Baffinland

TECHNICAL SUPPORTING DOCUMENT

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

TSD 20

Hydrodynamic Modelling Report—Milne Port

HYDRODYNAMICS TECHNICAL SUPPORTING DOCUMENT SUMMARY

The hydrodynamics Technical Supporting Document provides an assessment of the Phase 2 Proposal's effects on local currents, waves, and sediment transport within Milne Inlet and uses desktop-based numerical modeling to characterize local currents and sediment transport resulting from tides, wind and wind-generated waves in the Milne Port area. The model also considers 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 and surface water.

With respect to currents, the simulation indicated that alongshore flow was mostly unaltered and that the addition of a second ore dock will have minimal additional impact outside of the embayment and immediate vicinity of the structure. Wave heights as the result of a second ore dock will increase up to 0.5 m and decrease radially outwards toward the centre of the inlet. Changes in erosion and sedimentation transport potential are predicted to occur predominantly in the area sheltered by the proposed Port expanstion and an increase in potential sediment deposition of approximately 12% is predicted relative to existing conditions.

Given the complexity of physical oceanographic processes within Milne Inlet and in Milne Port, a number of assumptions and limitations must be considered with respect to interpretation of results. For instance, for this study, changes in currents, waves, and sediment transport conditions between the existing and proposed Project are considered qualitative and relative as opposed to quantitative and absolute.

RÉSUMÉ DE LA DOCUMENTATION TECHNIQUE COMPLÉNTAIRE SUR L'HYDRODYNAMIQUE

La documentation technique complémentaire sur l'hydrodynamique comporte une évaluation des impacts de la proposition de la phase 2 sur les courants, les vagues et le transport des sédiments à Milne Inlet et utilise la modélisation numérique pour caractériser les courants locaux et le transport des sédiments résultant des marées, du vent et des vagues dans la région du port de Milne. Le modèle tient également compte des 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 et les eaux de surface.

Relativement aux courants, la simulation a indiqué que le débit le long du littoral était essentiellement inchangé et que l'ajout d'un second quai aurait un impact additionnel minimal à l'extérieur de l'embarcadère et à proximité immédiate de la structure. La hauteur des vagues résultant d'un second quai augmentera jusqu'à 0,5 m et diminuera radialement vers le centre de l'entrée. On prévoit que les changements dans le potentiel de transport des sédiments et l'érosion se produiront principalement dans la zone abritée par l'expansion du port proposée et une augmentation du dépôt potentiel de sédiments d'environ 12 % est prévue par rapport aux conditions existantes.

Compte tenu de la complexité des processus océanographiques physiques à Milne Inlet et au port de Milne, un certain nombre d'hypothèses et de limites doivent être considérées lors de l'interprétation des résultats. Par exemple, pour cette étude, les changements dans les courants, les vagues et les conditions de transport des sédiments entre le projet existant et le projet proposé sont considérés comme qualitatifs et relatifs par opposition à quantitatifs et absolus.

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ᐃᓱᒪᒋᓪᓗᒋᑦ ᐃᖏᕐᕋᓂᖏᑦ, ᑕᐅᑐᙳᐊᕈᑎ ᓇᓗᓇᐃᖅᓯᓪᓗᓂ ᓯᕗᔭᖅᐸᓯᐅᑉ ᐃᖏᕐᕋᓂᖓ ᓱᕋᓗᐊᖅᓯᒪᖏᑦᑐᖅ ᐊᒻᒪᓗ ᐃᓚᓯᓂᖅ ᑭᖑᓪᓕᕐᒥᒃ ᓴᕙᕋᔭᒃᓴᓄᑦ ᐅᒥᐊᕐᔪᐊᑉ ᐃᐱᖅᓯᒪᕝᕙᐊ ᒥᑭᑦᑐᒥᒃ ᐊᒃᑐᐃᓂᕐᑲᕋᔭᕐᓂᐊᓂᒃ ᖄᒃᑲᓐᓂᐊᒍᑦ ᓯᓚᑖᑕ ᐊᕙᓗᓂᐊᑕ ᐊᒻᒪᓗ ᓴᓂᕌᑕ ᓴᓇᔭᐅᔩᑉ ᐱᕐᑯᑎᕐᔪᐊᑉ. ᒪᓕᖏᑕ ᐳᖅᑐᓂᖏᑦ ᓴᖅᑭᑦᑐᑦ ᑭᖑᓪᓕᖓᓂ ᓴᕙᕋᔭᒃᓴᓄᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᐱᖅᓯᒪᕝᕙᖓ ᐱᕈᕋᔭᖅᑐᖅ 0.5 ᒦᑕᒥᒃ ᑲᑕᕆᐊᖅᐸᓪᓕᐊᓗᓂ ᐅᖓᓪᓗᖅᐸᓪᓕᐊᓗᓂ ᐃᒪᖓᒍᑦ. ᐊᓯᔾᔨᐅᑎᔪᑦ ᓄᖑᓴᐃᓂᐊᓄᑦ ᓯᕗᔭᖓᓂᒃ ᓯᐅᖅᑲᓪᓗ ᓯᕗᔫᖅᑕᖅᑐᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᓯᒪᓪᓗᑎᒃ ᓴᖅᑭᒃᑲᔭᕐᓂᖏᑕ ᐅᖅᑯᐃᓯᒪᓂᐊᑕ ᑎᓖᒍᑦ ᐊᑐᕈᒪᔭᐅᔫᑉ ᐅᒥᐊᕐᔪᐊᓕᓈᕕᐅᑉ ᐊᖏᓕᒋᐊᕈᑖᓄᑦ ᐊᒻᒪᓗ ᓯᐅᖅᑭᖅᐸᓪᓕᐊᓂᖓ ᐊᖏᓕᒋᐊᕋᔭᕋᓱᒋᔭᖅ 12% ᐅᓪᓗᒥ ᓴᖅᑭᓲᑉ ᓴᓂᕌᒍᑦ.

ᐱᓪᓗᒋᑦ ᐱᔭᓇᑐᔫᓂᖏᑕ ᐊᑐᓪᓚᓇᒃᑑᑉ ᑕᕆᐅᑉ ᐊᐅᓚᓂᕆᓲᖏᑕ ᐃᓗᐊᒍᑦ ᕿᓪᓚᐊᑕ ᑕᕆᐅᖓᓂ ᐅᒥᐊᕐᔪᐊᓕᓈᕕᐅᑉ ᐃᐱᖅᓯᒪᕝᕙᐊᓂ, ᖃᔅᓯᒐᓚᑦ ᐃᓱᒪᓕᐅᕆᓃᑦ ᑭᒡᓕᓯᓂᐊᕆᔪᓪᓗ ᐃᓱᒪᒋᔭᐅᔭᕆᐊᖅᑲᖅᑐᑦ ᐱᓗᐊᖅᑐᒥᒃ ᐊᒃᑐᐊᓃᓪᓚᑦ ᐃᓱᒪᓕᐅᕆᓂᕐᒥᒃ ᑕᑯᔅᓴᕈᖅᑐᓄᑦ. ᑐᑭᓕᐅᑎᓗᒍ, ᖃᐅᔾᔮᔅᓯᑎᒍᑦ, ᐊᓯᔾᔨᐅᑎᔪᑦ ᐃᖏᕐᕋᓂᓐᓂᑦ, ᒪᓕᖏᓂᒃ, ᐊᒻᒪᓗ ᓯᐅᖅᑭᖅᑕᓐᓂᐊᑕ ᐃᓕᖅᑯᓯᖏᓂᒃ ᐊᑯᓐᓂᐊᒍᑦ ᐊᑐᖅᑑᑉ ᐆᒃᑐᖅᑕᐅᔾᔪᓪᓗ ᐱᓕᕆᓂᖏᒍᑦ ᐃᓱᒪᒋᔭᐅᕚᑦ ᓇᐉᓴᐅᑎᑐᐊᒃᑯᑦ ᐊᖏᓕᒋᐊᕆᔾᔪᑦ ᓴᓂᕌᑕ ᐱᐅᓂᖅᑲᓂᐅᑉ ᑭᒡᓕᖅᑲᓪᓚᕆᓐᓂᐅᓪᓗ.

GOLDER

REPORT

BAFFINLAND IRON MINES CORPORATION MARY RIVER PROJECT - PHASE 2 PROPOSAL

TSD#20: Hydrodynamic Modelling Report - Milne Port

Submitted by:

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FIGURES

APPENDICES

LIST OF ACRONYMS

Term	Abbreviation
Baffinland Iron Mines Corporation	Baffinland
Canadian Hydrographic Service	CHS
Conductivity and temperature with depth	CTD
Global Self-consistent Hierarchical, High-resolution Geography Database	GSHHG
Golder Associates Ltd	Golder
High water level	HWL
Mean sea level	MSL
Million tonnes per annum	Mtpa
North American Regional Reanalysis	NARR
Nunavut Impact Review Board	NIRB
Technical Support Document	TSD
Topex Poseidon	TPXO

1.0 INTRODUCTION

The Mary River Project (the Project) is an operating iron ore mine located in the Qikiqtani Region of Nunavut (Figure 1.1). 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 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 ore carrier 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.

LEGEND

- PROJECT SITE
- COMMUNITY
- FUTURE SOUTH RAILWAY
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA
- SHIPPING ROUTE
- SIRMILIK NATIONAL PARK
- WATER

0 125 250

1:5,000,000 KILOMETRES

REFERENCE(S)

BASE MAP: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
PROJECT LOCATION

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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25mm

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 Supporting Document (TSD) specifically addresses the following Project effects on the marine physical environment related to the Phase 2 Proposal:

- Potential effects of installing a second ore dock (and associated marine infrastructure) on near-shore currents, waves, and sediment transport in Milne Port.

Hydrodynamic modeling[1] was performed to evaluate the potential effects of the new ore dock structure on near-shore currents, waves and sediment transport, based on proposed shipping operations under the Phase 2 Proposal. The objectives of this work were:

- To characterize the deep-water wave climate offshore of Milne Port based on existing data and hindcast winds during the open water season and transformation to the nearshore;
- To develop an integrated hydrodynamic and sediment transport potential numerical model that is driven by site-specific wind, tide, and temperature/salinity forcing; and
- To evaluate the relative incremental changes in near-shore currents, waves, and sediment transport resulting from the proposed construction of the second ore dock capable of berthing Cape size vessels.

1.3 Key Assumptions and Model Limitations

No direct field measurements of waves, currents and sediment transport in Southern Milne Inlet were available to describe or characterize local wave climate, current and sediment transport conditions proximal to the proposed port expansion or to validate the numerical models which are applied in this region for the assessment of Project effects. As outlined in Appendix B, calibration of the local port area model was limited to a comparison with measured water levels and a broad comparison with the results from a previous modelling study (CORI 2014). Given the complexity of physical oceanographic processes within Milne Inlet and in the area of Milne Port, several key assumptions and limitations should be considered with respect to the interpretation of results presented in this report - as follows:

- Changes in currents, waves and sediment transport conditions between the existing and proposed project are considered qualitative and relative as opposed to quantitative and absolute.
- Changes in waves and sediment transport potential have been evaluated for a limited set of idealized storm conditions representing a range of return periods that include typical and extreme conditions. Potential long term morphological changes have not been simulated owing to the lack of available information for model calibration or validation.
- Model prescribed stratified temperature and salinity profiles were considered constant in time over short time scales. This was validated by the relatively small changes in temperature and salinity measurements reviewed during August in Milne Inlet.

[1] A hydrodynamic model is a tool that uses numerical (computational) methods to describe hydrodynamic processes (e.g. currents and water levels) in space and time using known physical process drivers and inputs, such as the tidal, wind and freshwater/saltwater effects.

- Changes in water temperature due to solar heating for deep fjord type environments occurs on the order of months. Therefore, heat flux through the surface was considered negligible in the short term model scenarios.
- Bed roughness was prescribed uniformly throughout the domain as the composition of the substrate across the domain was unknown outside of the immediate Port area.
- Sediment fractions outside of measurement points were interpolated to more remote grid cells in the model domain in order to account for spatial variability and sediment thickness was prescribed as a uniform depth of 5 m.

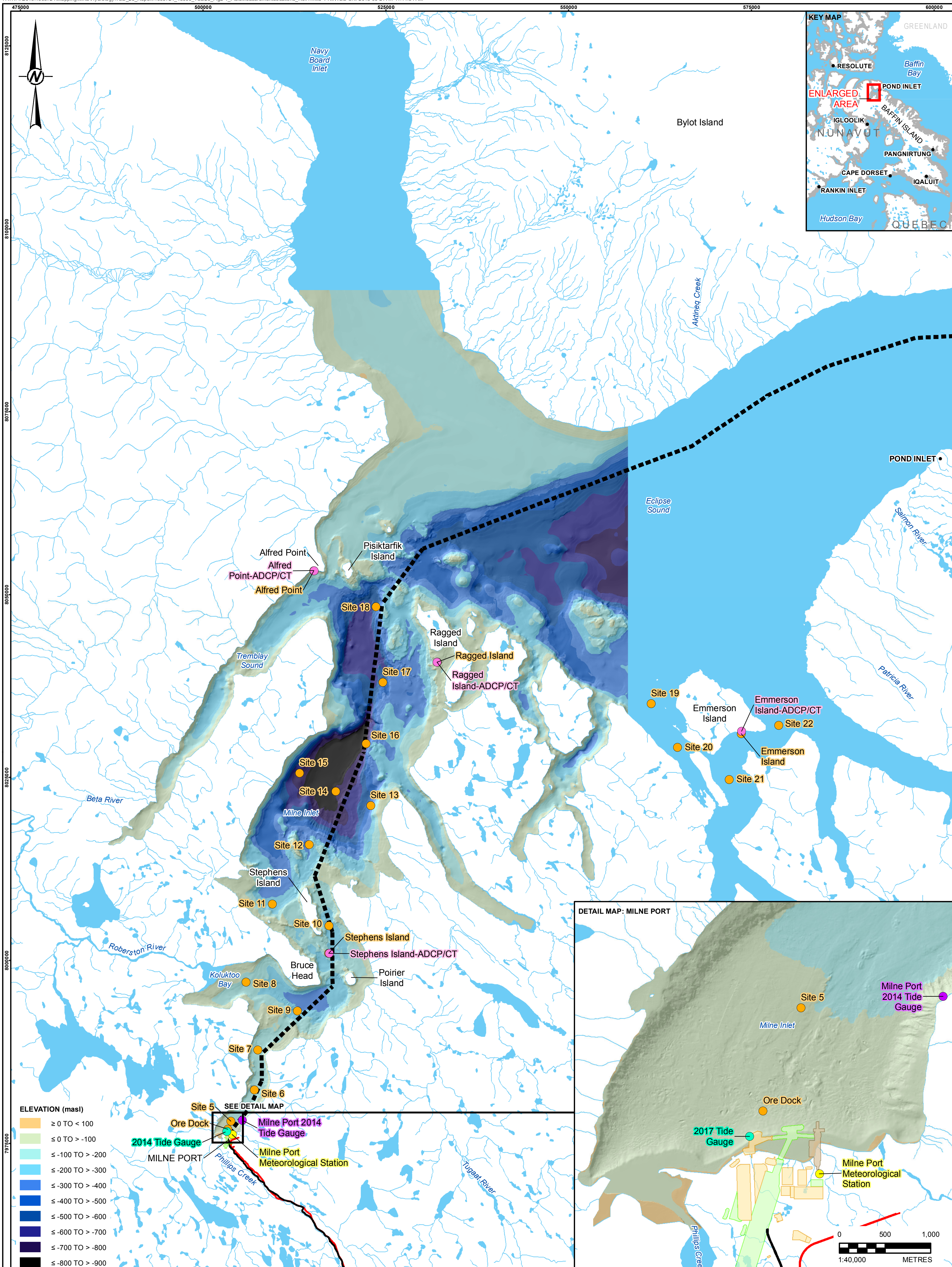
2.0 PHYSICAL ENVIRONMENT REVIEW

Milne Inlet is located along the northern coast of Baffin Island in the Qikiqtani Region of Nunavut. The inlet is at the southern extent of a network of fjords connecting to Baffin Bay. Milne Inlet runs nearly north-south extending to Eclipse Sound and Navy Board Inlet (Figure 1.1). Sea ice covers the inlet from approximately November to mid or late July. Mean sea ice thickness is estimated as 1.6 m in most years (Knight Piésold 2010).

The general physical conditions in Milne Inlet are controlled by wind and atmospheric systems, tides and tidal currents, waves, runoff, and sea ice. Physical characteristics of the marine environment are described in greater detail in Appendix A. The available data and information pertaining to Milne Inlet (inclusive of Milne Port) are as follows:

- Bathymetric and topographic data were compiled to create a dataset covering Milne Inlet and extending north to Navy Board Inlet and Eclipse Sound. Data sources included: geophysical surveys collected by Terra Remote Sensing (2008), and Enterprises Normand Juneau Inc. (2010), and hydrographic surveys collected by Canadian Hydrographic Service (CHS) from 1964 to 2014.
- Shorelines were delineated at the mean high water line using a combination of a Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG; NOAA 2016), aerial imagery of the site, and low water shorelines from CHS maps.
- Tides and water levels at the site were derived from a combination of measured data and harmonic constituents extracted from Topex Poseidon (TPXO) 8.0 database (Appendix B).Historical water levels measured at the site include five temporary stations installed by CHS from 1964-1988. Recent water level measurements were collected at Alfred Point, Stephens Island, Emmerson Island, and Ragged Island in 2014 with subsequent measurements at Stephens Island in 2015 and 2016. A tide gauge was installed near the port from August 2014 to August 2015 (Golder 2017c). There is good agreement with the tidal harmonics measured in recent data collection efforts with the historical measurements and extracted harmonics for the site.
- Water column properties including the spatial and temporal trends in salinity and temperature in the inlet were measured in 2014, 2015, and 2016 at selected sites around the study area (Figure 2.1). Conductivity and temperature with depth profiles (CTD) were measured around the inlet at twenty-three locations in August 2014, three profiles in October 2014, eighteen profile locations in August 2015, and thirteen profile locations in August 2016. In addition to vertical profiles, time series of temperature and salinity were measured at set depths on subsurface tautline moorings at four locations in 2014 from August to October, and additional measurements at Stephens Island from August 2015 to August 2016. Data collection efforts and data were provided by ASL Environmental (ASL 2015) and CORI.

- Site specific wind data were acquired using two primary data sources, measured wind at Milne Camp close to the Port, and regional reanalysis wind provided by North American Regional Reanalysis (NARR) at select grid points close to the project site. Measured wind data from the meteorological station are available from 2006 to 2015. NARR data were downloaded from 1979 to 2006.
- Current speed and direction were measured at four locations in Milne Inlet (Alfred Point, Emmerson Island, Ragged Island, and Stephens Island) during the 2014 open water season using subsurface tautline moorings deployed by ASL Environmental and CORI. Current measurements at Stephens Island were continued from August 2015 to August 2016 by ASL Environmental and CORI.
- Freshwater discharge into Milne Inlet was estimated for two primary sources: Phillips Creek, and Robertson River. Discharge at Phillips Creek was estimated using stream gauge measurements available at a location further inland from 2011 to 2015. Discharge estimates for Robertson River were scaled from Phillips Creek to represent the larger drainage basin.
- Sediment characteristics in the Milne Port area were summarized for the offshore regions based on surface grab samples collected by Sikumiut Environmental Management Ltd in 2016 and geotechnical boreholes and cores sampled in 2016 by Hatch Ltd (Hatch 2017). Intertidal sediment observations were documented during a site visit in July 2017 by Golder. This site visit included a beach photo survey and sediment characterization along the intertidal and beach area at the Port site.



LEGEND

- COMMUNITY

OCEANOGRAPHIC SOURCES

- 2014 TIDE GAUGE
- 2017 TIDE GAUGE
- CTD PROFILE
- METEOROLOGICAL STATION - WIND
- MOORING
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- SHIPPING ROUTE (APPROXIMATE)
- WATERCOURSE
- EXISTING ORE DOCK
- NEW ORE DOCK AND CAUSEWAYS
- EXISTING FREIGHT DOCK AND CAUSEWAY
- WATERBODY

0 10 20
1:500,000 KILOMETRES

NOTE(S)

masl = METRES ABOVE SEA LEVEL

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES. GEOGRAPHIC NAMES, 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
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
SUMMARY OF BATHYMETRIC DATA AND FIELD MEASUREMENT LOCATIONS

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	2.1

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

3.0 NUMERICAL MODEL DEVELOPMENT

A qualitative three-dimensional (3-D) hydrodynamic model was developed using Deltares's Delft3D-FLOW (Roelvink and Banning 1994; Deltares 2011) to assess relative incremental changes in nearshore currents proximal to the proposed port expansion. The model was then subsequently coupled to Delft3D-WAVE and Delft3D-MOR in order to assess waves and sediment transport.

3.1 Flow Modelling

The qualitative model consisted of a regional domain and a local domain informed with measured bathymetry and fit to local land boundaries (Appendix B). Boundary conditions in the regional model were forced with tidal constituents derived from a global database (TPXO 8.0) and local model boundary conditions were prescribed using the regional model. Additionally, design winds and measured salinity and temperature profiles at select dates were used to force the model domain. The models were calibrated using on-site measurements of water level as well as currents in the regional model.

3.2 Wave Modelling

A standalone steady-state wave model of southern Milne Inlet in the vicinity of Milne Port consisting of a coarse and nested domain was forced with hindcast significant wave height, peak period, and direction along the open boundary and design winds across the model domain (Appendix B). Additionally, the wave model was coupled with the local flow model to simulate wind-wave-current interactions and ascertain nearshore radiation stresses at the head of Milne Inlet.

3.3 Sediment Transport Potential

Sediment transport potential and erosion and deposition patterns were computed within the local flow model. The model was defined such that the non-cohesive bedload and suspended load transport were simulated. Delft3D-Flow calculates the three-dimensional transport of suspended sediments by solving the three-dimensional advection-diffusion equation for the suspended sediment. The exchange of sediment with the bed is calculated by computing the sediment flux from the bottom layer, which translates into a source/sink of sediment in the bottom layer and used to update the bathymetry. The sediment transport model in Delft3D-Flow also accounts for changes in fluid density associated to the suspended fraction, sediment settling as a function of modelled sediment concentration and hindered settling fall velocity, and effect of sediment concentration on dispersive transport. Available field data was used to characterize sediment fractions and initialize their spatial distribution across the model domain. Model output consisted of erosion/sedimentation rates, suspended sediment concentration and sediment transport patterns, which were qualitatively compared to morphological indicators derived from aerial imagery of the Milne Port nearshore areas and observations from a site visit.

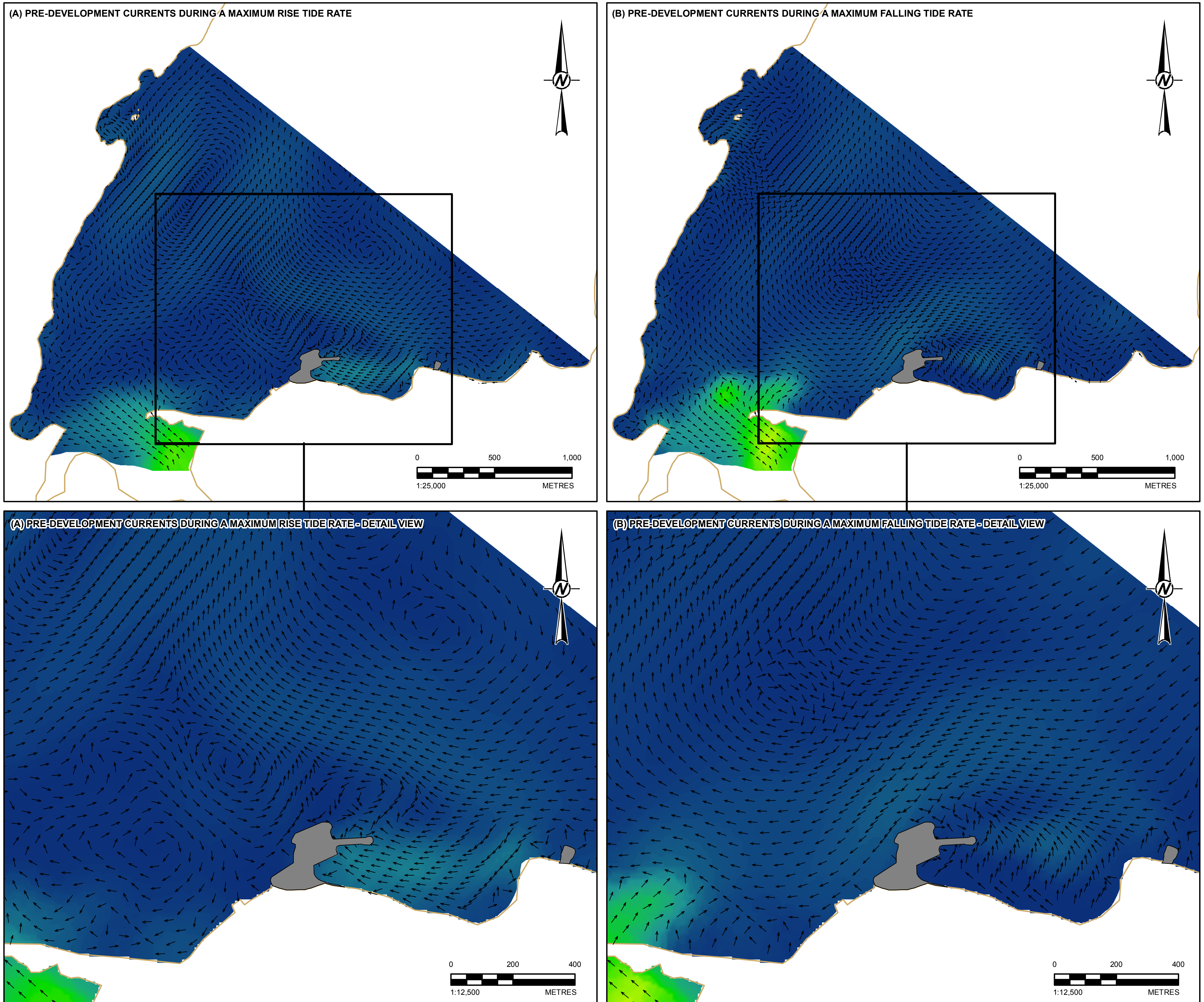
4.0 NUMERICAL SIMULATIONS OF EXISTING CONDITIONS

Hydrodynamic simulations pre and post Milne Port expansion were carried out under design wind and wave conditions during the ice free period August 7-20, 2014. This period was chosen as it represents sufficient time after ice-off for stable stratification to form in Milne Inlet and occurs after Phillips Creek freshet.

