Kimberley Technology Solutions Pty Ltd

Kimberley Supply Chain Cluster EIA - Phase 2

Marine Modelling of Coastal Processes and Construction Impacts

April 2021

Executive summary

Kimberley Technology Solutions Pty Ltd (KTS) propose to construct and operate an oil & gas supply base as part of a multi-user supply chain cluster (the proposal) on Cockatoo Island ~7 km off the Western Australian coast within the Buccaneer Archipelago (between Irvine Island and Koolan Island) and ~130 km north of Derby. Developments will comprise an upgraded airfield and a wharf, as well as other related support infrastructure. This investigation addresses a Western Australia (WA) Environmental Protection Authority (EPA) Notice Requiring Further Information (NRFI) for further assessment on the 2017 Referral submission regarding the environmental factor of coastal processes. Since the 2017 Referral to the EPA, there have been design changes of the proposed wharf to reduce potential marine environmental impacts. The proposed wharf area will involve the reclamation of ~6.2 ha of primarily intertidal flats immediately to the east of the existing mining marine structures. The objectives of the investigation are to determine the:

- Potential impacts to coastal processes (water currents, accretion/erosion zones) and benthic community habitats (BCH) (e.g. hard coral) from the proposed wharf with three-dimensional (3D) hydrodynamic modelling.
- Construction-related impacts from turbidity and sedimentation on BCH in terms of increased suspended solids (SS) and sedimentation.

A summary of this investigation's findings include:

- The impact of the proposed wharf on:
  - Changes to current speeds are limited to areas along the existing mine marine infrastructure to the west, along the proposed wharf and the small bay immediately to the east. However, these changes are modest and will not materially affect currents that alter coastal processes or conditions typically experienced by BCH.
  - Changes to bed shear stresses are limited to areas along the proposed wharf. These changes are modest and will not materially affect zones of accretion/erosion or conditions typically experienced by BCH.
- The effect of construction-related turbidity inputs of the proposed wharf include:
  - At the start of construction the potential impacts from sedimentation and increased SS above ambient levels are not predicted for any BCH in the two bays immediately to the east.
  - However, towards the completion of the construction when the turbidity source is closer to these bays to the east, potential sedimentation and increased SS impacts may occur in the small adjacent bay, but not the larger bay further to the east.
  - The direct (proposed wharf footprint) and indirect (from smothering by sedimentation and insufficient light from increased SS) losses of BCH are a very low percentage of the local regional spatial coverage (<0.1%).

Monitoring (e.g. visual plume observations), preventative controls (e.g. geotextile fabric) and mitigation measures (e.g. construction schedule) to manage the risk of potential construction impacts to the BCH of the two eastern bays will be incorporated into the Construction Environmental Management Plan.

This report is subject to, and must be read in conjunction with, the limitations, assumptions and qualifications throughout the Report.

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1. Introduction

Kimberley Technology Solutions Pty Ltd (KTS) propose to construct and operate an oil & gas supply base as part of a multi-user supply chain cluster (the proposal). The proposal is located on Cockatoo Island ~7 km off the Western Australian coast within the Buccaneer Archipelago (between Irvine Island and Koolan Island), ~130 km north of Derby. The proposal will support green- and brown-field developments off the north-western coast of Western Australia (WA) and the expansion of non-oil and gas activities, as well as reduce the operating costs of the mine on Cockatoo Island through shared infrastructure. Developments will comprise an upgraded airfield and a wharf, as well as other related support infrastructure that will benefit other industries.

The proposal was originally referred to the Department of Agriculture, Water and the Environment (DAWE) and the Western Australian Environmental Protection Authority (EPA) in 2017. On 30 January 2018 KTS received an EPA Notice Requesting Further Information (NRFI) for further assessment of the environmental factor of coastal processes on the basis of WA Department of Transport (DoT) advice, namely:

To enable this for your proposal, the following information is requested "quantified data and/or a report needs to be provided about the tidal dominated coastal processes, sedimentation, geomorphology and circulations, presented as engineering drawings and scientific plots and how they will be impacted by the proposal."

At a meeting with DoT on 2 March 2018 KTS committed to carry out modelling of typical tidal and wind conditions to address the NRFI. DoT indicated that the proposal's effects on coastal process during cyclonic conditions was also required. This position was maintained during a subsequent 5 April 2018 meeting. On 22 April 2020 DoT responded as follows:

As requested we have reviewed the GHD letter dated 2 April 2020. Our recommendations to EPA are unchanged. We are happy to encourage GHD to discuss with EPA directly on those matters. As a technical advisor to EPA we are happy to provide our service when requested by EPA. The proposed Cockatoo Island Infrastructure Project is within the Coastal Area 1 defined by the State Coastal Planning Policy (https://www.dplh.wa.gov.au/getmedia/954ec170-7b12-40b7-9708-800114a9826e/SPP-CST-SPP2-6_Policy). The Policy has clearly stated that 'The storm event for erosion and accretion should be based on ocean forces and coastal processes, which have a one percent or one-in-one hundred probability of being equalled or exceeded in any given year over the planning timeframe' and 'The allowance for the current risk of erosion should be based on a tropical cyclone storm event for areas one and two. For every development proposal within the WA's cyclonic coast (Area 1 and 2), DoT has been providing EPA with consistent advice on the required coastal process impact assessment. Extreme cyclone storms are the key geophysical processes that shape coastal morphology.

GHD maintains that the predicted effects of the proposed wharf on coastal processes (and the maintenance of ecosystem values) during cyclonic conditions will not be discernible from the existing (baseline) condition. Hence, GHD and KTS are of the view that cyclonic modelling is not needed for environmental assessment of this proposal because:

- DoT's regional guidance on cyclonic modelling does not consider its applicability to this proposal. The proposed wharf development is on an island with a steep and rocky shoreline that will have no effect/impact on coastal processes relative to the existing (baseline) condition during cyclones.
- The small spatial footprint of the proposed wharf development will be dwarfed by the size and intensity of a cyclonic event. Such an event will pose a large stressor on the marine

ecosystem (e.g. hard corals) of the region regardless of whether the wharf element of the proposal is implemented.

- In short, quantifying the effects/impacts of the proposal relative to the existing condition via cyclonic modelling will not be discernible.

Hence, cyclonic modelling is not considered relevant for the EPA to evaluate the effect of the proposed wharf on coastal processes and the maintenance of environmental values.

Since the referral to the EPA in 2017, there have been changes to the proposal's footprint. Changes to the design of the proposed wharf will reduce potential marine environmental effects. The revised wharf design now extends to the west (i.e. nearer to the existing mine), not as far offshore from the shoreline, and the outer edge follows the contour of the existing shelf prior to the steep slope into deeper waters. These design updates yield the following environmental improvements:

- There will be a markedly smaller reclamation footprint over deeper waters (>5 m).
- The proposed wharf reclamation area follows the intertidal shelf morphology thereby minimising potential areas of accretion and erosion due to local changes in water currents.
- Turbidity impacts during construction will be less because reclamation will predominantly occur on the shallow intertidal shelf with a marked reduction of turbidity from not extending the reclamation into deeper waters.
- Noise impacts during construction will be less as the new design requires no sheet piling along the offshore edge of the proposed wharf and fewer pylons for the berths.

The proposed wharf area will involve the reclamation of ~6.2 ha of primarily intertidal flats immediately to the east of the existing marine structures of the mine (Figure 1). Two stages are planned for the proposed wharf, namely:

- Initially stage 1 will be developed with an area of ~2.1 ha to service Berth 1.
- At a later date, stage 2 will be developed with an area of ~4.2 ha to service Berths 2 and 3.

Figure 1 Area of wharf reclamation circled in red (left) and close-up with Stage 1 outlined in transparent yellow shading (right).

1.1 Objective and Scope

1.1.1 Coastal Processes

The environmental objective as stated in the EPA's Environmental Factor Guideline for Coastal Processes is to '*maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected*'. For the proposed wharf the environmental value of maintenance of ecosystem values is of potential concern (but not landforms amenity, recreation, tourism and commercial-industrial-urban use).

The wharf development has the potential to alter tidal currents and impact the maintenance of ecosystem values, primarily those associated with of the two (small and large) bays to the east. Hence, any changes to the patterns of accretion and erosion within these bays may negatively impact on benthic communities and habitats (BCH) (e.g. hard corals). Potential coastal processes effects/impacts on the maintenance of ecosystem values from the proposed wharf are evaluated with hydrodynamic modelling over a typical range of tidal and wind driven forcing. The wharf development's effects/impacts due to changes in predicted areas of accretion and erosion on BCH (e.g. hard coral) is then assessed.

1.1.2 Construction Impacts

Potential construction-related impacts of the proposed wharf on proximal BCH are evaluated that include:

- Increased turbidity in the water column with the potential to decrease underwater light sufficiently to impact benthic primary producers such as proximal hard corals.
- Sedimentation has the potential to cause smothering of BCH.

1.2 Disclaimer

This report: has been prepared by GHD for Kimberley Technology Solutions Pty Ltd and *may only be used and relied on by Kimberley Technology Solutions Pty Ltd for the purpose agreed between GHD and the Kimberley Technology Solutions Pty Ltd as set out in section … of this report.*

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2. Description of the Environment

2.1 Tides

Tidal plane information from Australia Tide 2018 (Department of Defence, 2018) is shown in Table 1 at Yampi Sound adjacent to Cockatoo Island. Typical spring and neap tidal ranges are ~8.8 m and ~2.2 m, respectively.

Table 1 Tidal levels at Yampi Sound

Datum	Water Level (m LAT)
Highest Astronomical Tide (HAT)	+11.0
Mean High Water Springs (MHWS)	+9.9
Mean High Water Neaps (MHWN)	+6.6
Mean Sea Level (MSL)	+5.5
Mean Low Water Neaps (MLWN)	+4.4
Mean Low Water Springs (MLWS)	+1.1
Lowest Astronomical Tide (LAT)	+0.0

2.2 Winds

The National Centers for Environmental Prediction (NCEP) Climate Forecasting System version 2 (CFSv2) winds (Kalnay *et al*., 1996; Kistler *et al*., 2001) served as temporally (hourly) and spatially (0.2°) varying model inputs (see Section 3.4). CFSv2 monthly wind roses at the proposed wharf location are shown in Figure 2. The wind regime is characterised primarily by northwesterly winds from September to March and southwesterly winds May to July.

