Appendix A

Updated modelling report

GEMCO Excess Water Disposal Project

Marine Discharge Modelling Report

GEMCO

20 January 2026

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Executive Summary

Groote Eylandt Mining Company (GEMCO) has carried out investigations of alternative disposal options for surplus mine water, which is currently discharged to bushland. The proposed alternative is to build a pipeline from the mine site to Milner Bay and discharge the mine water via an ocean diffuser near GEMCO's port facility on the western coast of Groote Eylandt, approximately 10 km north of the mining operations (the Proposal).

GEMCO engaged GHD Pty Ltd to undertake hydrodynamic modelling of the proposed discharge to predict the extent of the marine mixing zone.

The following scope has been undertaken:

– Near-field modelling of a range of outfall configurations to recommend an appropriate diffuser concept design for the marine discharge. The concept design is a ~150 m long diffuser of 30 alternating 150 mm ports discharging north-westward and south-eastward at the seabed in an average depth of ~8.5 m.
– Marine trigger values were derived from available site-specific water quality data and literature. Dilution targets were defined on the basis of representative water quality concentrations within the discharge, ambient marine waters and adopted trigger values. Sediment quality trigger values were on the basis of default Australian regulatory levels.
– A three-dimensional (3D) far-field hydrodynamic model was developed for the regional marine waters around the Proposal. The model was calibrated and validated against measured currents and water levels at Milner Bay. The spatial resolution of the model was refined with smaller model cell sizes of ~30 m in the vicinity of Groote Eylandt and the proposed marine outfall site. Additionally, a two-dimensional (2D) wave model was established and validated against measurements of significant wave height, peak wave period and mean wave direction from a location in Milner Bay. The wave radiation stresses generated by the 2D model were used as inputs into the 3D model to incorporate the influence of waves on the transport and dispersion of the mine discharge water in the modelling assessment.
– The diffuser concept design was incorporated into the 3D far-field model along with an operational discharge flowrate of 80 GL/a to simulate the transport and dispersion of the mine water discharge plume over a one year period, thereby accounting for seasonally varying met-ocean conditions at the site.
– A cumulative impact assessment of the mine water discharge and the existing treated effluent discharge at Milner Bay was also undertaken that included the simulated transport, dispersion, deposition and resuspension of suspended sediments from the proposed diffuser and sewage treatment plant (STP) outlet.

Based on conservative assumptions of mine water quality, dilution targets of 42-fold for the mixing zone of **potential indirect effects** related to nitrate enrichment, 35-fold for the mixing zone for **potential direct effects** related to salinity reduction, and 9-fold for the mixing zone of **potential metals/metalloids exposure** (within the water column) have been defined for this study. The indirect effects are only likely to represent a risk if the receiving marine environment is not flushed rapidly enough, with algal blooms potentially arising in stagnant zones (though this was not predicted for this site). Further, potential direct effects related to salinity reduction are only expected to yield ecological impacts when occurring at the seabed in the presence of benthic primary producers (seagrass or corals) that are unable to escape the plume.

The far-field simulations yielded the following predictions:

– The outer extent of the surface mixing zone for **potential indirect effects** (42-fold dilution target related to nitrate enrichment) is predicted to extend ~650 m north and ~550 m southeast from the diffuser. With the inclusion of wave effects, the predicted distances reduce to ~630 m north and ~460 m southeast from the diffuser. When the cumulative effect of the treated effluent discharge is simulated, the 99th percentile extent of the predicted nitrate mixing zone marginally increases a further ~140 m northward.
– The outer extent of the surface mixing zone for **potential direct effects** (35-fold dilution target related to salinity reduction) is predicted to extend ~400 m north-northwest and ~350 m southeast from the diffuser. With the inclusion of wave effects, the predicted distances reduce to ~400 m north-northwest (i.e. similar) and ~300 m southeast from the diffuser. No observable difference in the 99th percentile extent of the salinity mixing zone was predicted from the cumulative effect of the treated effluent discharge.

– There was no predicted mixing zone for **metals and metalloids exposure** (9-fold dilution for aluminium), meaning the dilution target was predicted to be achieved within the spatial scale of one model cell (i.e. <20 m distance from the diffuser). This outcome was similar both with and without wave effects.
– There was no predicted mixing zone at the seabed due to the buoyant nature of the discharged mine water and treated effluent discharge plumes (i.e. discharge salinities lower than seawater).
– Predicted flushing rates of the near-shore receiving waters encompassing the mixing zone are rapid, with e-folding timescales (the time to exchange ~63% of the volume with surrounding ambient waters) averaging 16 hours with a range of 6 to 35 hours. The PIANC (2008) standard for marinas states e-folding times of less than four days represent good flushing.
– The sediment dispersion simulations predict the following:
  - The zone of influence, where changes in suspended sediments may be detectable, but are not expected to impact on benthic communities, was predicted to extend up to ~1,250 m northward and ~220 m to the south-east of the diffuser. Highly localised zones of deposition exceeding the zone of influence threshold were predicted to occur only at the end of the Milner Bay jetty structure.
  - No zones of moderate or high impact in regards to suspended sediments or deposition from the mine water discharge were predicted in the vicinity of the mine water discharge diffuser.
  - Sediment deposition is predicted to result in metals/metalloid toxicants within the sediments that are a factor of 18 lower than the most stringent sediment quality limit (for silver). This is equivalent to 18 years of simulated deposition without any sediment transport events or biological uptake of silver for accumulation to yield toxic levels above the sediment threshold. Further, accumulation of sediments is predicted to occur only within localised zones at the end of the jetty structure.
– In short, the potential for metals/metalloids bioaccumulation is considered low, given the very low predicted risks of exposure related to metals/metalloids within the water column and within the sediments.

