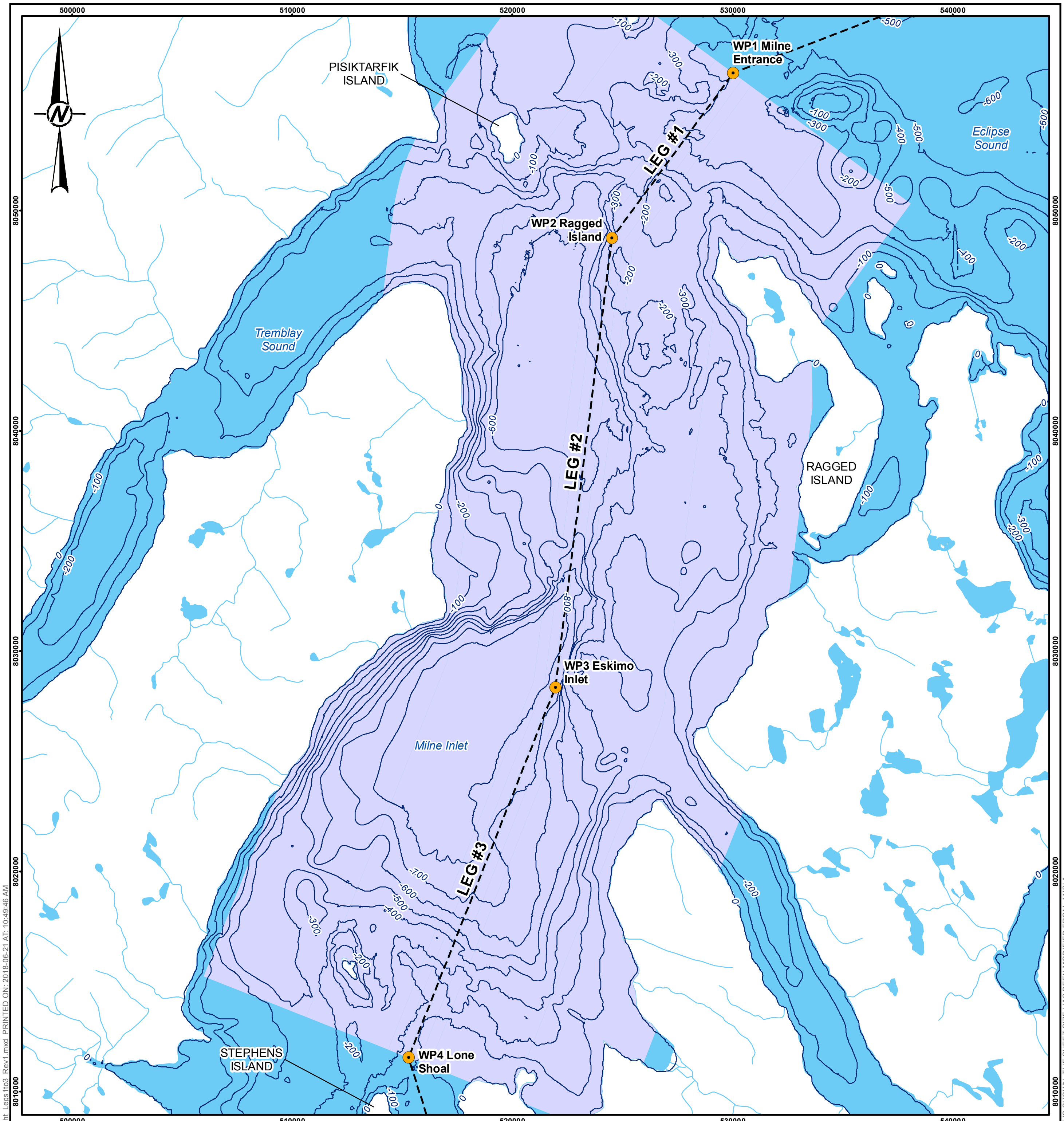

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (100 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 5 10

1:250,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
PANAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 1-3)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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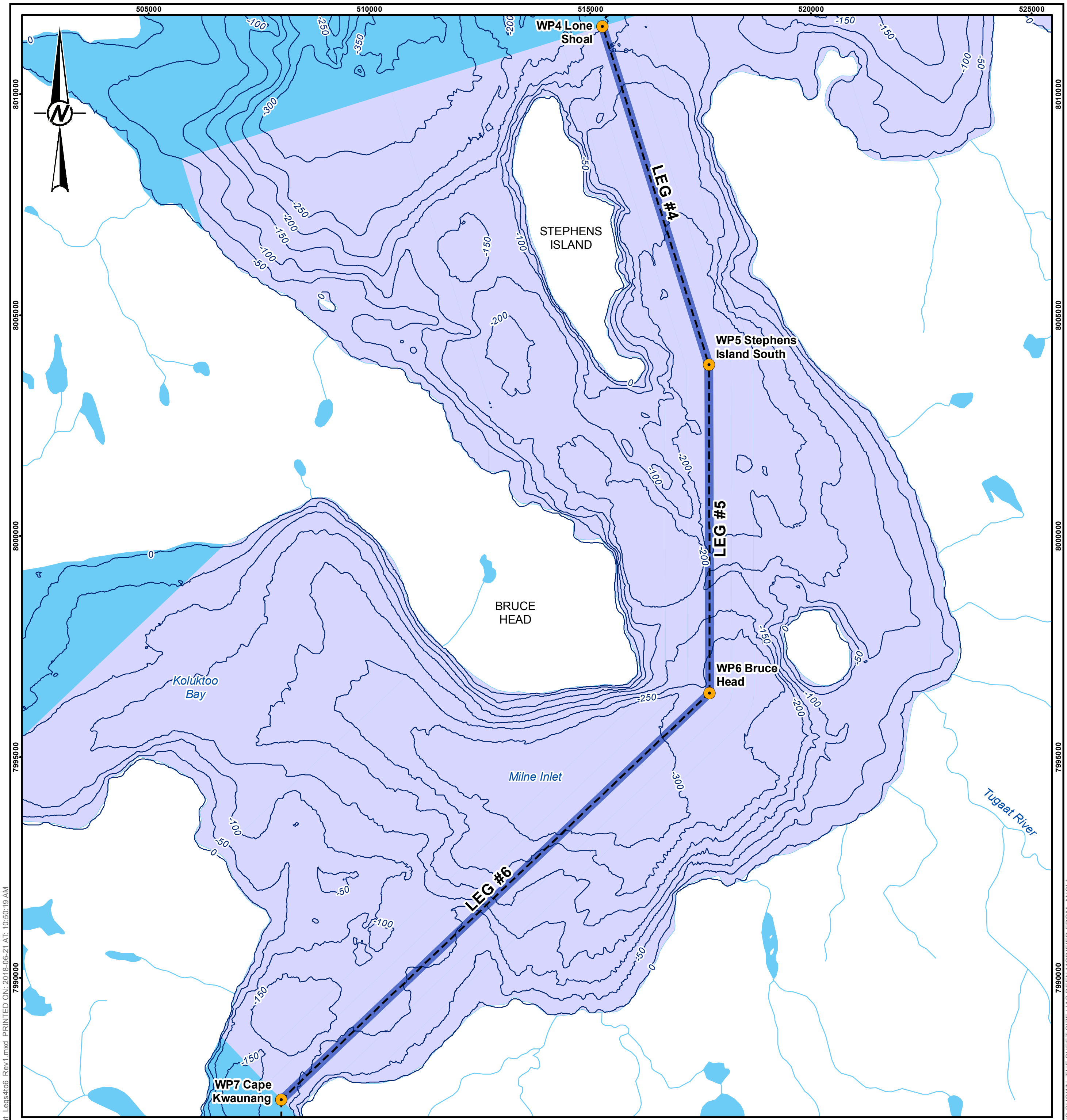

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
PANAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 4-6)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
1663724	18000	1	A-5