2.3 Physical Attributes

The shorelines are steep and rocky and not susceptible to erosion.

There are several intertidal beaches that include:

- A small beach in the bay (hereafter referred to as Bay 1) within the proposed wharf development footprint that was identified by GHD (2017a) to not materially contribute to longshore sediment transport.
- Beaches at the central shorelines of the adjacent eastern bays (Bay 2 and 3).

Refer to the bathymetry (Figure 6) described in Section 3.2 for a visual representation of the underwater morphology in the local area of the proposed wharf. The bays lie over intertidal shelfs of ~±4 m AHD depth. There is a steep slope between these intertidal shelves and the deeper waters (>20 m). At the headlands between bays, the intertidal shelf is very narrow. On the basis of this characteristic morphology, benthic primary producers that require complete immersion at all times (e.g. hard corals) are likely to only inhabit the upper portions of the slope (escarpment) to the deeper waters and not the intertidal shelves, because of air exposure on the intertidal shelf and insufficient light in deeper waters (e.g. >20 m).

The sediments on the basis of visual analysis of photos (GHD 2017b) are primarily sand, which suggests the high tidal-induced currents maintain low fines (e.g. clay and silt) content. The small beach in Bay 1 under the proposed wharf footprint is of low ecological value and heavily impacted by past and ongoing mining operations that are immediately adjacent to the west (GHD 2017b).

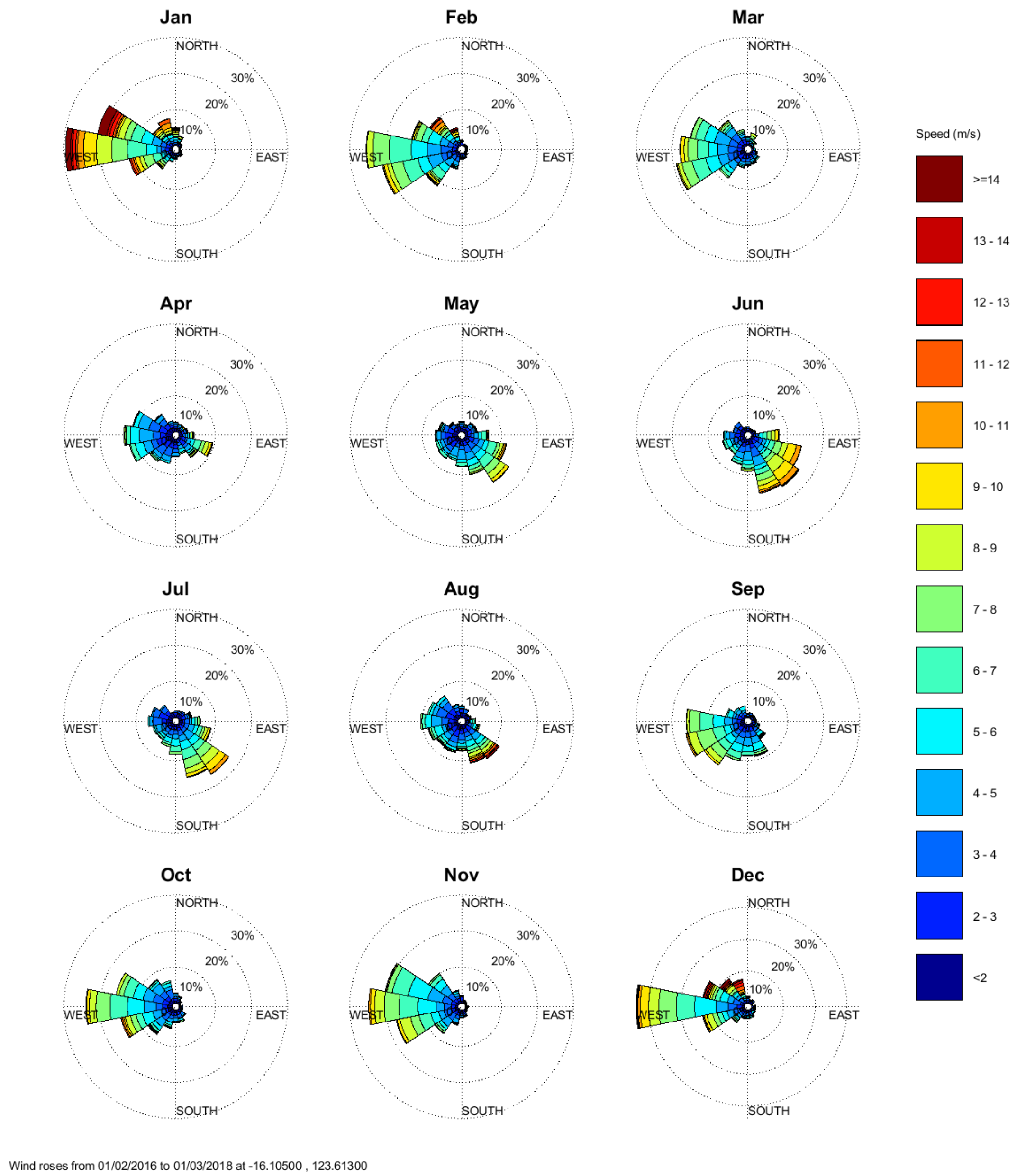

Figure 2 Monthly wind roses from CFSv2 dataset at Cockatoo Island (-16.105, 123.613) near the proposed development over the period of February 2016-February 2018.

2.4 Benthic Community Habitat

GHD (2017b) described the benthic community habitat (BCH) (Figure 3) and hard coral (Figure 4) spatial distributions, and areal estimates of BCH and hard coral cover (Table 2) across the proposed wharf area (Bay 1) and the two bays to the east (Bays 2 and 3). Hard corals (Figure 4) primarily occur along the slope between the intertidal flats of the bays and the deeper waters, and off the interspersed headlands (refer to bathymetry of Figure 6). As mentioned beforehand, presumably exposure of hard corals to air on the intertidal flats and light limitation at depth along the slope to deeper waters limits the spatial extent of hard corals over a narrow region on the underwater escarpment. Macroalgae occurrence along the offshore half of the intertidal shelf of Bay 3 is likely because of greater resilience to air exposure (Figure 3).

Table 2 Summary of hard coral and macroalgae coverage area estimates (GHD 2017b).

Parameter	Bay A	Bay B	Bay C	Total
Total Surveyed Area (ha)	7.55	3.47	19.64	30.66
Hard Coral Area				
Calculated Hard Coral Coverage (ha)	0.20	0.72	4.00	4.92
% Hard Coral Cover	3%	21%	20%	16%
Macroalgae Area				
Calculated Macroalgae Coverage (ha)	0.19	0.16	1.15	1.5
% Macroalgae Cover	3%	5%	6%	5%

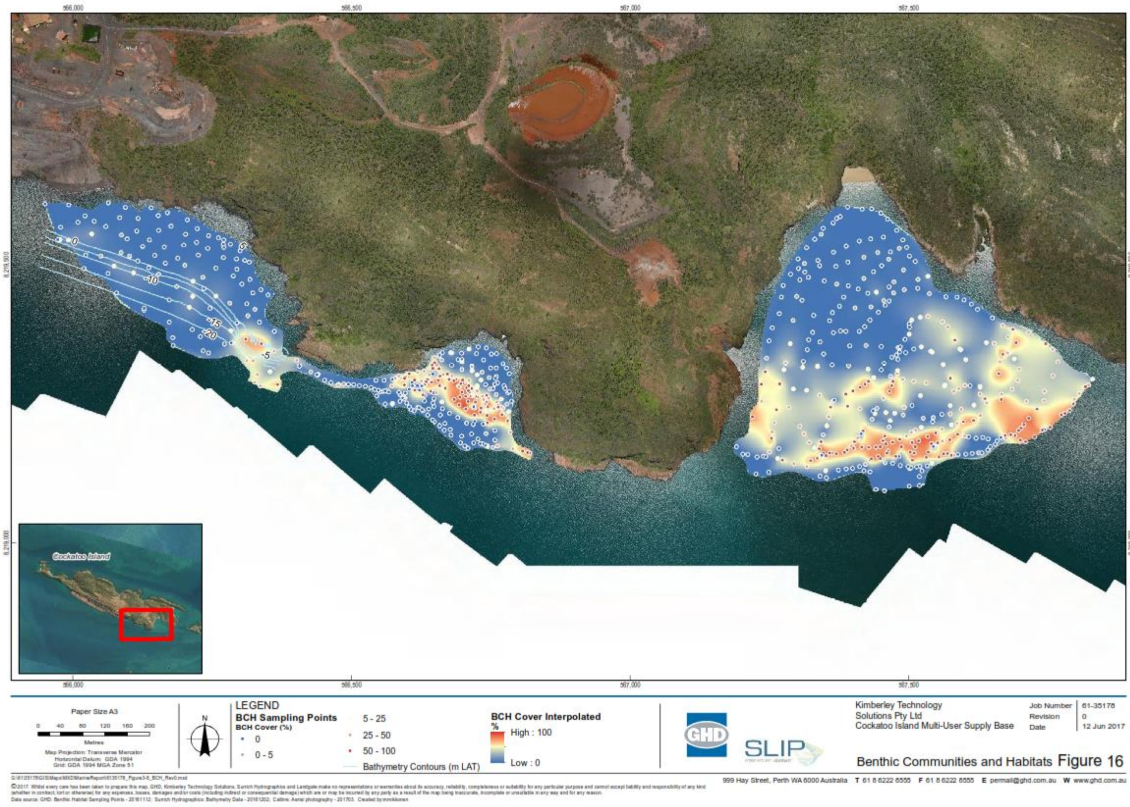

Figure 3 Spatial distribution and abundance of of BCH (GHD 2017b).