The risks of potential indirect ecological impacts from nitrate enrichment are reduced by the rapid flushing of the Proposal's marine waters. Additionally, direct impacts to benthic primary producers at the seabed from salinity reductions is very low because the low salinity of the discharges constrain the mixing zone to the surface waters. Impacts to benthic communities related to the discharge of suspended sediments were not predicted. Further, no zones of exposure to metals/metalloids within the water column or sediments were predicted, and as such the risk of bioaccumulation of metals/metalloids is also low. The discharge scenario evaluated in this study poses a low level of environmental risk.

The predictions presented in this study are considered to be conservative for the following reasons:

– The discharge of 80 GL/a defined by GEMCO represents the assumed peak flow. The discharge rate in the model was held constant over a one-year simulation duration and therefore overestimates the likely discharge volumes on an annual timescale, which during operations are expected to average 60 GL/a.
– Concentrations of analytes within the discharge were generally defined as the 95th percentile of historical measurements from the site and therefore are over-estimates of loads for the majority of the time.
– Though the hydrodynamic model was verified with measured currents that were well reproduced, current speeds are marginally under-estimated. This underestimates the simulated flushing of the nearshore environment relative to actual conditions, and thereby likely over-predicts the spatial extent of the mixing zone.
– All water quality analytes were treated as numerically conservative tracers (except for pH, which was evaluated with a separate model that accounts for pH buffering processes, and suspended solids that were explicitly modelled as particles with resuspension and settling). In general, this assumption will over-estimate the spatial extent of the mixing zone, as it neglects transformation processes such as decay, degradation and biological uptake.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

Groote Eylandt Mining Company (GEMCO) operates a manganese mine on Groote Eylandt, located within the Gulf of Carpentaria approximately 650 km southeast of Darwin and 50 km off the Arnhem Land coast. The open pit mining operations intercept groundwater and rainwater within the mine pits, which is subsequently dewatered and partially utilised for operational needs (manganese ore processing, dust suppression and washdown facilities). Excess mine water, surplus to operational needs, is currently released to the surrounding bushland with conditions.

Recent years have seen increases in mine water volumes driven by increased mine production, greater depths of mining and closer proximity of mine pits to the coast. Tropical Cyclone Megan generated 680 mm of rainfall over 16-17 March 2024 that also introduced significant volumes of runoff to the mine pits. Additionally, GEMCO is predicting a future change in water quality, primarily related to marginal increases in salinity, that may yield the water unfit for disposal to bushland. GEMCO has therefore carried out an investigation of alternative options for excess water disposal. The proposed alternative option is to pipe the mine water to Milner Bay and discharge via a new ocean diffuser located near GEMCO's port facility on the western coast of Groote Eylandt, approximately 10 km north of the mining operations (the Proposal).

1.1 Purpose of this report

GEMCO engaged GHD Pty Ltd to undertake hydrodynamic modelling of the proposed marine discharge to predict the extent of the marine mixing zone. This report presents the inputs, methodology and outcomes of the hydrodynamic modelling undertaken.

1.2 Scope and limitations

The following scope has been undertaken:

- Near-field modelling of a range of outfall configurations was undertaken to recommend an appropriate diffuser concept design for the marine discharge.
- On the basis of marine trigger values that were derived from available site-specific water quality data and literature, dilution targets were defined for a range of parameters within the discharge.

  A three-dimensional (3D) far-field hydrodynamic model was developed, calibrated and validated for the south-western region of the Gulf of Carpentaria with refined resolution in the vicinity of Groote Eylandt and the proposed marine outfall site. The preliminary diffuser configuration that was developed via near-field modelling was incorporated into the 3D far-field model. The proposed discharge of 80 GL/a of excess mine water was simulated in the far-field model over a one-year period to account for seasonally varying met-ocean conditions at the site. The discharge rate represents the likely peak daily flow rate of future operations, which is estimated by GEMCO to be ~25% greater than average daily discharge rates. Nevertheless, as a conservative measure, the peak flow rates are adopted throughout the entire year-long simulation for this modelling assessment.
- The far-field modelling scenario was used to define the spatial extent of the mixing zone beyond which all parameters are predicted to be diluted to a sufficient degree to satisfy the adopted marine trigger values.

The above scope informed the Environmental Referral Report that was submitted to the NT EPA on 11 March 2025. The NT EPA determined that the Proposal would be assessed by Supplementary Environmental Report (SER), with a direction to address regulator and public comments and to include additional information. Of the comments received, the following topics have been addressed within this report via updated modelling:

- Inclusion of waves within the modelling to account for the influence of vertical circulation on plume dispersion
- Direct modelling of suspended solids discharged via the ocean diffuser
- An assessment of potential cumulative impacts that may arise from interactions between the mine water discharge plume and the existing discharge of treated effluent at Milner Bay
- The potential for biomagnification and bioaccumulation of metals and metalloids present in the discharge

This report has been prepared by GHD for GEMCO and may only be used and relied on by GEMCO for the purpose agreed between GHD and GEMCO as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than GEMCO arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared the MIKE model and PHREEQC Model (collectively referred to as the "Model") for, and for the benefit and sole use of, GEMCO to support the assessment of the environmental mixing zone and must not be used for any other purpose or by any other person.

The Model is a representation only and does not reflect reality in every aspect. The Model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Model. Accordingly, the outputs of the Model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

The information, data and assumptions ("Inputs") used as inputs into the Model are from publicly available sources or provided by or on behalf of the GEMCO, (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Model as further Inputs becomes available.

The Model is limited by the mathematical rules and assumptions that are set out in the Report or included in the Model and by the software environment in which the Model is developed.

The Model is a customised model and not intended to be amended in any form or extracted to other software for amending. Any change made to the Model, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Model including any outputs.