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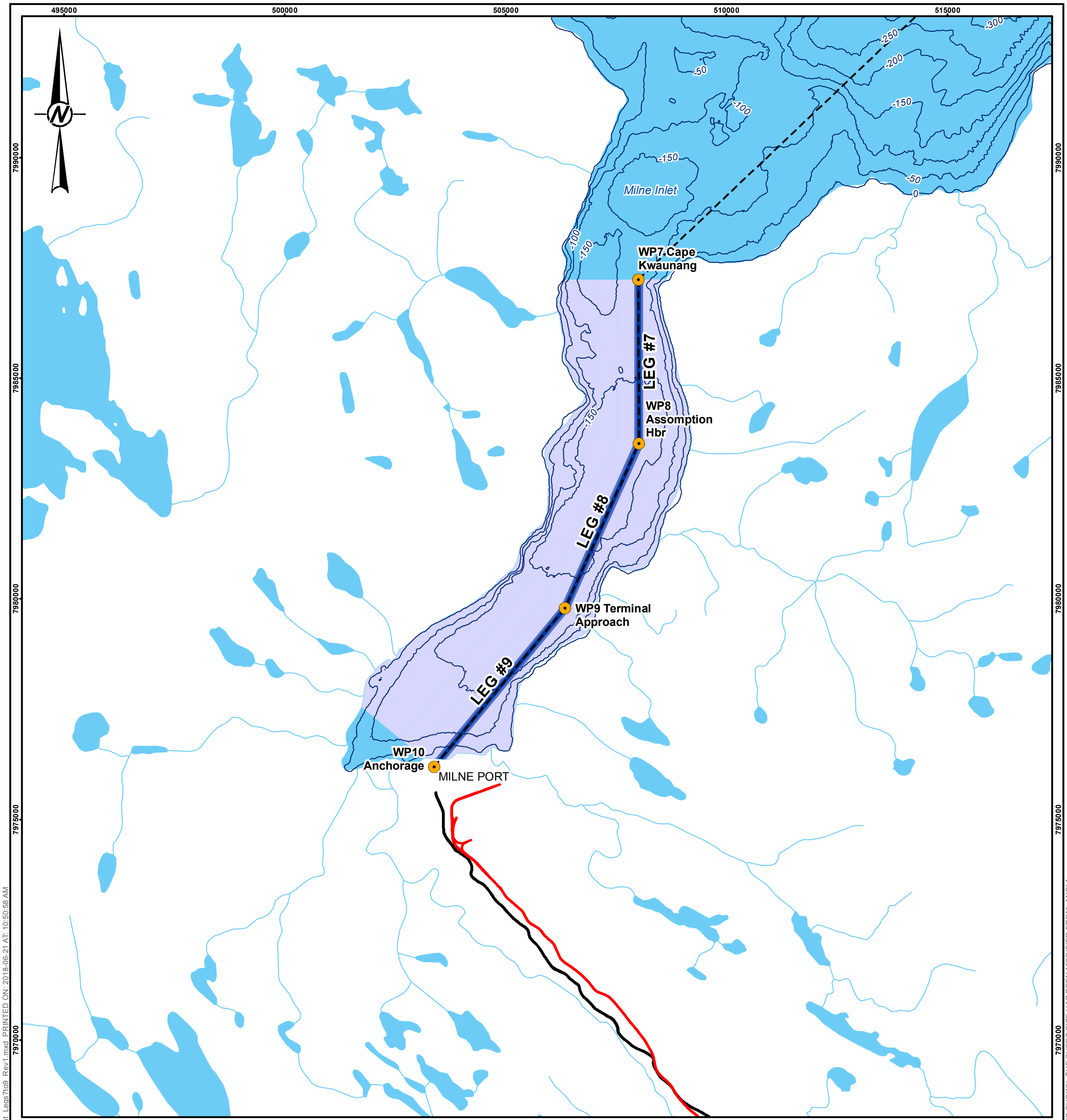

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017.
3. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
PANAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 7-9)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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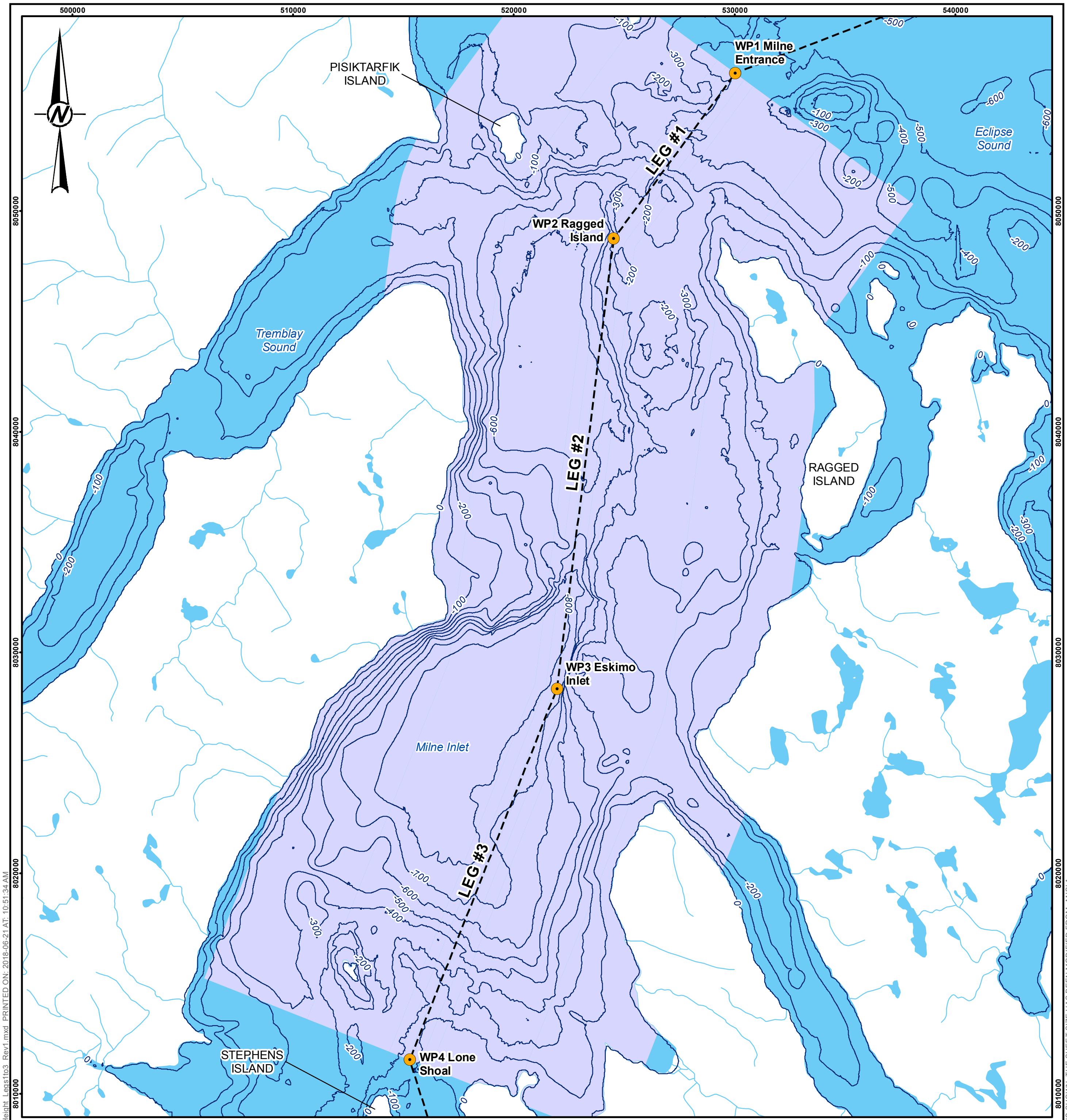

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (100 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 5 10

1:250,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
POST PANAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 1-3)

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
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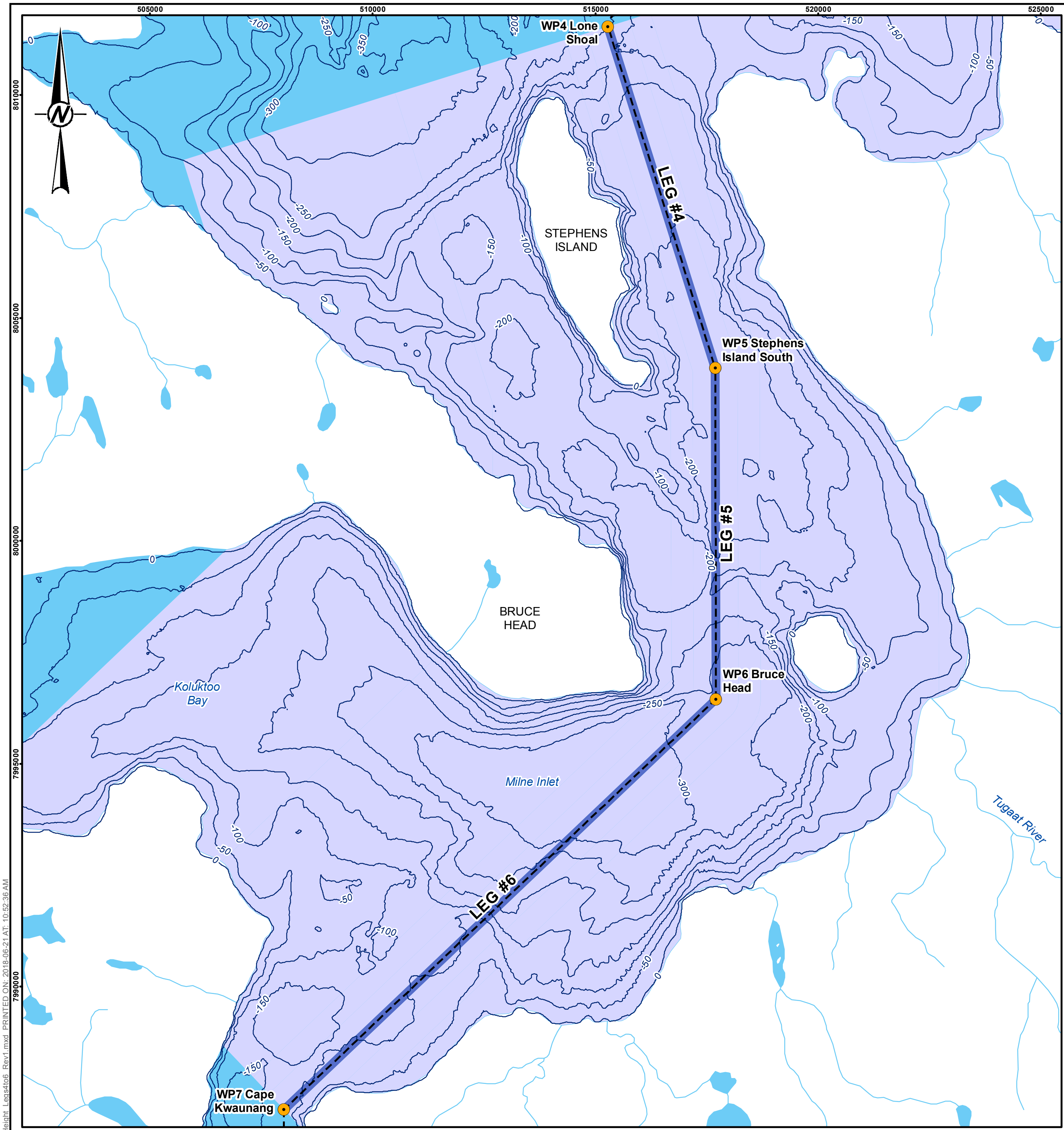

LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
POST PANAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 4-6)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
1663724	18000	1	A-8

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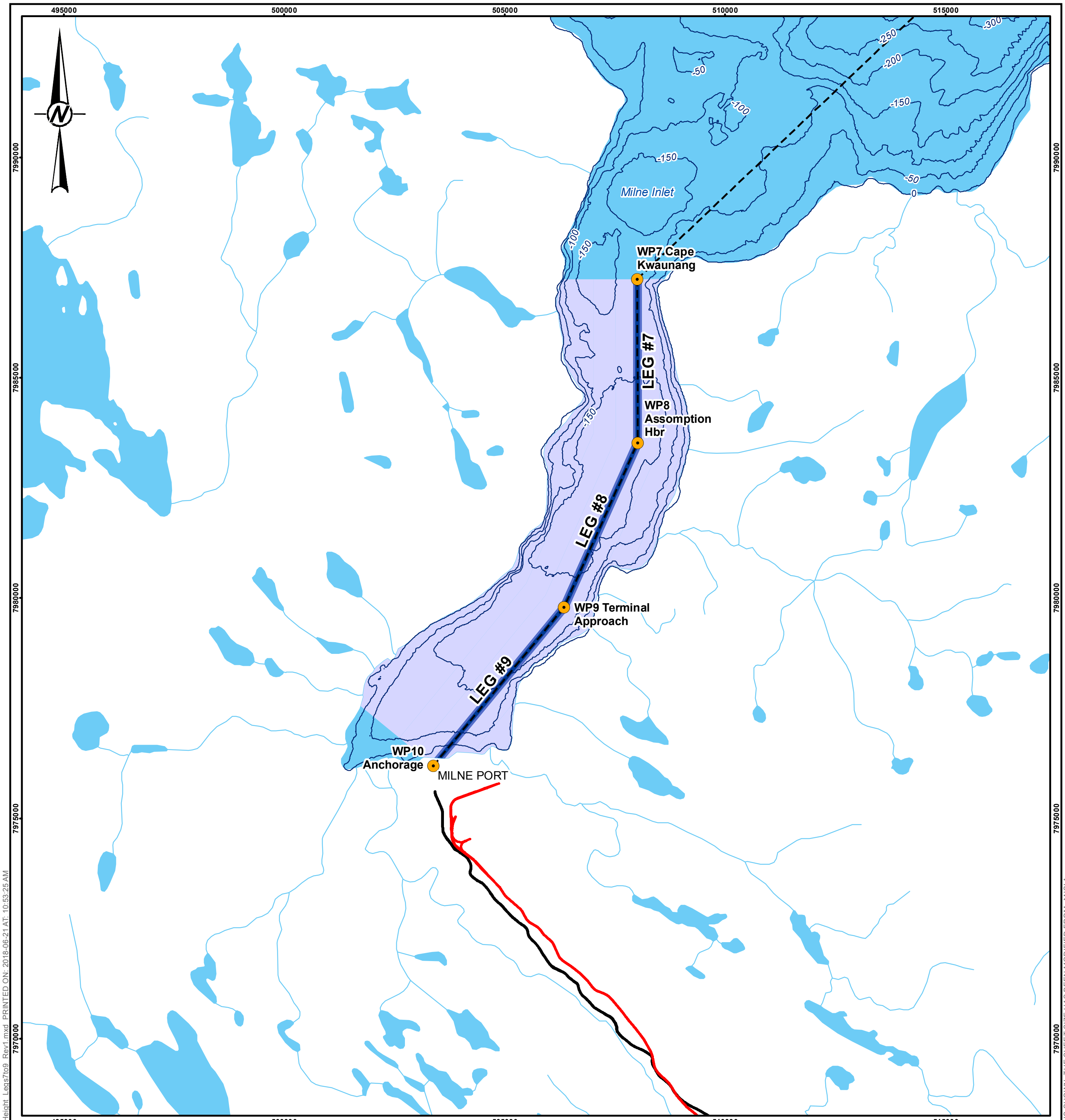


LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017.
3. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

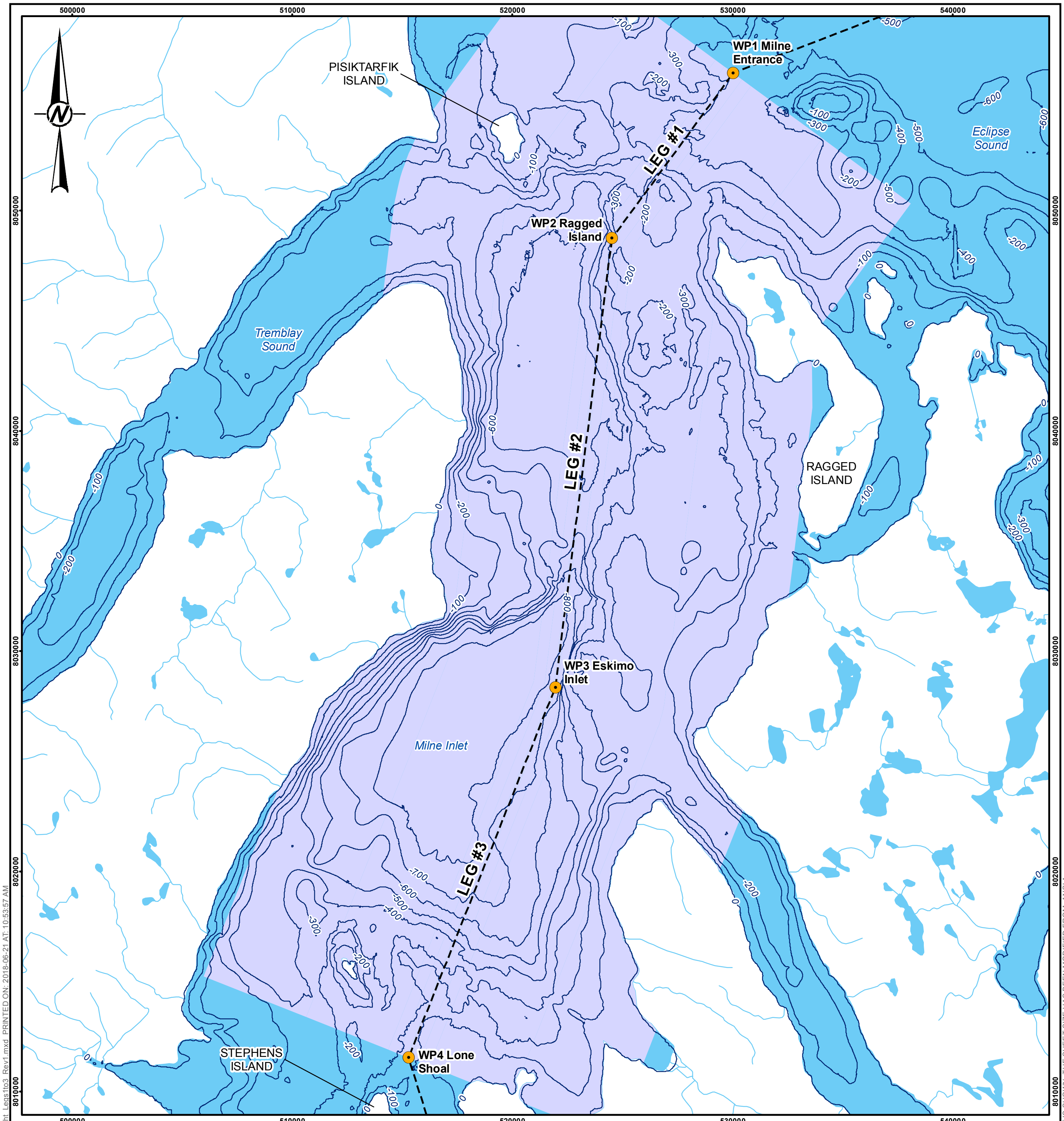
PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
POST PANAMAX VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 7-9)