4.1 Currents

Currents in the local model were simulated across multiple tidal cycles under steady state wind from the northeast. The wind was prescribed so that it ramped up in intensity to the 1 in 50 year return period (Appendix B). The local flow model was coupled to the wave model so that the radiation stresses of wind generated surface waves were included in the currents. A northeast wind was chosen as it represented the longest fetch direction for wave heights and therefore created the greatest potential for strong nearshore currents resulting from wave-current interactions. With wind and wave effects included, the mean flow in the Milne Port area exhibited complicated circulation patterns (i.e. eddies and gyres) and a clockwise circulation was observed (Figure 4.1; a,b). This is in contrast to what is understood to be a general counter-clockwise circulation in Milne Inlet, observed in previous modelling efforts (CORI 2014) and in this work using a spring and neap tidal cycle with no wind or wave effects (Figure 4.2). However, given the idealized northeast wind and steady state wave conditions, which led to dominance of the depth averaged velocities by the inclusion of wave stresses and wind generated surface flows, the clockwise circulation is considered reasonable and agrees with the wind forcing.

The current speeds in the vicinity of Milne Port were less than 0.2 m/s, but occasionally peaked to near 0.35 m/s (Figure 4.1; c,d). The strongest currents in the model were near the outlet of Phillips Creek, reaching speeds of up to 2 m/s. The currents appear to spread into and out of the space behind and to the east of the existing ore dock on rising and falling tides, respectively. In a rising tide the tendency was for an inflow of water behind the existing ore dock and in a falling tide an outflow was created. The current speed was weakest in the shallow water directly behind the existing ore dock (i.e. sheltered) and strongest in the area between the existing ore dock and the eastern shoreline. This is particularly true during a falling tide. Flows in the shallow nearshore areas adjacent to the port are more strongly influenced by the strength of the wind and presence of waves (Figure 4.1; c,d). In deeper water, currents decrease in intensity with depth and are weakest at the bed.



LEGEND

- MEAN CURRENT DIRECTION
- SHORELINE
- MODELLED EXISTING ORE DOCK

DEPTH AVERAGED VELOCITY (m/s)

HIGH : 2

LOW : 0

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE **PRE-DEVELOPMENT CURRENTS DURING A MAXIMUM RISE TIDE AND FALLING TIDE RATE UNDER NORTHEAST WINDS WITH A WAVE ENVIRONMENT**

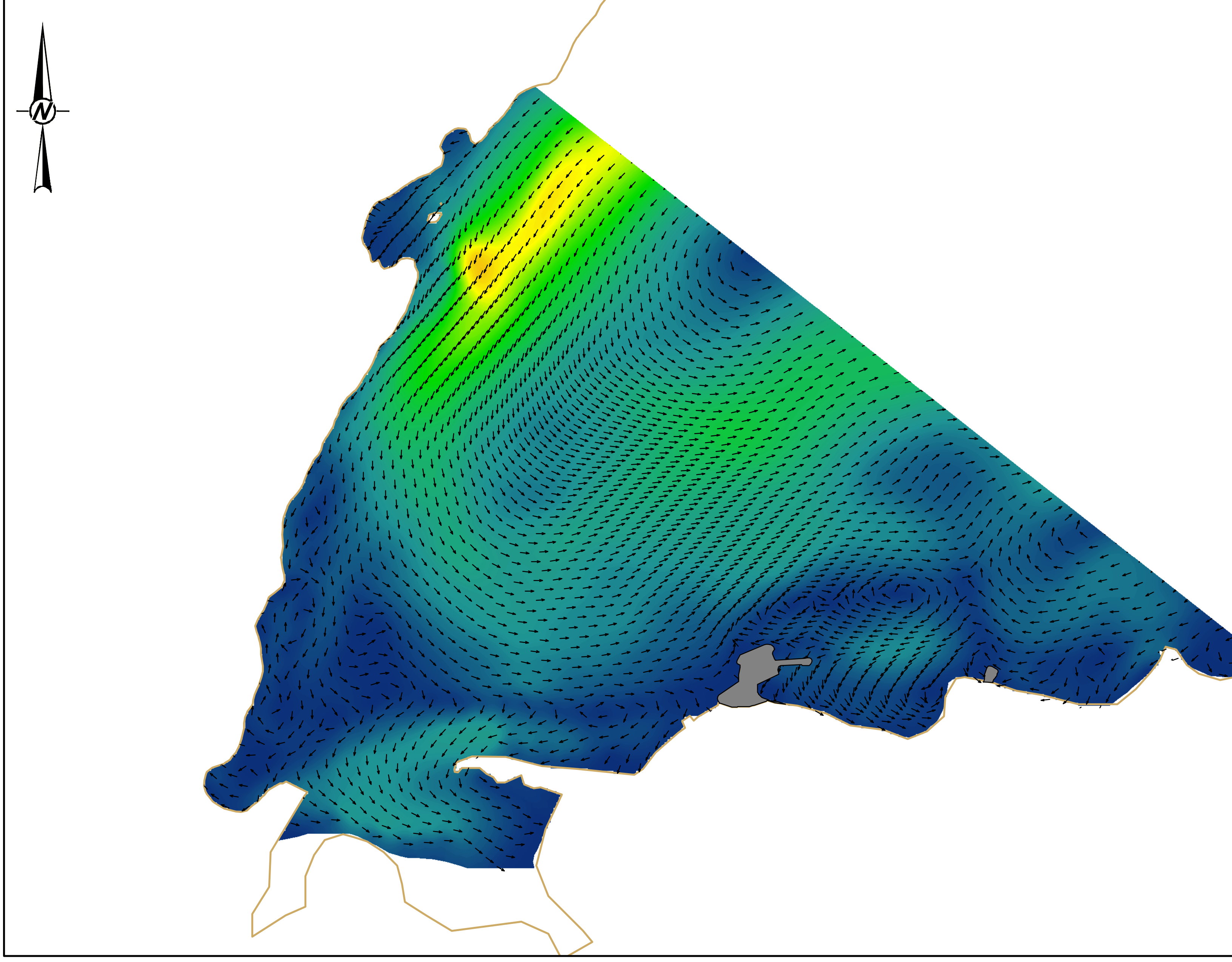
CONSULTANT

GOLDER

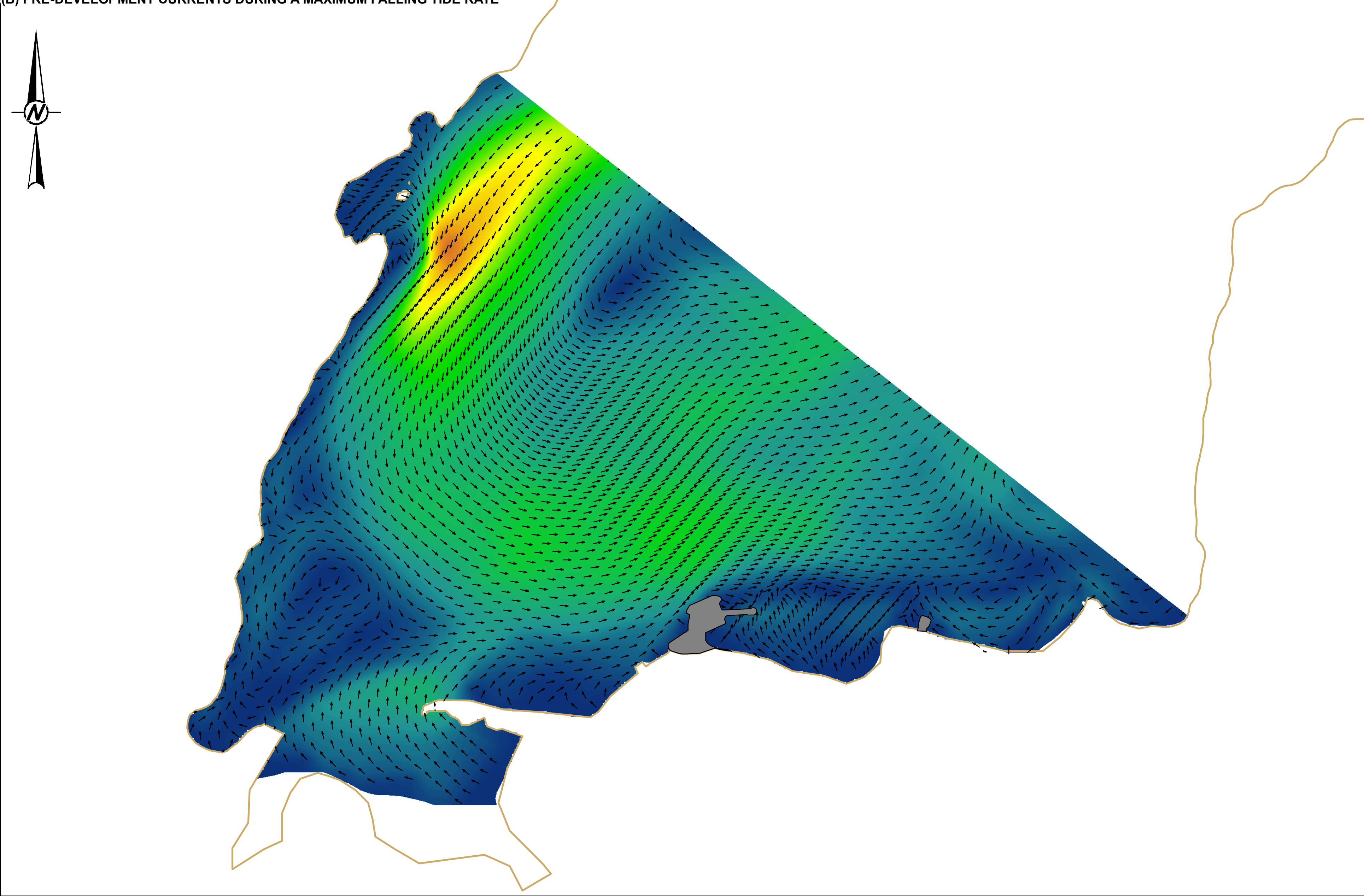
YYYY-MM-DD	6/21/2018
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.1

(A) PRE-DEVELOPMENT CURRENTS DURING A MAXIMUM RISE TIDE RATE



(B) PRE-DEVELOPMENT CURRENTS DURING A MAXIMUM FALLING TIDE RATE



LEGEND

- MEAN CURRENT DIRECTION
- SHORELINE
- MODELLED EXISTING ORE DOCK

DEPTH AVERAGED VELOCITY (m/s)

HIGH : 0.2

LOW : 0

0 500 1,000

1:20,000 METRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE **PRE-DEVELOPMENT BACKGROUND FLOW DURING A MAXIMUM RISE TIDE RATE AND FALLING TIDE RATE WITHOUT WIND OR WAVES**

CONSULTANT: GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.2

4.2 Wind-generated Waves

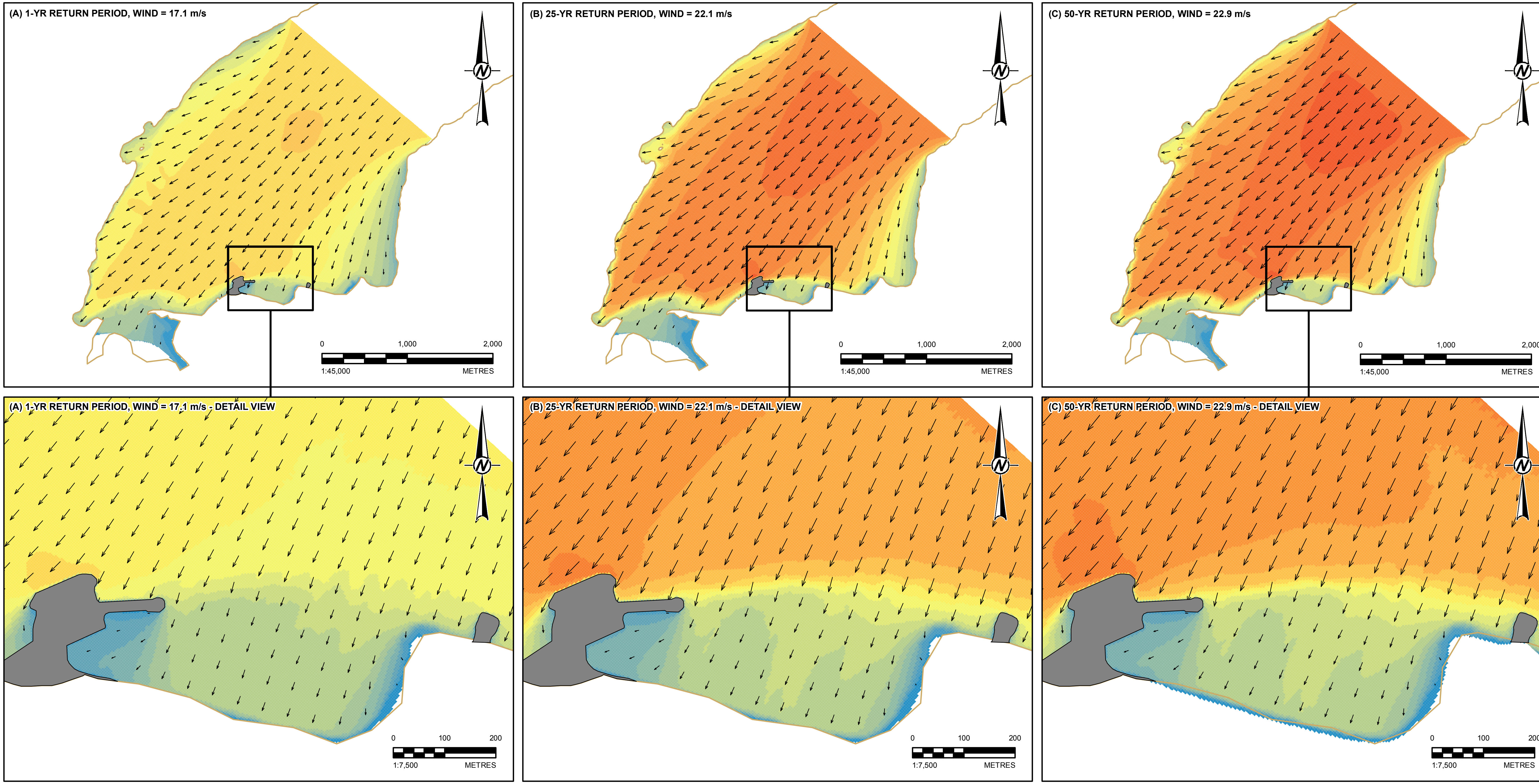
The wind-generated wave environment was assessed under steady state winds from the northeast and northwest. Each wave scenario was simulated at mean sea level (MSL) and high water level (HWL). The HWL corresponds to the value used in previous design work and with typical high tide levels (Amec Foster Wheeler 2010).

The northeast winds, being the strongest and longest fetch, generated waves with the largest significant wave height. The simulated wave fields, illustrated as significant wave height and direction, for MSL and HWL are presented in Figure 4.3 and Figure 4.4, respectively, for a wind return period of 1-, 25- and 50-years. The wave propagation trends under both water levels and all return periods are similar. The model indicates that the waves approach the inlet head and propagate in a southwesterly direction with some minor refraction towards the shoreline in the embayment located at the southeast and west of the inlet. The waves approaching the existing ore dock of Milne Port refract around the structure. Transformations are more pronounced east of the port because of the lateral extension of the breakwater.

The model indicates, for a northeast wind, a short region of wave growth along the fetch followed by spreading of wave energy away from the central axis of the inlet towards the shoreline of the inlet and the head of the inlet. The maximum wave height occurs along the central axis of the inlet approximately 1 km from the open boundary. The significant wave height decreases as a result of refraction and energy dissipation along the shoreline at the head of the inlet in regions where the water depth is reduced. This pattern is particularly apparent on the shallow nearshore shelf directly east of Milne Port. The model indicates an average decrease of 50% in significant wave height in this shallow region, represented by observation point 2, under MSL compared to the waves north of Milne Port in the deeper open water region of the inlet, as represented by observation point 6. Similarly, an average wave height decrease of 27% is observable under HWL condition in this region. The model indicates an increase in wave height directly in front of the existing ore dock of Milne Port because of wave reflections from the ore dock sheet pile walls. Such reflections are not observed directly in front of the breakwater as the riprap armour is not as reflective and is an effective absorber of wave energy. The model suggests that wave reflections from the port propagate further north under larger wave conditions (e.g. 50-year wind return period) as illustrated in Figure 4.3 and Figure 4.4.

The model indicates that northwest winds generate substantially smaller waves at the head of Milne Inlet because of both lower wind speeds and significantly shorter fetches in this direction. The significant wave height under the northwest wind condition for MSL and HWL are presented in Figure 4.5 and Figure 4.6, respectively. The wave propagation trends under both water levels and all return periods are similar. The model indicates that the waves propagate and progressively increase in height to the southeast reaching a maximum in the embayment at the southeast corner of the inlet head. The waves approaching Milne Port existing ore dock change to a more southerly direction towards the shoreline as a result of refraction.

The maximum significant wave height and its associated peak period for the northwest winds is 0.8 m and 2.4 s respectively (e.g. 50-year return period). As with the northeast wind conditions, wave reflection occurs on the windward side of the existing ore dock, with the largest reflection occurring with the largest wave conditions (50-year return period; Figure 4.5 and Figure 4.6). The model predicts an average wave height decrease in the shallow shelf east of Milne Port of 22% and 25% for the MSL and HWL condition, respectively. However, a near complete reduction in wave height occurs on the east side in the wave shadow zone in the lee of the ore dock, indicated by near zero wave heights in this region.

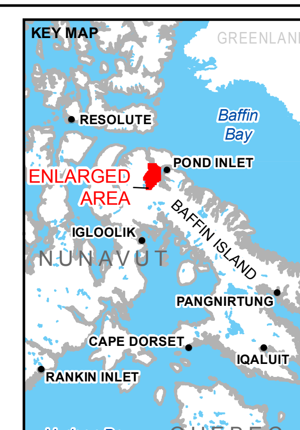


LEGEND

- MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)
- SHORELINE
- MODELLED EXISTING ORE DOCK

SIGNIFICANT WAVE HEIGHT (m)

- HIGH : 2
- MID : 1
- LOW : 0



REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

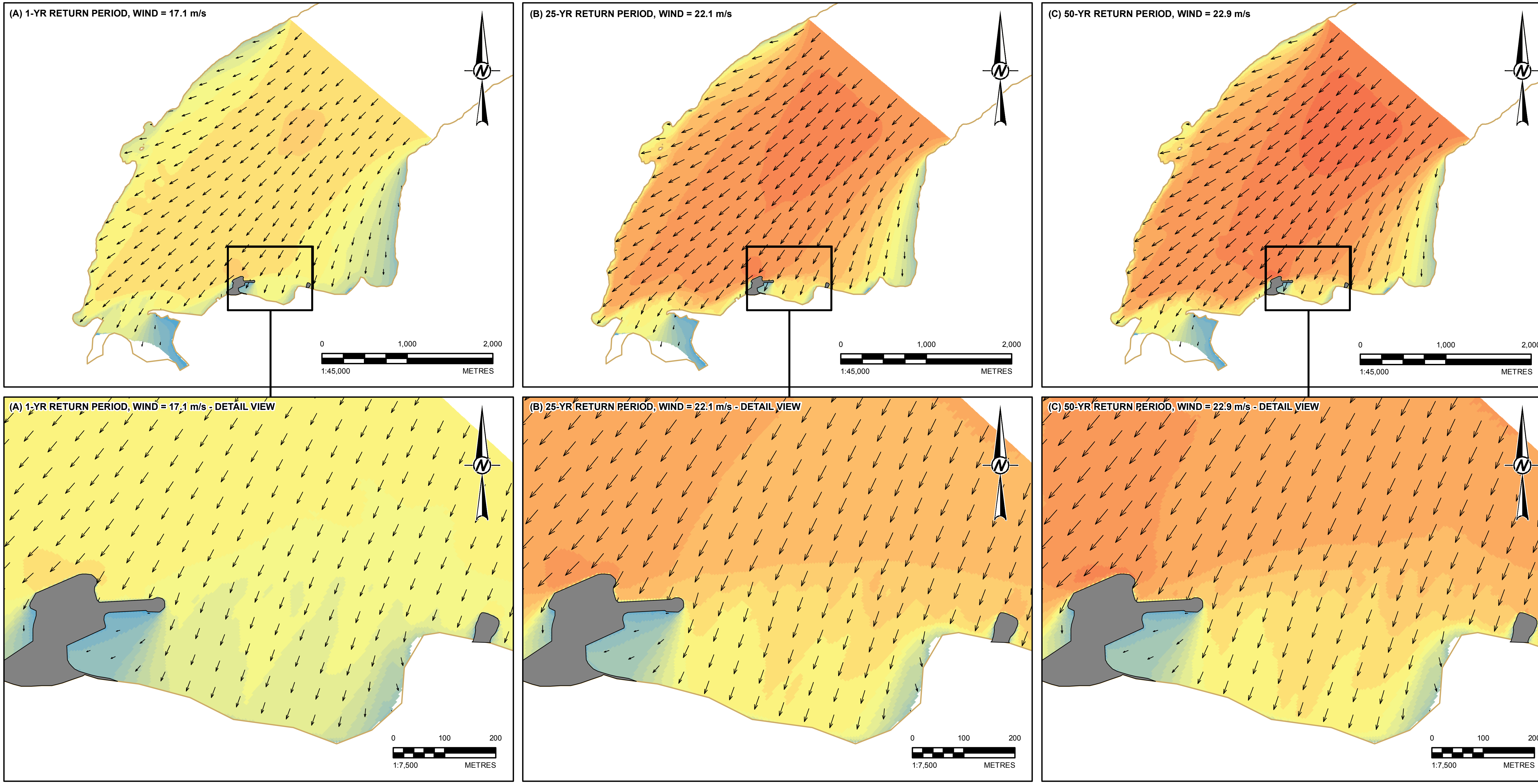
PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

TITLE
PRE-DEVELOPMENT STEADY-STATE MEAN SEA LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHEAST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.3



LEGEND

MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)

SHORELINE

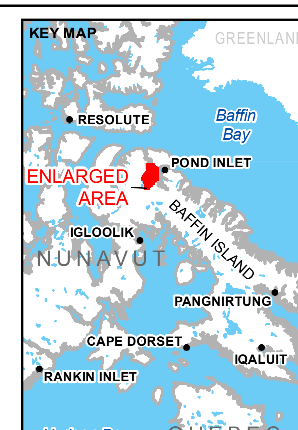
MODELLED EXISTING ORE DOCK

SIGNIFICANT WAVE HEIGHT (m)