GHD has prepared this report on the basis of information provided by GEMCO and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Site Context

The Proposal site is situated in the vicinity of GEMCO's port operations on the northwestern coast of Groote Eylandt (Figure 1). The proposed diffuser location is approximately 300 m south of the Milner Bay wharf structure, where GEMCO also discharges treated effluent. Monitoring of currents and waves by GEMCO using an Aquadopp current profiler has also been carried out in the vicinity of the proposed diffuser site.

The region is populated with many islands (of which Groote Eylandt is the largest), with Connexion Island being the nearest at approximately 4.2 km west of the Groote Eylandt coast. The narrow span between Connexion Island and Groote Eylandt results in elevated current speeds through the contraction.

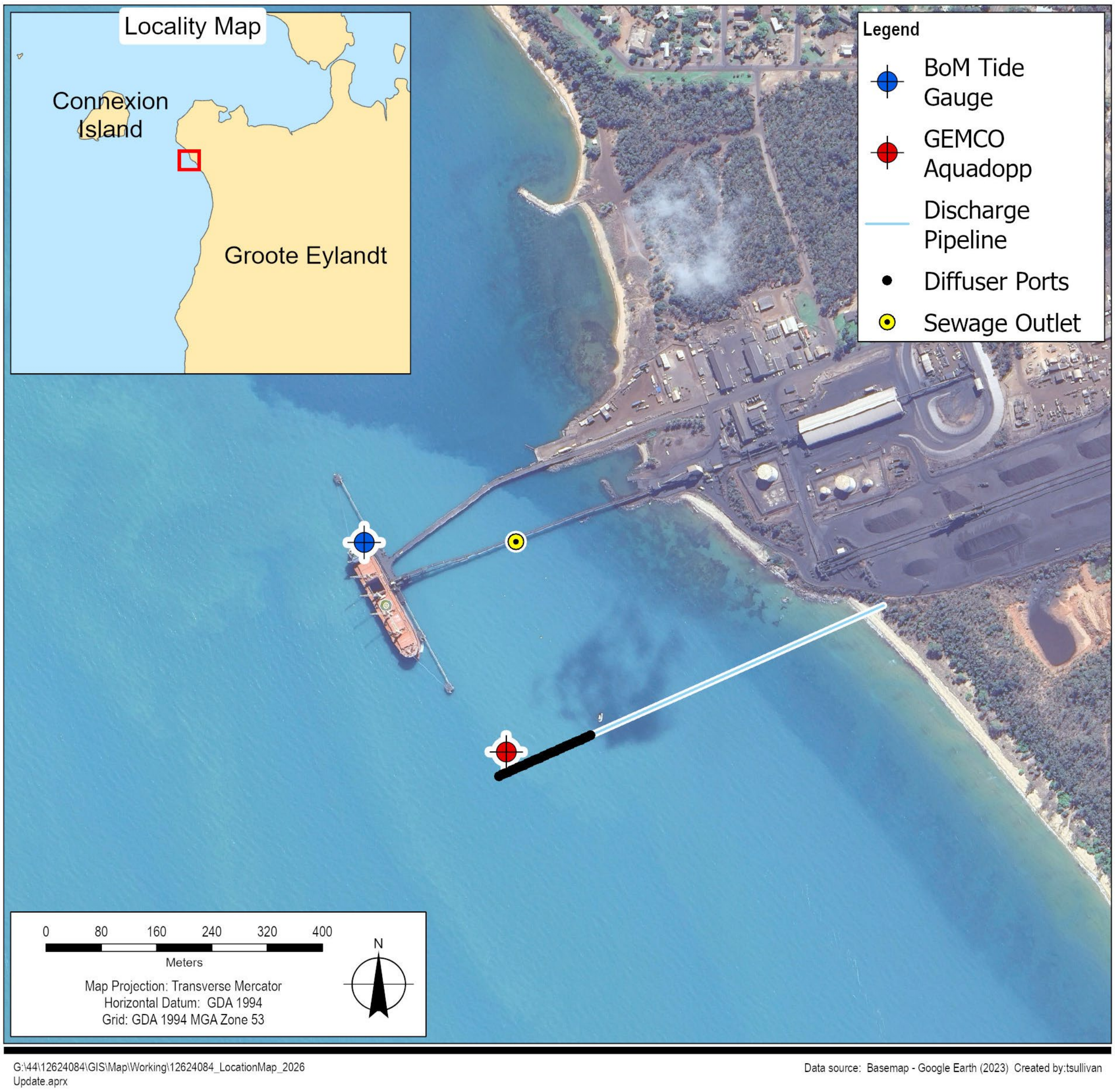


Figure 1 Site location including proposed discharge pipeline, diffuser and oceanographic monitoring stations.

2.1 Tides

Tides near the Proposal site are measured by the Bureau of Meteorology's (BoM's) tide gauge located at Milner Bay (depicted in Figure 1). The tide gauge has been operational since 1993. Tidal characteristics for Milner Bay are summarised in Table 1.

The tidal range at Milner Bay is reasonably large at 2.4 m (difference between HAT and LAT). Tides have mixed semidiurnal variations, with typically two high tides and two low tides each day. The greater diurnal range (the difference between MHHW and MLLW) is moderate at 1.3 m.

Table 1 *Tidal data for Milner Bay*

Tidal Datum	Tide Level (m relative to LAT)
Highest Astronomical Tide (HAT)	2.4
Mean Higher High Water (MHHW)	1.8
Mean Lower High Water (MLHW)	1.7
Mean Sea Level (MSL)	1.20
Mean Higher Low Water (MHLW)	0.7
Mean Lower Low Water (MLLW)	0.5
Lowest Astronomical Tide (LAT)	0.0

Source: Australian Hydrographic Office (2026)

2.2 Currents

Currents were measured continuously via an Aquadopp current profiler that was deployed at the GEMCO port facility (Figure 1). Time-series plots of measured current speeds and directions spanning January 2022 to May 2023 are presented in Figure 2. The current pattern demonstrates a strong tidal influence, with speeds reaching peaks of 0.5-0.6 m/s during spring tides and 0.3-0.4 m/s during neap tides. Directions typically alternate south-easterly and north-westerly, which is aligned to the orientation of the coastline at the Proposal site. Onshore currents (north-easterly) occur infrequently, while offshore currents directed towards the west are also rare in the measured data.