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
1663724	18000	1	A-9



LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (100 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 5 10

1:250,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE

CAPESIZE VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 1-3)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
1663724	18000	1	A-10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm

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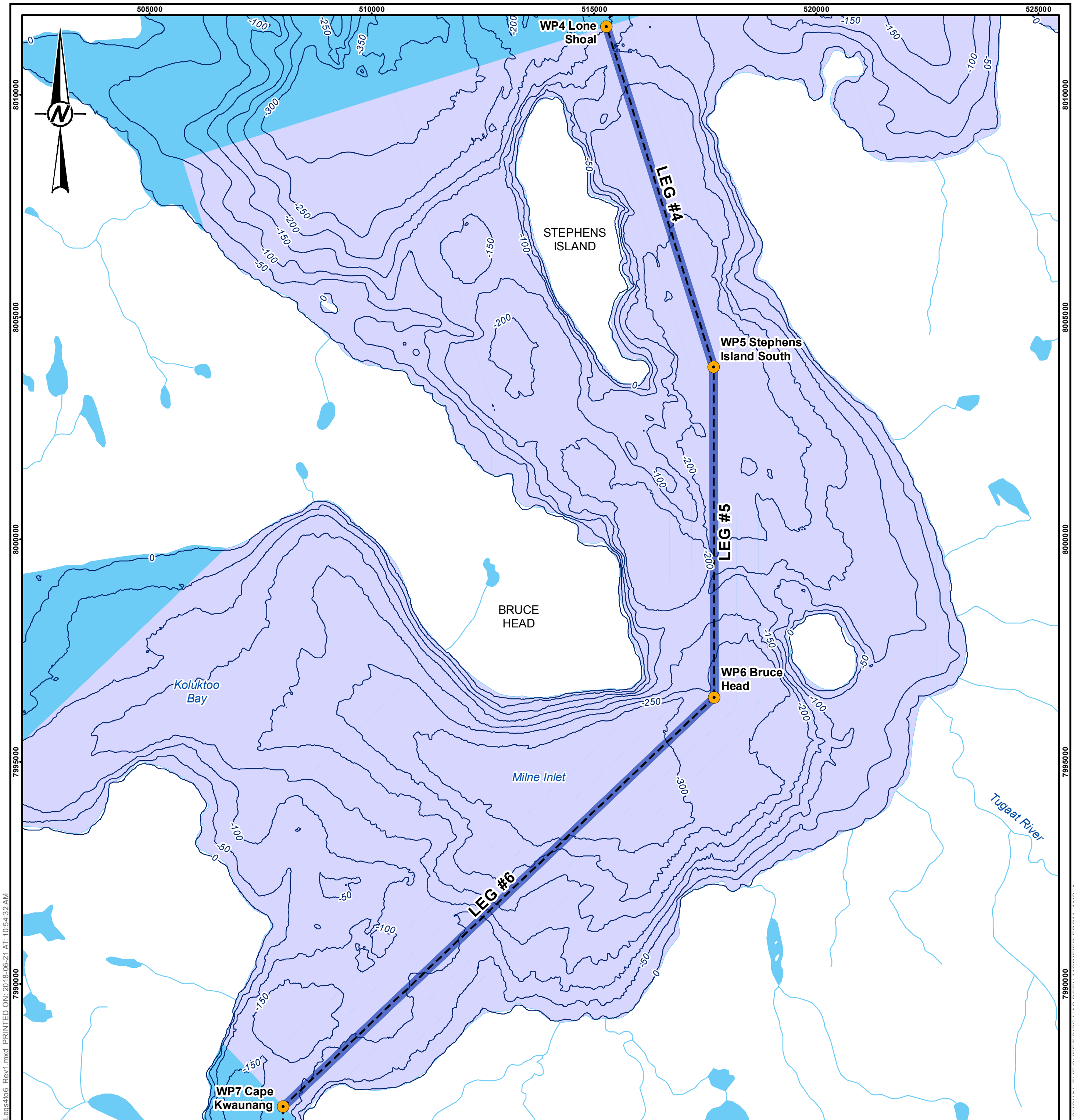


LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

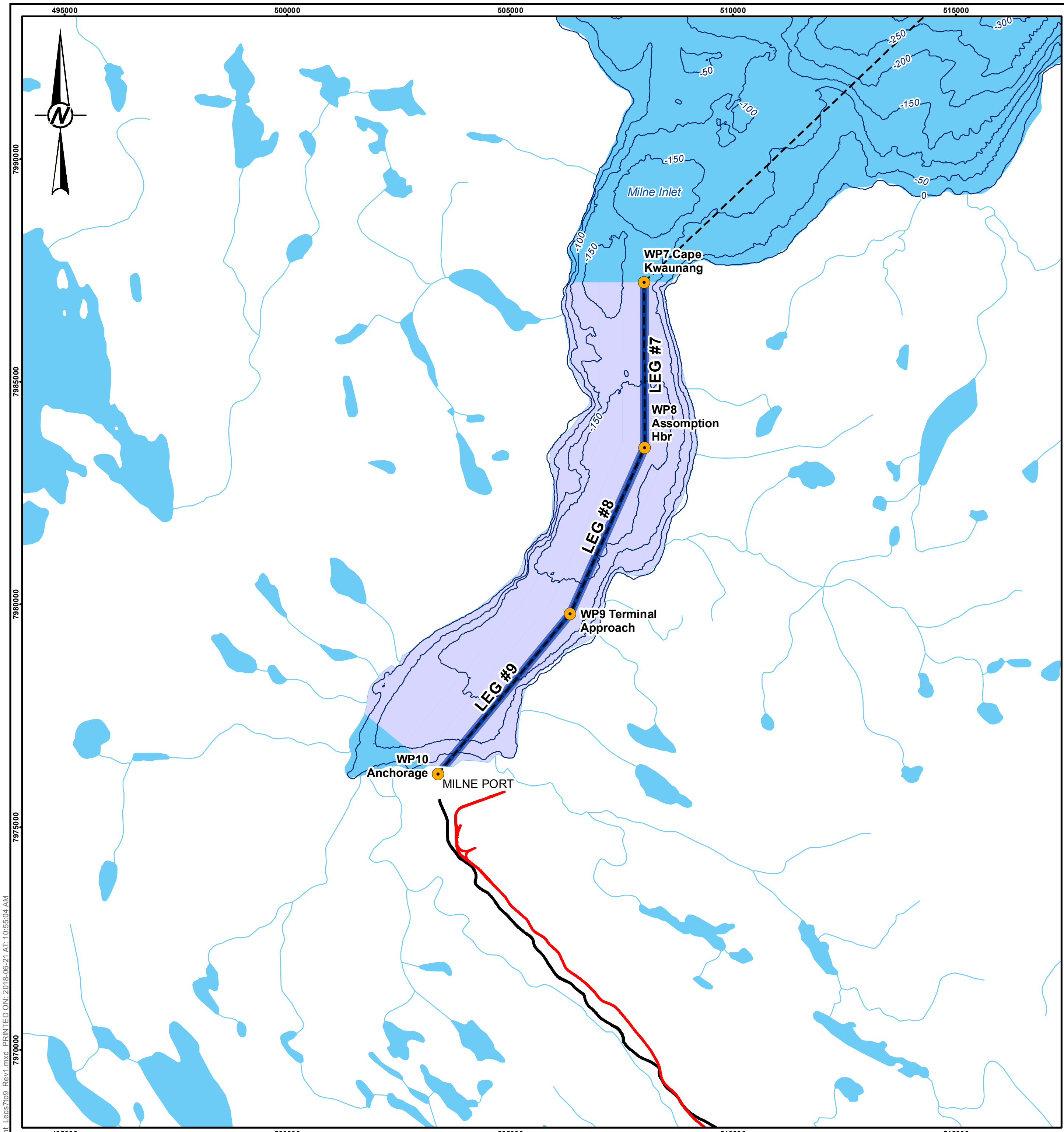
TITLE
CAPESIZE VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 4-6)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
1663724	18000	1	A-11