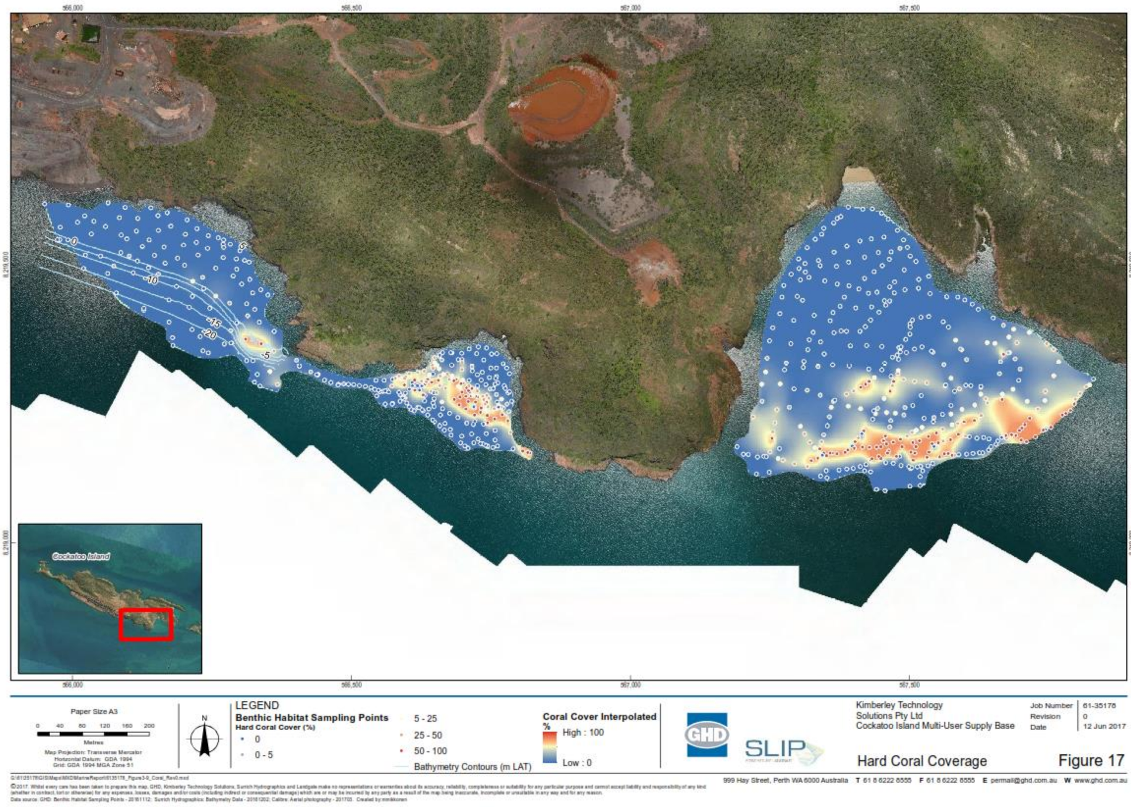

Figure 4 Spatial distribution and abundance of hard corals (GHD 2017b).

3. Three-Dimensional Model

Three-dimensional (3D) simulations with the Danish Hydraulic Institute's (DHI's) MIKE 3 Flexible Mesh (FM) hydrodynamic model were used to evaluate the effect of the proposed wharf on coastal processes during ambient conditions. Further, construction-related releases of fine particles (i.e. clay and silt) and subsequent sedimentation impacts were also evaluated with the MIKE Mud Transport (MT) module. The 3D hydrodynamic model was configured with spatially varying winds over the surface and tidal-oceanographic currents and water levels along the boundaries. Further details regarding the 3D hydrodynamic modelling are described in the remainder of this Section.

3.1 MIKE 3 Flexible Mesh

MIKE 3 FM is an industry standard for 3D hydrodynamic modelling. The model domain in MIKE 3 FM is defined horizontally by an irregular network of triangles (the model cells) that are split into vertical layers. For each model cell, MIKE 3 FM simulates a range of hydrodynamic properties including, but not limited to, current speed, current direction, water level and salinity. MIKE 3 FM is driven by user-defined environmental inputs (e.g. water level variations at open boundaries, wind speeds and directions over the surface, and point-source inputs such as turbidity generated during breakwater construction).

3.2 Model Domain

The model domain, mesh and bathymetry are shown in Figure 5. Mesh element sizes range from ~10 km at the offshore boundaries (Figure 5) to ~40-50 m in the vicinity of the proposed wharf (Figure 6). The model bathymetry was based on DHI's C-Map database of digitised nautical charts. The vertical layering was configured as follows:

- Sigma coordinate system of the three top layers of the upper 10 m that expand and contract in response to tidal and non-tidal water level variations.
- Fixed coordinate system of five lower layers with 5, 10, 15, 20 and 40 m thicknesses.

3.3 Open Ocean Boundary Inputs

Model inputs of spatially varying water level and currents along the offshore boundaries were from DHI's Global Tide Model astronomical tides (Cheng and Andersen 2010) and oceanographic currents from the Hybrid Coordinate Ocean Model (HYCOM) (Chassignet et al. 2007). An example of the model's offshore inputs at the middle of the northern open boundary from February-May 2016 are illustrated for water levels in Figure 7; and v-currents (north-south) and u-currents (east-west currents) in Figure 8.

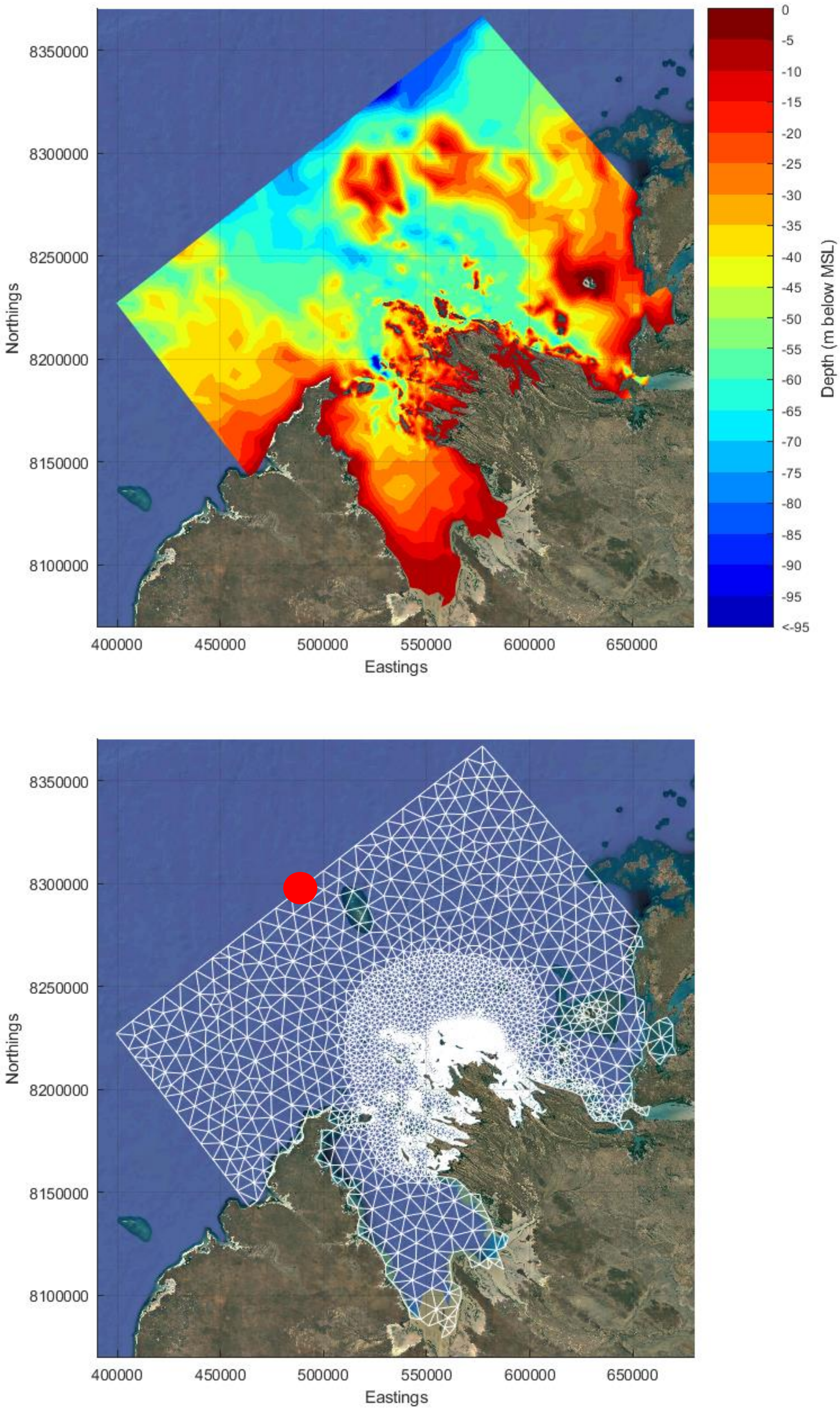

Figure 5 Model bathymetry (top) and mesh (bottom) of the entire domain. Red circle denotes the middle of northern offshore boundary.

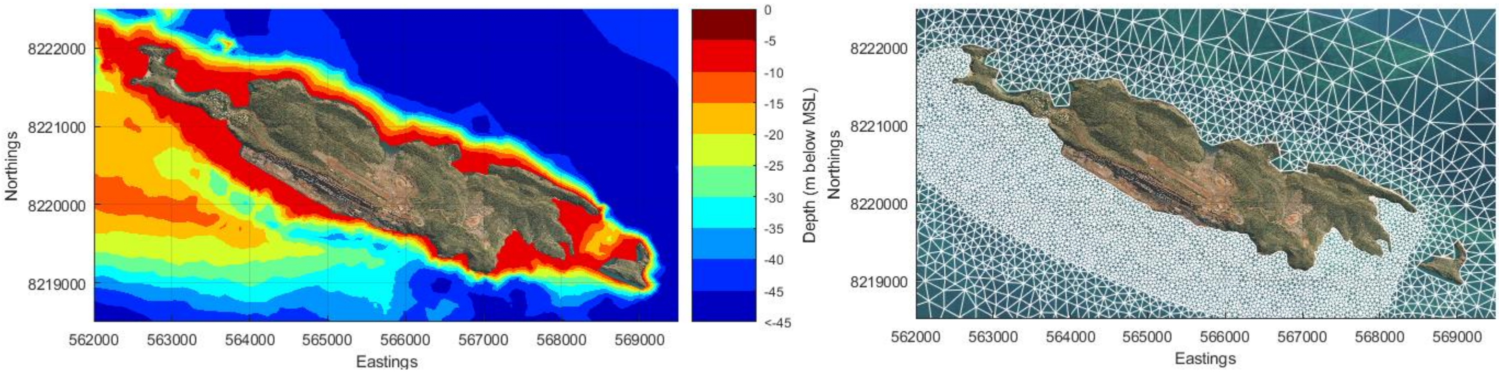

Figure 6 Model bathymetry (left) and mesh (right) around Cockatoo Island.