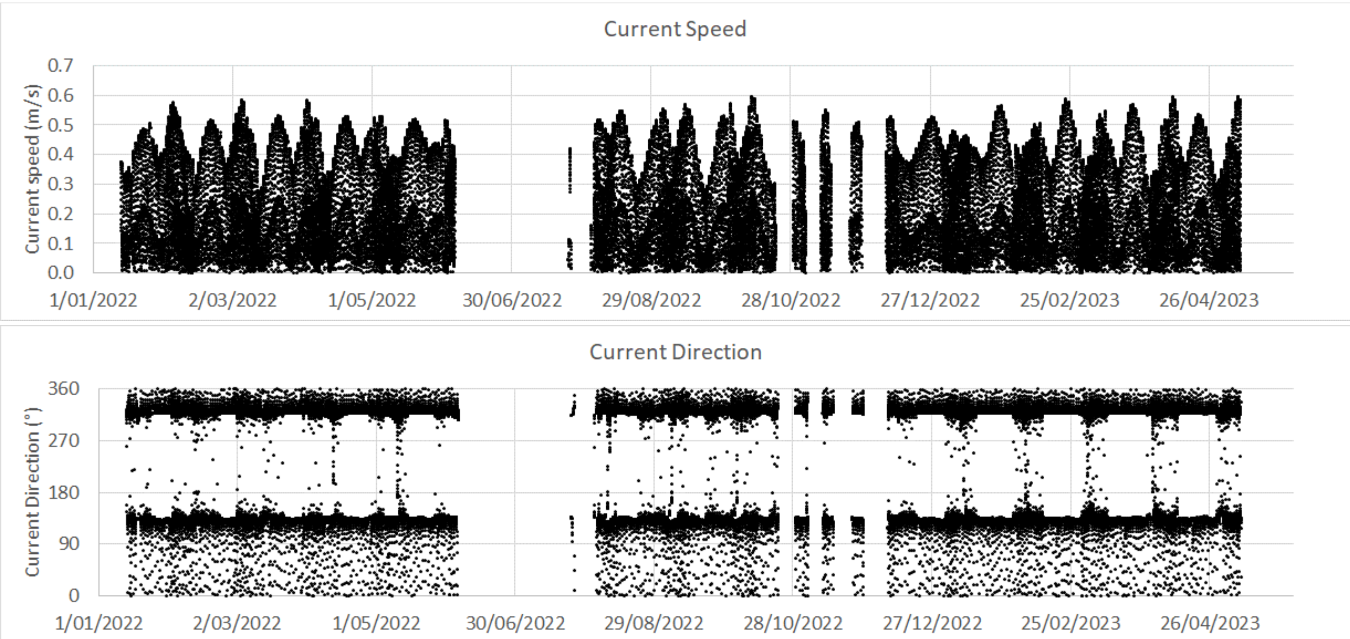


Figure 2 ***Measured current speeds (top) and directions (bottom) at GEMCO port.*** [1]

North-westerly currents are dominant within the dataset, occurring 65% of the time, while south-easterly currents occur 30% of the time. North-westerly currents are also generally faster as demonstrated by the statistical distribution of current speeds in Figure 3, with a median current speed of 0.3 m/s compared to 0.13 m/s for south-easterly currents.

[1] Note: Convention for current directions is the direction the current is going 'to'

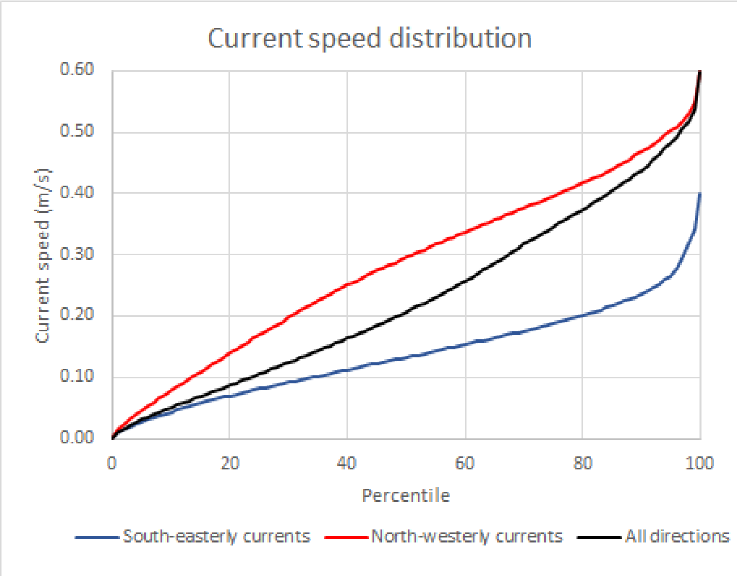


Figure 3 ***Statistical distribution of all currents (black), south-easterly currents (blue) and north-westerly currents (red).***

2.3 Waves

The Proposal site, located on the northwest coast of Groote Eylandt, is sheltered from offshore swells that penetrate into the Gulf of Carpentaria from the north. Further, it is protected from more locally generated swells that may form within the Gulf of Carpentaria and approach Groote Eylandt from the east or south. Any swells approaching the site from the west will be greatly fetch-limited, as there is less than 50 km of ocean between the Proposal Site and the Arnhem Land coast for swells to form. An example snapshot of simulated waves in the Gulf of Carpentaria from the Centre for Australian Weather and Climate Research (CAWCR) wave hindcast aggregated collection dataset (Durrant *et al*., 2019) is presented in Figure 4.