LEGEND

- SHIPPING ROUTE WAYPOINT
- SHIPPING ROUTE (APPROXIMATE)
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- WATERCOURSE
- WATERBODY

WAKE HEIGHT (m)

- 0 - 0.05
- 0.05 - 0.10
- >0.10

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

1. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES.
2. MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017.
3. HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
SHIP WAKE AND PROPELLER WASH ASSESSMENT – PHASE 2 PROPOSAL

TITLE
CAPESIZE VESSEL WAKE HEIGHT PREDICTION (NORTHERN SHIPPING ROUTE LEGS 7-9)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	GC
PREPARED	LMS
REVIEWED	PO
APPROVED	PR

PROJECT NO.	PHASE	REV.	FIGURE
1663724	18000	1	A-12

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm

APPENDIX B

Expanded Prop Wash Results

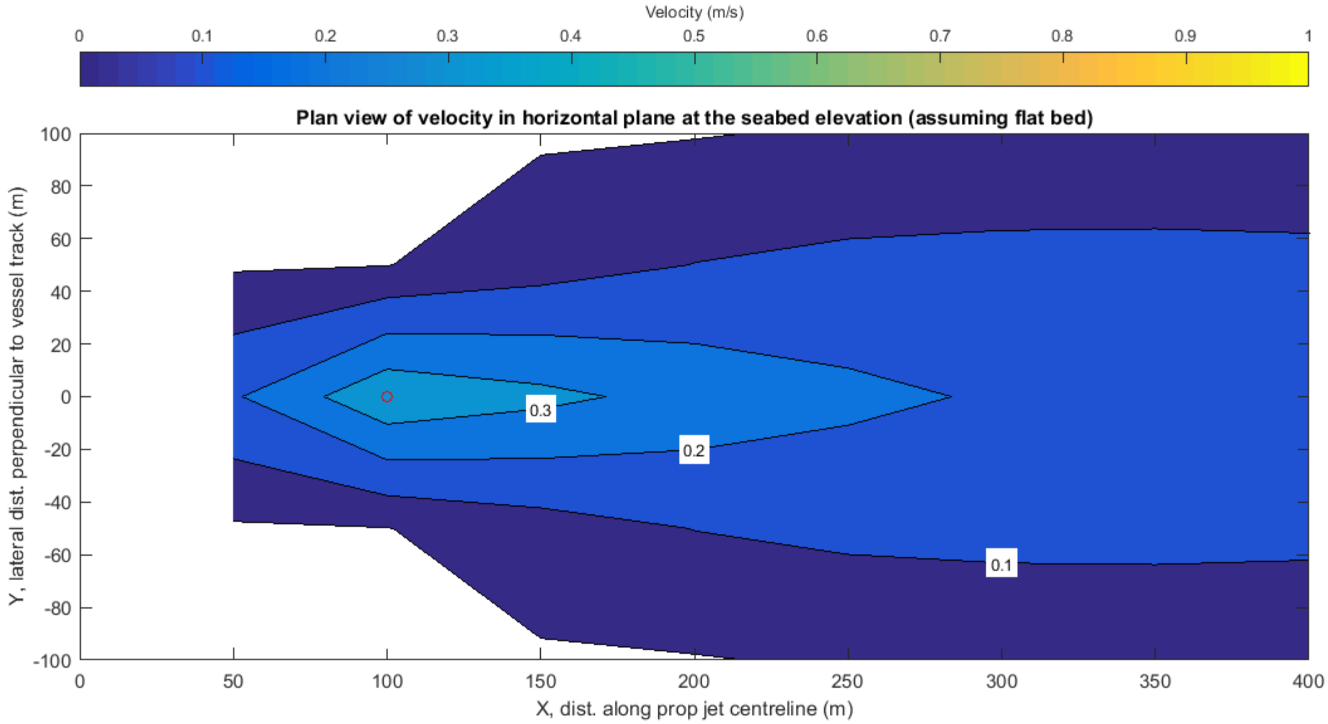

Figure 1: Plan view of vessel propeller generated velocities behind the main propeller for a tugboat at the seabed elevation. **Labels have units of m/s**

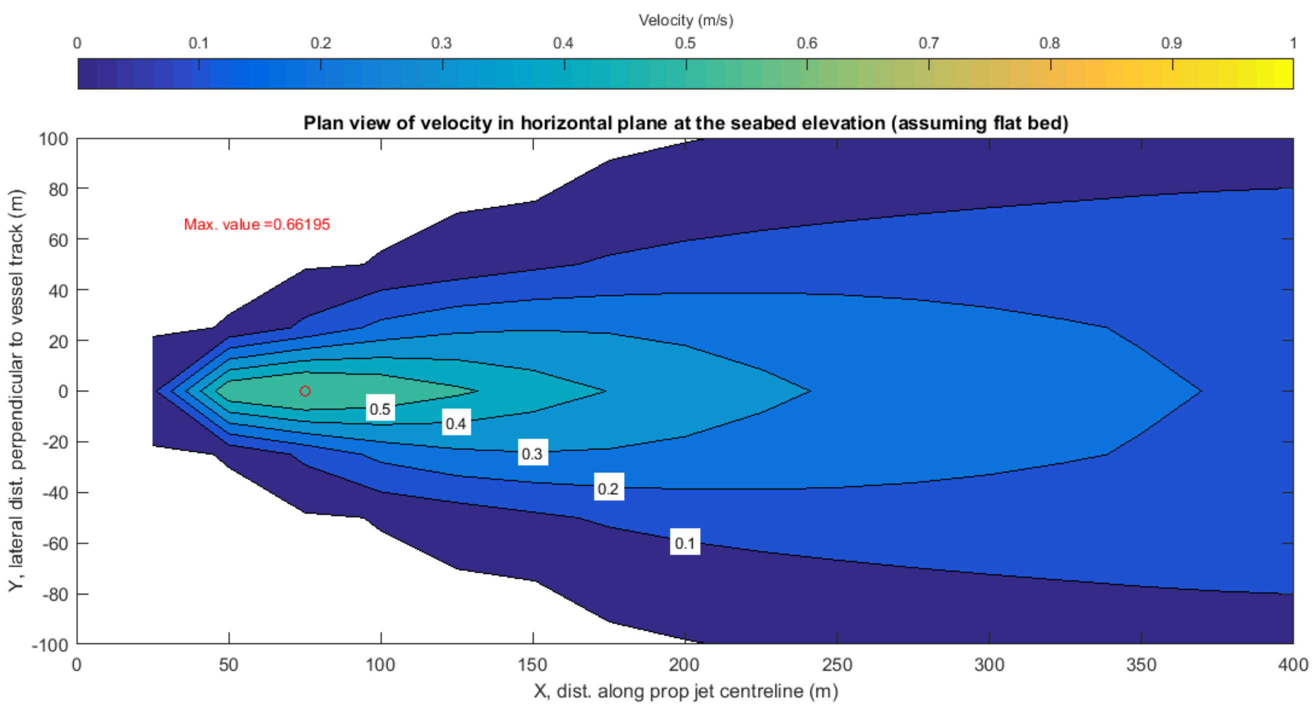

Figure 2: Plan view of vessel propeller generated velocities behind the main propeller for a Supramax ore carrier at the seabed elevation. **Labels have units of m/s**

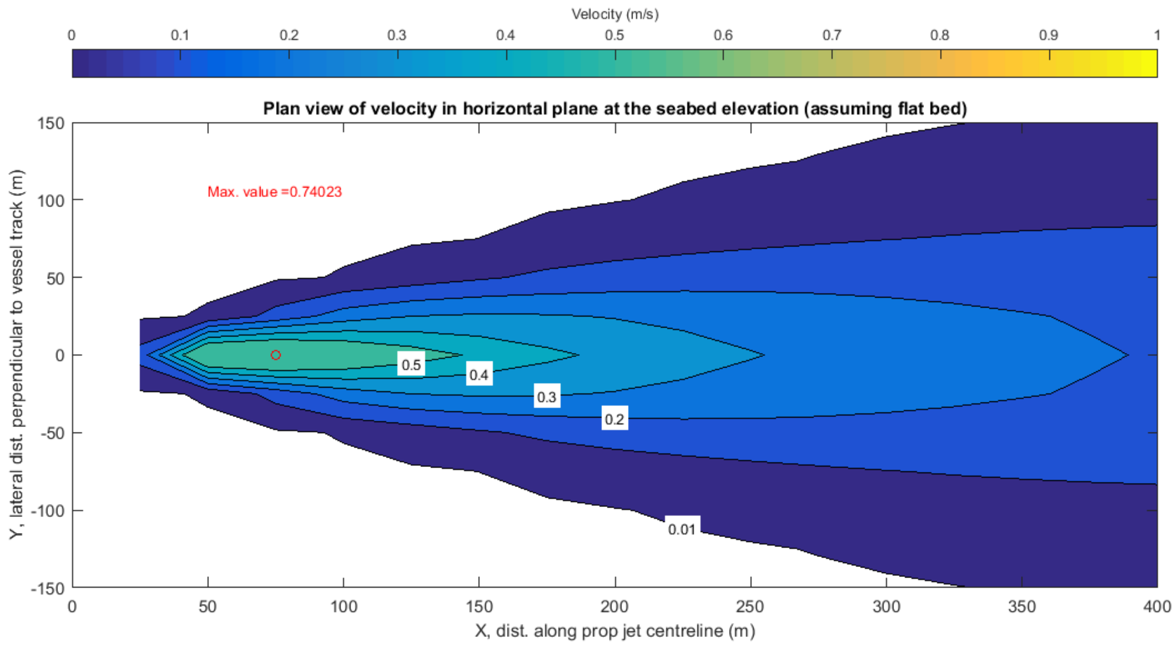

Figure 3: Plan view of vessel propeller generated velocities behind the main propeller for a Post-Panamax ore carrier at the seabed elevation. **Labels have units of m/s**