HIGH : 2

MID : 1

LOW : 0



REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

CONSULTANT

GOLDER

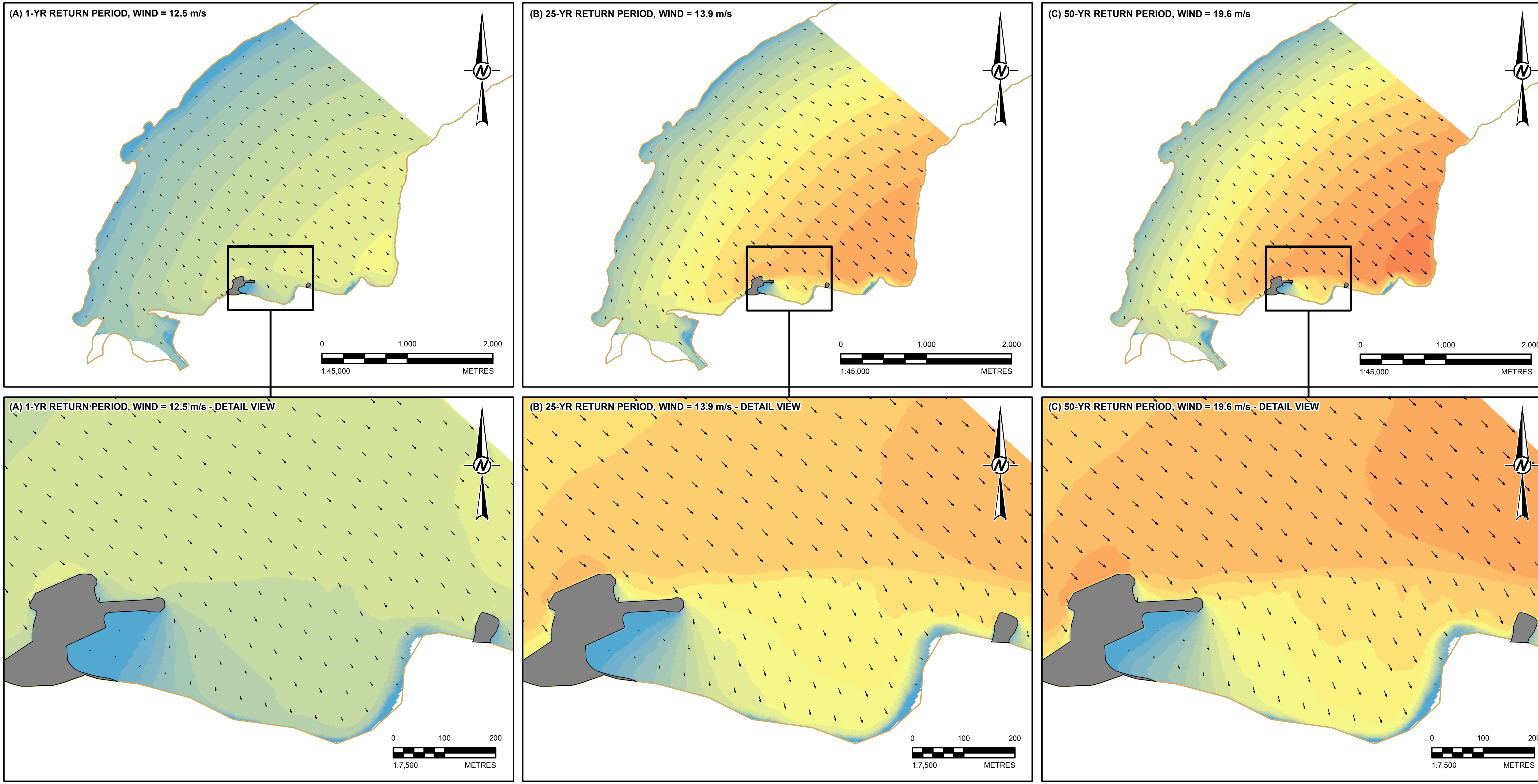
YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
PRE-DEVELOPMENT STEADY-STATE HIGH WATER LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHEAST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.4

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

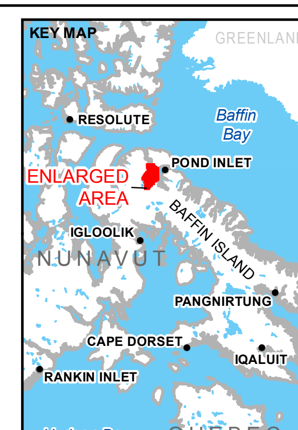


LEGEND

- MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)
- SHORELINE
- MODELLED EXISTING ORE DOCK

SIGNIFICANT WAVE HEIGHT (m)

- HIGH : 1
- MID: 0.5
- LOW : 0



REFERENCE(S)

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

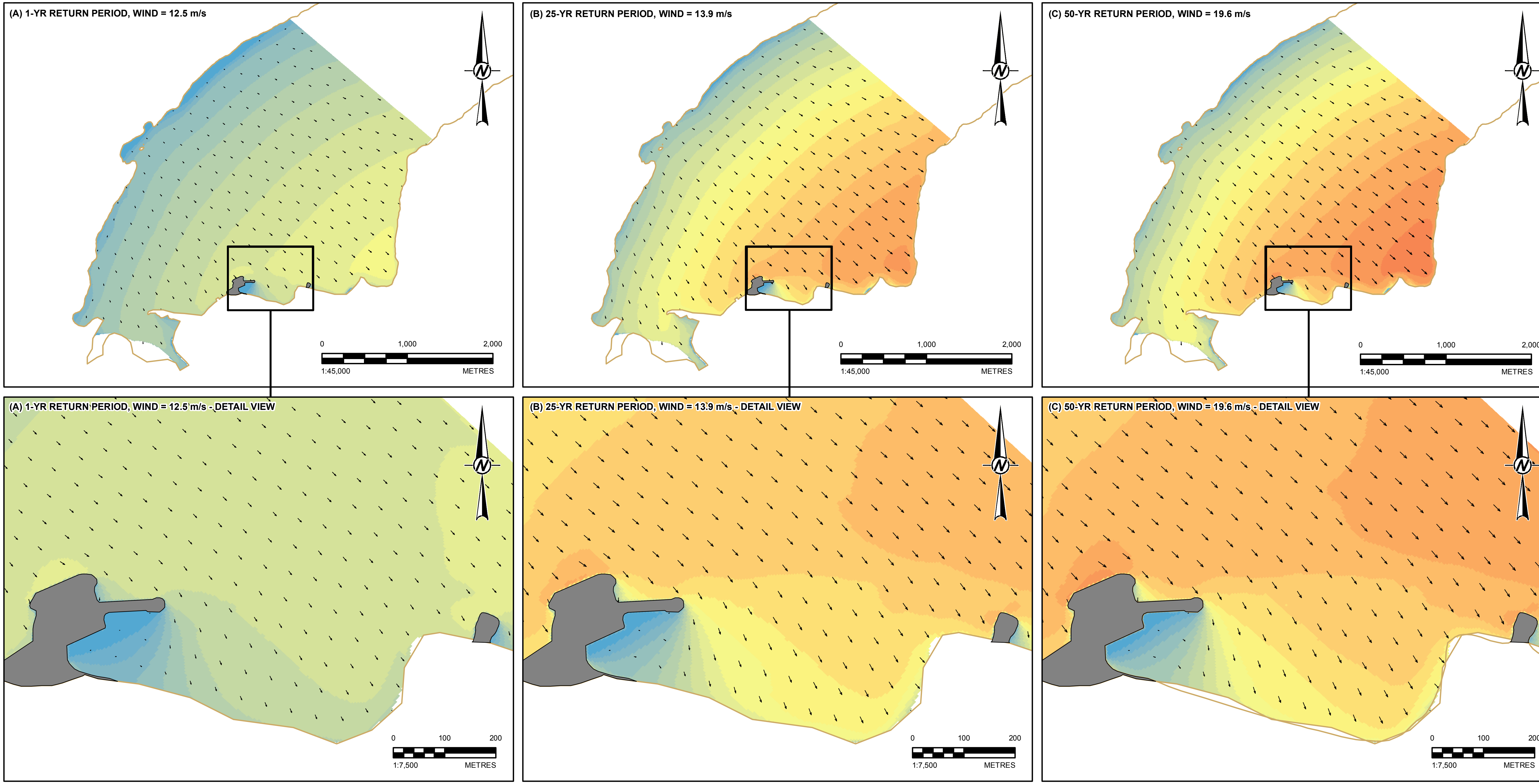
PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

TITLE
PRE-DEVELOPMENT STEADY-STATE MEAN SEA LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHWEST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.5



LEGEND

→ MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)

SHORELINE

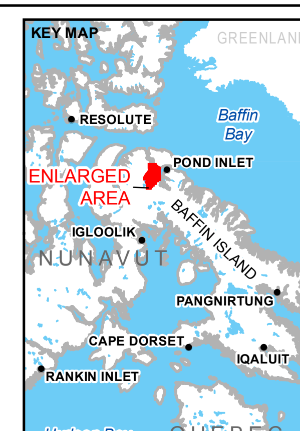
MODELLED EXISTING ORE DOCK

SIGNIFICANT WAVE HEIGHT (m)

HIGH : 1

MID : 0.5

LOW : 0



REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

TITLE
PRE-DEVELOPMENT STEADY-STATE HIGH WATER LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHWEST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.6

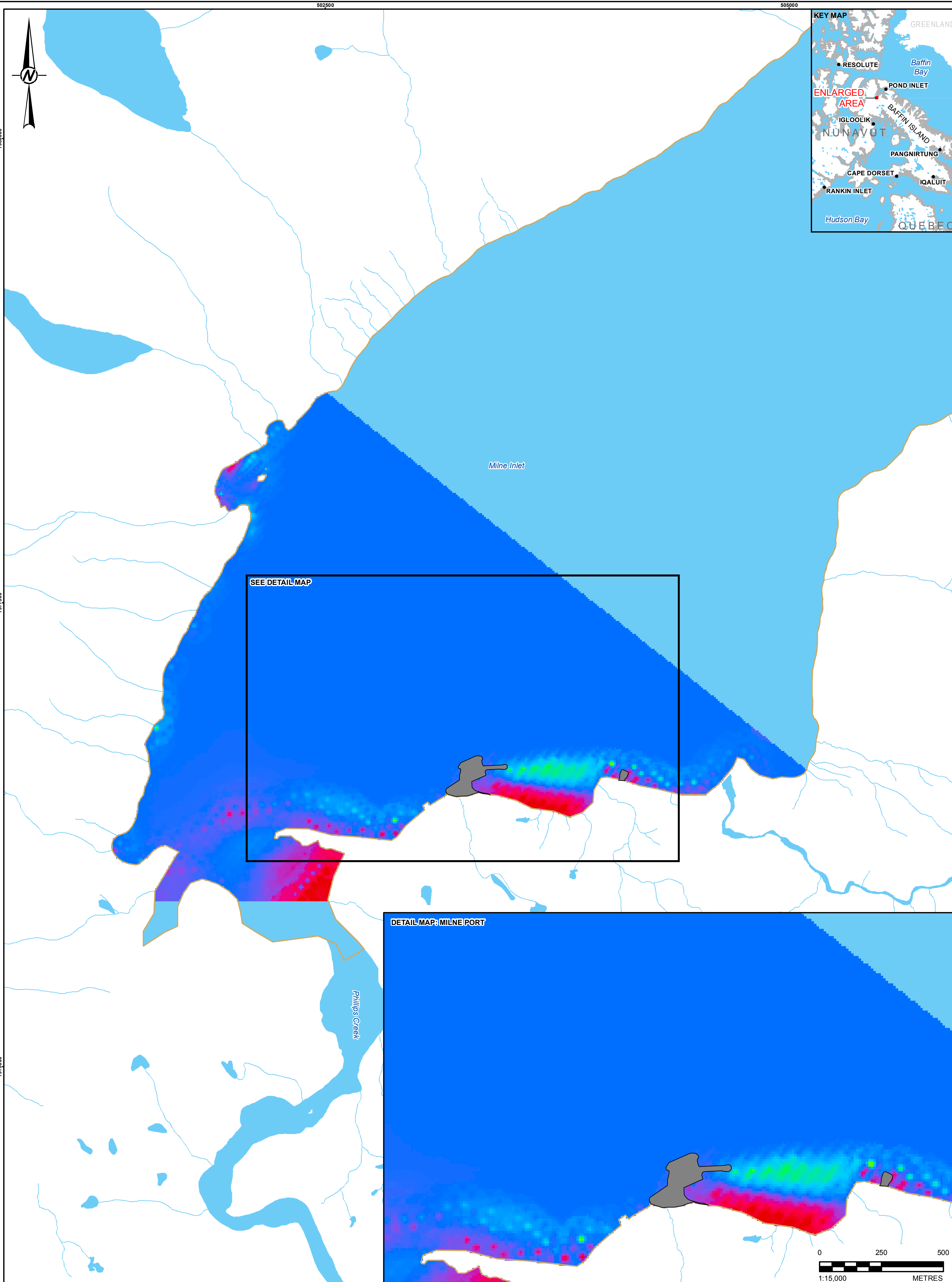
4.3 Nearshore Sediment Transport

Waves approaching the shoreline in the vicinity of Milne Port are responsible for generating oscillatory and steady currents which mobilize and transport sediment in the alongshore and cross-shore directions. Based on interpretations from recent and historical aerial photos and observations gathered during the site visit the nearshore environment at the head of Milne Inlet is characterized by the presence of several morphological indicators, including several beaches and spits that are indicative of a wave-dominated environment (Appendix A).

Sediment transport characteristics in the project area were assessed using the inline Sediment Transport module incorporated in the DELFT-3D package. The model was used to estimate the mobilisation of sediments in the Project area, calculate Eulerian sediment transport rates, and evaluate the potential rate of erosion and deposition under the existing configuration and proposed expansion of the Port. Details and assumptions regarding the specific inputs including sediment characteristics and the depth of sediment available for the sediment transport analysis are included in Appendix B.

The erosion and accretion trends were analyzed in a series of idealized storm simulations, with a duration of 5 days, under a sustained northeast wind. Northeast winds were chosen to simulate the most conservative scenario for sediment transport as it is the direction of maximum fetch and also the direction from which the wind blows with any significance for generating waves that approach the Port. The wind was prescribed so that it ramped up in intensity to the 1 in 50 year return period (Appendix B). Coupling of the wave model with the flow model indicates that northeast winds and waves drive a steady longshore current at the shoreline that moves to the southwest along the head of Milne Inlet.

Under existing conditions, the model predicts that sediment transport potential is most likely to occur primarily on the south shore of Milne Inlet in relatively shallow water (Figure 4.7). Net sediment deposition is represented as positive values in Figure 4.7, and erosion as negative values. Sediment deposition is most likely to occur at the mouth of Phillips Creek on the delta and in the sheltered space immediately to the east of the ore dock. The model suggests that under NE winds and waves, the longshore current along the southern shore of Milne Inlet is from east to west. There is a potential for erosion on the outer edge of the nearshore shelf presumably due to wave shoaling and breaking in this area.



LEGEND

SHORELINE

WATERCOURSE

MODELLED EXISTING ORE DOCK

WATERBODY

CUMULATIVE SEDIMENT EROSION AND DEPOSITION (%)

High : 9.5

Low : -9.5

0 500 1,000

1:20,000 METRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. GEOGRAPHIC NAMES, 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
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
PRE-DEVELOPMENT SEDIMENT TRANSPORT POTENTIAL FROM A NORTHEAST IDEALIZED WIND TIME SERIES (120 HOURS)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	4.7

5.0 NUMERICAL SIMULATIONS OF PROPOSED PORT CONSTRUCTION

5.1 Currents

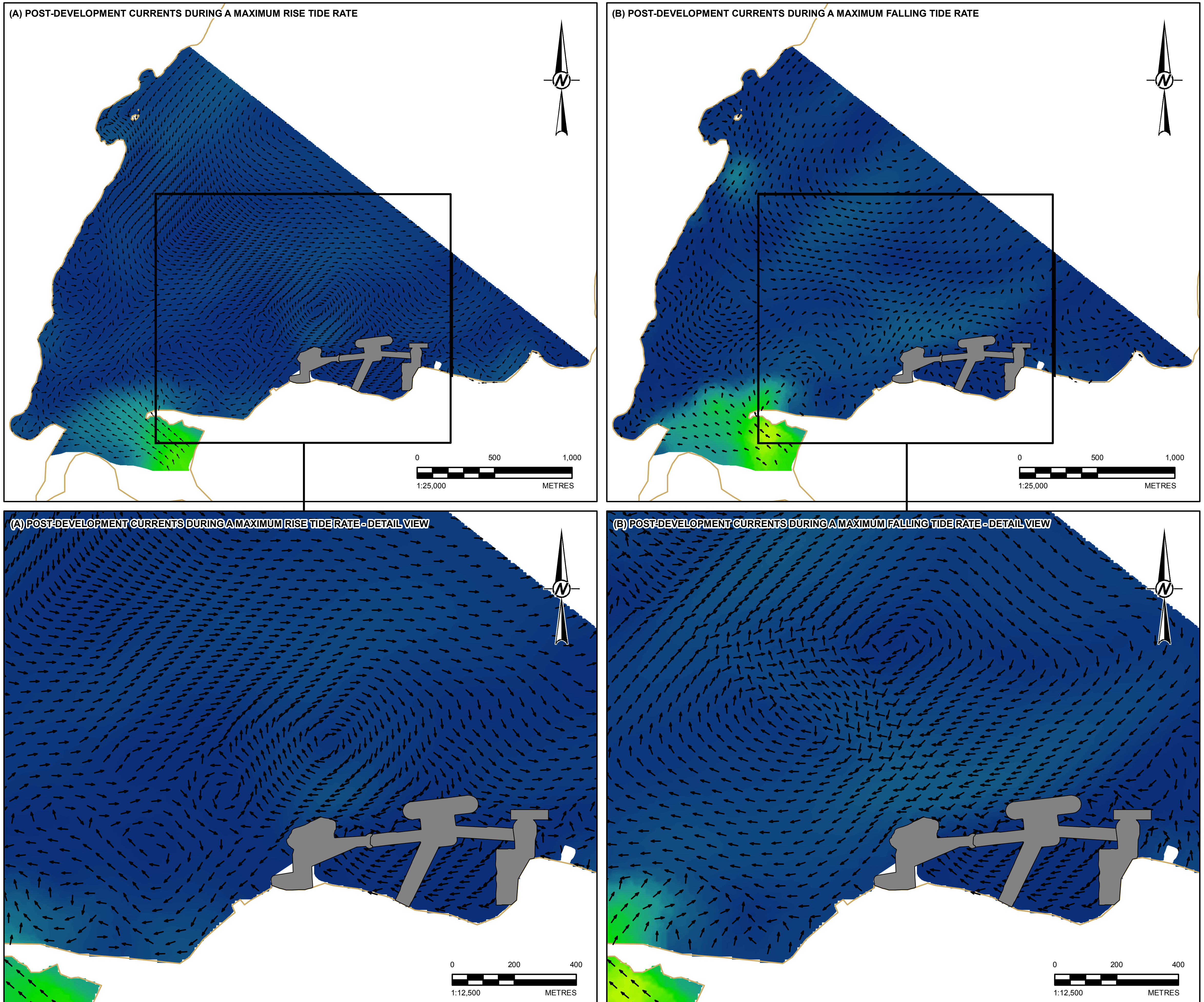
Currents in the local model with the proposed ore dock expansion were simulated across multiple tidal cycles under the same steady state northeast winds as described in Section 4.1. The local flow model was coupled to the wave model, in the same manner as described Section 4.1, so that the radiation stresses of wind generated surface waves were included in the currents. The mean background flow in Milne Inlet during a rising and falling tide, in both speed and direction, was unaltered under the ore dock expansion (Figure 5.1; a,b). Current flow in this area exhibited complicated circulation patterns (i.e. eddies and gyres) and a clockwise circulation was observed. The causeway connection between the proposed ore dock and the freight dock results in a closing off of the area between the east end of the existing ore dock and the adjacent shore (Figure 5.1; c,d). This results in two isolated bodies of water that are separated by the new ore dock’s main access causeway. As a result, the flow velocities in these isolated areas are weaker and driven by wind and locally formed waves but not tides. In front of the proposed ore dock, the flow velocities are relatively unchanged. This is due to the deep water directly in front of the proposed ore dock that is also present under existing conditions. Additionally, the longshore current persists in a clockwise direction on the seaward side of the proposed ore dock.

5.2 Wind-generated waves

The wind-generated wave environment with the proposed ore dock was assessed under the same steady state wind conditions as for the existing condition simulations described in Section 4.2: northeast and northwest winds were simulated for a MSL and HWL. The simulated wave environment, represented by significant wave height and direction, is presented in Figure 5.2 through Figure 5.5.The models suggest that the proposed ore dock does not have a noticeable effect on the wave environment in Milne Inlet for either the northeast and northwest wind, other than in the immediate vicinity of Milne Port.

The model indicates an increase in significant wave height on the seaward side of Milne Port due to wave reflections off the proposed ore dock. A maximum increase of 36 cm and 10 cm in significant wave height was found seaward of the proposed ore dock and freight dock for the northeast and for the northwest wind, respectively. A small localized wave increase occurs on the seaward side of the breakwater East and West of the proposed ore dock due to interactions of reflected waves from the two ore docks and freight dock. Waves are reflected to the northeast or northwest (dependent on the wind direction) by the sheet pile structure of the proposed ore dock and freight dock.

The model predicts that the largest reduction in wave height resulting from the proposed ore dock would occur on the lee side of Milne Port. A near complete reduction of wave heights occurs in the area between the two ore docks and between the proposed ore dock and freight dock because of the complete blockage of offshore wave energy in this region. Waves in this region are generated within the enclosed area in the proposed Project condition



LEGEND

- MEAN CURRENT DIRECTION
- SHORELINE
- MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

DEPTH AVERAGED VELOCITY (m/s)

HIGH : 2

LOW : 0

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

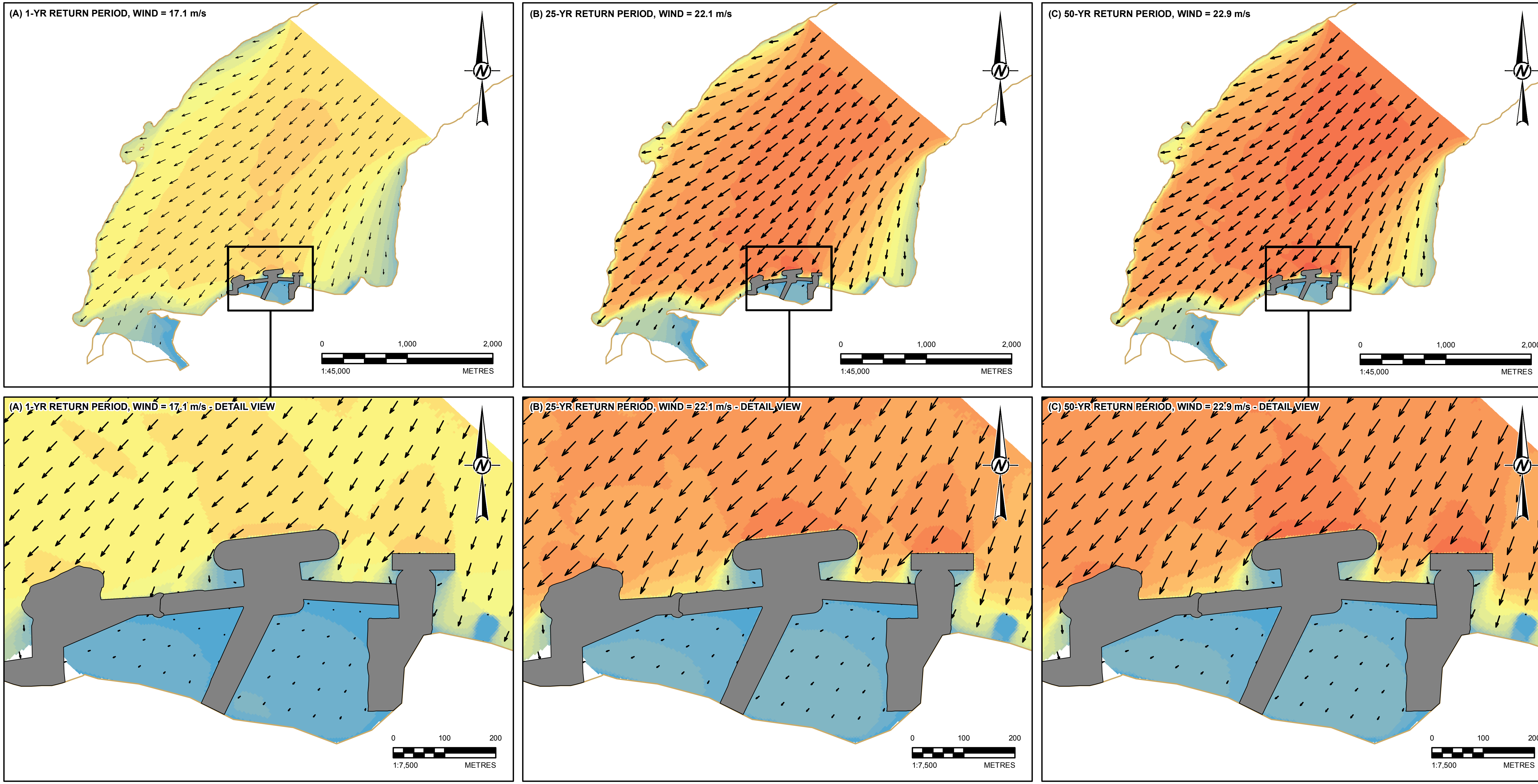
TITLE **POST-DEVELOPMENT CURRENTS DURING A MAXIMUM RISE TIDE AND FALLING TIDE RATE UNDER NORTHEAST WINDS WITH A WAVE ENVIRONMENT**

CONSULTANT

GOLDER

YYYY-MM-DD	6/21/2018
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	5.1

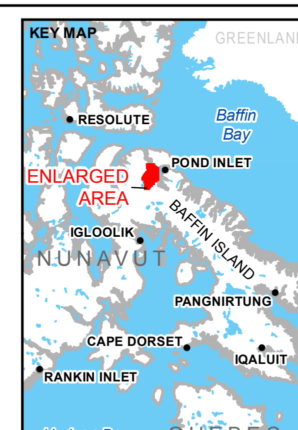


LEGEND

- MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)
- SHORELINE
- MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

SIGNIFICANT WAVE HEIGHT (m)