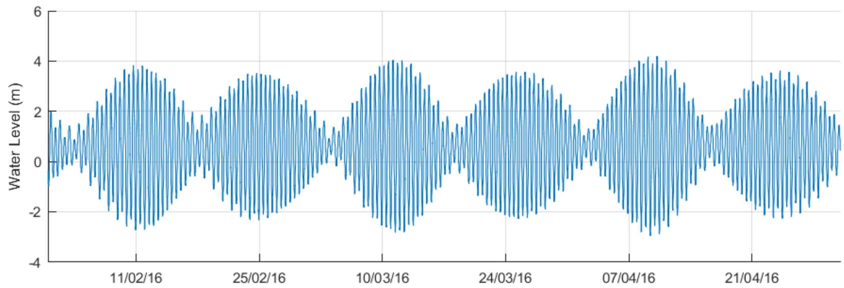

Figure 7 Water levels at the middle of the northern offshore open boundary from February-April 2016.

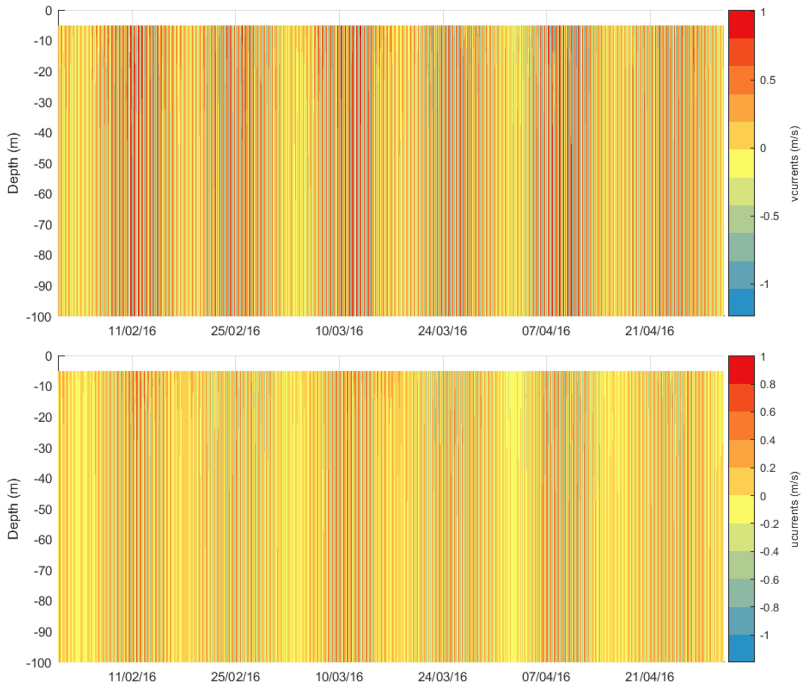

Figure 8 V- (top) and U- (bottom) currents at the middle of the northern open boundary from February to April 2016.

3.4 Wind Forcing

Seasonal wind patterns were described previously in Section 2.2 as monthly wind roses at the proposed wharf location. Spatially variable CFSv2 wind forcing was applied to this investigation's simulations. A comparison of Bureau of Meteorology (BoM) wind speed and wind direction measurements at Adele Island (station number 200735) and the corresponding CFSv2 grid cell indicate very good agreement (Figure 9), which provides confidence that the spatially varying wind model inputs are an accurate representation of this key input to properly resolve the local and regional surface currents.

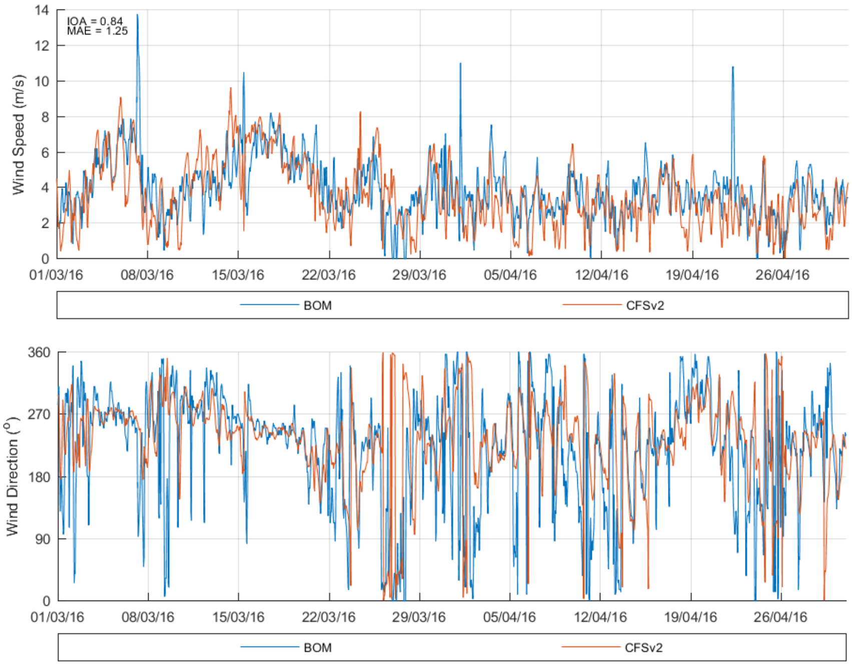

Figure 9 Wind speed (top) and direction (bottom) at BoM Adele Island station with corresponding CFSv2 data from March to April 2016.

3.5 Construction Inputs

The simulated fine particles (i.e. clay and silt) that are generated during the construction of the proposed wharf were configured into five (5) groups on the basis of particle diameters and settling velocities (Table 3). Only the fines component of the fines component of the suspended solids (SS) is simulated because these are transported sufficient to affect turbidity and sedimentation of key BCH identified by GHD (2017b). Because particle size distribution (PSD) data is not available of the reclamation material, each of the five particle groups were assumed to comprise 20% of the fines material.

Table 3 Fines particle percentages and settling velocities of reclamation material.

Generic Group	Diameter (µm)	PSD (%)	Settling velocity (cm/s)
Clay	0-4	20	0.00033
Very Fine Silt	4-8	20	0.0030
Fine Silt	8-16	20	0.012
Medium Silt	16-31	20	0.045
Coarse Silt	31-63	20	0.18

A 0.4 kg/s mass flux of fines during daylight (12 hours per day) was estimated from:

- An average of 1,450 m^3/day of wharf development per day as advised by KTS.
- Assuming 1% of the reclamation material is comprised of fine particles. KTS note that '*The fill on Cockatoo comprises sands and overburden from the mining operation. It is largely free of fine silts and clays.*' Hence, this 1% of fines fraction of the reclamation material is likely to be an over-estimate. For example, RPS APASA (2016) used 1.5% fines for the core material of the Ocean Reef breakwater construction.

- Assuming only 50% of the fines are released into the marine waters during construction because of decreases from the use of geotextile fabric with a nominal pore size of 100 µm. The small pore size will reduce flow into the interstitial voids of the recently constructed breakwater thereby decreasing the release of fines. A 50% reduction in the release of fines is likely to be conservative as the geotextile fabric likely yields a greater reduction in the release of fines.

Two construction cases are evaluated, namely at the western extent of the proposed wharf during the start of construction, and at the eastern extent of the proposed wharf near the completion of construction.

Net sedimentation of fine particles was simulated with Mike MT with the following key industry-standard model parameters:

- Critical shear stress for deposition is <0.07 N/m^2. This value is in the upper range of values for fine sand and coarse silt, hence settling of fines is allowed for relatively simulated high shear stresses and is thereby an overestimate of sedimentation of clay, and very fine to medium silt diameters.
- Critical shear stress for resuspension/erosion >0.1 N/m^2. This value is typical for fines.

3.6 Three-Dimensional Model Scenarios

The 3D modelling scenarios of this investigation are summarised in Table 4. To ensure current speeds and directions in the model domain achieve realistic dynamic conditions, a simulation warm-up period of ~1 week was carried out with the remainder of the model run used for scenario analysis.

Table 4 Summary of simulation scenarios.

<table>
<tr><th>Scenario</th><th>Wharf Development</th><th>Hydrodynamic Simulation Warm-Up</th><th>Hydrodynamic and Particle Simulations</th><th>Coastal Process Analysis</th><th>Construction Analysis</th></tr>
<tr><td>Water Level Verification & Baseline Scenario</td><td>No</td><td rowspan="2">21–28 February 2016</td><td rowspan="2">1 March–30 April 2016</td><td>Baseline</td><td>Start of wharf construction</td></tr>
<tr><td>Wharf Scenario</td><td>Yes</td><td>Wharf Proposal</td><td>End of wharf construction</td></tr>
</table>

3.6.1 Model Verification

Demonstration of model performance of simulated water levels versus astronomical (predicted) tides used the following metrics:

- **Percentile probability distributions** of simulated water levels and astronomical (predicted) tides are a graphical comparison of the statistical spread at a particular location (e.g. water level range at a site). This comparison illustrates the percentage of time that the model is under- or over- predicting the astronomical (predicted) tides;
- **Mean Absolute Error (MAE)** is a quantitative measure of the differences between the simulation and measurements at a particular location. Specifically, it is the average of the absolute differences between the simulated predictions and the measured observations at each time step. Lower MAEs represent better model performance. This metric is an easily interpretable and more natural measure than the commonly used root-mean-squared error (Wilmott 1982), because it is less influenced by extreme values (i.e. outliers). The **MAE** is calculated as:

$$\boldsymbol{MAE} = \frac{\sum_{i=1}^{n}|S_i - O_i|}{n}$$

where:

- S_i = Simulated value at comparison time i;
- O_i = Observed value at comparison time i; and
- n = number of comparison measurements.