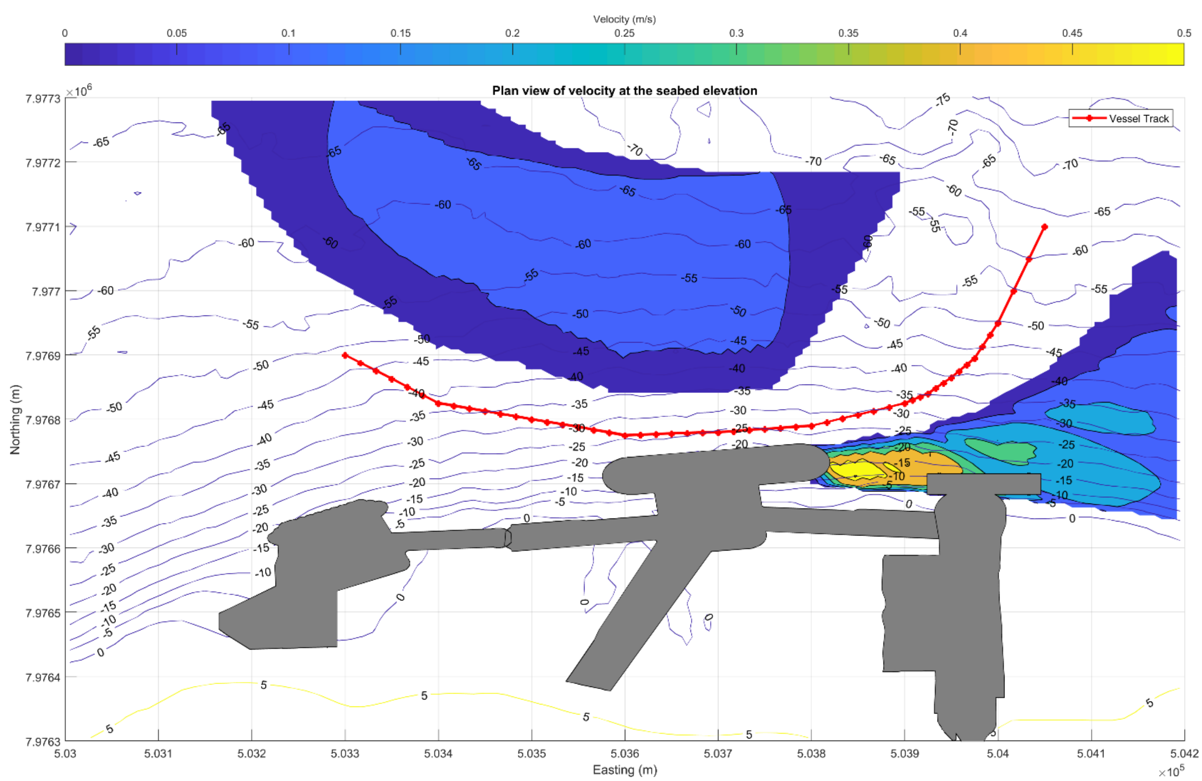

Figure 4: Map of maximum seabed velocities behind the main propeller for a tugboat along a possible ship track at the berthing area for the proposed ore dock

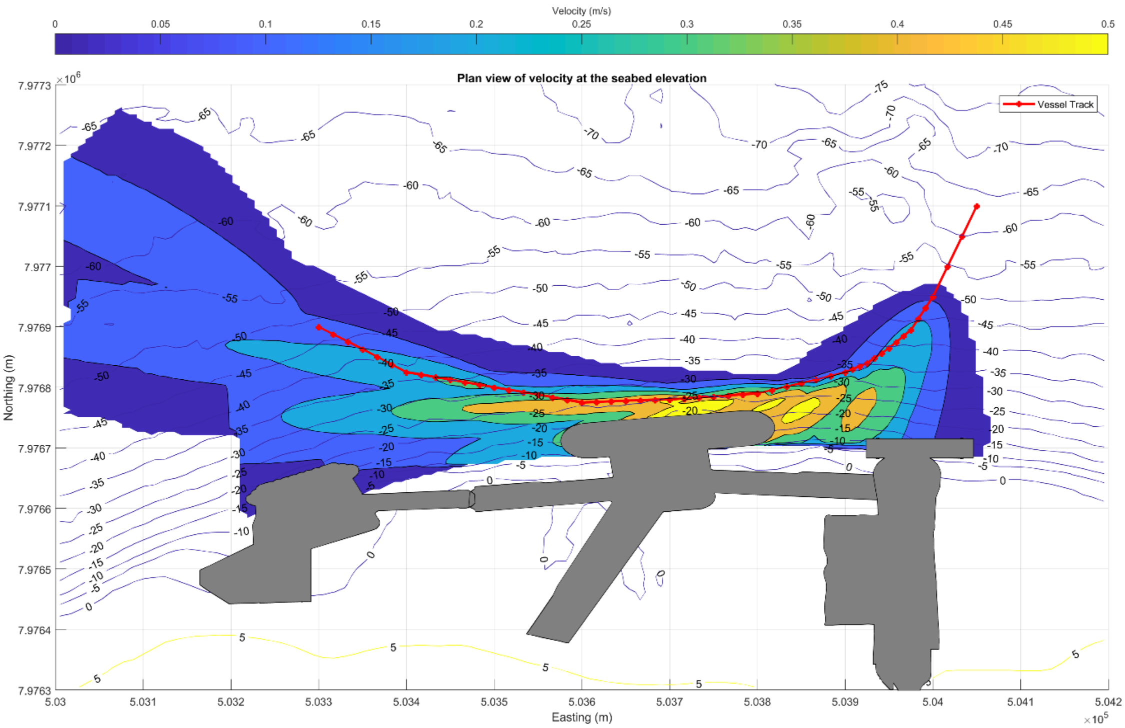

Figure 5: Map of maximum seabed velocities behind the main propeller for a Supramax ore carrier along a possible ship track at the berthing area for the proposed ore dock

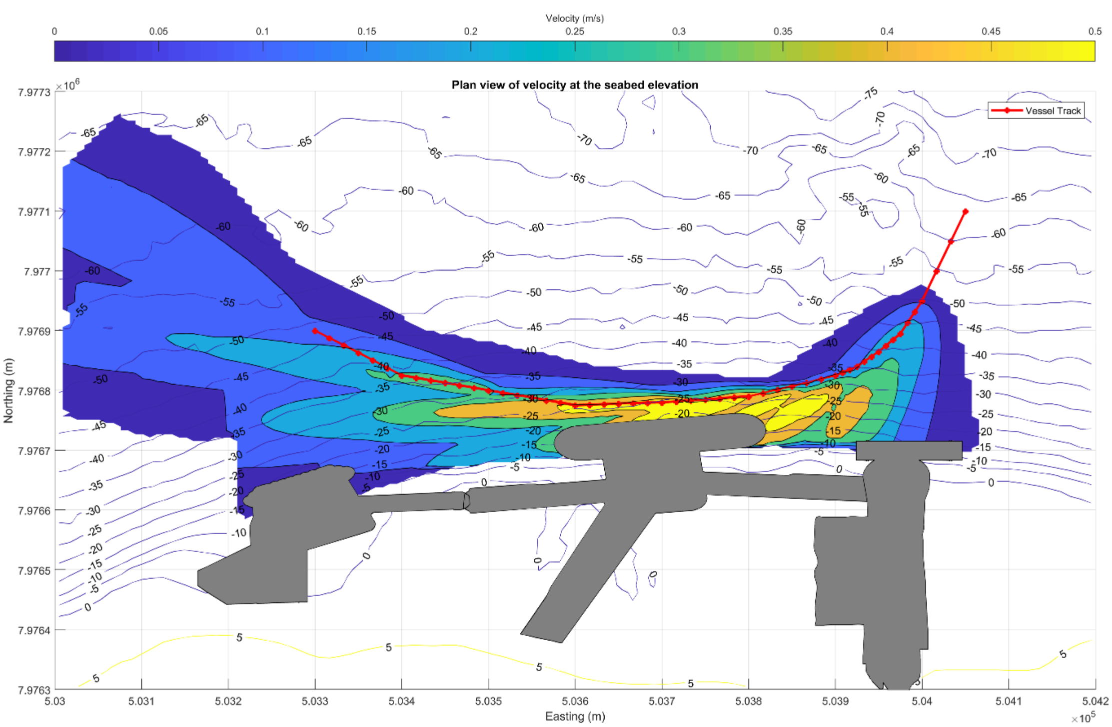

Figure 6: Map of maximum seabed velocities behind the main propeller for a Post-Panamax ore carrier along a possible ship track at the berthing area for the proposed ore dock