- HIGH : 2
- MID : 1
- LOW : 0



REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

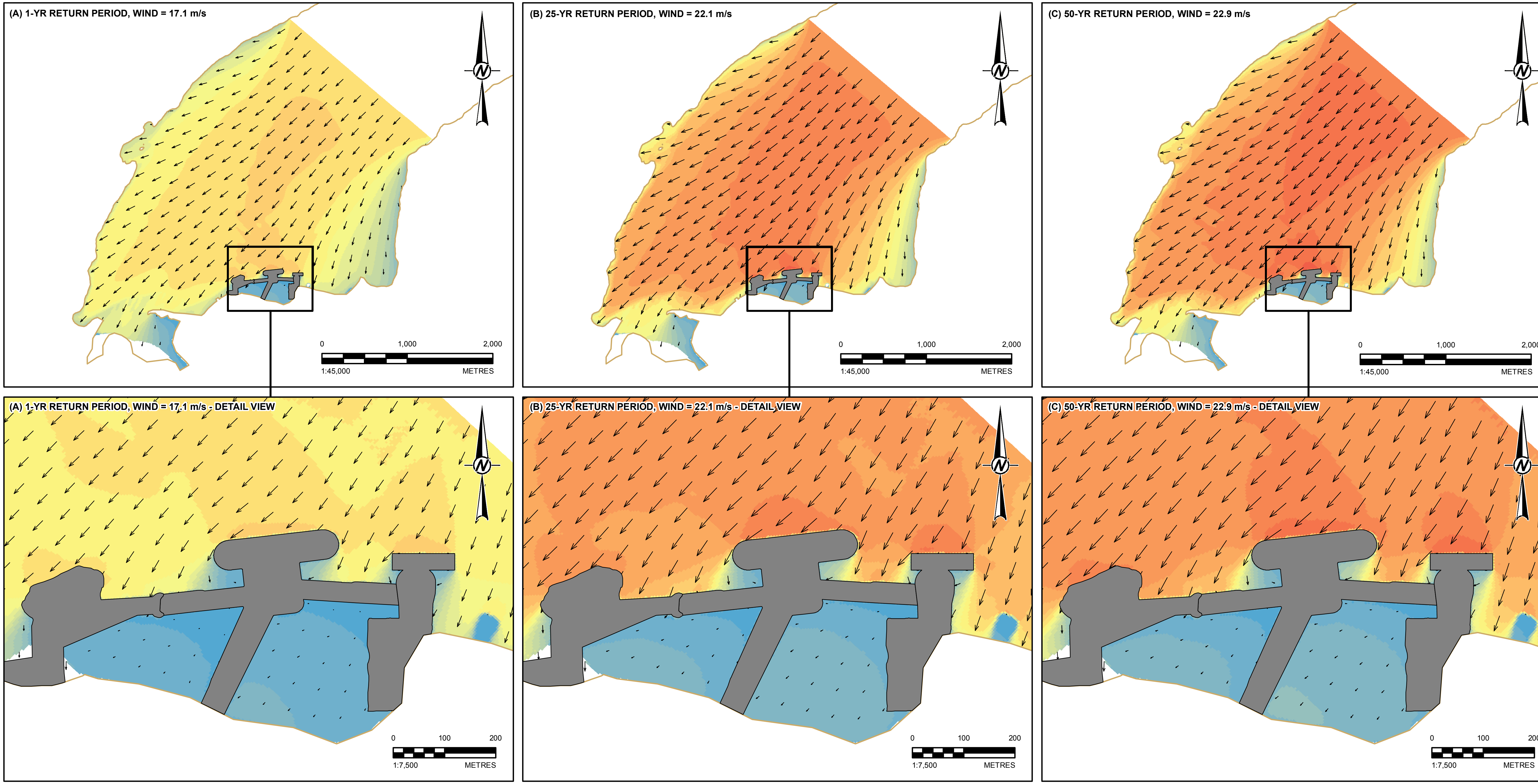
CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
POST-DEVELOPMENT STEADY-STATE MEAN SEA LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHEAST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	5.2



LEGEND

MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)

SHORELINE

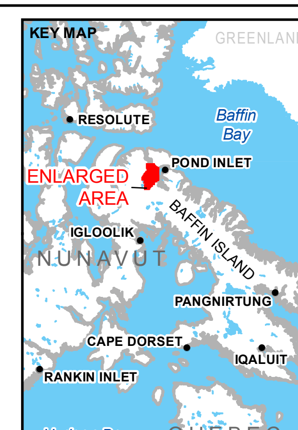
MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

SIGNIFICANT WAVE HEIGHT (m)

HIGH : 2

MID : 1

LOW : 0



REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

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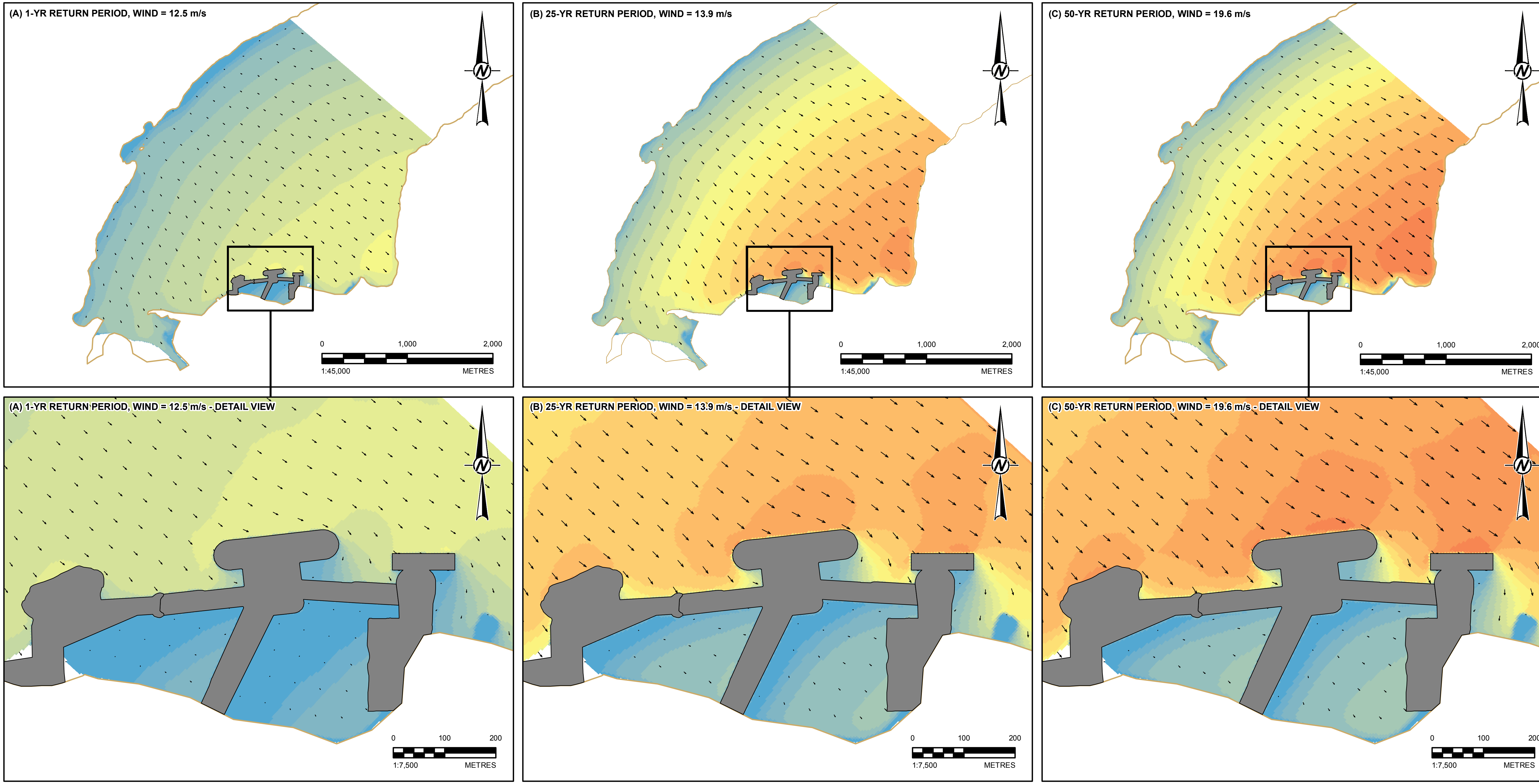
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
POST-DEVELOPMENT STEADY-STATE HIGH WATER LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHEAST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	5-3



LEGEND

MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)

SHORELINE

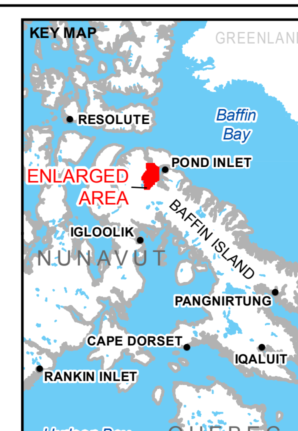
MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

SIGNIFICANT WAVE HEIGHT (m)

HIGH : 1

MID : 0.5

LOW : 0



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BAFFINLAND IRON MINES CORPORATION

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
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PREPARED	AA
REVIEWED	PR
APPROVED	PR

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

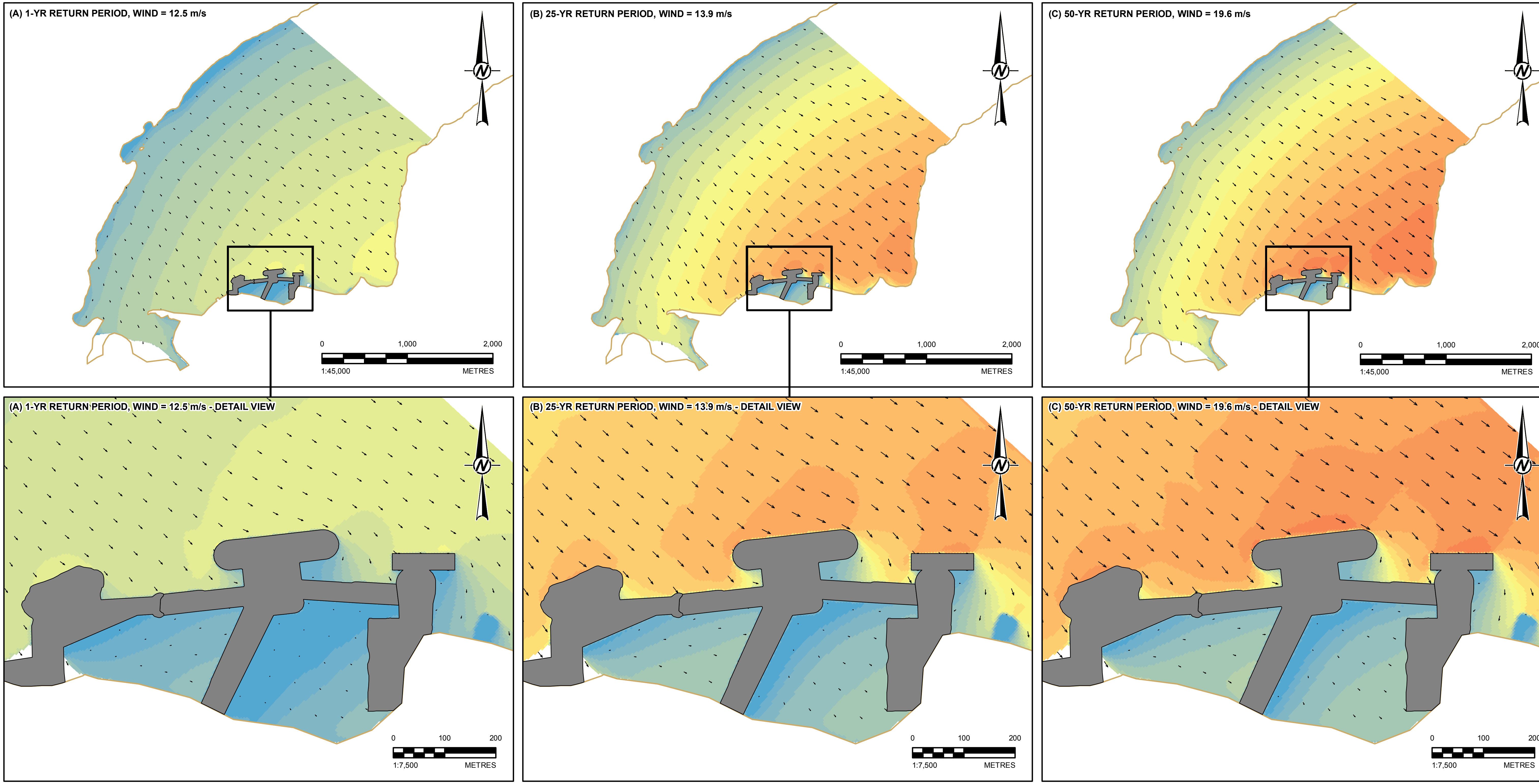
PROJECT

HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE

POST-DEVELOPMENT STEADY-STATE MEAN SEA LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHWEST STORM EVENTS

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	5.4



LEGEND

MEAN WAVE DIRECTION (SCALE: 100 m IN LENGTH = 1 m/s)

SHORELINE

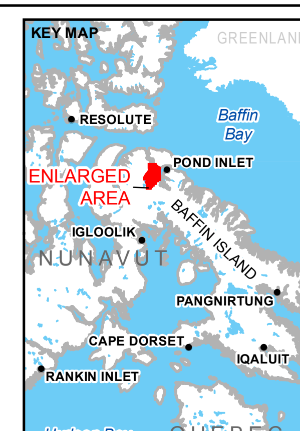
MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

SIGNIFICANT WAVE HEIGHT (m)

HIGH : 1

MID : 0.5

LOW : 0



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MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

CONSULTANT

GOLDER

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PREPARED	AA
REVIEWED	PR
APPROVED	PR

TITLE
POST-DEVELOPMENT STEADY-STATE HIGH WATER LEVEL WAVE HEIGHTS FOR 1-, 25-, AND 50-YEAR NORTHWEST STORM EVENTS

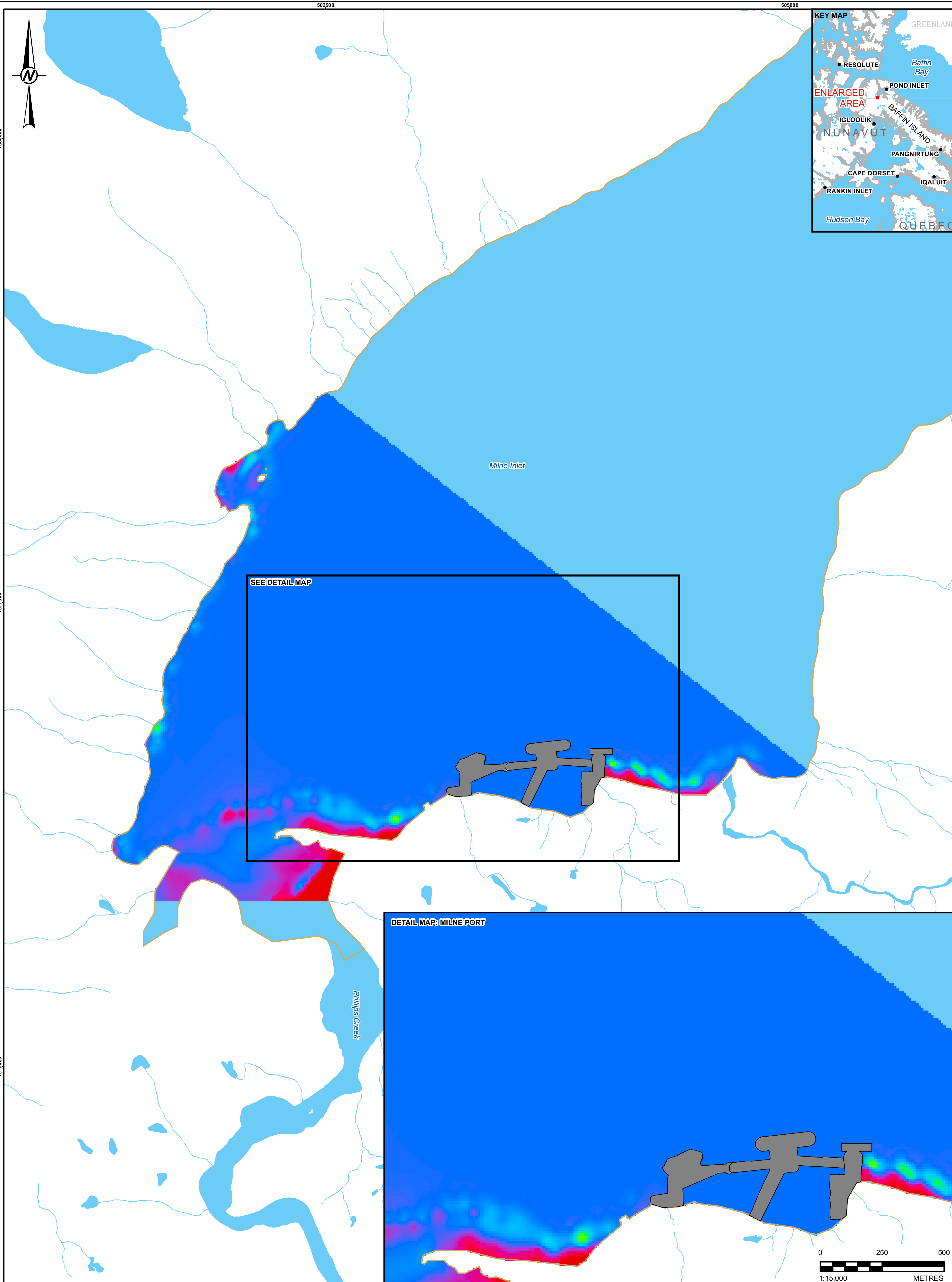
PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	5.5

5.3 Nearshore Sediment Transport

The potential effects of the new ore dock structure on sediment transport patterns and rates of potential erosion and deposition were evaluated by comparing the changes in the cumulative potential erosion and deposition patterns at the end of the 5-day simulation of sustained northeast winds.

Similar to the existing condition, most of the sediment transport occurs on the southern shore of Milne Inlet (Figure 5.6). Net sediment deposition is represented as positive values and erosion as negative values. The model suggests that the addition of the proposed ore dock would not affect the sediment transport patterns in the delta area at the mouth of Phillips Creek. In the embayment behind and to the east of the existing ore dock, the model indicates the following:

- No significant sediment transport is expected to occur in the areas landward of the new ore dock as these areas will be isolated from Milne Inlet as a result of the proposed construction. Formerly, sediment transport in this area would have been largely trapped or contained by the existing ore dock to the west and freight dock to the east; small amounts of sediment may be lost into deeper water from this area under existing conditions; the latter loss will no longer occur under the proposed Project (Phase 2 Proposal).
- Directly seaward of the new ore dock, the water is relatively deep, as in the existing condition, and the wave and current generated bed shear stress is insufficient to drive significant sediment transport.
- It is likely that the freight dock will represent the end of the alongshore transport cell and will act to trap most of the sediment moving to the west; a small proportion of westward alongshore transport may be lost into deeper water at the freight dock.



LEGEND

SHORELINE

WATERCOURSE

MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

WATERBODY

CUMULATIVE SEDIMENT EROSION AND DEPOSITION (%)

High : 9.5

Low : -9.5

0 500 1,000

1:20,000 METRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. GEOGRAPHIC NAMES, 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
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
POST-DEVELOPMENT SEDIMENT TRANSPORT POTENTIAL FROM A NORTHEAST IDEALIZED WIND TIME SERIES (120 HOURS)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	5.6

6.0 EFFECTS ASSESSMENT SUMMARY

The focus of this report was to describe existing current and sediment transport conditions in the Project area, and evaluate the relative incremental changes in near-shore currents, waves, and sediment transport resulting from the construction of a second ore dock immediately east of the existing ore dock, as part of the proposed Milne Port expansion for the Phase 2 Proposal. A summary is provided below on the simulated changes in currents, waves, and sediment transport potential following construction of the new ore dock in Milne Port.

6.1 Currents

In the area directly behind the new ore dock and freight dock (i.e. the wetted area cut-off from Milne Inlet), an average reduction in current speed between 0.05 and 0.15 m/s is predicted (Figure 6.1). Little to no change is predicted to occur in front of the new ore dock or in the adjacent nearshore areas, and the small simulated changes in these areas can be attributed to deviations in the numerical solution (Appendix B). Therefore, the simulations indicate that the alongshore flow will remain mostly unaltered. This is in good agreement with the notion that the existing port structure has already altered alongshore flow in this area and that the new ore dock, also perpendicular to the shoreline, will have minimal additional impact outside of the embayment and immediate vicinity of the structure.

6.2 Wind-generated Waves

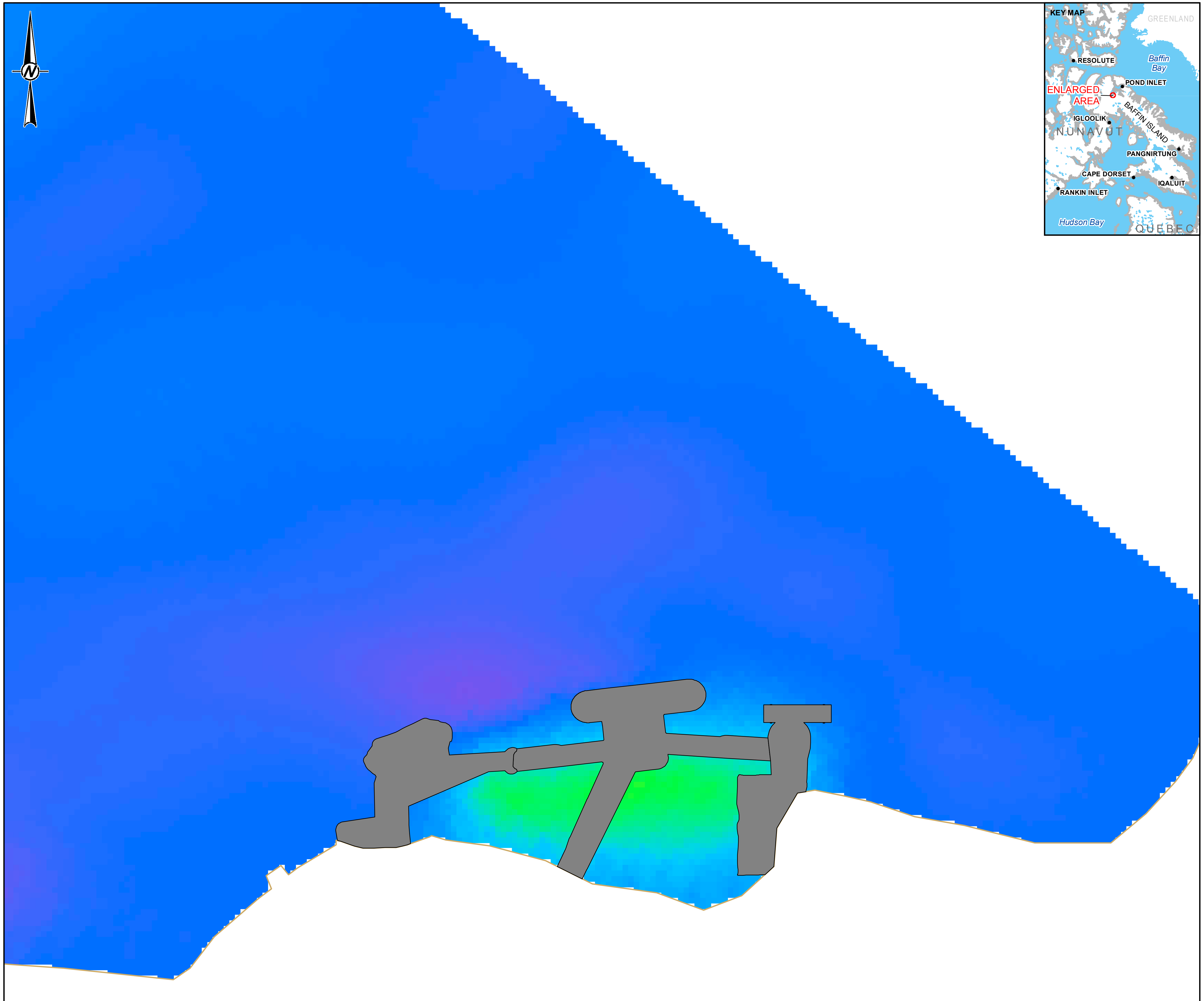
The relative difference in the 50-year return period significant wave height is largest directly on the lee side of the Milne Port expansion. The model predicts a near complete reduction of the waves resulting from the segregation of the area caused by the secondary causeways connecting the new ore dock to the existing ore dock and freight dock (Figure 6.2). Waves on the lee side of the Milne Port expansion are predicted to be locally generated within the area of segregation.

The expansion results in a wave height increase of up to 0.4 m on the seaward side of the new ore dock and freight dock, decreasing radially outwards towards the center of the inlet (Figure 6.2). This wave height increase diminishes to less than 10% past 210 m north of the new ore dock. This change can be explained by wave reflections, which are not present at this location in the existing condition, and the resulting increased wave amplitude from constructive interference between incoming and reflected waves. In contrast, the area directly seaward of the existing ore dock exhibits little to no change, indicating that the reflections occurring at this location are present during both pre- and post-construction stages of the Phase 2 Proposal.

6.3 Sediment Transport

Changes in erosion and deposition and sedimentation transport potential, represented as the percentage increase or decrease between the existing and proposed condition occur predominately in the area sheltered by the proposed ore dock and approved freight dock (Figure 6.3). Net changes in sediment erosion and deposition is represented as positive and negative values, respectively. As discussed in Section 5.3, there is minimal to no sediment transport in the areas behind the proposed ore dock. As a result of the proposed construction the existing erosion and deposition patterns are expected to disappear, a function of these areas being isolated from Milne Inlet. This is indicated by a reduction in sediment transport potential behind the proposed ore dock of approximately 10%.