- **Index of Agreement (IOA)** is a measure of the average differences between simulated and observed values relative to the range of values in the observation data (Wilmott 1982). It is between 0 and 1 with values near 0 representative of large (i.e. poor model performance) and small (i.e. good model performance) relative differences, respectively. Wilmot et al. (1985) suggest that IOA values that are meaningfully greater than 0.5 represent good model performance and those approaching 1 represent excellent model performance. The **IOA** is calculated as:

$$\boldsymbol{IOA} = 1 - \frac{\sum_{i=1}^{n}(S_i - O_i)^2}{\sum_{i=1}^{n}(|S_i - \bar{O}| + |O_i - \bar{O}|)^2}$$

where further to the definitions for MAE:

- $\bar{O}$ = The mean of the observations during the comparison period.

3.6.2 Hydrodynamic Impact Assessment

The depth-averaged current speeds and bed shear stresses for the baseline case are used to characterise the key physical oceanography measures that influence coastal processes along the southern shoreline of Cockatoo Island. For both of these simulated variables, the 50th, 80th, 95th and 99th percentile differences between the proposed wharf and baseline simulations are used to discuss the potential effects of the development on the coastal process of southern Cockatoo Island.

3.6.3 Construction Impact Assessment

Mike MT is used to simulate the excess fines SS above ambient levels due to construction of the proposed wharf. The following typical impact thresholds are used to evaluate if any impacts are likely during the proposed wharf's construction:

- <u>SS of 1 mg/L:</u> This is a direct model output. The SS impact threshold of 1 mg/L is evaluated spatially as temporal 80th, 95th and 99th percentile contours ror the two construction scenarios (start and end of proposed wharf construction). For example, the 80th percentile contour envelopes the area that contains model grid cells >1 mg/L for 80% of the time (alternatively, outside of this contour >1 mg/L concentrations are only exceeded for 20% of the time).
- <u>Sedimentation of 3 mm:</u> This is a direct model output. It is plotted for the two construction scenarios at the completion of the 60 day simulation.
- <u>Sedimentation rate of 10 g/m^2/day:</u> The average sedimentation rate (g/m^2/day) is calculated as the sedimentation mass (g/m^2, a direct model output) divided by ~60 days (i.e. the duration of the simulation).

4. Results

4.1 Model Verification of Water Levels

Simulated water levels were verified with predicted (astronomical) tides (i.e. XTide model predictions accessed via the T-bone website http://tbone.biol.sc.edu/tide). The model performance in regards to water levels from 1 March -30 April 2016 at Cockatoo Island is illustrated in Figure 10. Generally, the model performance was very good whereby:

- The IOA value was 0.99, which represents excellent model performance.
- The MAE value of 0.36 m was low relative to the range of water levels (~10 m).
- The model simulated the timing of water level fluctuations very well (Figure 10).

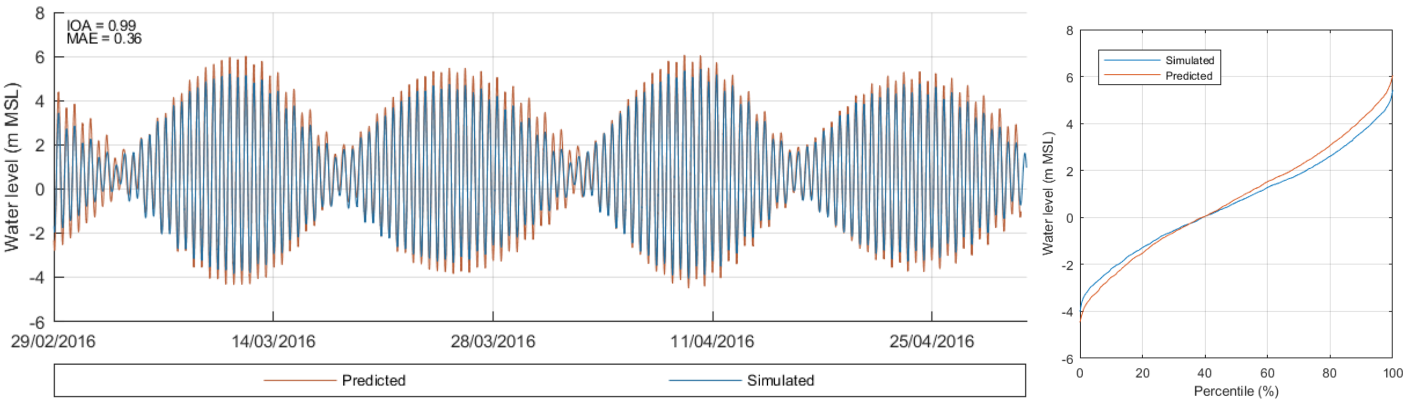

Figure 10 Predicted (astronomical) tidal levels and simulated water levels near western shoreline of Cockatoo Island (left panel: time series, right panel: percentile distribution) from March-April 2016.

4.2 Coastal Processes

4.2.1 Ambient Currents

Simulated current speeds of the baseline case in the vicinity of the proposed wharf are illustrated in Figure 11 where:

- Generally current speeds increase with water depth (refer to Figure 6 for bathymetry).
- Median current speeds range from >0.1 m/s (near shoreline) to 0.2 m/s (near slope to deeper waters) over the proposed wharf area (Bay 1), and the intertidal shelves of adjacent Bays 1 and 2 to the east. The maximum median currents in the deep waters to the southeast of the proposed wharf ranged from 0.3-0.4 m/s.
- The 80th percentile current speeds are <0.1-0.2 m/s in the shallow waters of the intertidal shelves over the proposed wharf area (Bay 1), and the adjacent Bays 2 and 3 to the east. The 80th percentile currents increase to 0.2-0.3 m/s along the slope between the shallow intertidal regions to deep waters. The maximum 80th percentile currents in the deep waters to the southeast of the proposed wharf range from 0.4-0.6 m/s.
- The 95th percentile current speeds are <0.1 m/s in the very shallow waters adjacent to the shoreline of the proposed wharf (Bay 1), and the adjacent Bays 2 and 3 to the east. The 95th percentile currents increase to 0.3-0.4 m/s across the slope of the shallow intertidal to deeper waters. The maximum 95th percentile currents in the deep waters to the southeast of the proposed wharf are 0.6-0.8 m/s.

- The 99th percentile current speeds are <0.1 m/s in the very shallow waters adjacent to the shoreline of the proposed wharf (Bay 1), and adjacent Bays 2 and 3 to the east. The 99th percentile currents increase to 0.3-0.4 m/s across the slope to deeper waters. The maximum 99th percentile currents in deeper waters to the southeast range from 0.7-0.9 m/s.

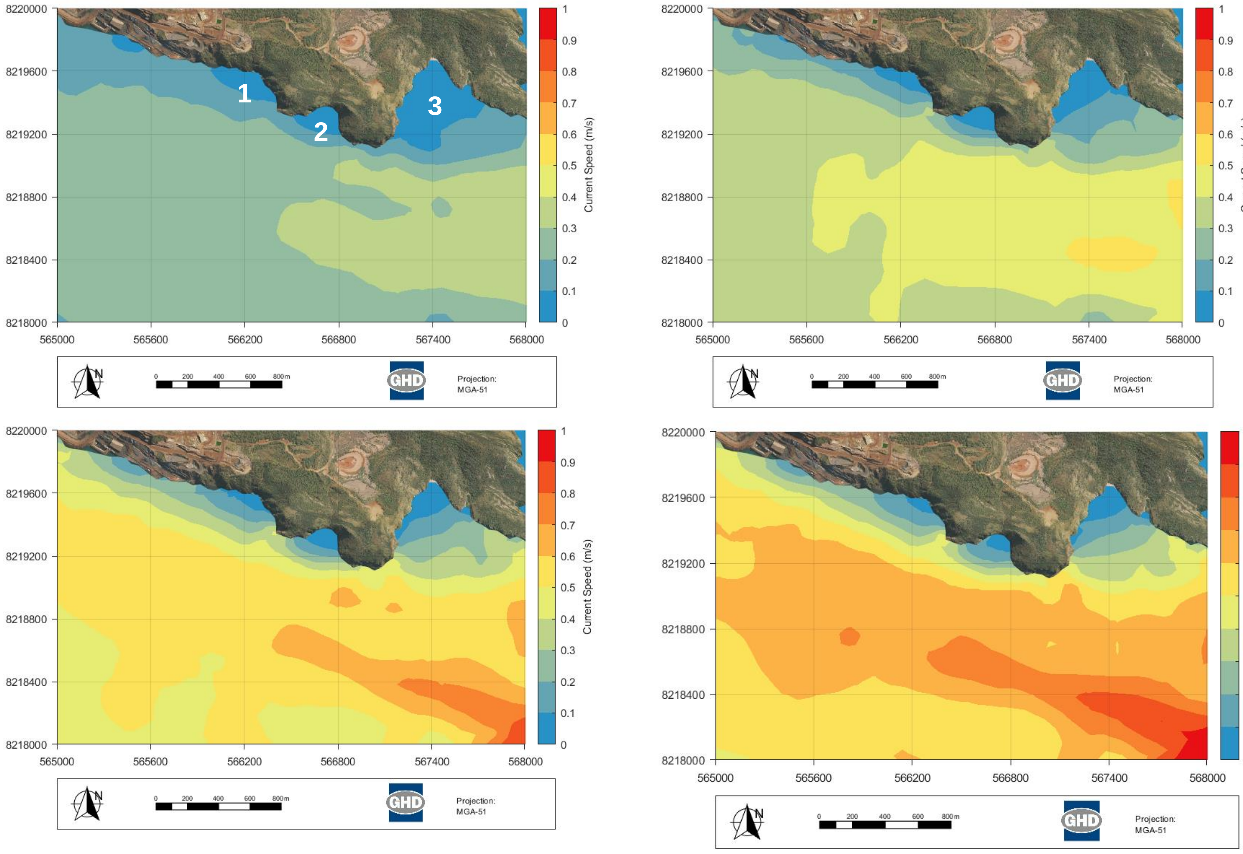

Figure 11 50th (top left)[1], 80th (top right), 95th (bottom left) and 99th (bottom right) percentiles of simulated depth-average current speeds for the baseline condition from February-April 2016.