Although Groote Eylandt provides a high degree of sheltering of the Proposal site from waves generated within the Gulf of Carpentaria, waves were included in the modelling assessment nonetheless, such that the influence of wave-generated vertical circulation in the water column on plume mixing and dispersion could be considered.

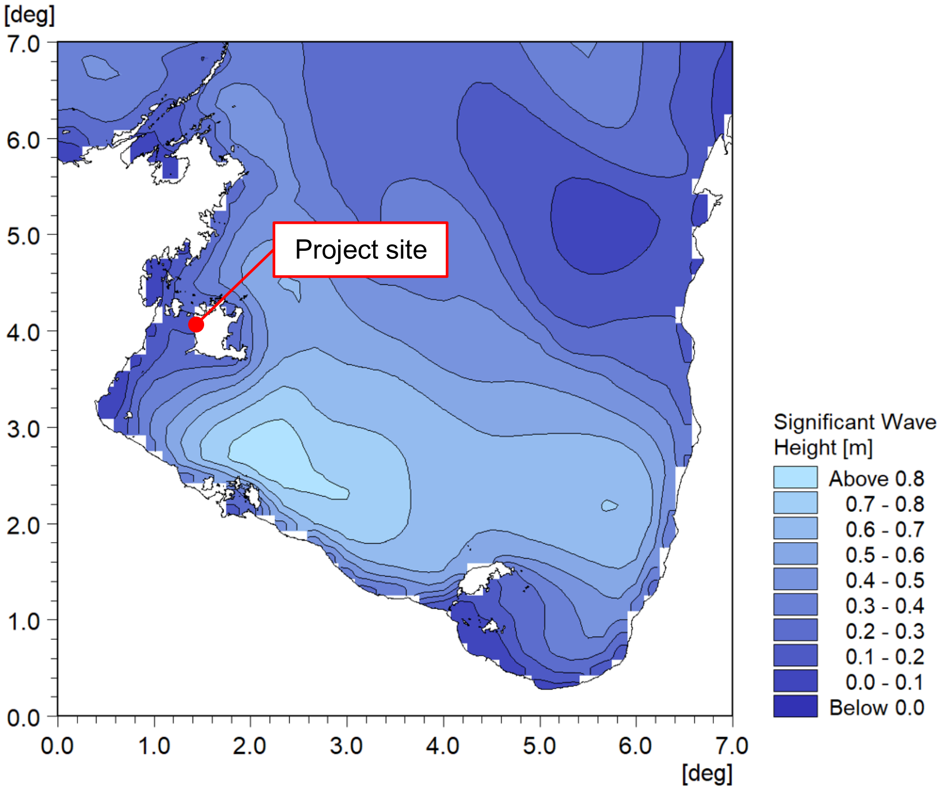


Figure 4 ***Snapshot of wave field from CAWCR wave hindcast model demonstrating sheltering at the Proposal site.***

2.4 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 inputs for the modelling. CFSv2 monthly wind roses from three years of wind data extracted for the CFSv2 node nearest to the Proposal Site are presented in Figure 5.

The wind regime is characterised primarily by generally moderate wind speeds 3-8 m/s. Wind directions vary seasonally with the dry season (April to August) being characterised by prevailing easterly and south-easterly winds, with more varied wind directions generally ranging from north-westerly to easterly during the wet season October to February). March and September are transitional periods with a mixture of the wet and dry season wind regimes.