There is no apparent change in sediment deposition or erosion seaward of the new ore dock resulting from currents or wind-generated waves, or in any of the nearshore areas to the east or west of the Port. The wind and wave conditions considered in the sediment transport simulations have a 2% likelihood of occurrence in any given year and a 40% chance of occurrence over the design life of the project.



LEGEND

SHORELINE

MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

Value

HIGH : 0.15

LOW : -0.15

0 200 400

1:7,000 METRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
AVERAGE ESTIMATED CHANGE IN CURRENTS

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
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REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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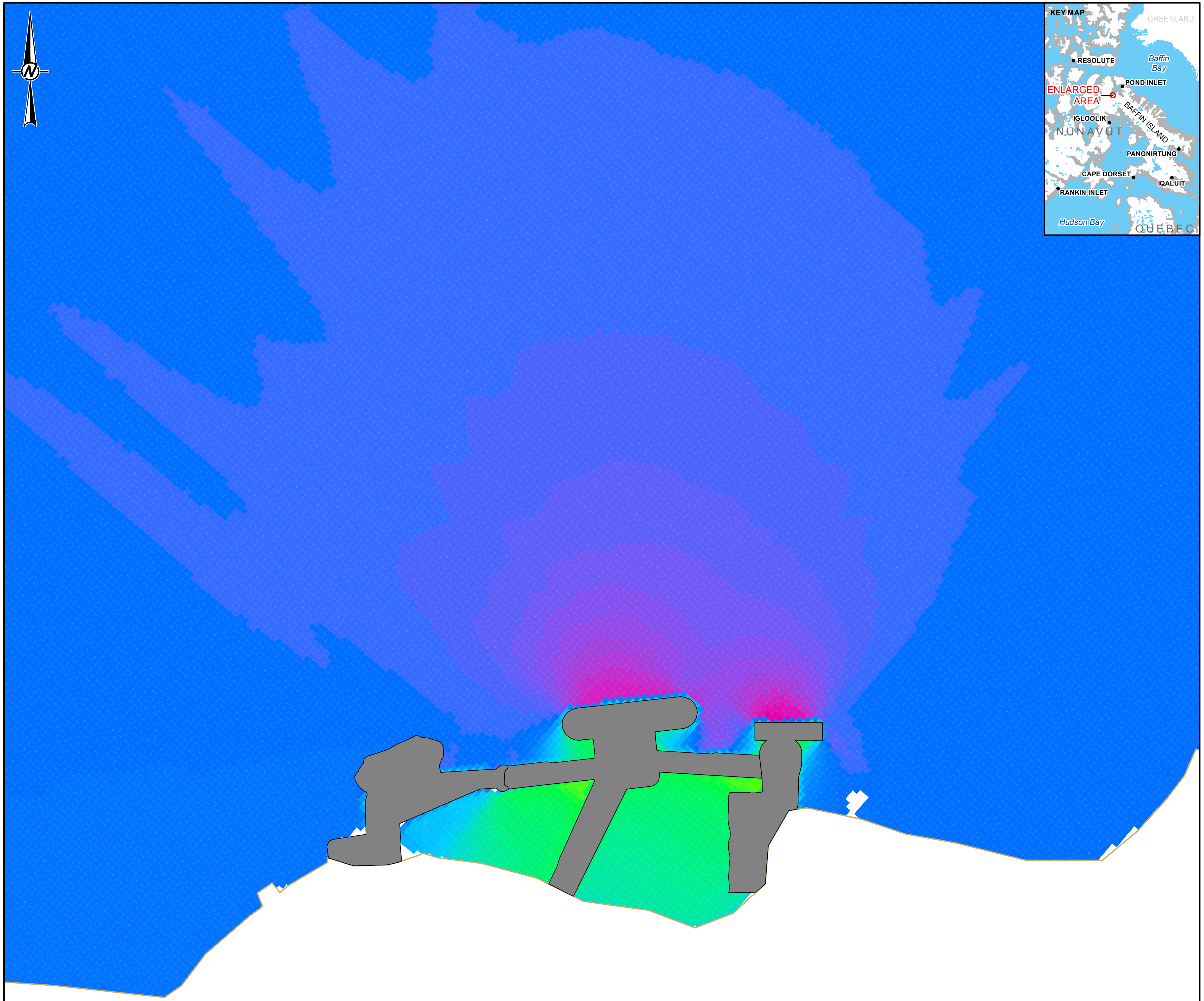

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
MAXIMUM ESTIMATED CHANGE IN WAVE HEIGHTS FOR THE 50-YEAR RETURN PERIOD WIND IN THE NORTHEAST DIRECTION

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	6.2

LEGEND

SHORELINE

MODELLED EXISTING AND PHASE 2 PROPOSAL ORE DOCKS

CUMULATIVE EROSION AND DEPOSITION (%)

HIGH : 9

LOW : -9

0 200 400

1:7,000 METRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CHART 4013647 DATA FOR MODELLING OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC.NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
MAXIMUM ESTIMATED CHANGE IN SEDIMENT TRANSPORT

CONSULTANT

GOLDER

YYYY-MM-DD	2018-06-21
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PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	18000	1	6.3

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25mm

7.0 STUDY LIMITATIONS

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8.0 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.

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Phil Osborne, PhD, PGeo (NAPEG registration L3986)
Principal, Senior Coastal Geomorphologist

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Water Resources Specialist

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Coastal Specialist

DC/PO/IC/DH/lih/lmk

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9.0 REFERENCES

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APPENDIX A

Metocean Data and Physical Characterization

1.0 A-1.0 INTRODUCTION

The purpose of this Appendix is to provide a review and summary of data used as a basis for the hydrodynamic modelling conducted as part of the Environmental Impact Statement (EIS) regarding for the Mary River Phase 2 Expansion Project (Phase 2). The hydrodynamic modelling was used to assess the potential project effects on the marine environment due the proposed construction and operation of a second ore dock to accommodate Cape sized vessels at the Port Site.

This appendix includes the following sub-sections:

- A-2.0 Site Conditions – Available data
- A-2.1 Topography and bathymetry
- A-2.1.1 Shoreline
- A-2.2 Water levels
- A-2.2.1 Tides
- A-2.2.2 Storm surge
- A-2.2.3 Sea level rise
- A-2.3 Water Column Properties
- A-2.3.1 CTD Profiles
- A-2.3.2 Salinity and temperature time series
- A-2.4 Wind
- A-2.5 Currents
- A-2.6 Creek hydrology
- A-2.7 Sediment characteristics
- A-2.7.1 Site visit – Beach photo survey
- A-3.0 References

This Appendix should be read in conjunction with the "*Important Information and Limitations of this Appendix"* as this forms an integral part of this document.

2.0 A-2.0 SITE CONDITIONS – AVAILABLE DATA

Milne Inlet is located along the Northwest coast of Baffin Island in the Qikiqtani Region of Nunavut. The inlet is at the southern extent of a network of fjords connecting to Baffin Bay. Milne Inlet runs nearly north-south extending to Eclipse Sound and Navy Board Inlet (Figure 1-1).

Milne Port is being developed at the southern end of Milne Inlet to support the Baffinland's iron ore exports via the Northern Shipping Route (from Milne Inlet to Baffin Bay) during open-water season (July-October). The general physical conditions at the site are controlled by wind and atmospheric systems, tides and tidal currents, waves, and sea ice. Air temperature typically ranges from -35 °C to 4.5 °C from winter to summer respectively. Sea ice covers the inlet from approximately November to mid- or late July the following year. Mean sea ice thickness is estimated as 1.6 m in most years (Knight Piésold, 2010).

The following subsections list the available data and information pertaining to the site.

2.1 A-2.1 Topography and Bathymetry

Milne Inlet is part of a complex and deep fjord system with several deep basins and mid-channel islands. The water depth near Milne Port is approximately 30 to 50 m and increases to 100 to 150 m water depth approximately 200 m north of the Port site. The inlet is U-shaped with consistent water depths along the middle of the channel with steeply sloping shorelines. A series of three sills are present along the fjord of Milne Inlet separatinging the deep basins of the inlet and which play a role in the circulation and dynamics. Phillips Creek is located to the west of Milne Port and has created a deltaic feature along the southern fjord-head of Milne Inlet. A deep basin is present in the channel near Koluktoo Bay with water depths reaching 318 m. Robertson River feeds into the west side of Koluktoo Bay. North of Koluktoo Bay are a series of small mid-channel islands and deep basins. The deepest portion of Milne Inlet reaches 841 m water depth. North of Ragged Island Milne Inlet joins Eclipse Sound to the east-northeast and Navy Board Inlet to the north.

The following is a summary of topographic and bathymetric datasets available to support the hydrodynamic model set up and ballast water modelling at the Milne Inlet and Port site (Figure A-2.1):

- Detailed geophysical surveys of the seafloor were undertaken by Terra Remote Sensing in September 2008 in the Milne Port vicinity. Subsequent single-beam surveys were undertaken by Enterprises Normand Juneau Inc. (ENJI) in September of 2010. These data were subsequently merged into a unified XYZ dataset, referenced vertically to Chart Datum and geodetic datum.
- Hydrographic surveys collected by Canadian Hydrographic Service (CHS) were collected in a series of depth soundings from 1964 to 1966. The data sets acquired from CHS include the following file numbers (year of collection):
  - 3380, 3395, 3477 (1964-1965)
  - 28956, 28962, 2301836 (1965-1966)
  - 66215 (1974)
- Hydrographic surveys collected by CHS were collected by multi-beam survey 2008 to 2014. The data sets acquired from CHS include the following file numbers (year of collection):
  - 4012386 (2008)
  - 4013439, 4013646, 4013647, 4013648 (2013-2014)

The data is referenced vertically to Canadian Geodetic Vertical Datum, CGVD28.

Recent CHS and contractor multibeam surveys provide good coverage of the Milne Inlet study area and good coverage for hydrodynamic model requirements. Data coverage becomes sparser in Eclipse sound.

2.1.1 A-2.1.1 Shoreline

Shoreline delineation is evaluated to develop the closed boundaries of the modeling grid. The following sources are used to construct the shoreline implemented in the model:

- GSHHG – A Global Self-consistent, Hierarchical, High-resolution Geography Database (NOAA 2016).
- Satellite imagery (Baffinland 2016, Bing Online Imagery 2003).
- Previous model boundary provided by Coastal and Ocean Resources Inc. (CORI 2014)

A comparison of the shoreline sources with the aerial images showed offsets in the horizontal position near the project site. Although the sources of the CORI shoreline data is unknown, it matches the full resolution GSHHG shoreline data sourced by NOAA. In the previous study (CORI 2014) the shoreline was not improved on the south boundary where the Milne Port is located. A high resolution shoreline was digitized close to the project site and replaced the GSHHS boundary to improve the geometry of the modelling mesh in this region and better capture the circulation in the intertidal zones of the upper fjord. The shoreline represent the high water level. The latter is considered important for resolution of wave and current processes in the vicinity of the Port.

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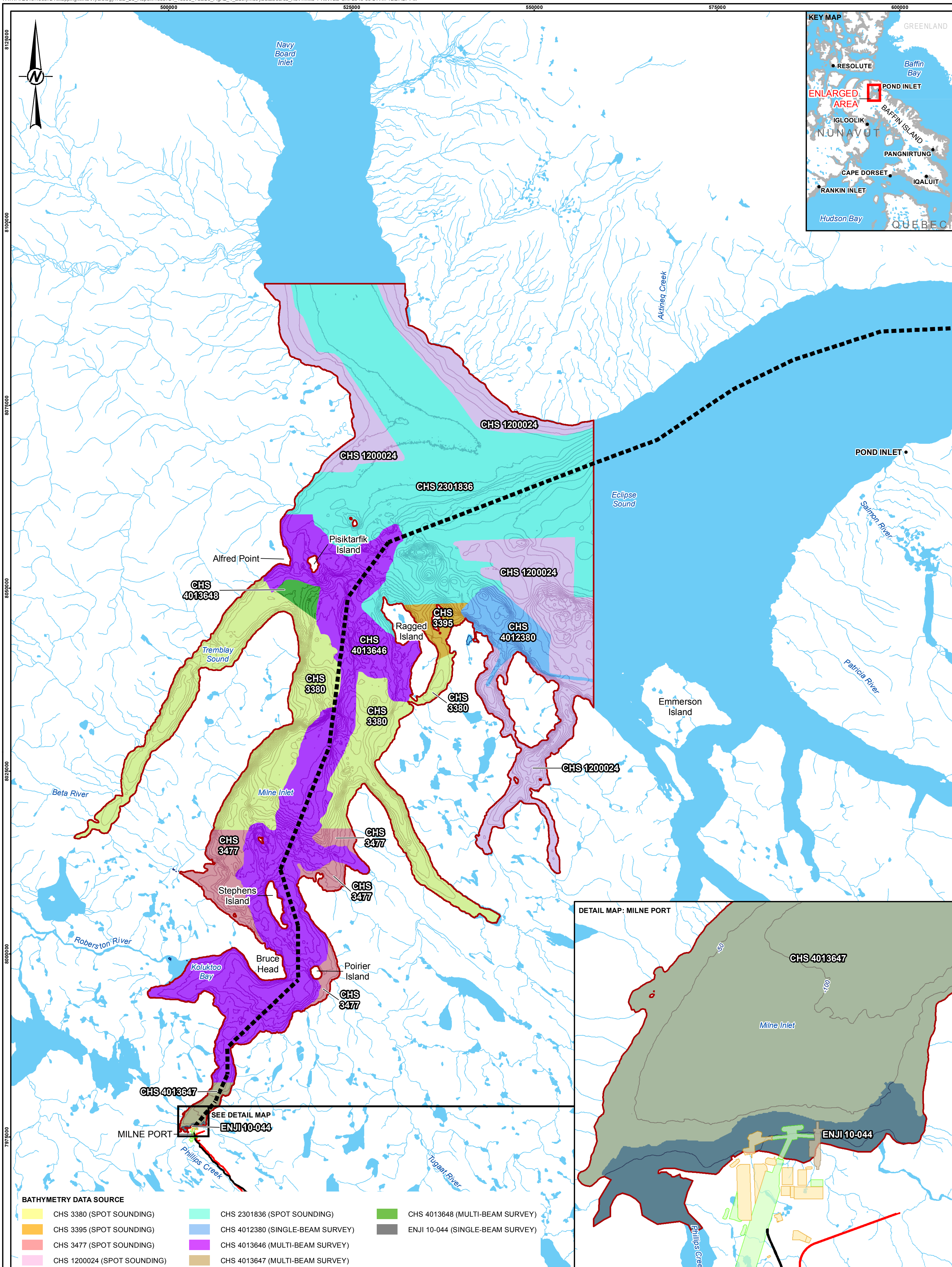

LEGEND

- COMMUNITY
- BATHYMETRIC CONTOUR (50 m INTERVAL)
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- SHIPPING ROUTE (APPROXIMATE)
- WATERCOURSE
- MODELLED AREA
- EXISTING ORE DOCK
- NEW ORE DOCK AND CAUSEWAYS
- EXISTING FREIGHT DOCK AND CAUSEWAY
- WATERBODY

0 10 20

1:500,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. BATHYMETRY CREATED BY GOLDER FROM MULTIPLE DATA SOURCES. CHART 3380, 3395, 3477, 1200024, 2301836, 4012380, 4013646, 4013647, AND 4013648 OBTAINED FROM THE CANADIAN HYDROGRAPHIC SERVICE AND PURSUANT TO CHS DIRECT USER LICENCE NO. 2017-0531-1260-G. ENJI CHART 10-044 OBTAINED FROM ENTREPRISES NORMAND JUNEAU INC. GEOGRAPHIC NAMES, 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
HYDRODYNAMIC MODELLING REPORT – MILNE PORT – PHASE 2 PROPOSAL

TITLE
OVERVIEW OF AVAILABLE BATHYMETRY DATA

CONSULTANT
GOLDER

YYYY-MM-DD	2018-06-21
DESIGNED	IC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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2.2 A-2.2 Water Levels

Temporal and spatial variation in water level is a key forcing condition of hydrodynamics in Milne Inlet. Water levels at coastal sites reflect the combined contribution from:

- Mean sea level
- Astronomical tides
- Meteorological effects ("water level residuals")

The tidal component of water levels is cyclical and largely predictable, being generated primarily by astronomical forcing.

Storm surge typically represents the greatest contribution to the residual water level, which is the difference between the absolute / total water level (as measured by a tide gauge) and the astronomical (tidal) component. The terms "storm surge" and "residual water level" are therefore used interchangeably in this report.

2.2.1 A-2.2.1 Tides

Astronomical tides and winds are important mechanisms forcing water level variation and circulation within the study area. Based on a review of potential data sources, direct water level measurements were available for the period between August and October 2014 at four locations within the modeling domain: Alfred Point, Ragged Island, Emmerson Island, and Milne Port. In addition, Golder extracted harmonic constants from the Topex Poseidon (TPXO) 8.0 database, the current version of global model of ocean tides, using Deltares' Delft Dashboard along the open boundaries. This database is built from track average data obtained with OSU Tidal Software (OTIS) and Laplace Tidal Equations (Egbert & Erofeeva, 2010).

The tides at the project site are semidiurnal. Minimum and maximum tidal ranges at the end of Milne Inlet are approximately 2.2 m to 2.3 m respectively (Knight Piésold 2010, CHS, tide station 5791). Five temporary tide stations were installed by CHS from 1964 -1988 in the region near Milne Inlet. A tide station was installed in Milne Inlet, near Milne Port by ASL Environmental Sciences Ltd (ASL) and Coastal and Ocean Resources Ltd (CORI) in the 2014 ice free season. Table A-2.1 summarizes the calculated tidal amplitudes and phases of the five CHS stations from 1964 -1988 analysed by Rabinovich and Fine (2010).

Table A-2.1: Tidal range and phases of temporary tide stations near Milne Inlet

Tidal Harmonic	Milne Inlet		Koluktoo Bay		Pisiktarfik Island		Pond Inlet		Nova Zembla Island	
	H (cm)	G (°)	H (cm)	G (°)	H (cm)	G (°)	H (cm)	G (°)	H (cm)	G (°)
Q_1	1.3	180.9	0.3	251.9	0.8	261.9	0.7	200.0	0.9	134.2
O_1	7.3	207.0	8.1	213.8	7.7	207.4	8.8	211.0	7.9	202.8
K_1	23.3	262.9	25.7	264.2	23.0	249.4	25.8	252.6	20.9	257.5
N_2	12.2	103.0	12.8	105.5	18.1	103.5	11.4	110.6	10.3	114.3
M_2	56.5	137.2	57.8	139.9	51.6	134.3	53.8	136.7	41.5	139.6
S_2	23.5	187.6	19.3	196.6	26.6	178.7	18.6	179.9	18.9	182.5
F (tidal factor)	0.38		0.44		0.39		0.48		0.48	

Note: H= height; G= tidal phases referenced to Greenwich, England. F= tidal factor ($\frac{K_1+O_1}{M_2+S_2}$); Table source: Rabinovich and Fine (2010).

Water level measurements recorded in 2014, 2015, and 2016 by ASL Environmental and CORI show good agreement with the tidal harmonics analysis results in Table A-2.1 (ASL 2014; CORI 2014).

2.3 A-2.3 Water Column Properties

The Arctic Ocean and Atlantic Ocean are both water mass sources for Baffin Bay and Milne Inlet. The structure of the water temperature and salinity in Milne Inlet changes seasonally and with depth. Observations of the vertical structure during winter with sea ice cover showed nearly uniform values with water temperature near -1.5 °C and salinity at 32 (Knight Piésold, 2010; Buckley et al., 1987). In open water season the water column structure becomes stratified with less saline warmer water in the surface layer extending to the pycnocline at approximately 5 to 10 m water depth. Below the pycnocline is a thin cold-saline water mass extending approximately to 30 m water depth. The lowest water mass is relatively uniform extending to water depths of >100 m (Fine and Rabinovich, 2013; Knight Piésold, 2010).

Water column data collection was undertaken in the study area in 1980, 1981, 2008, 2010, 2014, 2015, and 2016. The measurements of water column properties include conductivity, temperature and depth profiles (CTD) and stationary measurements at select locations, with results summarized in the below sections.

2.3.1 A-2.3.1 CTD Profiles

The water column structure of Milne Inlet varies with depth and from ice-cover season to open water season. During ice-cover season CTD profiles collected near Cape Hatt in June 1980 by Buckley et al (1987), showed the water column was well mixed with water temperature near freezing (-1.5 °C) and salinity values of 32 PSU from near the surface to 35 m water depth. Below 35 m the salinity gradually increased to 32.5 and above. A uniform water column density for under the ice conditions are typical for the region and reflect convective overturning driven by water cooling near the surface layer and brine rejection (Knight Piésold, 2010; Buckley et al, 1987).

In open water season the water column becomes stratified with three distinct density layers. The surface layer has the highest freshwater input from surface runoff, creek/river discharge, and sea ice melt. The thin surface layer has been observed to be 2 to 5 m thick with a temperature range of 0.5 °C up to 10 °C and a salinity range from 5 to 30 PSU (CORI, 2014; Buckley et al, 1987). The pycnocline typically begins at depths between 5 to 10 m water depth and extends to 30 to 50 m water depth (Buckley et al., 1987; Fissel et al. 1981). The intermediate water layer below the pycnocline is generally from 50 to 100 m water depth and can be characterized by nearly steady temperature and salinity year round and spatially along Milne Inlet to Eclipse Sound. In the stable intermediate water layer, temperature is around -1.5 °C and salinity is 32.3 PSU (CORI, 2014). Below 100 m water depth the temperature and salinity gradually increase to relatively warmer and saltier water as values approach -0.5 °C and 33.5 PSU respectively at depths below 200 m (CORI, 2014).

Of the three distinct water masses, only the surface layer varies spatially and temporally. Spatially, slight differences were observed along and across Milne Inlet. Surface water temperature was highest Milne Port, with surface water temperature gradually decreasing along Milne Inlet towards Eclipse Sound and Cape Hatt. The upper water mass tended to extend to 3 m water depth close to Milne Port and increase to 5 m water depth moving north. Salinity follows a similar trend along the channel with the upper layer thickness slightly increasing along the channel (CORI 2014). Slight local variations in across channel stratification were observed near Ragged Island to Alfred Point, while across Milne Inlet near Eskimo Inlet temperature and salinity were horizontally layered. The majority of CTD profiles collected in the region were measured in August, while a few additional samples were collected later in the open water season in October. The surface water mass was variable from the August profiles to the October profiles (CORI 2014). In the upper 5 m, salinity varied from 5-10 PSU in August to 29-30 in October. Additionally salinity decreased from 10 m water depth through to the seabed by 0.5-1 PSU from August to October. Similarly temperature in the upper 5 m varied from 4-7 °C in August to -0.5 °C in October. At depths below 15 m temperature increased by 1-2 °C for all locations (CORI 2014).

The spatial and temporal trends described for the 2014 data collection effort by CORI (2014) and ASL (2014) were consistent with observations of CTD profiles measured by Buckley et al (1987), Knight Piésold (2010), and CORI (2016). The consistency indicates that seasonal trends and variability, particularly in the surface layer, have been relatively stable for the extent of the studies conducted in the region (1987 to 2016).

Recent available CTD profile data collected at Milne Inlet include 23 profiles collected in August 2014, and 3 profiles collected October 2014 (ASL 2014, CORI 2014). In August 2015, 18 CTD profiles were collected, and 13 additional CTD profiles were collected in August 2016 (ASL 2015; CORI 2016). Table A-2.2 provides a summary of CTD profiles collected from 2014-2016 and profile locations. Plots of CTD profiles measured in 2014 can be found in the CORI 2014 report in section 3.7.

The CTD data coverage provides good spatial distribution of water column properties within Milne Inlet. The majority of profiles were collected in the month of August. Time series data and the profiles collected in October demonstrate that there are temporal variations, primarily in the upper water column structure, and the transition from August to October is not as well documented in CTD profiles.

Table A-2.2: CTD profile locations and sampling events

Station	Latitude (°N)	Longitude (°W)	Approx. Max. Sample Depth (m)	Dates Sampled			
Ore Dock	71.89218	80.90273	47	Aug-14	-	Aug-15	Aug-16
Stephens Island	72.10737	80.49917	145	Aug-14	-	Aug-15	Aug-16
Ragged Island	72.46245	80.048	50	Aug-14	Oct-14	Aug-15	-
Alfred Point	72.57606	80.54727	47	Aug-14	Oct-14	Aug-15	-
Emmerson Island	72.36517	78.8226	57	Aug-14	Oct-14	-	-
Site 5	71.90228	80.89075	92	Aug-14	-	Aug-15	Aug-16
Site 6	71.94029	80.79725	146	Aug-14	-	Aug-15	Aug-16
Site 7	71.98953	80.78345	116	Aug-14	-	Aug-15	Aug-16
Site 8	72.07235	80.82967	137	Aug-14	-	Aug-15	Aug-16
Site 9	72.03675	80.62513	230	Aug-14	-	Aug-15	Aug-16
Site 10	72.14095	80.49721	233	Aug-14	-	Aug-15	Aug-16
Site 11	72.16817	80.72319	283	Aug-14	-	Aug-15	Aug-16
Site 12	72.24073	80.57346	193	Aug-14	-	Aug-15	Aug-16
Site 13	72.28783	80.32516	263	Aug-14	-	Aug-15	Aug-16
Site 14	72.30577	80.46474	236	Aug-14	-	Aug-15	Aug-16
Site 15	72.3285	80.6109	220	Aug-14	-	Aug-15	Aug-16
Site 16	72.36382	80.34004	274	Aug-14	-	Aug-15	-
Site 17	72.43878	80.26983	285	Aug-14	-	Aug-15	-

Station	Latitude (°N)	Longitude (°W)	Approx. Max. Sample Depth (m)	Dates Sampled			
Site 18	72.53128	80.29395	292	Aug-14	-	Aug-15	-
Site 19	72.40543	79.18366	160	Aug-14	-	-	-
Site 20	72.3508	79.08184	268	Aug-14	-	-	-
Site 21	72.30959	78.87793	289	Aug-14	-	-	-
Site 22	72.37353	78.66968	193	Aug-14	-	-	-

2.3.2 A-2.3.2 Salinity and Temperature Time Series

Time series of salinity and temperature were measured at four locations (Stephens Island, Ragged Island, Alfred Point, and Emmerson Island) for two months in 2014, and additional measurements were collected at Stephens Island from August 2015 to August 2016 (ASL 2014; CORI 2014; CORI 2016). The CT sensors on the Ragged Island, Alfred Point, and Emmerson Island moorings were deployed at approximately 40-45 m water depth, while the Stephens Island CT sensor was deployed at approximately 151 m water depth during the 2014 deployment and 81 m water depth during the 2015-2016 deployment. Table A-2.3 summarizes the station, data collection duration, depth, and location. Time series plots for the temperature and salinity can be found in CORI 2014 (page 71 and 76), ASL 2015 (page 16 to 18), and CORI 2016 (page 17 to 19). Time series of temperature and salinity values correspond with CTD profiles collected along Milne Inlet. The time series data provide good representation of temporal variances at the four deployment sites.