Predicted changes to current speeds were evaluated by differencing the simulated current speeds at each time step of the proposed wharf model run by those of the existing baseline, and evaluating the 50th, 80th, 95th and 99th percentiles of these differences (Figure 12). The following changes in currents are predicted due to placement of the proposed wharf into Bay 1:

- The median change was limited to the eastern half of the proposed wharf (Bay 1) and the headland immediately to the east with decrease current speeds of 0.01-0.05 m/s within 100-150 m of the shore.
- The 80th percentile change was limited to a small region within ~200 m of the middle of the proposed wharf (Bay 1) and a small region within ~50 m of the western shoreline of Bay 2 to the east with increased current speeds of ~0.01-0.02 m/s.
- The 95th percentile predicts increased current speeds of 0.01-0.03 m/s along the nearshore waters (within 150 m) 500 m to the west of the proposed wharf (Bay 1), within 400 m along the nearshore waters of the proposed wharf, and within Bay 2 to the east.
- The 99th percentile change in current speeds was limited to within ~400 m to the west and along the proposed wharf (Bay 1), and Bay 2 to the east, with an increase of ~0.01-0.05 m/s.

[1] A – proposed development, B – small bay immediately to the east, C – larger to the east

These differences in current speeds are within ~10% of the baseline nearshore current speeds and are primarily limited to the west along the existing mine marine infrastructure, along the proposed wharf (Bay 1), and in Bay 2 to the east. This magnitude of change is highly unlikely to cause any material change in water currents that existing BCH experience. Changes to the current speeds in larger Bay 3 to the east are not predicted as a result of the proposed wharf.

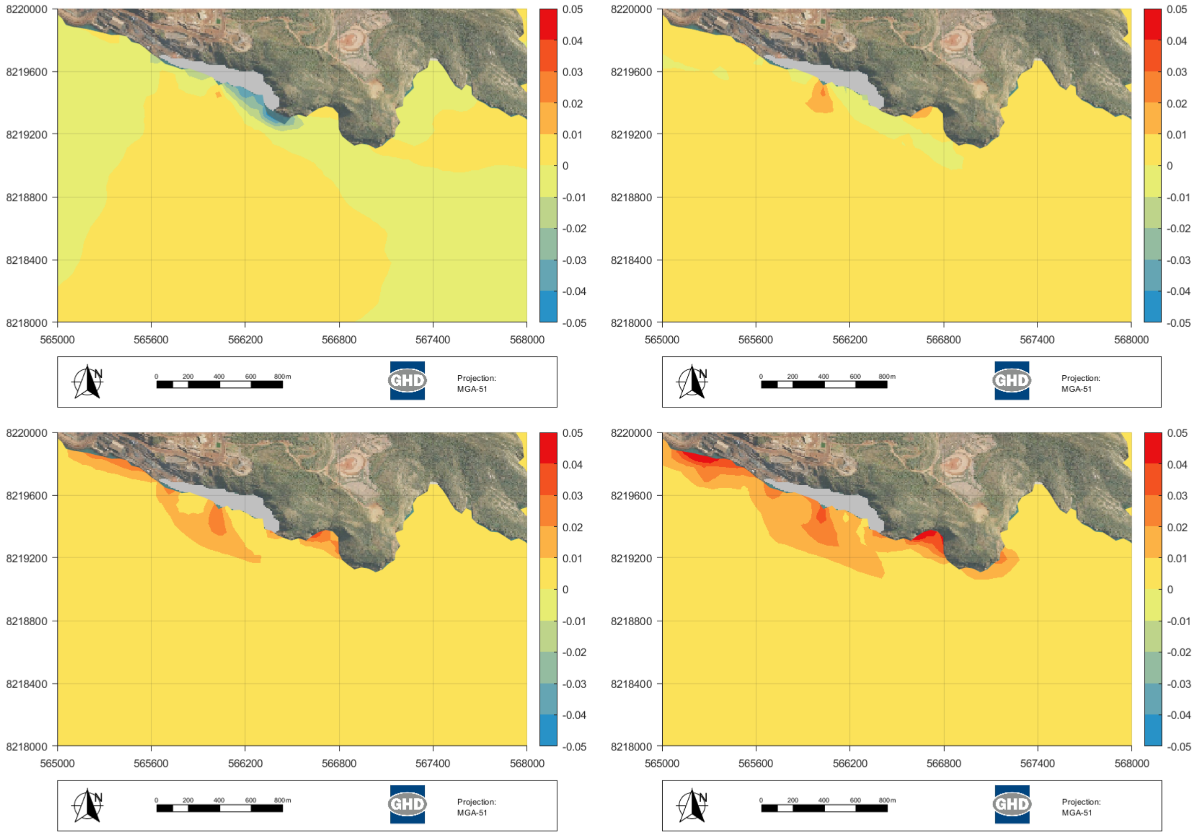

Figure 12 50th (top left), 80th (top right), 95th (bottom left) and 99th (bottom right) percentile of in depth-averaged current speed differences of the proposed and the baseline scenarios from March-April 2016.

4.2.2 Bed Shear Stress

Simulated bed shear stresses of the baseline case in the vicinity of the proposed wharf are illustrated in Figure 13 where:

- Generally, bed shear stresses increase with water depth (Figure 6) due to the concomitant increase in current speeds (Figure 11).
- Median bed shear stresses are <0.05 N/m^2 over the area of the proposed wharf (Bay 1), Bays 2 and 3 to the east. The maximum median stresses (0.2-0.4 N/m^2) occur in deep waters southeast of the proposed wharf.
- The 80th percentile bed shear stresses are <0.05 N/m^2 in the shallow intertidal waters over the area of the proposed wharf (Bay 1), adjacent Bays 2 and 3 to the east. The 80th percentile stresses increase to 0.2 N/m^2 at the slope to deeper waters. The maximum 80th percentile stresses (0.4-0.6 N/m^2) occur in deep waters to the southeast of the proposed wharf.
- The 95th percentile bed shear stresses are <0.1 N/m^2 in the shallow intertidal waters of the proposed wharf area (Bay 1), adjacent Bays 2 and 3 to the east. The 95th percentile stresses increase to 0.4 N/m^2 across the slope to deeper waters. The maximum 95th

percentile stresses (0.6-1.2 N/m^2) occur in the deep waters to the southeast of the proposed wharf.

- The 99^{th} percentile bed shear stresses are <0.2 N/m^2 in the shallow intetidal waters of the proposed wharf area (Bay 1), adjacent Bays 2 and 3 to the east. The 99^{th} percentile stresses increase to 0.6 N/m^2 at the slope to deeper waters. The maximum 99^{th} percentile stresses (0.6-2 N/m^2) occur in the deep waters to the southeast.

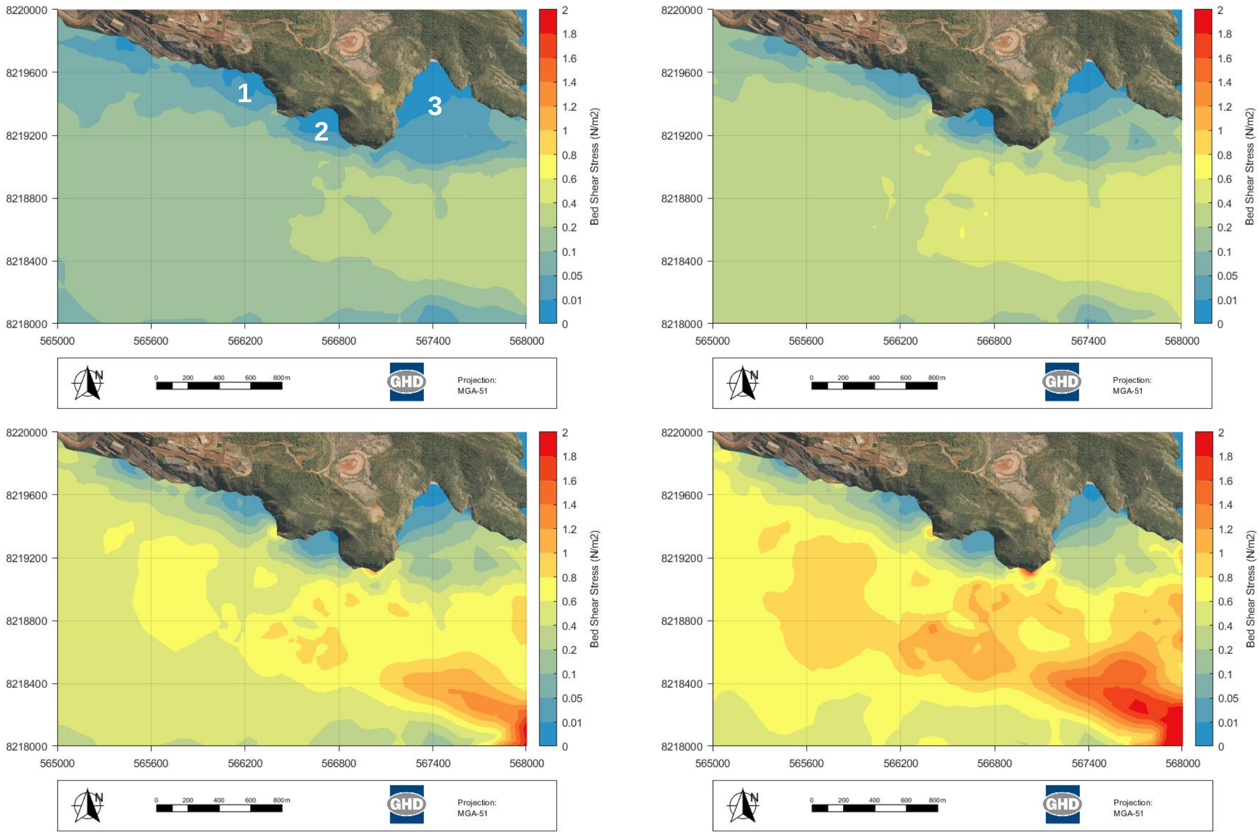

Figure 13 50^{th} (upper left)[2], 80^{th} (upper right), 95^{th} (lower left) and 99^{th} (lower right) percentiles of simulated bed shear stresses for the baseline scenario from March-April 2016.