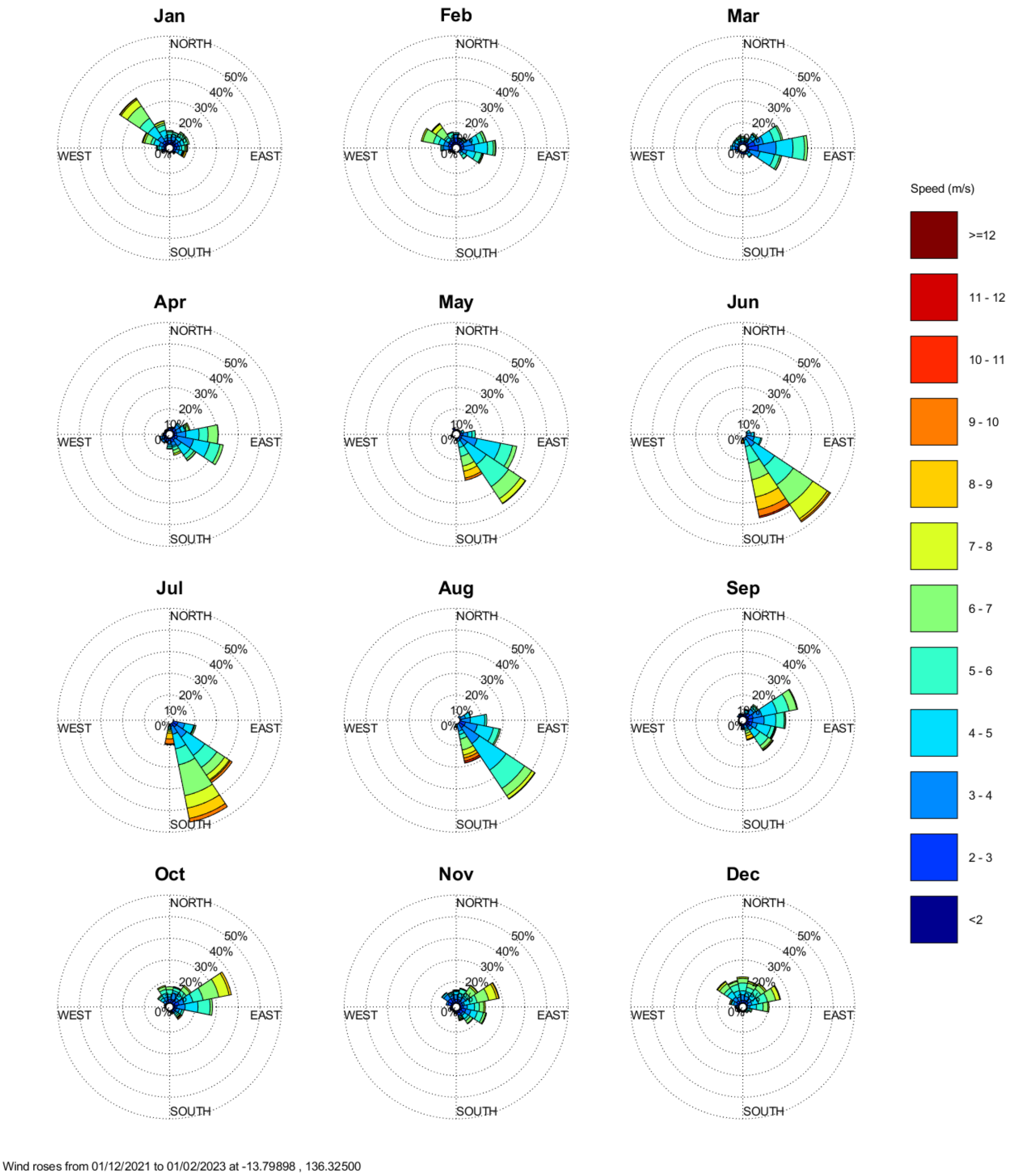


Figure 5 ***Monthly wind roses from CFSv2 dataset at Groote Eylandt over the period of 2021-2023.*** [2]

Hourly filtered wind measurements from BoM station 14518 at Groote Eylandt Airport are highly variable compared to the hourly modelled CFSv2 data (Figure 6) indicating significant wind gusts and potential measurement noise in the BoM dataset. However, daily filtered BoM measurements compare well with CFSv2 data (Figure 7) at Groote Eylandt. This provides confidence that the CFSv2 inputs are a reasonable representation of the underlying trend in wind speeds and directions and, while short-period gusts are not captured, the data represents winds for the purposes of a long-term mixing zone assessment with reasonable accuracy.

[2] Note: Convention for wind directions is the direction the wind is 'from'

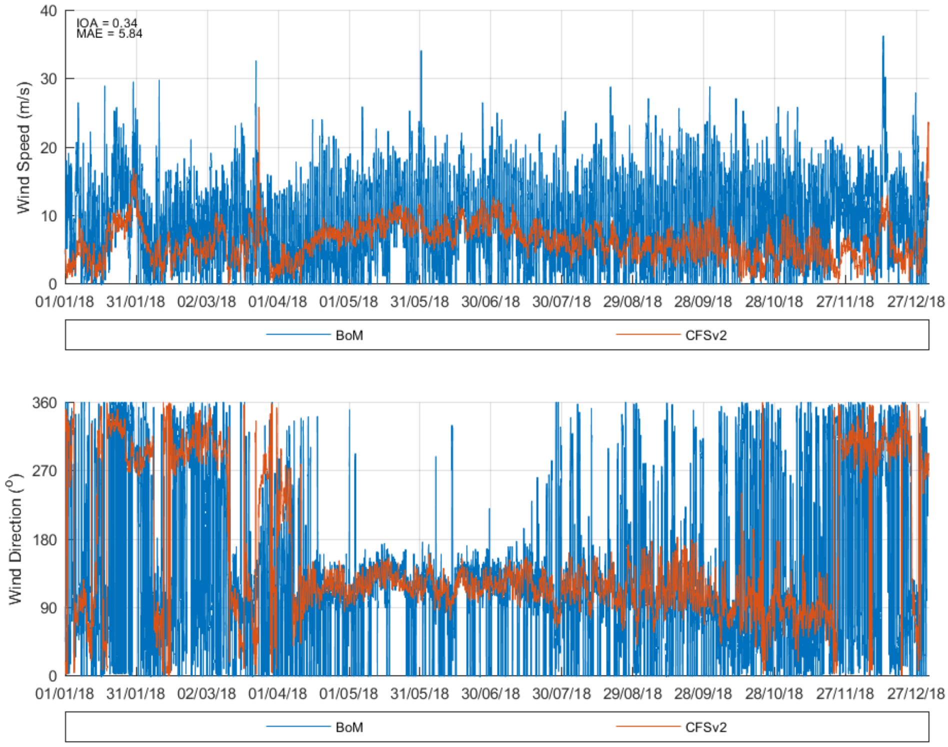


Figure 6 ***Comparison of hourly CFSv2 simulated data and hourly filtered BoM measurements at Groote Eylandt during 2018.***