Table A-2.3: Summary of Salinity and Temperature Timeseries Data

Station	Deployment Date	Recovery Date	Mean Depth (m)	Latitude (DD.dddd)	Longitude (DD.dddd)	Mean Salinity (PSU)/ Mean Temperature (°C)	Minimum Salinity (PSU)/ Mean Temperature (°C)	Maximum Salinity (PSU)/ Mean Temperature (°C)
Alfred Point	08-Aug-2014	09-Oct-2014	42	72.57605N	78.54648W	31.5 / 0.4	30.0 / -1.6	32.3 / 2.6
Ragged Island	08-Aug-2014	09-Oct-2014	44	72.46223N	80.04913W	31.7 / 0.0	30.5 / -1.5	32.3 / 1.7
Emmerson Island	08-Aug-2014	09-Oct-2014	41	72.36787N	78.82102W	31.6 / 0.4	30.6 / -1.1	32.5 / 1.8
Stephens Island	07-Aug-2014	03-Dec-2014	151	72.10712N	80.49693W	32.8 / -1.1	32.7 / -1.2	32.9 / -1.0
Stephens Island	23-Aug-2015	17-Aug-2016	81	72.10683N	80.49708W	32.3 / -0.9	31.0 / -1.6	32.8 / 1.2

Note: Data summarized above were measured and reported by ASL Environmental, ITR, and CORI (ASL 2014; ASL 2015; CORI 2014).

2.4 A-2.4 Wind

Wind induced circulation is one contributing factor to the hydrodynamics and circulation patterns of Milne Inlet. The near surface water layers are typically stratified during the open water season, so wind plays an important role in mixing near surface layers, and supressing or promoting upwelling and downwelling patterns and estuarine circulation in the fjord.

There are two sources of wind data near the project site; a meteorological station near Milne Port and North American Regional Reanalysis (NARR) data. The meteorological station is located at Milne Port at 71.886°N and 80.885°W. Data are available for the station from 2006 to 2015. CORI (2014) conducted an analysis comparing NARR wind data with the measured wind data at the Milne Port station and found there was good agreement between the two data sets from July 1 to October 31, 2014 to use the NARR spatial data for modelling (CORI, section 3.5, 2014).

The North American Regional Reanalysis (NARR) is a regional reanalysis of North America containing temperatures, winds, moisture, soil data, and dozens of other parameters. Produced by the National Centers for Environmental Prediction (NCEP), the NARR model takes in, or assimilates, a great amount of observational data to produce a long-term picture of weather over North America.

The NARR products are on the Eta 221 32 km grid at 29 pressure levels in the Lambert conformal conic projection. The 3-hourly u- and v-wind data at 10 m were downloaded for January 2014 to January 2017, extracted and gridded to a regular geographical grid with a horizontal resolution of 0.25◦latitude and longitude. The extracted data were concatenated into a single wind time series. The closest grid cell centered at: 72.0371◦N and 81.111◦W approximately 17 km from Milne Port. (https://www.esrl.noaa.gov/psd/data/narr/format.html)

Figure A-2.2 shows the time series of monthly average wind data of the NARR grid and Milne Port Station. Historical NARR data were analyzed in the current study (i.e. from 1979 to 2006) along with available meteorological data measured at the Milne Port meteorological station. Measured wind data shows a higher wind speed compared to NARR grid points. Table A-2.4 provides a summary of the statistics of wind speeds at select NARR grid points and the Milne Port Station. Both measured and modelled wind speed time series are in good agreement. However, wind speeds at the NARR grid point closest to the project site are lower in magnitude compared with the measured data at the Milne Port Station.

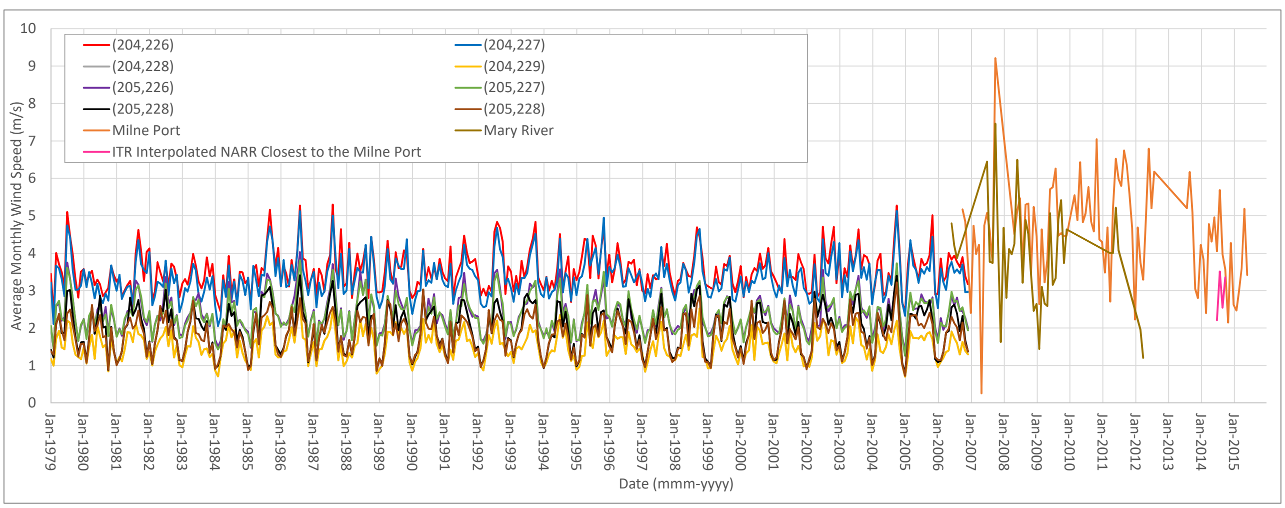

Figure A-*2.2*: Monthly mean wind speed time series for ten grid points of NARR network

Table A-2.4: Wind Speed Statistics

Station ID	Monthly Mean Wind Speed (m/s)	Monthly Max wind Speed (m/s)	Monthly Min Wind Speed (m/s)
NARR (204,226) 1979 - 2006	3.5	5.3	2.3
NARR (204,227) 1979 - 2006	3.4	5.1	2.1
NARR (204,228) 1979 - 2006	1.5	2.6	0.7
NARR (204,229) 1979 - 2006	1.5	2.6	0.7
NARR (205,226) 1979 - 2006	2.4	4	1.4
NARR (205,227) 1979 - 2006	2.4	3.8	1.3
NARR (205,228) 1979 - 2006	2	3.4	0.8
NARR (205,229) 1979 - 2006	1.8	3.2	0.7
NARR ITR 2014	2.9	3.5	2.2
Measured Milne Port 2006 - 2015	4.5	9.2	0.3
Measured Mary River 2006 - 2012	3.9	7.5	1.2

The wind speeds measured at Milne Port Station, an approximately 9 year data set, were used in an extreme value analysis to determine return intervals for select wind events. Figure A-2.3 shows the wind speed and direction distributions for wind measured during the ice free season (July to October) and in all seasons. The dominant wind direction during the ice free season is from the Northeast. While wind directions for all records throughout the year show dominant winds from the Northeast and Southeast. Average wind speed during the ice free season from the Northeast is 6.7 m/s. Table A-2.5 provides a summary of return intervals for wind events from the Northeast based on the Milne Port Station data.

The dominant wind direction from the Northeast aligns with the largest fetch direction for Milne Port. Wind speed and direction near the surface of Milne Inlet are expected to be topographically controlled to a significant degree.

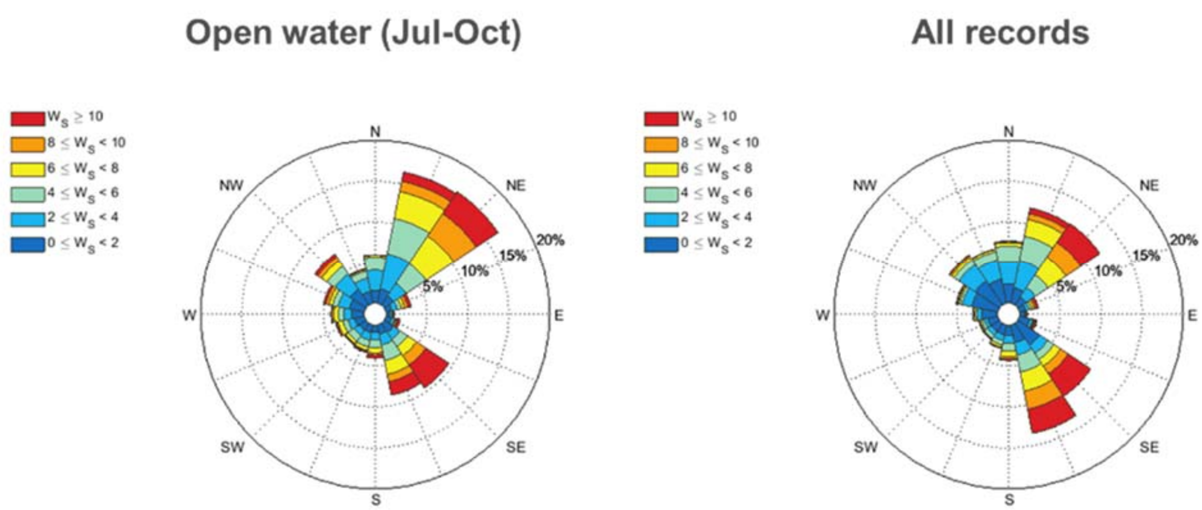

Figure A-2.3: Wind rose of the open water season (left) and all records (right) measured at Milne Port Station from 2006 to 2015.

Table A-2.5: Milne Port return intervals for wind events from the Northeast (30 to 60 degrees) during the ice free season (July to October)

Return Interval (years)	Wind Speed (m/s)	95% Confidence Interval (m/s)
1	17.1	16.0 to 18.1
2	18.5	16.9 to 20.1
5	20.2	17.7 to 22.3
10	21.0	18.2 to 23.7
25	22.1	18.8 to 25.5
50	22.9	19.2 to 26.7
100	23.7	19.6 to 27.8

2.5 A-2.5 Currents

Current circulation in the region is determined by the northward flowing West Greenland Current moving along the Greenland coast and the southward flowing Baffin Current moving along western Baffin Bay (Fissel et al., 1982; Tang et al., 2004). Within Milne Inlet the mean measured current speeds are generally 5 cm/s or lower and maximum speeds reaching 20 to 30 cm/s (CORI 2014; ASL 2014; ASL 2015; Fine and Rabinovich 2013; Rabinovich and Fine 2010; Buckley et al., 1987). Circulation within the inlet is driven by three primary processes; tidal circulation, wind induced circulation, and estuarine circulation. Tidal circulation is considered to be the primary driver of currents in the inlet, with wind induced currents as the secondary driver (CORI 2014). Due to the low current speeds in the inlet, current circulation in general is low, however, counter clockwise rotation was observed by Buckley et al (1987) along Ragged Channel near Cape Hatt, and similar surface counter clockwise rotation was observed in hydrodynamic models and acoustic Doppler current profiler (ADCP) data collected at site in 2014 and 2015 (ASL 2014; ASL 2015; CORI 2014).

The counter clockwise rotation was associated with tidally driven currents and mean barotropic circulation from long term wind induced currents. Tidally driven current circulation is primarily from the M2 semidiurnal frequency and K1 diurnal frequency (Buckley et al 1987; CORI 2014). A spectral analysis of the measured currents at the project site showed near surface counter clockwise rotation associated with the M2 tidal constituent (CORI 2014). Although the winds at Milne Inlet do not have a dominant direction, the mean wind induced currents also showed mean counter clockwise circulation with flows moving into the inlet (south) along the western side (including the Alfred Point mooring location) and flows moving out of the inlet (north) along the eastern side (including the Ragged Island mooring location) (CORI 2014). The vertical structure measured along the inlet showed surface currents were generally the strongest, with current speeds weakening with depth (CORI 2014; ASL 2014; ASL 2015; Knight Piésold 2010).

Current data available at the project site includes:

- Two bottom mounted ADCP measurements collected in September 2010 at the Milne Port facility, and select vessel based ADCP transects in August 2010 collected by Knight Piésold
- Current profiles collected from ADCP tautline moorings from August 2014 to October 2014 at three sites near Ragged Island, Alfred Point, and Emmerson Island

- Current profiles collected from ADCP tautline moorings from August 2014 to March 2015 near Stephens Island
- Current profiles collected from ADCP tautline moorings from August 2015 to August 2016 near Stephens Island

Additional current data and drogue drifter data were measured near Cape Hatt in 1980 and 19881 by Buckley et al (1987); however, that data was not used for this scope of work as it was not within our model domain.

2.6 A-2.6 Creek Hydrology

The two primary sources of fresh water discharge into the Milne Inlet system are Phillips Creek and Robertson River. Phillips Creek is adjacent to Milne Port on the west side of the project site and has an estimated drainage basin of 1,000 km^2 (Knight Piésold 2010; CORI 2014). Robertson River flows into Koluktoo Bay and has an estimated drainage area of 4,000 km^2 (Knight Piésold 2010; CORI 2014). ITR and CORI used estimated monthly average discharges based on gauged stream river flow measurements collected at Phillips Creek to generate daily discharge estimates for both Phillips Creek and Robertson River. The flow measurements collected at Phillips Creek are from a point upstream from the mouth where the drainage basin area is approximately 250 km^2. Estimates for discharge at Phillips Creek at the entrance to Milne Inlet are multiplied by 4 to linearly increase the flow for a 1000 km^2 drainage area. The average monthly river flows at Phillips Creek used are 41.9 litres/second/square kilometers (l/s/km^2) in July, 21.1 l/s/km^2 in August, and 9.2 l/s/km^2 in September (Knight Piésold 2010; CORI 2014). The flow measurements collected in 15 minute intervals at the Phillips Creek station from 2011-2015 were obtained through Knight Piésold Consulting. Monthly averages and the raw data provide adequate information regarding freshwater inputs that can be scaled to apply to Phillips Creek and Robertson River.

2.7 A-2.7 Sediment Characteristics

The ore dock is situated on a delta front with water depths ranging from approximately 5 m to 30 m along the slope edge. In the nearshore region around the dock, the beach, and intertidal areas are gently sloping along a series of cuspate spits features. The spit features were present before the construction of the existing ore dock in 2014. The Milne Port shoreline has two sources of new sediment with a small creek to the east and Phillips Creek to the west of the dock. Sediment distribution along Milne port is largely inherited from glacio-fluvial origins with minor spatial variations reflecting proximity to local sediment sources, variations in alongshore sediment transport potential, wave and energy, and water depth. Previous studies characterizing the sediment along the shoreline and intertidal zone have not been identified. Surface sediment samples at Milne Port have been measured along the ore dock, and proposed site for the additional ore dock construction primarily focusing on sediment near the delta slope and immediately offshore. The samples were collected as geotechnical borehole investigations (Hatch, 2017) and surface grab samples as part of the marine effects monitoring program (SEM, 2017).

Borehole locations for the geotechnical investigation were focused around the ore dock extension structure in water depths from 5 m to 30 m. Borehole locations and results can be found in Table 2-1 in the Hatch (2017) report. Sediment sample results from the geotechnical investigation revealed primarily sandy surface sediments with a mean diameter (D_{50}) ranging from 0.27 mm to 0.2 mm. Sediments near the delta slope in water depths of approximately 5 to 10 m were predominantly medium sandy material with traces of silt and gravel. Moving offshore to water depths near 30 m, sediment samples contained a larger percentage of fines (~ 20-40%) with the material characterized as silty sand.

The marine effects assessment conducted by SEM (2017) included sediment grab samples with a petit ponar sampler. Samples were collected along an eastern, western, northern, and coastal transect. A summary of the sediment sample locations and water depth are provided in Table 3.17 of the SEM 2017 report along with the sample results. Samples collected along the western and eastern transects trace the delta front and provide grain size distributions for sediments along where the ore dock extension would be constructed. Sediment samples west of the existing ore dock were approximately 10% gravel, 60 % sand, 25% silt, and 5% clay with an estimated D_{50} of 0.12 mm. Sediment samples east pf the existing ore dock were approximately 10% gravel, 70 % sand, 15% silt, and 5% clay with an estimated D_{50} of 0.3 mm near the dock and decreasing to approximately 0.1 mm east.

Sediment west of the existing ore dock has a higher percentage of fines and a smaller D_{50} value than sediment east of the ore dock.

2.7.1 A-2.7.1 Site Visit-Beach Photo Survey

A site visit was carried out by Golder metocean team member (Dana Oster – Coastal Geomorphologist), and Baffinland employee (Dominic Ritgen - Environmental Coordinator) on 20 July 2017. The objectives of the site visit were to conduct a beach photographic survey to observe and better characterize the shoreline and inter-tidal morphology and sediments.

The site inspection commenced at approximately 7:30 Eastern Daylight Time (EDT) and concluded at approximately 9:30 EDT. The survey began on the east side of the carrier loading ramp (approximately 1 km east of the existing ore dock) and moved west to the pocket beach west of the existing ore dock. During the survey, GPS tagged photographs were collected and photos were taken progressing alongshore, across select transects perpendicular to shore, and close ups of the sediment.

Key observations include:

- The beaches and nearshore deposits at the site appear to be formed in massive deposits of sands, gravels and cobble material which are likely glacial or glacio-fluvial in origin.
- Beach's along the eastern cusp are primarily composed of medium-fine sand (estimated D_{50}= 0.25 mm) in the intertidal zone with medium-coarse pebbles armouring the beach berm and high tide area (Figure A-2.4) indicative of effective wave sorting. A low backshore berm is also present behind and above the existing high water mark which is most likely a relict berm from a historical post-glacial shoreline position. Pebbles in the upper inter-tidal zone are flat and moderately rounded. Accretion of fine sand (estimated D_{50}= 0.1 to 0.2 mm) is visible along the eastern side of the riprap perpendicular to the shoreline (Figure A-2.5). The riprap is part of the sealift supply ramp.
- A short segment of accreted medium-fine sand is evident along the western side of the shore perpendicular rip rap at the sealift supply ramp possibly due to local wave sheltering effect caused by the supply ramp. Scattered medium pebbles are present along intertidal beach located further west of the supply ramp. A spit like feature with large ridges running parallel to shoreline characterizes this section of shoreline (Figure A-2.6). Sand and fine sediment (possibly iron ore dust) has accumulated behind the spit feature and long crested bedforms with crests oriented perpendicular to the shoreline are located in this area (Figure A-2.6 and Figure A2.7). The tide was observed to flood rapidly across this sand flat and spit and is most likely responsible for generating these bedforms. The beach along the western edge of the spit feature is composed of medium fine sand with scattered medium pebbles along the intertidal zone (Figure A-2.8). Pebbles armour the berm slope at the upper extent of the inter-tidal zone.

- The beach east of the existing ore dock is relatively straight for a distance of approximately 500 m, gently sloping and composed of medium fine sand. The beach is backed by very large berms with the high tide line extending to the base of the berms. The berms have a layer of dust (most likely iron ore dust) accumulation overtop of the sand and gravel that comprises the berms (Figure A-2.9). Two inactive relict creek channels are present that cut through the large berms. The back beach berms in this area appear to be composed of inter-bedded layers of gravel, sand, and silt from larger scale fluvial or glacio-fluvial deposition (Figure A-2.10).
- Sediment distribution along the large straight beach east of the ore dock is primarily medium fine sand on the eastern and western ends, and pebble armouring is present along the upper beach of the central section of the beach (Figure A-2.11). Accretion of fine sand is evident along the eastern side of the riprap at the ore dock and the pebble armouring is not present indicative of a net depositional environment at this location (Figure A-2.12).
- The two beaches west of the ore dock surveyed were gently sloping with medium sand and more substantial pebble armouring along the intertidal beach (Figure A-2.13 and Figure A-2.14) and appear to be sediment starved.

The typical beach sand size was medium to fine sand (approximately D_{50}= 0.2 to 0.3 mm) across the shoreline of the port area. Armouring was observed along the berm and high tide regions of the beach, and was more common at the intertidal elevations of the beach along the straight sections of the beach in the middle of the cusps. The grain size observed on the shoreline is similar to the geotechnical and ponar grab samples measured further offshore. A data gap exists for sediment characterization in the nearshore regions between low tide and approximately 5 m water depth. Given the consistency of sediment size between the intertidal region and delta slope 5 m to 30 m water depth, it is reasonable to assume the grain size is the same in the area without data.

Figure A- 2.1: Eastern cuspate beach with medium fine sand, and pebble armoring upper beach and berm.

Figure A- 2.2: Eastern accretion of fine sand along perpendicular riprap.

Figure A- 2.3: Western accretion of medium fine sand along perpendicular riprap and ridge and shore perpendicular bedforms along spit feature.

Figure A- 2.4: Sand flat with ripples in backshore of spit feature west of supply ramp.

Figure A- 2.5: Western shoreline of spit feature, and sand and gravel along intertidal beach.

Figure A- 2.6: Straight beach east of ore dock with large berms and iron ore dust accumulation on berms.

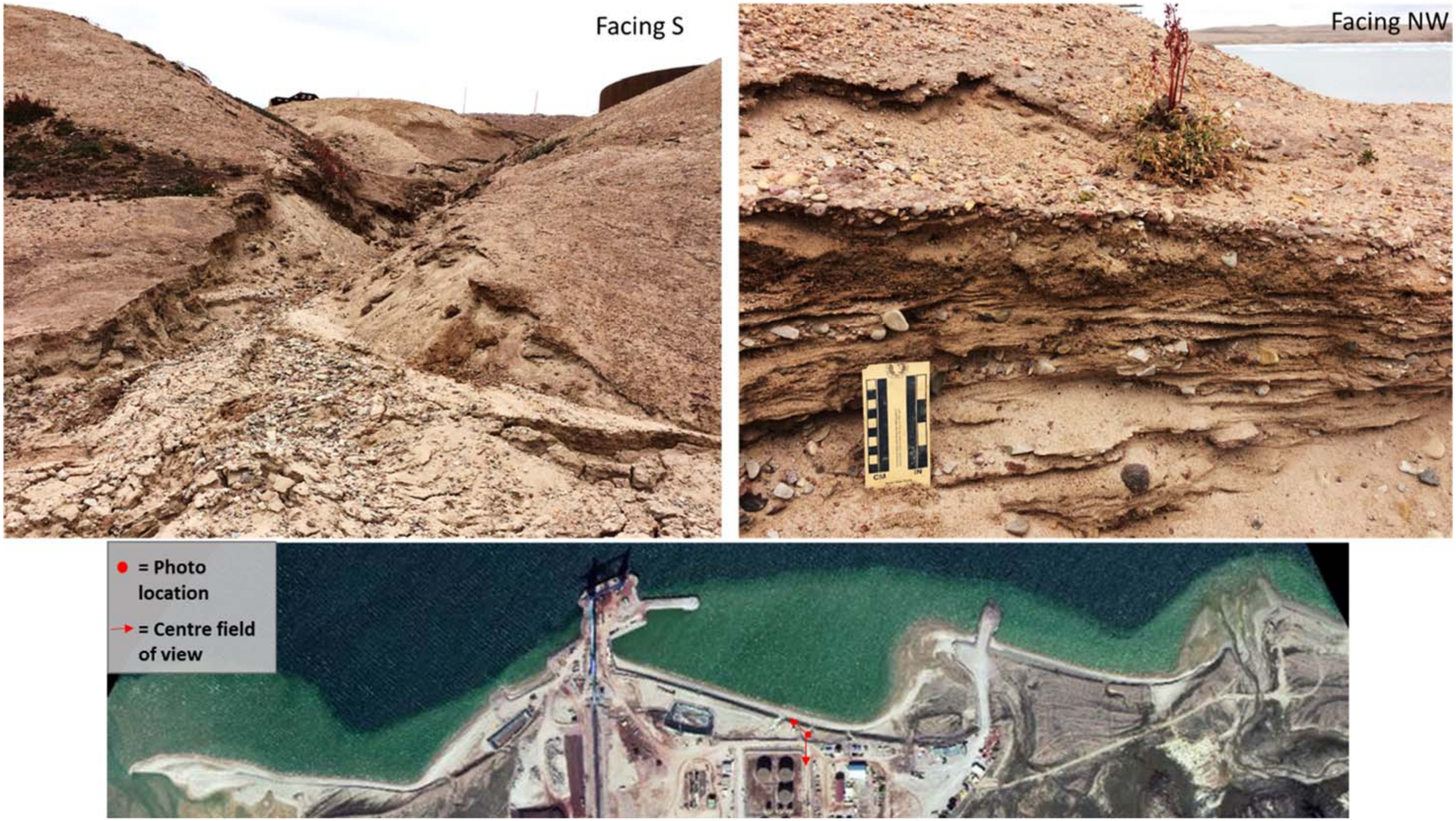

Figure A- 2.7: Inactive drainage channel cutting through berm and bedded layers of sand, silt, and gravel the berm is composed of.