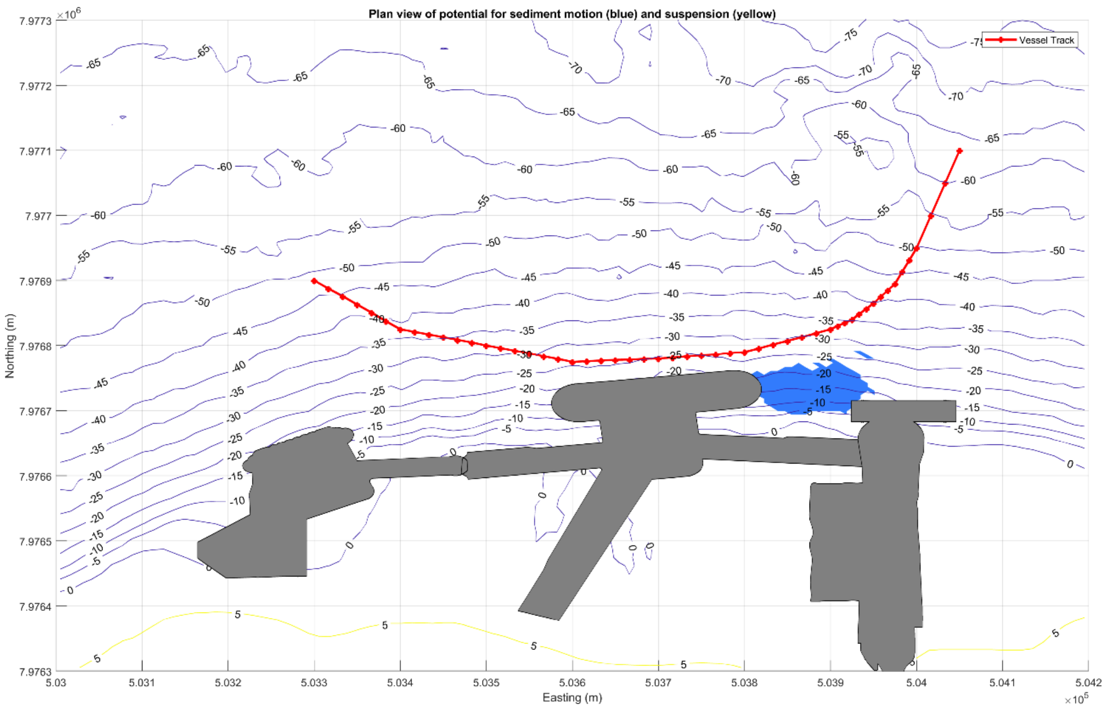

Figure 7: Map of sediment motion potential behind the main propeller for a tugboat along a possible ship track at the berthing area for the proposed ore dock

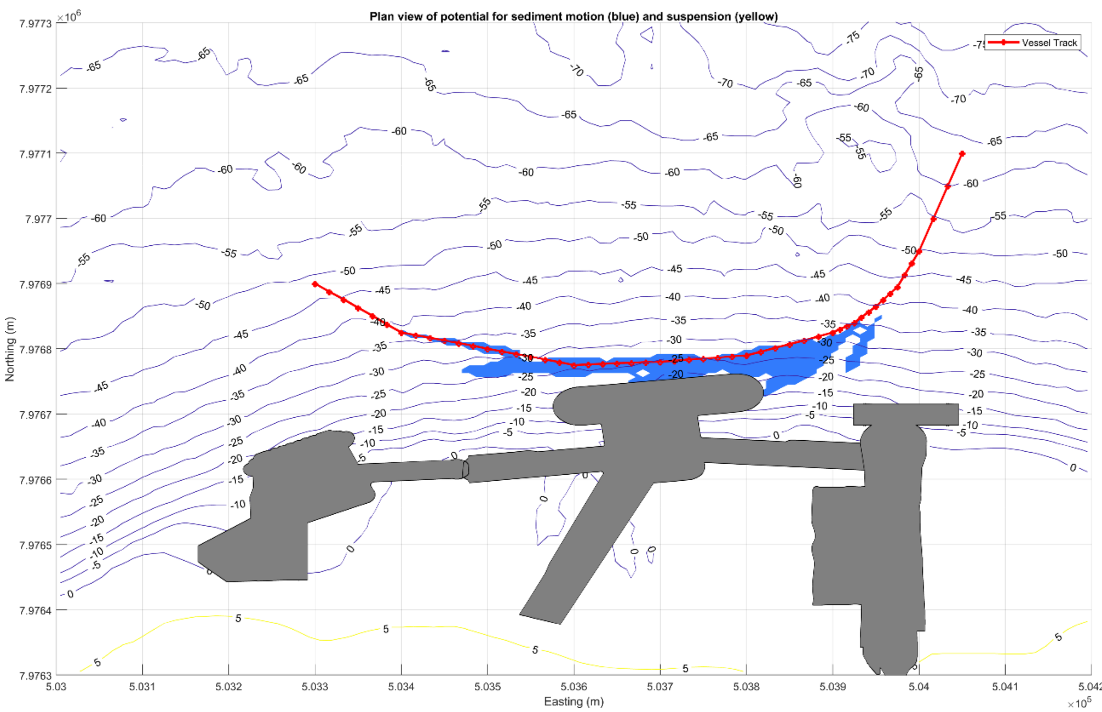

Figure 8: Map of sediment motion potential behind the main propeller for a Supramax ore carrier along a possible ship track at the berthing area for the proposed ore dock

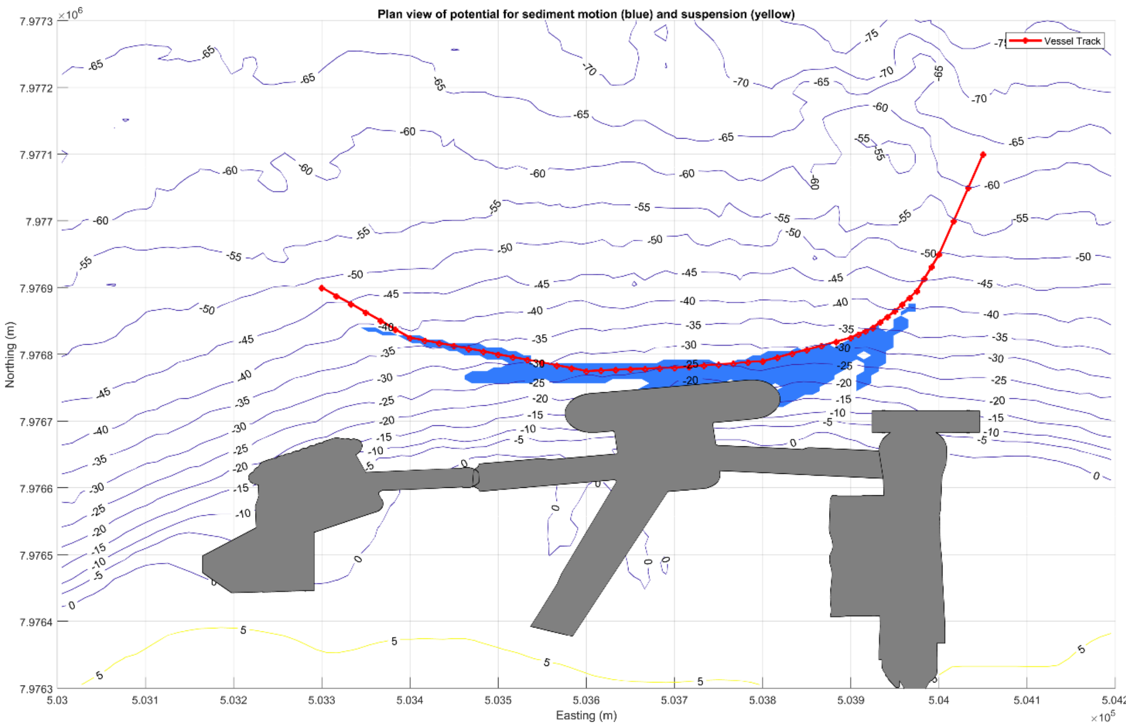

Figure 9: Map of sediment motion potential behind the main propeller for a Post-Panamax ore carrier along a possible ship track at the berthing area for the proposed ore dock