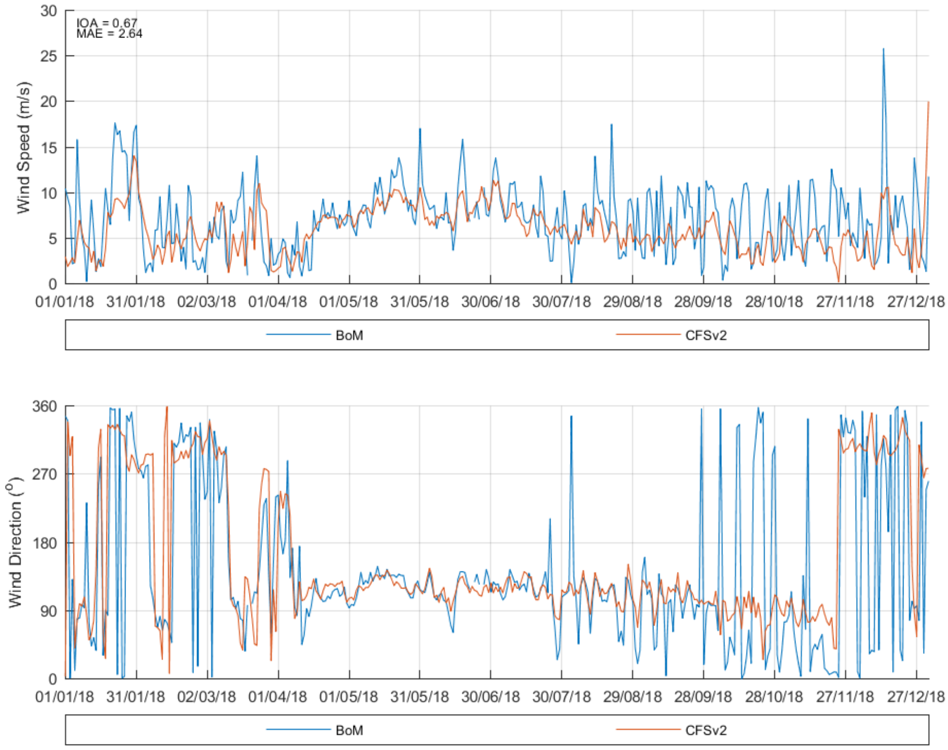


Figure 7 ***Comparison of daily filtered CFSv2 simulated data and daily filtered BoM measurements at Groote Eylandt during 2018.***

2.5 Ambient turbidity/suspended solids

GEMCO carries out monthly marine monitoring within the Milner Bay environment as part of the STP discharge monitoring program, and annual monitoring as part of the marine environmental monitoring program (MEMP). Turbidity and total suspended solids (TSS) are measured in both programs, with certain sites from these programs suitable to define baseline conditions within the marine environment relevant to the Proposal. Establishment of a baseline dataset of ambient TSS is necessary for this study to develop thresholds for assessment of impacts related to TSS/turbidity within the mine water discharge plume.

From the MEMP, sites PN1-PN4 and PS13-PS16 were selected as suitable locations to represent ambient conditions, each located approximately 400 m north ('PN' locations) and south ('PS' locations) from the port. From the STP monitoring program, location WDL67BC was utilised, which is approximately 800 m south of the port.

Both datasets have a consistent record of field turbidity measurements, however the TSS data has many gaps due to the high limit of reporting (LOR) of 5 mg/L for the STP data and the MEMP data from 2021 onwards (the previous LOR adopted was 1 mg/L). As such, many of the TSS samples returned 'non-detect' (LOR) results. To develop a more consistent record of TSS, a relation between TSS and turbidity was established from the seven MEMP sampling events from 2014-2020 with a lower TSS LOR of 1 mg/L, where coincident in-field turbidity measurements were also available. The linear relation is displayed in Figure 8 with a correlation coefficient (r^2) of 0.77, which indicates a reasonable correlation between the two datasets. The linear slope of the regression line is 0.92 (i.e. measured TSS a factor of 0.92 times measured turbidity).

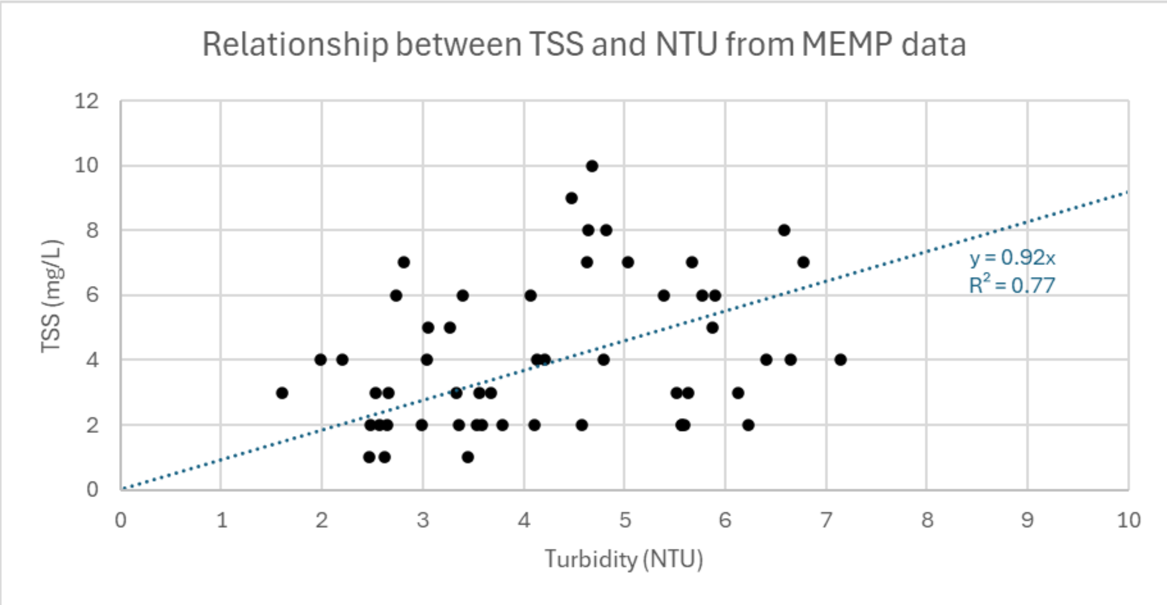


Figure 8 ***TSS versus turbidity relation including linear regression line and correlation coefficient***

This relation was applied to the long record of turbidity measurements throughout the STP program to produce a more consistent record of TSS to define baseline conditions. The approach of deriving predictive relationships between turbidity and TSS is supported by the WA EPA (2021) guidance, which is recommended by NT EPA (2023) as leading practice in the assessment of dredging impacts.