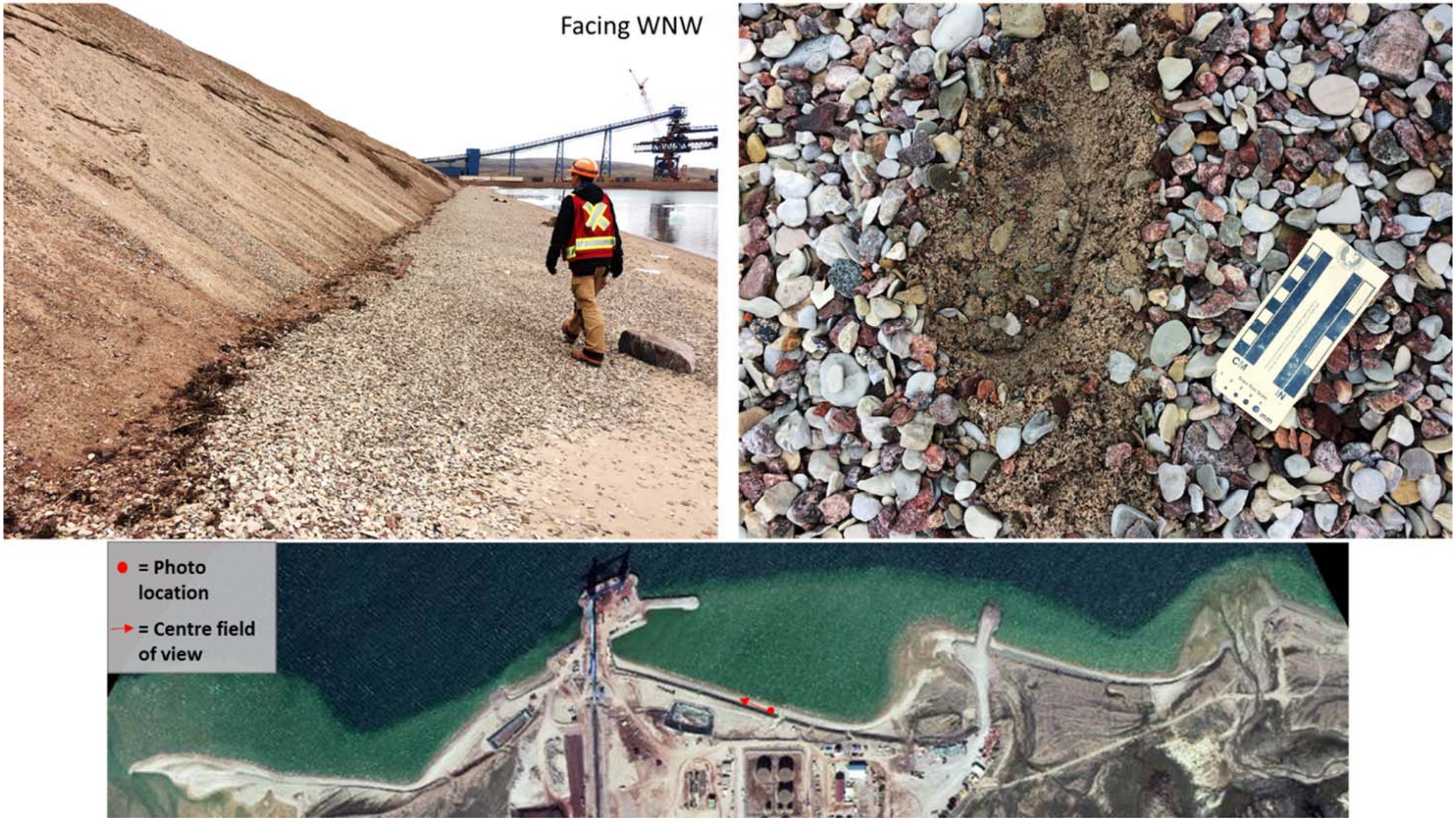

Figure A- 2.8: Pebble armouring of the high tide region of the beach along the middle of the straight segment.

Figure A- 2.9: Fine sand accretion along the eastern side of the ore dock riprap.

Figure A- 2.10: Pocket beach west of ore dock and east of small craft boat launch with medium sand and pebble armoring the intertidal beach.

Figure A- 2.11: Western beach with medium sand and pebble armouring the intertidal beach.

3.0 A-3.0 REFERENCES

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IMPORTANT INFORMATION AND LIMITATIONS OF THIS APPENDIX

This appendix was prepared for the exclusive use of Baffinland Iron Mines Corporation, its assignees and representatives, and is intended to serve as a summary of available data on Milne Inlet oceanography and previous ballast water modelling efforts. This appendix is limited to a summary of existing data and oceanography conditions related to the Project. This appendix is not intended to identify or evaluate potential project related effects.

The conditions of the study area are based on information obtained from a literature review, publically available data sources, and field investigations conducted by previous consultants on behalf of Baffinland.

The findings documented in this appendix have been prepared for specific application to this Project. Golder makes no other warranty, expressed or implied.

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APPENDIX B

Numerical Model Set-Up and Calibration

B-1.0 INTRODUCTION

This appendix describes the numerical models, their domains and set-up employed in this study. Three distinct models were used: the hydrodynamic model, the wave model and the nearshore sediment transport model, which consist of the coupling of the two aforementioned models. The details regarding the computational mesh, bathymetry, boundary conditions, forcing inputs, and model controls applied to the models are described in the following sections.

B-2.0 HYDRODYNAMIC MODEL DESCRIPTION

A variable resolution hydrodynamic numerical model was developed to propagate tides and currents into Milne Inlet and assess the potential for project related impacts. Two model domains were developed as part of the hydrodynamic model. Figure B-2.1 presents the regional domain encompassing Eclipse Sound and Milne Inlet in northwest of Baffin Island and shows the boundary limits of the local domain that incorporates the southern portion of Milne inlet, in the vicinity of the Project site. The hydrodynamic model was developed using Delft3D, a Deltares' three-dimensional (3-D) hydrodynamic model (Roelvink and Banning 1994; Deltares 2011). Delft3D is a state-of-the-art modeling system that computes flows, wave transformation, sediment transport, and seabed changes.

B-2.1 Regional Model

The regional numerical model was developed to propagate tides and currents (generated from tides, winds, density and salinity changes) from northwest Baffin Island toward the Project site at the head of Milne Inlet. This 3-D regional model considers the stratification effects of temperature and salinity.

The bathymetry data described in Appendix A section 2.1 was applied to represent the seabed boundary within the regional domain. Bathymetric data was interpolated onto a structured rectilinear mesh with grid cell resolution of 1 km x 1 km. The boundary of the mesh was fitted to the curvature of the mean high water level shoreline (Appendix A section 2.1.1). The vertical dimension of the computational domain was discretized in 15 sigma layers. The thickness of these layers are defined as percentages of the total depth at each point in space. Smaller percentages are assigned at the near-surface region and near-bed region to capture the steep variations in the salinity and temperature profiles and also the variations resulting from complex bathymetry. High resolution is not needed in the mid water column and therefore, higher percentages were assigned. This mesh encompasses the entire hydrodynamic modelling domain with two open boundaries: (1) in the east-west direction in Eclipse Sound and (2) in the north-south direction in Navy Board Inlet, northwest of Milne Inlet (Figure B-2.1).

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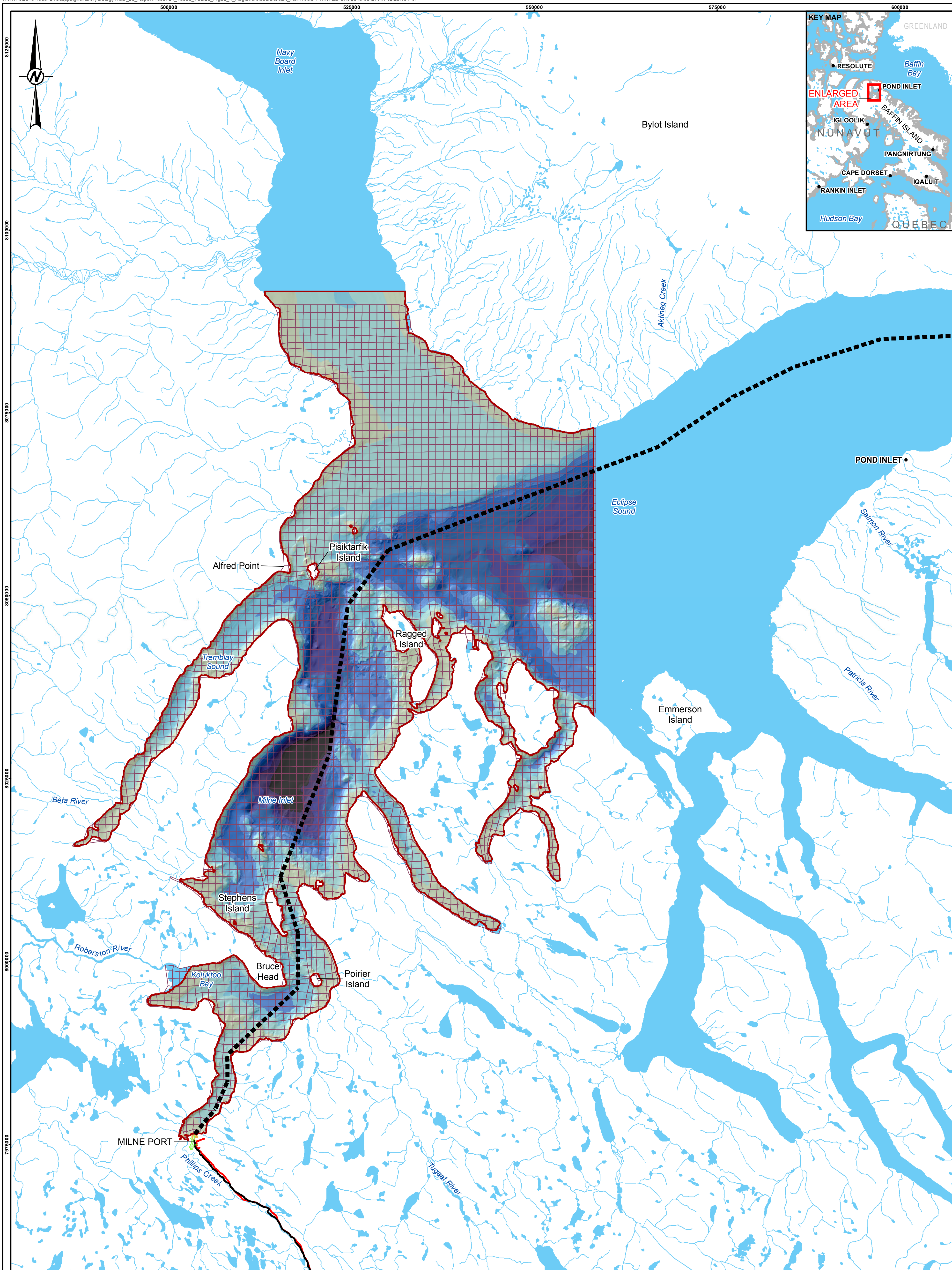

LEGEND

- • COMMUNITY
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- SHIPPING ROUTE (APPROXIMATE)
- WATERCOURSE
- MODELLED AREA
- REGIONAL NUMERICAL MODEL DOMAIN
- EXISTING ORE DOCK
- NEW ORE DOCK AND CAUSEWAYS
- EXISTING FREIGHT DOCK AND CAUSEWAY
- WATERBODY

ELEVATION (masl)

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NOTE(S)

masl = METRES ABOVE SEA LEVEL

REFERENCE(S)

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

TITLE
REGIONAL NUMERICAL MODEL DOMAIN

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B-2.1.1 Boundary Conditions and Environmental Forcing

Astronomical tides and winds are important mechanisms forcing water level variation and circulation within the study area; therefore, these mechanisms are used to prescribe the model forcing and boundary conditions. The water level boundary conditions prescribed along the north and east domain boundaries were obtained from the TPXO 8.0 tidal model developed by the College of Earth, Ocean and Atmospheric Sciences of the Oregon State University. This tidal model is linked to Delft3D-Flow via a MATLAB based tool called Delft Dashboard. The database includes thirteen major tidal constituents (M2, S2, N2, K2, K1, O1, P1, Q1, MF, MM, M4, MS4, and MN4 – Appendix A section 2.2.1) distributed with 0.25 degree resolution. Discharge from two fresh water inflows, Phillips creek and Robertson River, were also applied to river intersections with the model boundaries as the estimated constant mean river discharge during the simulation period of the open water season between July and October 2014.

The effects of salinity and temperature were considered in the boundary and initial condition. Monthly salinity and temperature profiles are available for Alfred Point, Ragged Island and Stephens Island (Appendix A section 2.3.2). The average value of the three locations in August was used to initialize the model and the boundaries were forced with a constant vertical profiles in August, September and October.

Wind effects were included as forcing in the regional model with a time series over the simulation period constructed from the data at the meteorological station at Milne Port (Appendix A section 2.4). Wind speed and direction were applied uniformly across the regional model domain.

B-2.1.2 Model Calibration and Verification

The regional domain was calibrated and validated by comparison of model output with water levels and currents measured at Alfred Point, Ragged Island and Stephens Island. The following sub-sections provide a discussion of the calibration and validation of the simulated water levels and currents.

The modelled water levels at the Alfred Point, Ragged Island and Stephens Island were compared with direct measurements from August 08, 2014 to August 31, 2014. The time series comparisons are shown in Figure B-2.2 to Figure B-2-4. There is a reasonable and acceptable agreement in both amplitude and phase between the modelled and measured data. The statistical parameters considered to evaluate the agreement were the root mean square error (RMSE) and coefficient of determination presented in Table B-2-1. The RMSE measures the scatter of residuals and the closer to zero the better the results. The coefficient of determination presents the strength of association between the measured and modelled dataset with a value of 1 representing a perfect association. The calculated RMSE values for all three location are below 0.2 m. While, the modelled water levels were generally in agreement with the measured water levels, the model over and underestimates the amplitudes at certain time periods. The highest coefficient of determination were found at Alfred Point and Stephens Island with a value of approximately 95%. The lowest coefficient of determination of 88.3% was found at Ragged Island.

Table B-2-1 Root mean square error and correlation between regional model results and measured data

Location	Root Mean Square Error (m)	Coefficient of Determination (%)
Alfred Point	0.12	95
Ragged Island	0.18	88
Stephens Island	0.11	96

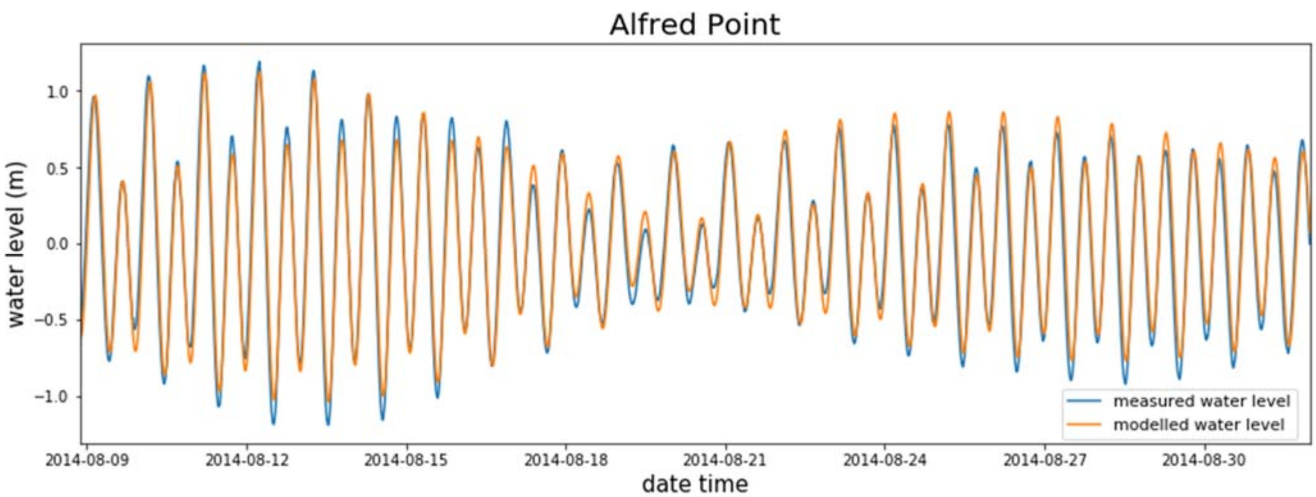

Figure B-2-2 Measured and modelled water level at Alfred Point for August 2014

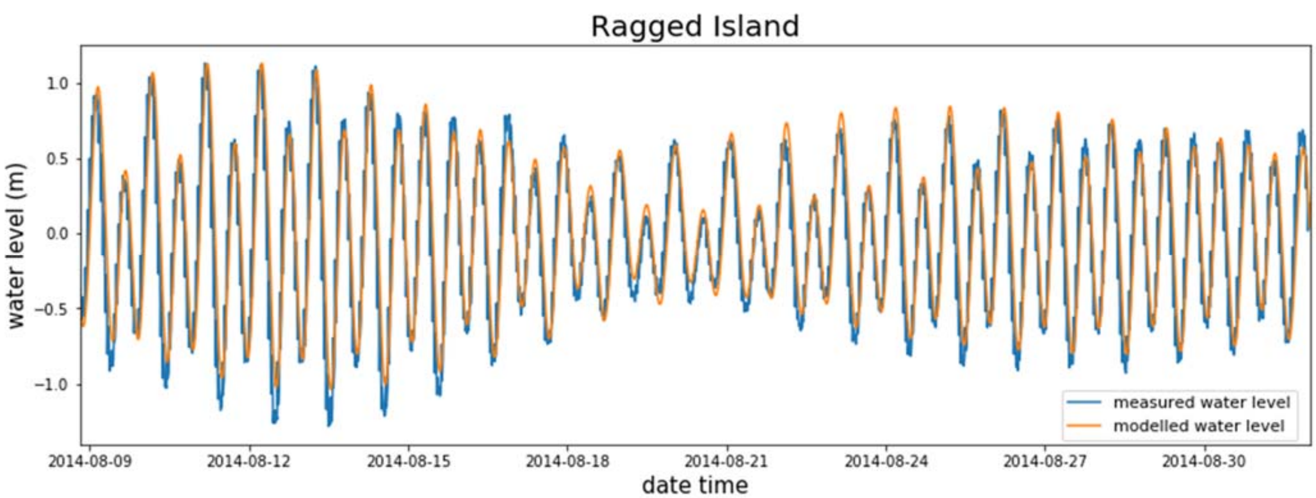

Figure B-2-3 Measured and modelled water level at Ragged Island for August 2014

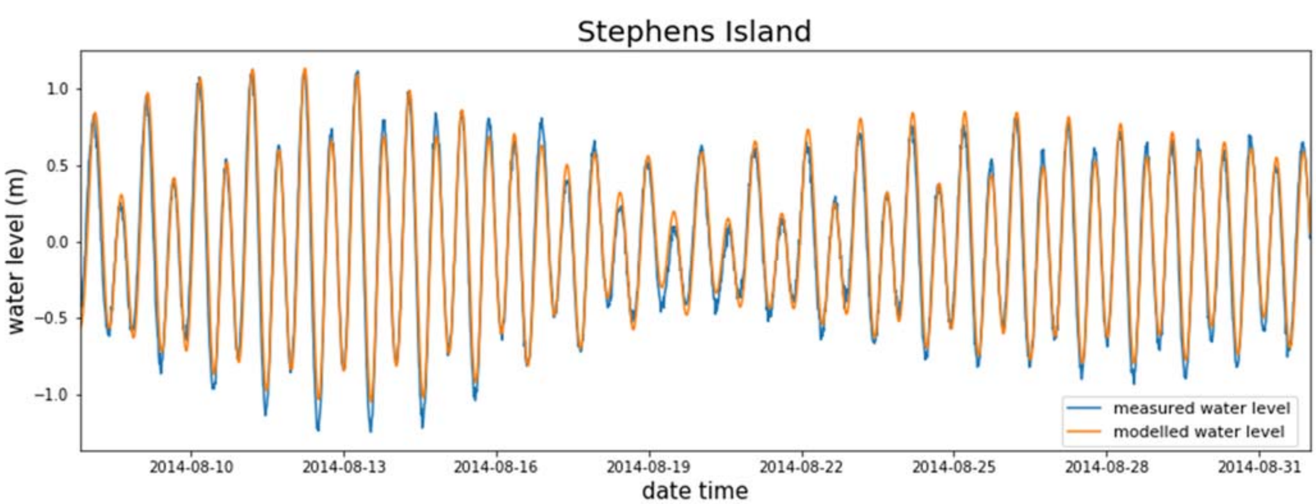

Figure B-2-4 Measured and modelled water level at Stephens Island for August 2014

The modelled water levels were calibrated with measured data as the local model boundary is prescribed as a water level time series obtained from the regional model. The modelled water levels were considered reasonable as they replicate closely the measured data in both amplitude and phase as can be seen visually in Figure B-2-2 to Figure B-2-4. This agreement in data is further supported by the RMSE below 0.2 and the coefficient of determination above 88% at all three location. Additionally, the water levels were as good in agreement at Stephens Island, the location furthest from the open boundaries, as they were at Alfred Point, the location closest to the open boundaries, both with a coefficient of determination of approximately 95% and with the lowest RMSE values. This suggests that the model propagates the water level well within the inlet. The lowest coefficient of determination and highest RMSE value (88.3% and 0.182, respectively) were found at Ragged Island. This is likely due to the following:

- Ragged Island's tide gauge is located within the bay (interior of the C-shape) with highly variable bathymetry.
- The coarseness of the regional model grid does not capture the detailed geometry of the tide gauge area well.
- The instrument used for measurement is located near the land boundary.

The modeled current velocities obtained with the regional model were verified with the measured data available data. The modelled current trends were in reasonable agreement at Stephens Island and Ragged Island but typically underestimated. The difference in the daily average values of the currents was 0.02 m/s at Ragged Island and 0.009 m/s at Stephen Island. The trend in modelled currents at Alfred Point was not in as good agreement with the measured data, likely due to the same reason as for the water level outlined above. However, the difference in daily averages was 0.027 m/s for the month of August. Despite this, the difference in daily averages at Alfred Point was 0.027 m/s, only 0.007 m/s more than Stephens Island, during the month of August. The modelled current speeds at all stations were within the same order of magnitude as the measured data. The difference in the daily average current speed are within acceptable limits.

B-2.2 Local Model

The local numerical model was developed to assess currents at Milne Port and for coupling with the wave module for the nearshore sediment transport simulations. The local model is simulated in 3D to capture the multidimensional hydrodynamic flows along with salinity and temperature stratification present in Milne Inlet. Model output was calibrated and validated to measured water levels from the Milne Port tide gauge located within the local domain. Model calibration and validation could not be performed on velocities as no velocity measurements existed within the local domain.

B-2.2.1 Computational Mesh and Bathymetry

The bathymetry within the local model was interpolated to the grid and smoothed. The horizontal domain consists of a rectilinear grid with a long fetch of 8.5 km and a resolution varying from 250 m x 50 m at the boundary down to 25 m x 50 m in the vicinity of Milne Port (Figure B-2-5). The vertical computational domain was discretized in 20 layers using sigma coordinates. The thickness of the layers is defined as a percentage of the depth in a given grid cell. Similar to the regional model (section B-2-1), smaller percentages were assigned to the near-surface sigma layers to capture wind generated currents and salinity and temperature induced density stratification and to the near-bottom region to capture bathymetry variations and near bed processes. The thickness of the middle layer was set as 10%. The remaining top and bottom layers thickness linearly decrease from 10% to 1%.