Predicted changes to bed shear stresses from the proposed wharf development were evaluated by differencing the simulated bed shear stresses at each time step of the proposed wharf simulation by those of the existing baseline, and plotting the 50^{th}, 80^{th}, 95^{th} and 99^{th} percentiles (Figure 14). The following changes in bed shear stresses were simulated as a result of the proposed wharf:

- The median change in bed shear stresses was low between -0.06 N/m^2 to 0.02 N/m^2.
- The 80^{th} percentile change in bed shear stresses was limited to a small region within ~100-200 m of the middle of the proposed wharf (Bay 1) with an increase of ~0.02-0.06 N/m^2.
- The 95^{th} percentile change in bed shear stresses was limited primarily to within ~400 m of the western half of the proposed wharf (Bay 1) with an increase of ~0.02-0.08 N/m^2.
- The 99^{th} percentile change in bed shear stresses was primarily limited to within ~500 m to the west and along the proposed wharf (Bay 1) with an increase of ~0.02-0.1 N/m^2.

These differences in bed shear stresses between the proposed and baseline scenarios constitute a ~10% change in the nearshore waters. Most of these differences are along the

[2] A – proposed development, B – small bay immediately to the east, C – larger bay to the east

proposed wharf (Bay 1). This magnitude of change is unlikely to materially modify the baseline zones of accretion and erosion including those in Bays 2 and 3 to the east.

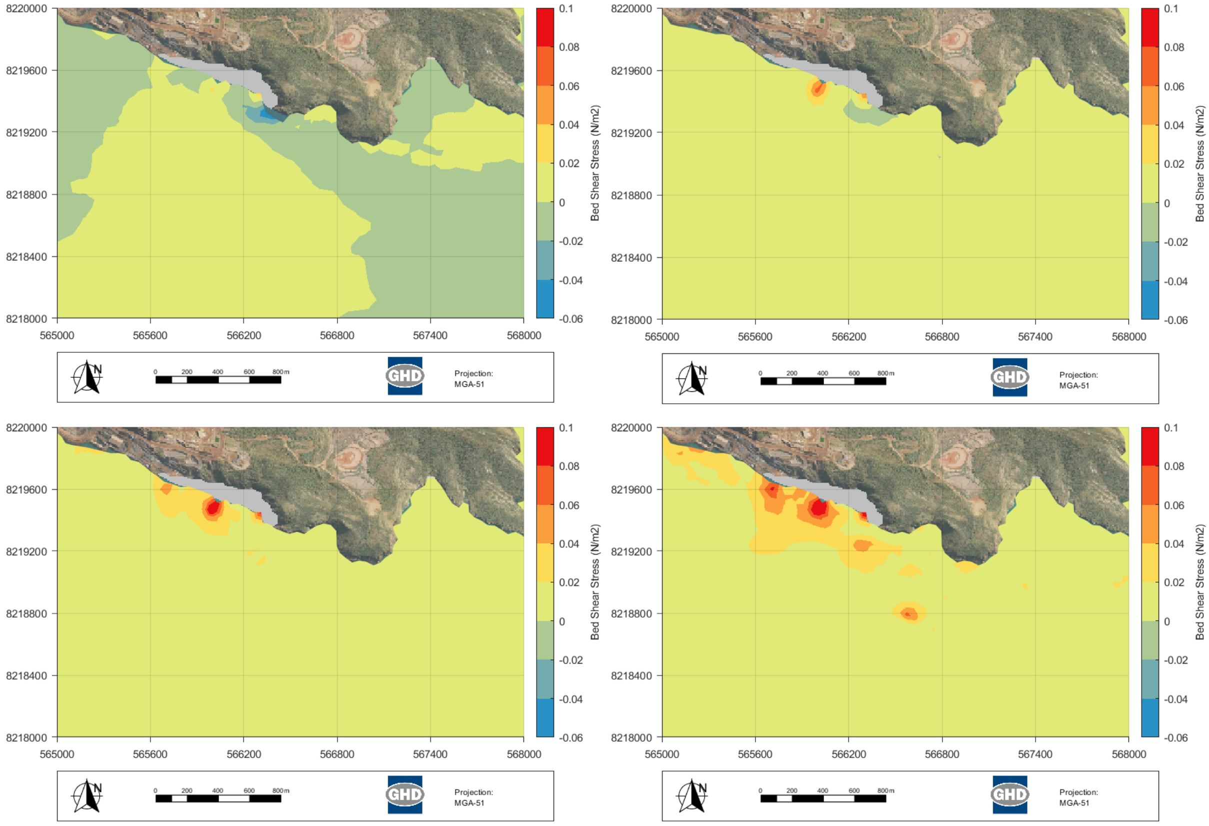

Figure 14 50th (upper left), 80th (upper right), 95th (lower left) and 99th (lower right) percentiles of bed shear stress differences between the proposed and the baseline scenarios from March-April 2016.

4.3 Construction Impacts

4.3.1 Suspended Solids

The predicted spatial distributions of construction-related excess (above ambient levels) SS fines (i.e. clay and silt) above ambient levels (based on maximum concentration through the water column at each time step) near the start and completion of the proposed wharf (Figure 15) are as follows:

- Because construction occurs 12 hours a day, the 50th percentile (median) spatial distribution of excess SS above 1 mg/L is not predicted.
- The predicted 80th percentile spatial distribution has:
  - A small excess SS increase (1-3 mg/L) at the start of construction limited to the proposed wharf area (upper left Figure 15).
  - A small excess SS increase (1-3 mg/L) in adjacent Bay 2 to the east of the proposed wharf near the end of construction (upper right Figure 15).
- The predicted 95th percentile spatial distribution has:
  - A small excess SS increase (1-3 mg/L) mostly near the proposed wharf and the existing mine marine infrastructure to the west at the start of construction (middle left Figure 15). A localised peak excess SS of 3-10 mg/L occurs in the immediate vicinity of the construction turbidity source at the western extent of the proposed wharf area.

- A small excess SS increase (1-3 mg/L) primarily near the proposed wharf and Bay 2 at the end of construction (middle right Figure 15). The western extent of the Bay 2 has a simulated excess SS increase of 3-5 mg/L.

- The predicted 99th percentile spatial distribution has:
  - A small excess SS increase (1-3 mg/L) limited to the proposed wharf area, the mining marine infrastructure and seawall to the west, and Bay 2 at the start of construction (lower left of Figure 15). Peak excess SS of 3-10 mg/L is limited near the construction turbidity source at the western proposed wharf area.
  - An excess SS increase of at least 1 mg/L along the proposed wharf, the small adjacent Bay 2, and the offshore portion of larger Bay 3 (lower right of Figure 15). Bay 2 is predicted to have an increase of 3-10 mg/L.

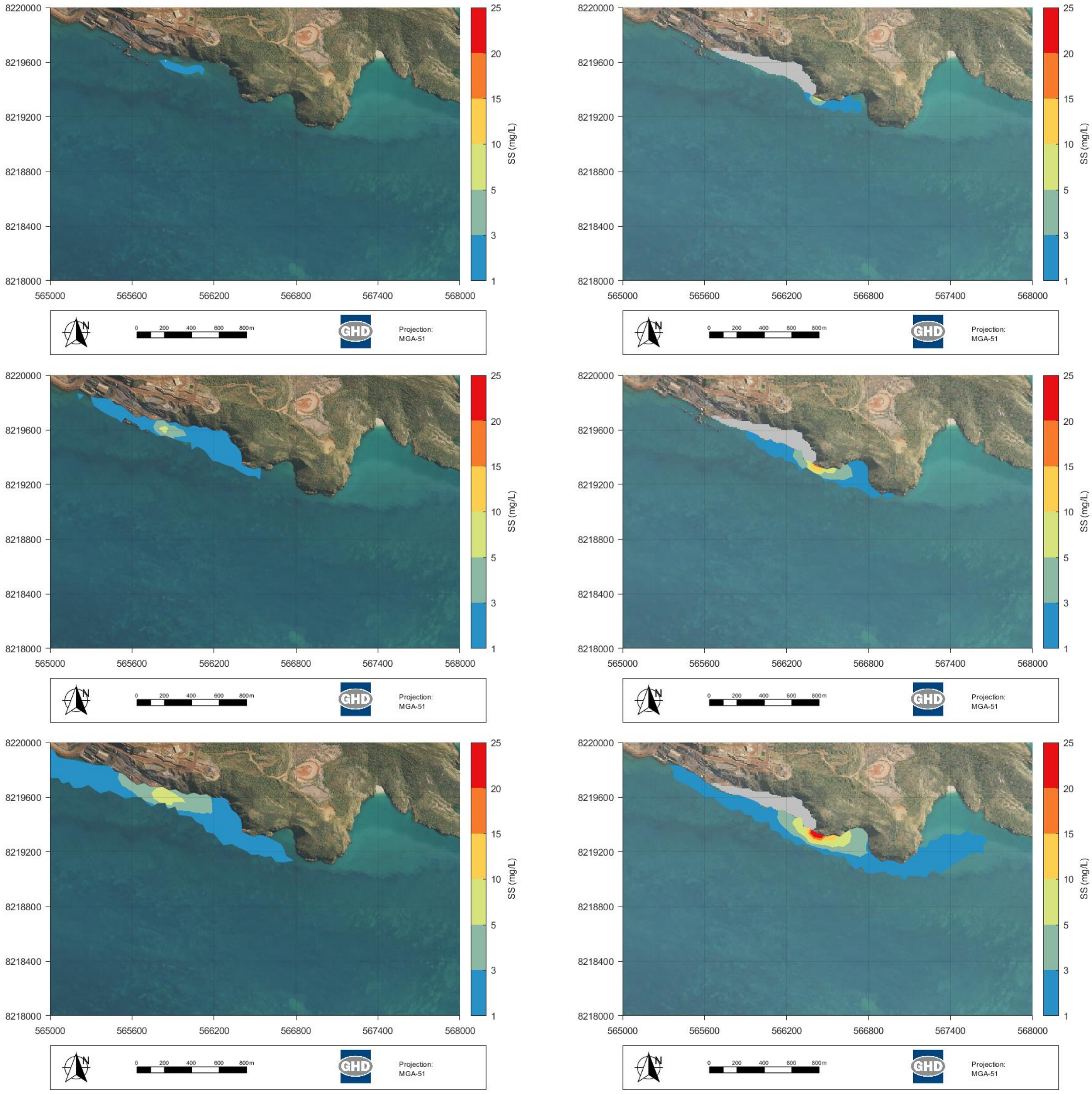

Figure 15 80th (upper), 95th (middle) and 99th (lower) percentiles of maximum excess SS through the water column at start of construction of western proposed wharf (left) and the completion of construction of eastern wharf (right) from March April 2016.