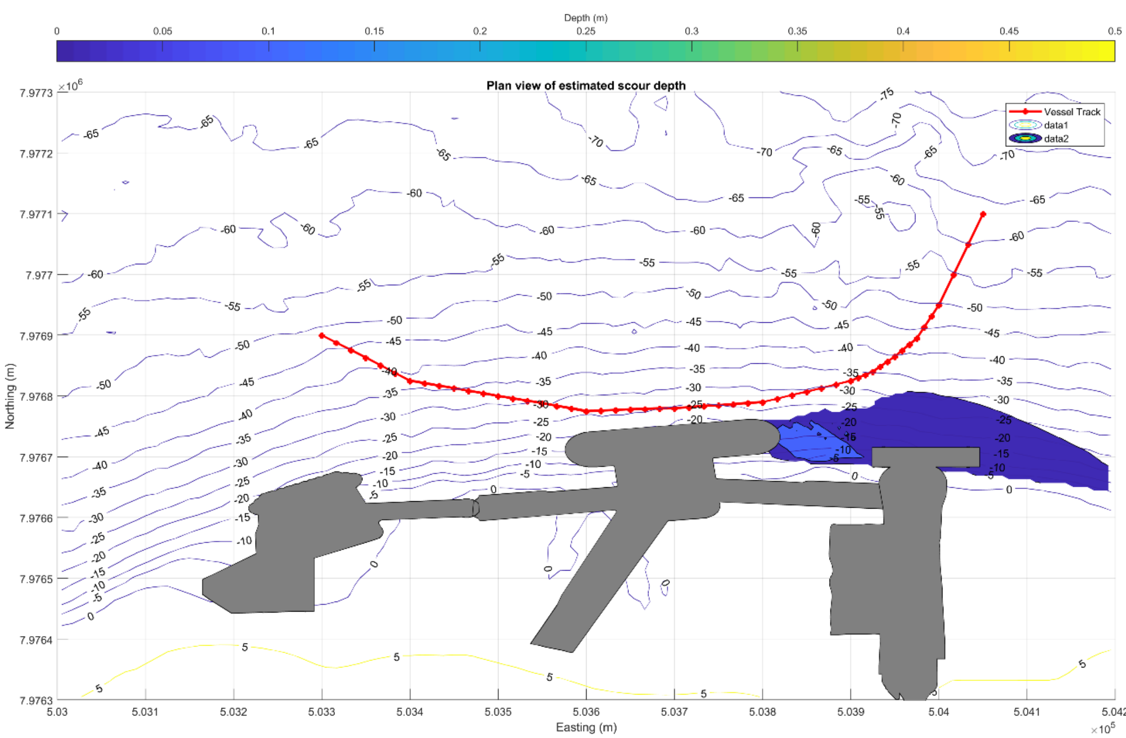

Figure 10: Map of estimated vessel propeller scour depth based on bed velocities for a tugboat at the proposed ore dock

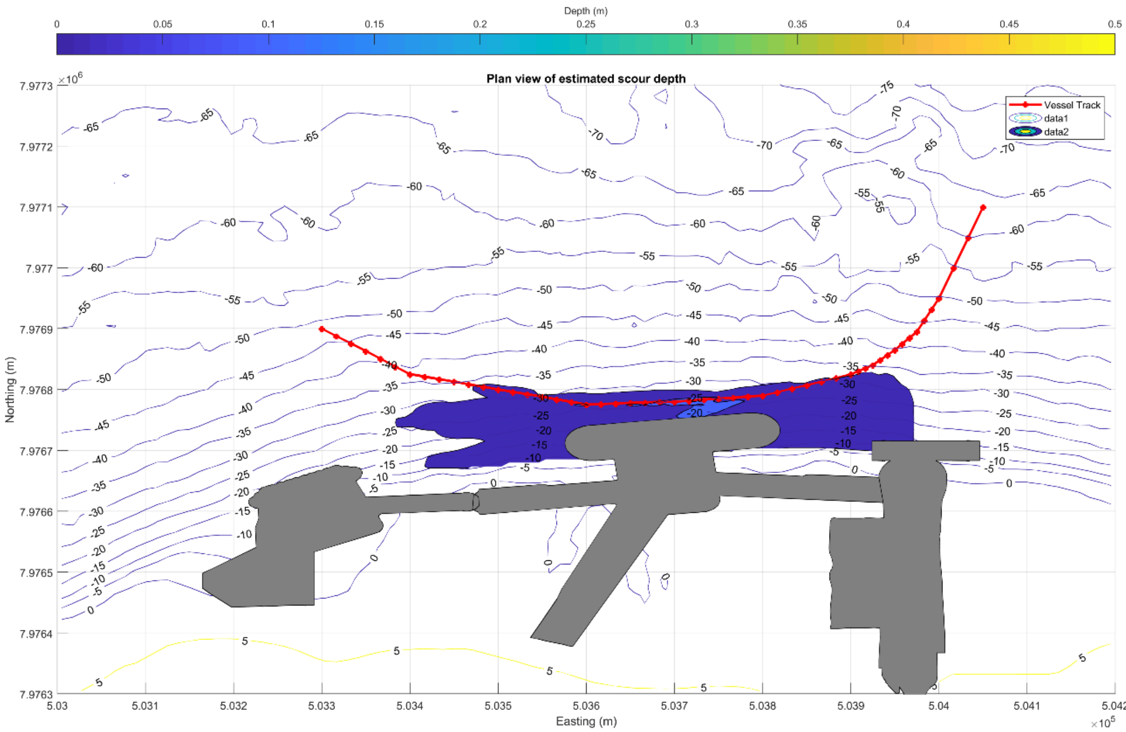

Figure 11: Map of estimated vessel propeller scour depth based on bed velocities for a Supramax ore carrier at the proposed ore dock

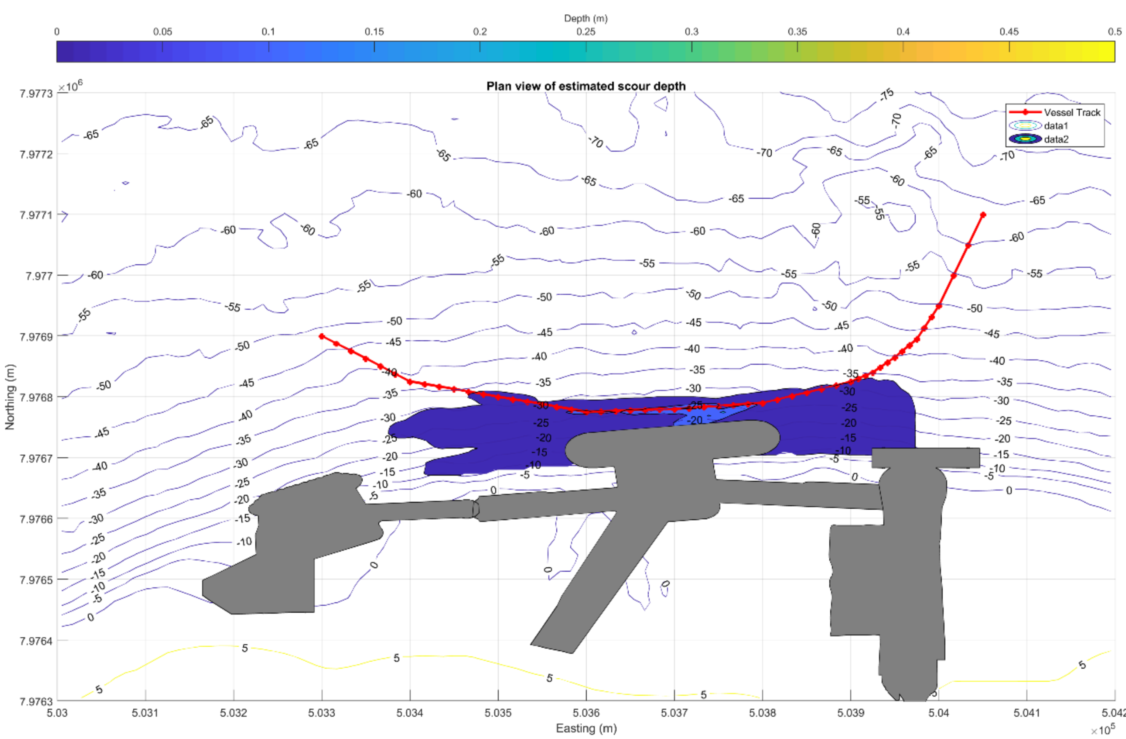

Figure 12: Map of estimated vessel propeller scour depth based on bed velocities for a Post-Panamax ore carrier at the proposed ore dock

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