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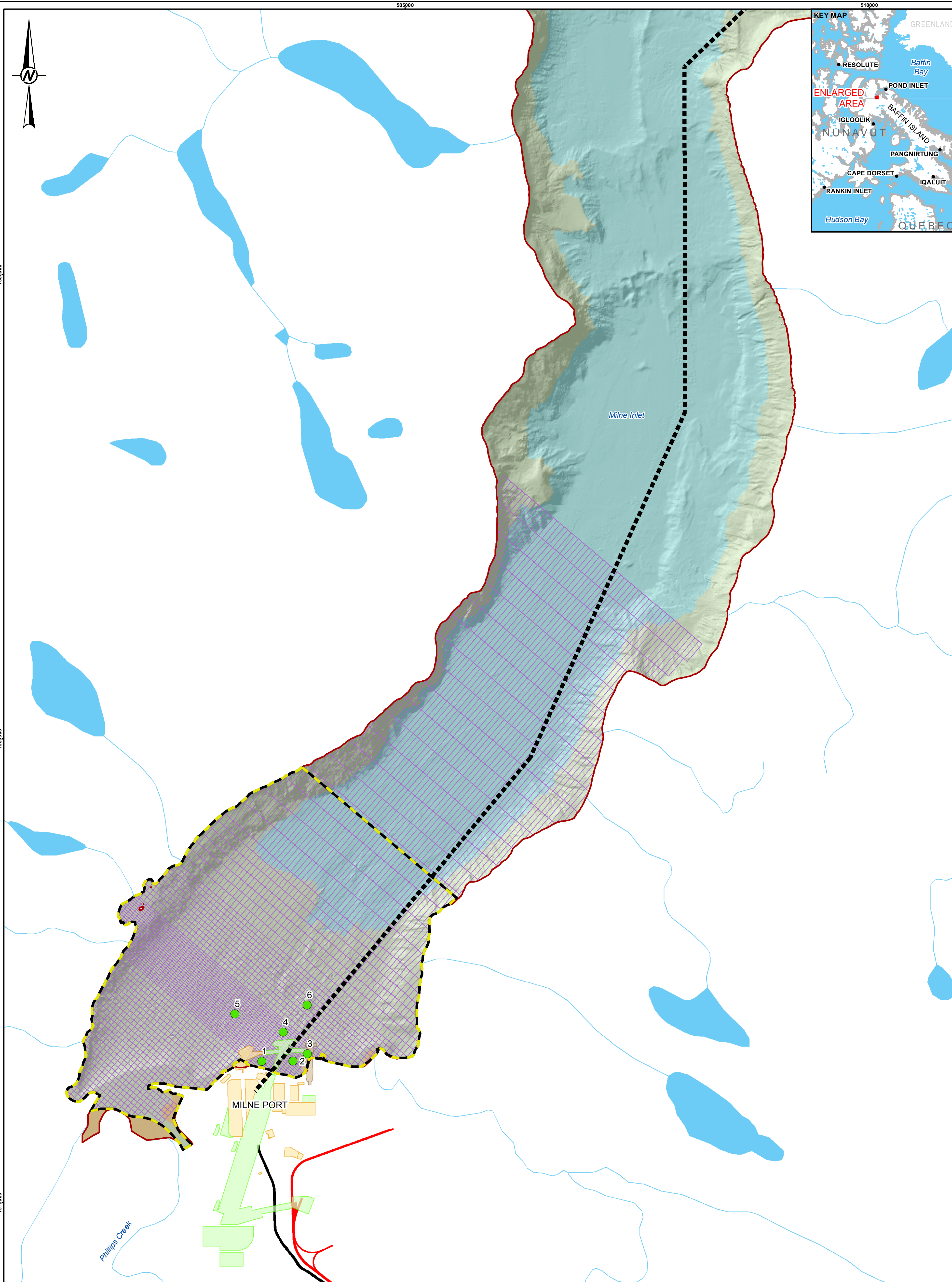

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TITLE
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CONSULTANT

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B-2.2.2 Boundary Conditions and Environmental Forcing

The local model contained one open boundary that was forced every 15 minutes with water level output from the regional model (Section B-2.1) and temperature and salinity corresponding to the average August CTD profile. In the same way discussed in Section B-2.1, fresh water discharge and wind components were applied to the local model. Discharge from Phillips creek was applied to the corresponding model boundary using estimated constant mean river discharge. Time varying wind speed and direction were applied uniformly to the model domain. The model was initialized with a temperature and salinity profile, assumed horizontally uniform, corresponding to the average August stratification determined from CTD casts. In prescribing a water level boundary condition the model calculates the boundary velocity profile, however, given the environment, a deep stratified fjord, the modeled velocities along the boundary intermittently indicated a velocity jet, a region of increased flow rate. To mitigate this the bathymetry in the vicinity of the boundary was further smoothed, the model domain was extended a distance of 8.5 km to provide sufficient separation between Milne Port and boundary instabilities and, as suggested in the Delft3D manual, an increased horizontal eddy viscosity was prescribed along the boundary.

B-2.2.3 Model Parameters

A summary of the various settings used in the local hydrodynamic model are given below:

- Time step: 0.25 s
- Boundary reflection parameter: 5000 s^2
- Manning Roughness Coefficient: 0.04
- K-Epsilon turbulence model
- Horizontal eddy viscosity: 1 m^2/s
- Horizontal eddy diffusivity: 10 m^2/s
- Horizontal eddy diffusivity and viscosity on boundary: 100 m^2/s

B-2.2.4 Model Verification

Water level output from the local model at the location of the Milne Port tide gauge were validated against measured water levels at the Milne Port tide gauge (Figure B-2-3). Water level measurements were unavailable until August 10, 2014. The modeled water level amplitudes are in good agreement with the measured water level amplitudes. At the start of the simulation the modeled water levels are out of phase, but become in phase towards the end of the simulation period. A statistical comparison of the water levels gives a RMSE of 0.19 m and a coefficient of determination of 96%. The RMSE value obtained from the water level comparison of the local model is 0.05 larger than the average RMSE of the regional model, indicating that this model is slightly less skilled at predicting the water level in comparison with the regional model. This is likely a result of the following: some model instabilities at the open boundary initiated from prescribing the boundary condition with water levels only and the steep bathymetry along the shoreline not well captured with the coarse sigma grid. However, the coefficient of determination is consistent with the coefficient calculated at Alfred Point and Stephens Island. The error values of the local model are within the range of the regional model, indicating acceptable performance from the local model.

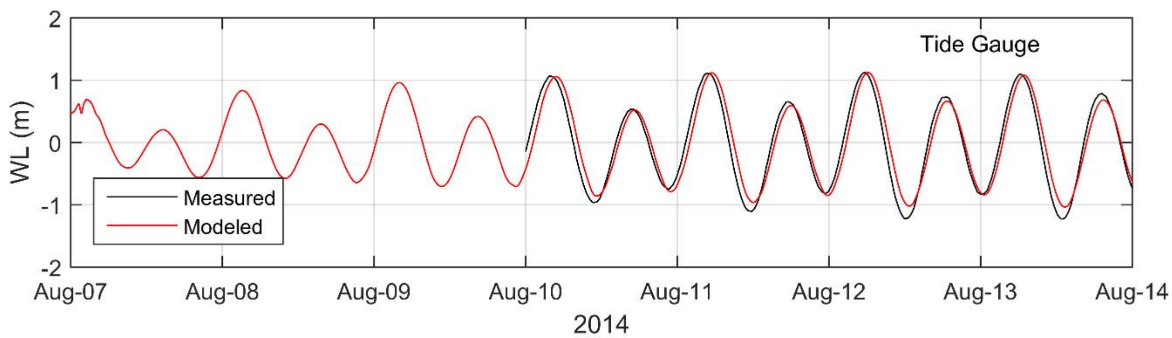

Figure B-2-6: Simulated and observed water levels at the location of the Milne Port tide gauge.

B-3.0 WAVE MODEL DESCRIPTION

An orthogonal square grid numerical model was developed to study steady-state wave environments at the head of Milne Inlet from wind-induced waves and for coupling with the hydrodynamic model to create the nearshore sediment transport model. The wave model includes a coarse grid and fine resolution nested grid (Figure B-3-1). The simulations were performed using the third generation of Simulating WAves Nearshore (SWAN) model through Deltares' Delf3D-Wave interface. The SWAN model simulated short-crested wind-generated waves using spectral properties (in all directions and frequencies) of random waves (The SWAN Team, 2017). The SWAN model accounts for wave propagation due to current and depth, dissipation from whitecapping, depth-induced wave breaking, bottom friction, refraction-diffraction (based on the mild-slope equation) and non-linear wave-wave interactions.

B-3.1 Computational Mesh and Bathymetry

The wave model domain consists only of the Milne Port area located at the head of Milne Inlet. The bathymetry within the study domain was spatially discretized in two rectilinear orthogonal grids (Figure B-3-1) – one with a 10 m spatial resolution, and the other with a 4 m spatial resolution. This grid encompasses the existing and Phase 2 proposed ore dock of Milne Port.

These grids were not fitted to the shoreline in order to keep their orthogonality. However, the grid cells have enough resolution to provide a reasonably accurate depiction of the shoreline shape. In addition, as the edge of the bathymetry is above the water level it provides a natural curved shoreline within the domain. The ore docks were added to the modelling domain as obstacles. For the post-development modelling scenarios, the Phase 2 Proposed ore dock was modelled in addition to the freight dock and existing ore dock. The floating spud barge of the freight dock was modelled in an East-West direction (forming a "T" with the rockfill causeway). In the post-development models, the enclosed area between the existing and freight dock and Phase 2 Proposal ore dock remained in the domain where the wave data modelled in this area is considered internal to the region.

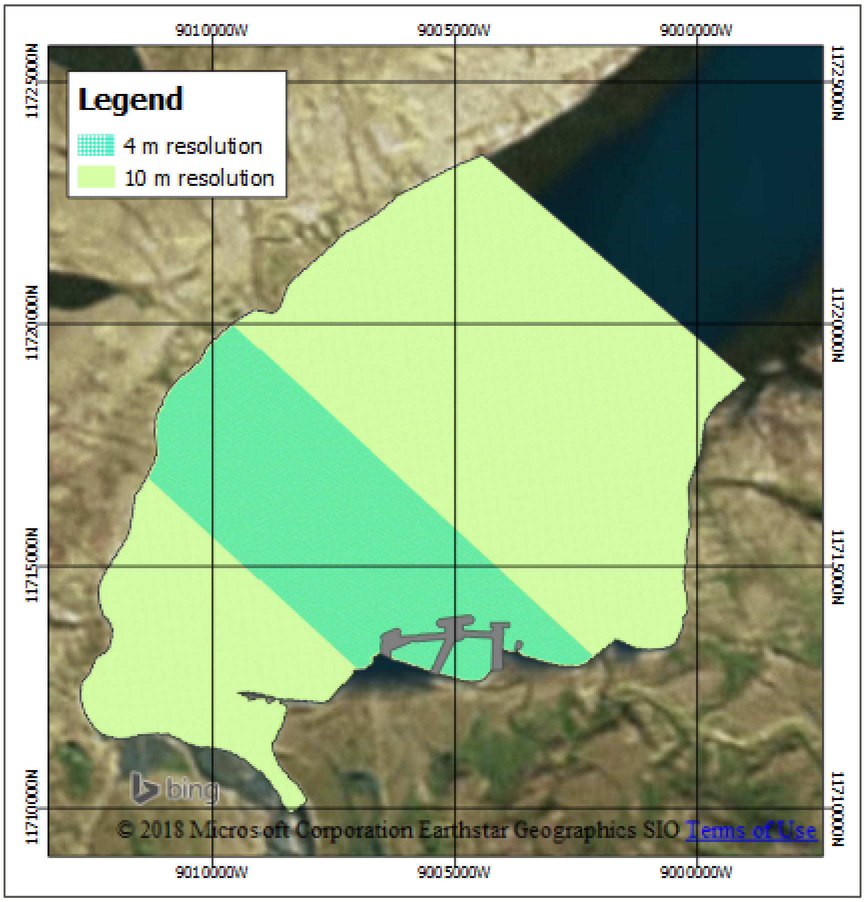

Figure B-3-1: Wave model domain of Milne Port at the head of Milne Inlet

B-3.2 Boundary Conditions and Environmental Forcing

The wave model simulated wind-generated waves; as such, the model and its boundary are driven by wind inputs. The wind was applied uniformly to the model domain according to the return period and prominent wind direction of the open water season (northeast and northwest) for the scenarios summarized in Table B-3-1.

Table B-3-1 Wind speeds for the open water season (July to October) for various return periods

Wind direction	Return period	Wind Speed (m/s)	Wind direction	Return period	Wind Speed (m/s)
45º (northeast)	1-yr	17.1	315º (northwest)	1-yr	12.5
	2-yr	18.5		2-yr	13.9
	5-yr	20.0		5-yr	15.6
	10-yr	21.0		10-yr	16.8
	25-yr	22.1		25-yr	18.4
	50-yr	22.9		50-yr	20.8

Wave conditions, significant wave heights, wave periods and directions, are prescribed at the open boundary of each model. The open boundary of the 10 m grid is oriented in the northwest direction to accommodate the boundary condition input parameters. The open boundary is perpendicular to the wind direction for northeast winds and thus the boundary condition is prescribed as a uniform wave condition in these scenarios (Table B-3-2). The significant wave height and period was calculated using the maximum possible fetch in the northeast direction within Milne Inlet (10 km) relative to the Port for the maximum wind speeds of each return period considered in this study (see Appendix A, section 2.4).

Table B-3-2 Significant wave height (H_s) and period (T) for the wave modelling uniform boundary condition for northeast wind scenarios based on a 10 km fetch.

Wind speed return period	Significant wave height, H_s (m)	Wave period, T (s)	Direction (º)
1	1.1	3.7	45
2	1.2	3.9	45
5	1.3	4.0	45
10	1.4	4.1	45
25	1.5	4.2	45
50	1.6	4.2	45

The open boundary is parallel to the wind direction for northwest wind scenarios, and thus requires a spatially-variable boundary condition to represent the growth of the wind-generated wave along this boundary. The wave conditions are prescribed by distance (fetch) from the start of the boundary located at the northwest corner. The boundary conditions used for the wind values by return period are presented in Table B-3-3.

Table B-3-3 Significant wave height (Hs) and period (T) for the wave modelling space-varying boundary condition for northwest wind scenarios.

Fetch (m)	1-yr		2-yr		5-yr		10-yr		25-yr		50-yr	
	H_s (m)	T (s)	H_s (m)	T (s)	H_s (m)	T (s)	H_s (m)	T (s)	H_s (m)	T (s)	H_s (m)	T (s)
187	0.09	0.83	0.10	0.86	0.13	0.95	0.14	0.98	0.16	1.02	0.18	1.05
458	0.14	1.12	0.15	1.16	0.21	1.28	0.23	1.32	0.26	1.37	0.28	1.41
748	0.17	1.31	0.19	1.36	0.26	1.51	0.29	1.55	0.33	1.62	0.35	1.66
1038	0.21	1.47	0.23	1.52	0.31	1.68	0.34	1.73	0.38	1.80	0.42	1.86
1340	0.23	1.60	0.26	1.65	0.35	1.83	0.39	1.89	0.44	1.96	0.47	2.02
1625	0.26	1.70	0.29	1.76	0.39	1.95	0.43	2.01	0.48	2.10	0.52	2.15
1928	0.28	1.80	0.31	1.87	0.42	2.06	0.46	2.13	0.52	2.22	0.57	2.28

The wind-generated wave conditions at the boundary were estimated using quantitative wave hindcast methods prescribed by the Automated Coastal Engineering System method (Leenknecht, Szuwalski, & Sherlock, 1992). Simulations for the wave models were performed for both a mean water level and high water level. The high water level condition was prescribed by adding 1.1 m of uniform depth above the mean water level.

B-3.3 Model Parameters

A summary of the various settings used in the wave model are given below:

- Wave spectral space using Joint North Sea Wave Project (JONSWAP; peak enhancement factor = 3.3) with refraction and frequency shift enabled
- Depth-induced breaking using the Battjes and Janssen (1978) model (α = 1.0, γ = 0.73)
- Bottom friction using JONSWAP (coefficient = 0.067 m^2/s^3)
- Diffraction (smoothing coefficient = 0.2, smoothing steps = 5)
- Wind growth enabled
- Whitecapping using Komen et al. (1984) method

B-3.4 Ore docks

The existing and Phase 2 proposed ore docks and freight dock were modelled as obstacles to take into account wave reflection. The ore docks we're described using two distinct material properties: sheet piles and armour stones (Figure B3-2). The proposed ore dock is planned to be built with similar materials to the existing dock and freight dock so the same material properties were used for the modelling of the existing and proposed ore dock. The mooring region of the existing ore docks is constructed with a series of sheet piles. This material was modelled using a reflection coefficient of 0.85, the median value for a smooth vertical structure (Reeve, Chadwick, & Fleming, 2012). The alpha (α) and beta (β) constituents of the transmission coefficient from Goda et al. (1967) were taken as 1.8 and 0.10 respectively, corresponding to a vertical thin wall (Deltares, 2016). The remaining portions of the ore dock constitute shore protection made of armour stone placed at a 1:1.5 slope. The reflection coefficient for armour stone was taken as 0.55, the median value for a rock breakwater (Reeve, Chadwick, & Fleming, 2012). The α and β constituents were taken as 2.6 and 0.15 respectively, corresponding to a dam with a 1:1.5 slope (Deltares, 2016).The height of the obstacle was set at 10 m to ensure no wave overtopping would occur.

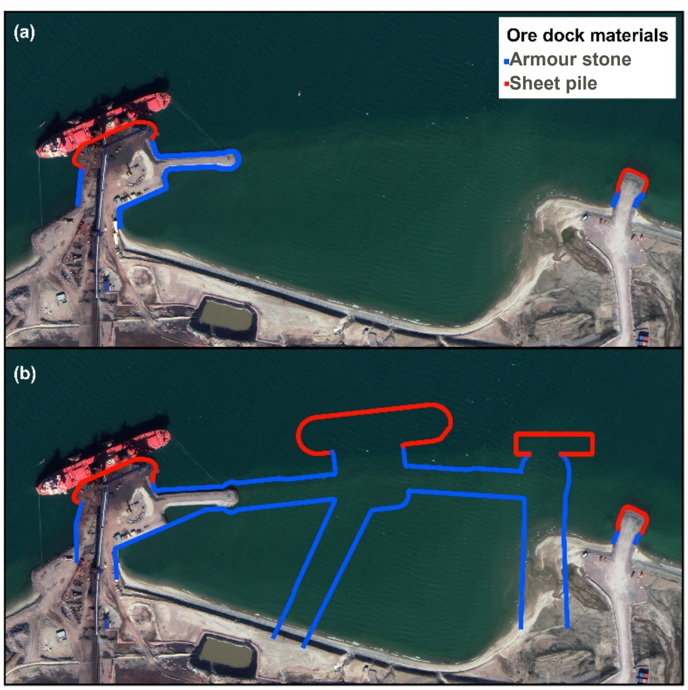

Figure B-3-2 Ore dock material characterization: (a) existing structure; (b) existing structure and proposed development

B-4.0 NEARSHORE SEDIMENT TRANSPORT MODEL

The sediment transport patterns near Milne Port were assessed using a nearshore sediment transport model assuming steady state wind conditions to simulate a series of idealized storms. The nearshore sediment transport model comprised the coupling of the local hydrodynamic model, providing currents, tides and sediment information with the wave model to provide wave height and period conditions, radiation stresses and orbital velocities. Deltares' Delf3D sediment module (incorporated in Delf3D-FLOW) was used. This modules models both suspended load using a 3-D advection-diffusion mass-balance equation and bedload transport using Van Rijn (1993) transport formula. The sediment transport model was simulated with winds from the northeast direction corresponding to the general direction of the longshore currents to provide the conservative idealized scenarios that would be conducive to causing morphological changes in the nearshore.

B-4.1 Model Coupling

The local hydrodynamic model was coupled with the wave model (section B-3.0) to form the sediment transport model. The wave model characteristics conducive to sediment transport, such as wave driven currents, enhanced turbulence and bed shear stress, are passed to the hydrodynamic model on an hourly basis. The water levels and wind from the hydrodynamic model is prescribed on an hourly basis to the wave model in order to account for tidal changes.

B-4.2 Boundary Conditions and Environmental Forcing

An idealised wind time series was used in the coupled hydrodynamic and wave model for the sediment transport. The time series have a duration of 7 days in the northeast direction. The first 144 hours is the average wind speed at 45° within ± 5º measured at Milne Port of 7.8 m/s. The last 24 hours represent a storm event, which is the maximum wind speed corresponding to the 50-year return period (22.9 m/s).

Discharge from Phillips Creek was applied to river intersection with the model boundaries using estimated constant mean river discharge. A concentration of fine sediment was prescribed in the Phillips Creek discharge.

Discharge from Phillips creek was applied to river intersections with the model boundaries using estimated constant mean river discharge

B-4.3 Sediment Characterization

Sediment grab samples were collected along the shoreline and offshore of the project area (SEM, 2016). Sediment characteristics on the proposed ore dock are characterized by borehole logs conducted by HATCH (2016). Visual observations were conducted by Golder along the beach on the project site (2017). Relevant information regarding sediment data is expanded on Appendix A, section 2.8.

The results of the analysis indicated that samples were all well graded with a percentage of gravel, sand and fines which was spatially varying. In all samples the content of clay was below 5%, leading to simplification of the model by excluding the cohesive fraction from the sediment transport assessment.

The sediment fractions of fines, sand and gravel, used for the initial characterization in the numerical model was determined by averaging fraction percentage within each individual sample set reported by HATCH (2016) and SEM (2016). The following values were selected as representative D_{50} of each sediment fraction: 2 mm for gravel; 0.2 mm for sand; and 0.1 mm for fines (I.e. minimum D_{50} size for non-cohesive fraction).

B-4.3.1 Sediment initiation

The spatial variability on the composition of the sediment samples was included in the model by initializing the model with representative percentages for each fraction (in terms of depth of the sediment layer). The identified areas correspond to: (1) inner harbour (HATCH, 2016 D001 and D002 samples); (2) west transect (SEM, 2016, SW series), (3) east transect (SEM, 2016, SE series), (4) east coastal transect (SEM, 2016, Coastal series); and (5) offshore transect (SEM, 2016, North series), as demonstrated in Figure B-4-1. Each area was prescribed a total sediment depth of 10 m to ensure enough sediments would be available throughout the simulation. The percentage (%) of each sediment fraction at each region is summarized in Table B-4-1. This sediment characterization was used in the hydrodynamic model to represent available sediment in different areas and assess the sediment transport patterns associated with existing and proposed conditions.

Table B-4-1 Sediment initiation value by areas

Region	Fines (%)	Sand (%)	Gravel (%)	Total sediment depth (m)
Inner Harbour	25	75	0	10
West Transect	30	60	10	10
East Transect	20	70	10	10
East Coastal Transect	70	20	10	10
North Transect	50	40	10	10

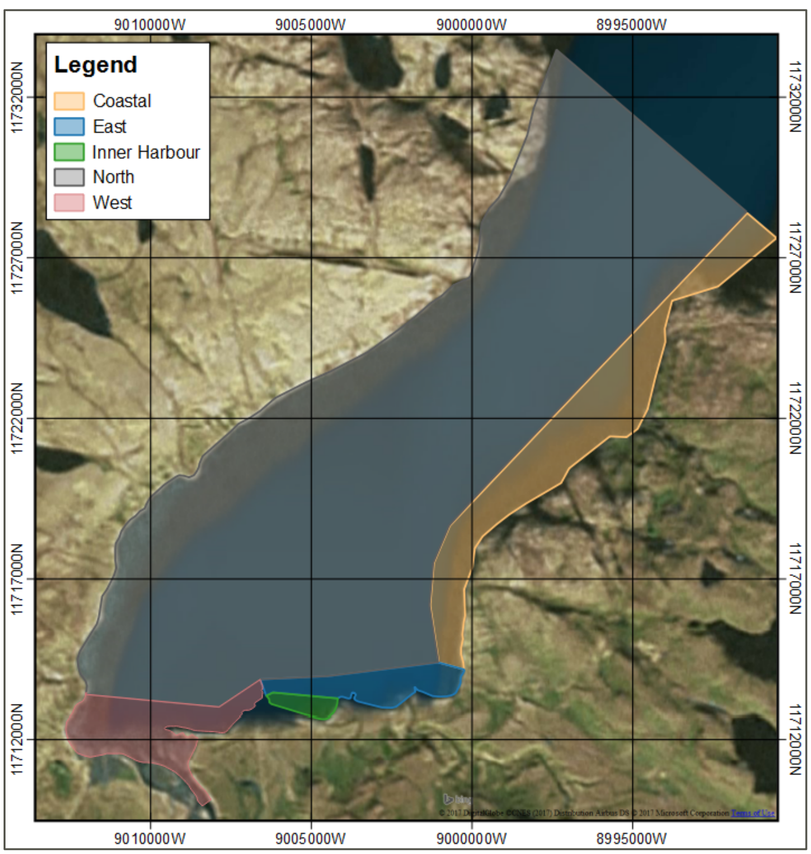

Figure B-4-1: Sediment initiation characterization region for the sediment transport model

B-4.3.2 Sediment Concentration

Initial sediment concentration within the domain is considered negligible. Water quality data for transects at the port provide estimates in the range of 1 mg/L. In order to simplify the model, a null value was selected as representative of background concentration to initialize the model. Given the low total suspended solids (TSS) in the port transects, this assumption is suspected to be irrelevant to assess changes in sediment transport patterns associated to the development of the proposed ore dock.

Flow and sediment data from Phillips creek was included in the nearshore sediment transport model. Monthly flow values are described in Appendix A, Section 2.6. A high-level assessment was completed to estimate the sediment concentration (TSS) for the creek. Based on the Clastic Yield, Geometric and BQART methods, the representative sediment concentration during the ice-free period was estimated at approximately 25 mg/L.

In order to represent the worst-case scenario, the higher flow rate (i.e. 41.9 m^3/s) was selected to represent the inflow of Phillips Creek into the project area.

B-4.4 Model Parameters

The sediment transport component of the model was initiated 48 hours after the start of the simulation to allow the hydrodynamic model to stabilize. Sediment transport calculations assumed dynamic bathymetry update from the change in sediment available.

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