Excess SS fine particles are not anticipated to have a material effect on the underwater light climate of benthic primary producers in Bay 2 and less so on Bay 3 at the start of wharf construction at the most westernmost extent of the development area (left panels Figure 15).

However, construction-related reductions in underwater light from elevated excess SS may occur towards the end of the wharf's construction at the easternmost extent of the development area (right panels Figure 15) with excess >1 mg/L for 5-20% of the time and excess SS >3 mg/L for ~1% of the time.

4.3.2 Sedimentation

The accumulated sedimentation thickness of construction-derived fine particles at the start and end of the construction period is illustrated in Figure 16, which indicates the following:

- At the start of wharf construction (left panel Figure 16), the sedimentation of fines over 2 months in excess of the impact threshold (3 mm) was limited to the immediate proximity of the proposed wharf area. Simulated sedimentation in Bays 2 and 3 were <3 mm and <1 mm, respectively.
- Near the end of wharf construction (right panel Figure 16), the accumulated sedimentation of fines over 2 months in excess of the impact threshold (3 mm) was predicted to occur near the eastern quarter of proposed wharf and much of Bay 2 to the east. Simulated sedimentation thickness in Bay 3 was >1 mm.

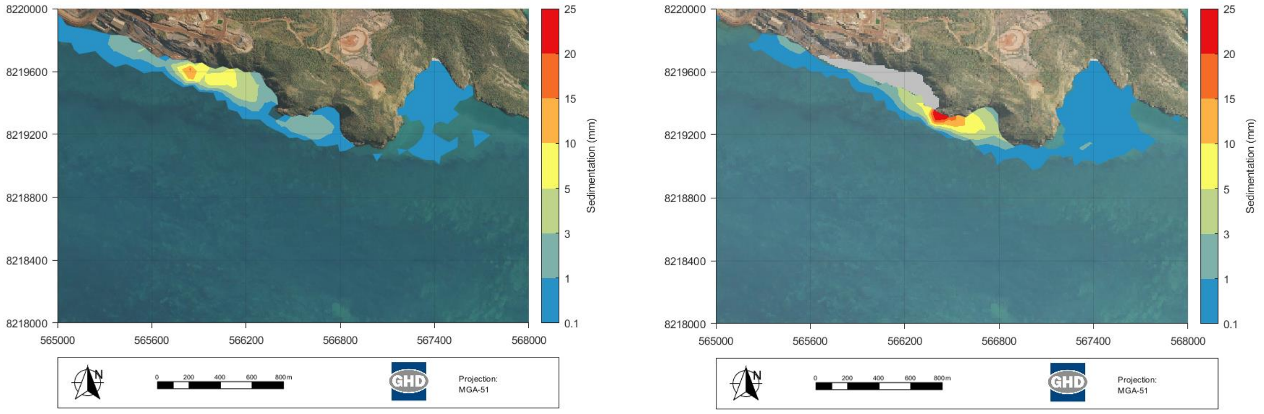

Figure 16 Sedimentation thickness (mm) of excess SS during start (left) and end (right) of construction at western and eastern extents of the proposed wharf from March April 2016, respectively.

The sedimentation rate of construction-derived fine particles at the start and end of the construction period are illustrated in Figure 17, which indicates the following:

- At the start of wharf construction (left panel Figure 17), the sedimentation rate over 2 months was in excess of the impact threshold (10 $g/m^2/day$) in the immediate area of the proposed wharf. Sedimentation rates in Bays 2 and 3 were >3 $g/m^2/day$ and >1 $g/m^2/day$, respectively.
- Near the end of wharf construction (right panel Figure 17), the sedimentation rate of fines over 2 months was in excess of the impact threshold (10 $g/m^2/day$) primarily along the western half of the small adjacent Bay B to the east and the eastern quarter of the proposed wharf. The sedimentation rate in Bay 3 was <3 $g/m^2/day$.

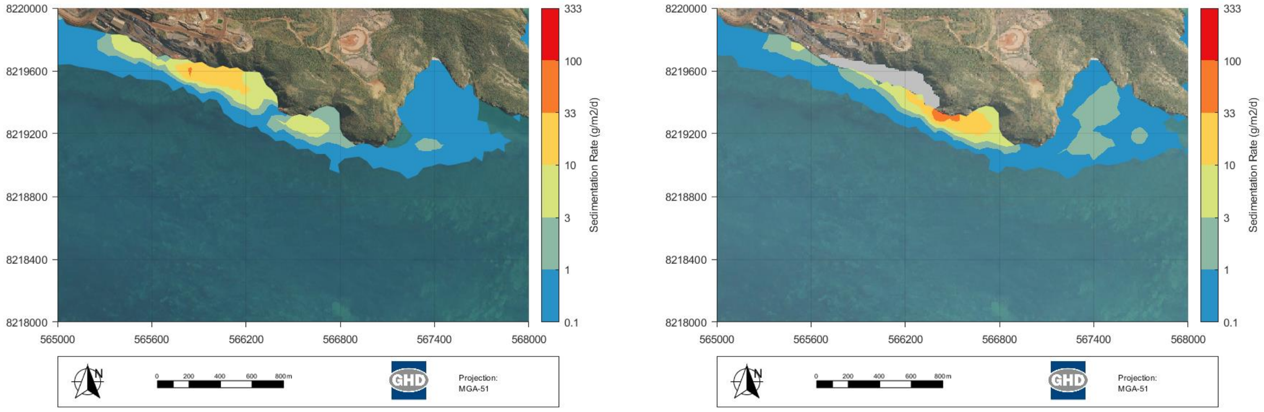

Figure 17 Sedimentation rate (g/m²/day) of excess SS during start (left) and end (right) of construction at western and eastern extents of proposed wharf from March-April 2016, respectively.

No impacts in terms of net accumulated sedimentation (left panel Figure 16) or sedimentation rate (left panel Figure 17) are predicted for any BCH in Bays 2 or 3 at the start of wharf construction (western extent of proposal footprint). However, towards the end of wharf construction (eastern extent of proposal footprint) when the construction turbidity source is closer to Bay 2, the sedimentation thickness (3 mm) and sedimentation rate (>10 g/m²/day) thresholds are exceeded across much of Bay 2.

5. Conclusions and Recommendations

5.1 Impacts to Coastal Processes and BCH

GHD (2017a) concluded the following in regards to coastal processes:

The wharf will run parallel to the shoreline and will not significantly affect or interrupt longshore current movements or existing coastal processes. Any residual impacts on sedimentation, geomorphology, current speeds and patterns will be localised and restricted to the vicinity of the wharf.

The 3D hydrodynamic modelling here supports the GHD (2017a) assessment in terms of the effect of the wharf proposal on coastal processes, namely that residual impacts to:

- Section 4.2.1 shows that predicted changes to currents will be localised, of low magnitude, and restricted to the vicinity of the proposed wharf. Hence, interruption of longshore currents or existing coastal processes is not predicted. Further, material changes to the water current climate experienced by BCH are not predicted.
- Section 4.2.2 shows that bed shear stresses will be localised, of low magnitude, and restricted to the vicinity of the proposed wharf with no material change to areas of erosion and accretion. Further, material changes to the zones of accretion and erosion experienced by BCH are not predicted.
- As noted in GHD (2017a) and Section 2.3, the steep hard shoreline of southern Cockatoo Island and lack of substantive beaches also precludes any material effects even if there were material changes to nearshore currents and/or zones of accretion and erosion, which are not predicted.

5.2 Construction Impacts to BCH from Construction-Related Fine Particles

Section 4.3.1 shows that excess SS is not predicted to greatly alter the underwater light climate of benthic primary producers in Bay 2 and not at all for those of Bay 3 at the start of wharf construction as the distance of the construction turbidity source allows considerable settling and/or dispersion prior to transport to these locations. However, elevated excess SS is predicted to be sufficient to impact on the underwater light climate in Bay 2 may near the completion of the wharf because the construction turbidity source will be adjacent to this water body, though materially elevated SS >3 mg/L above ambient levels is only predicted for 1-5% of the time during construction periods.

Section 4.3.2 shows that minimal sedimentation (left panel Figure 16) or sedimentation rate (right panel Figure 17) impacts on BCH are predicted in Bays 2 or 3 at the start of wharf construction. However, towards the end of wharf construction when the turbidity source is closer to Bay 2 the sedimentation (3 mm) and sedimentation rate (>10 g/m^2/day) impact thresholds are exceeded across much of Bay 2.

GHD (2017c) carried out a BCH local area unit (LAU) impact assessment (including Cockatoo, Irvine, Bathurst islands) to evaluate whether direct (Bay 1) and indirect (Bays 2 and 3) impacts are material on a regional context on the basis of an LAU area of ~200 km^2 (40 km^2 land), which is reproduced in Table 5. Supposing conservatively that construction-related sedimentation caused 50% mortality of the hard corals and macroalgae in Bay 2 due to indirect impacts, the values in parentheses in Table 5 are the percentage losses from direct (Bay 1) plus indirect (Bay 2) impacts. The direct (GHD 2017c) and indirect (this investigation in parentheses in Table

5) losses of BCH are very low percentage of the LAU at 0.02% and 0.05% for hard corals, respectively, and 0.05% and 0.06% for macroalgae, respectively.

Table 5 BCH pre-European area estimates, and historic and proposed wharf area and percentage loss estimates. Values in parentheses assume indirect impact mortality of 50% of benthic communities in Bay 2.

BCH Type	MScience (2007)					GHD (2017c)	
	Pre-Euro Cockatoo (ha)	Pre-Euro Irvine & Bathurst (ha)	Pre-Euro LAU (ha)	Historic Losses for Cockatoo (ha)	% Historic Losses	Proposed Direct and Indirect Losses Bay A (ha)	% Proposed Losses
Coral	65	969	1034	1.2	0.1%	0.2 (0.56)	0.02% (0.05%)
Macroalgae	54	369	423	3.5	0.8%	0.19 (0.27)	0.05% (0.06%)
Other	55	412	467	NA	NA	NA	NA
Total	174	1750	1923	NA	NA	NA	NA

Monitoring (e.g. visual plume observations), preventative controls (e.g. geotextile fabric) and mitigation measures (e.g. construction schedule) will be used to manage the risk of construction-related impacts to the BCH of Bay 2, which will be incorporated into the Construction Environmental Management Plan.

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