The full TSS record, supplemented with the converted turbidity data, is presented in Figure 9. TSS was generally below 10 mg/L across most sampling events, though, for safety reasons, vessel-based sampling typically occurs during calmer ocean conditions when TSS/turbidity tends to be lower. Nevertheless, this yields a conservatively low baseline dataset for TSS to derive impact thresholds to apply to the modelling assessment, as described further in Section 3.6.

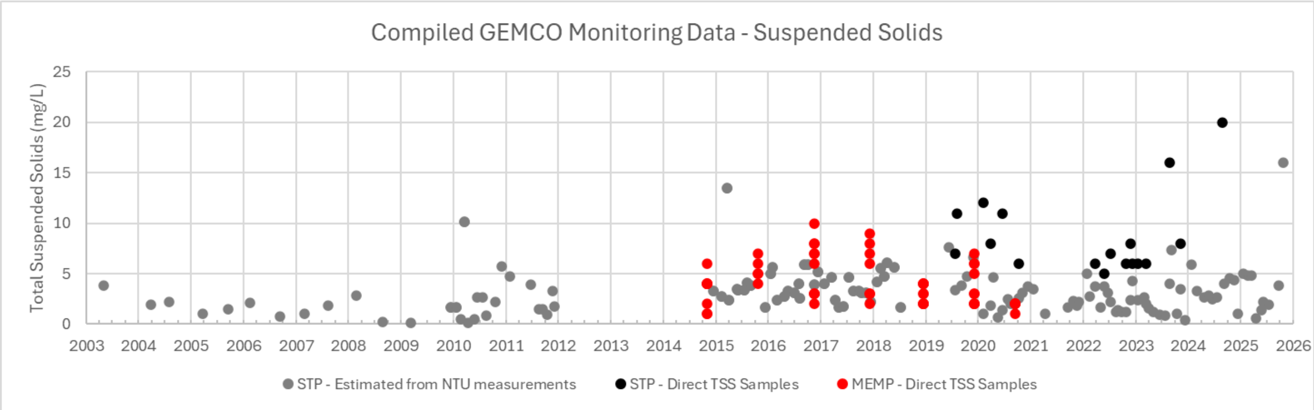


Figure 9 ***Compiled record of TSS from direct samples (red and black) and converted turbidity data (grey)***

2.6 Treated effluent discharge

Approximately 300 meters north of the proposed diffuser, there is an existing outlet that discharges treated effluent from GEMCO's port facilities into Milner Bay (as shown in Figure 1). Data provided by GEMCO indicates that the discharge generally fluctuates between 6 and 8 L/s, with peak flows of ~10 L/s.

The treated effluent discharge was incorporated within the modelling to allow a cumulative impact assessment of potential changes to marine water quality from both the treated effluent and mine water discharges occurring simultaneously. Adopting a conservative approach, a constant treated effluent discharge of 10.9 L/s (representative of peak flows) was adopted as a model input.

3. Methodology

3.1 Overview of modelling approach

Modelling for this study was undertaken in two phases, namely:

– **Near-field modelling** (Section 3.2). The primary purpose of the near-field modelling was to determine an appropriate diffuser concept design that would yield elevated levels of dilution in close proximity to the outlet over a range of mine water discharge flowrates (allowing for potential future increase in mine production beyond 80 GL/a).
– **Far-field modelling** (Section 3.9). The adopted diffuser concept design from the near-field modelling assessment was incorporated into the 3D far-field model. The 3D far-field model was the primary tool to predict dilution of the excess mine water discharge in the marine environment for the nominated flowrate, including dynamically varying tidal, wave and wind conditions. The far-field model was also used to simulate the dispersion of suspended sediments within the discharge, as well as to carry out a cumulative impact assessment of the treated effluent discharge operating concurrently with the mine water discharge.

3.2 Near-field modelling

3.2.1 Near-field concept

The near-field region refers to the immediate area around the outlet/diffuser where the discharged water undergoes momentum-driven or buoyancy-driven transport and enhanced mixing along its trajectory through the water column (i.e. prior to surfacing, impinging on the seafloor, or achieving neutral buoyancy). The highest rates of mixing and dilution typically occur through these near-field mixing processes relative to natural background levels of mixing via dispersion by ambient currents (i.e. far-field dilution).

In the case of a discharge of excess mine water of lower density (due to lower salinity) than the seawater (due to higher salinity), the buoyant plume will rise toward the sea surface and the near-field region terminates at the point where the plume surfaces, ceases to rise in the water column due to interaction with a density layer (stratification), or loses its upward buoyancy because it has undergone sufficient dilution to have the same density as the ambient the waters.

3.2.2 Modelling approach

Near-field modelling was carried out with the industry standard Updated Merge 3 (UM3) model of the Visual Plumes software suite by the United States Environmental Protection Agency (US EPA) (Frick et al. 2001). In this setting, the near-field simulation of the excess mine water discharge with UM3 terminates when the buoyant plume intersects the sea surface. At this point, the near-field jet and/or plume mixing processes are no longer simulated with UM3.

Several concept designs of the diffuser were evaluated with UM3 to determine a submerged outlet configuration with adequate near-field dilution. The diffuser concept design was determined through an iterative approach that is detailed in Section 3.3. The following three discharge rates were considered in the near-field analysis to determine the diffuser concept design:

– **Scenario 1**: 60 GL/a.
– **Scenario 2**: 112.5 GL/a.
– **Scenario 3**: 150 GL/a.

Scenario 1 corresponds to the far-field scenario (80 GL/a), which adopted a higher discharge rate in the 3D hydrodynamic modelling. The discharge rate for Scenario 1 is based GEMCO's estimate of likely average daily flows of 60 GL/a and a peak discharge of 80 GL/a. For the purposes of near-field modelling to evaluate an adequate diffuser concept design, the 60 GL/a flow rate was used as a lower bound to assess the diffuser performance for this typical condition. The far-field modelling of Scenario 3 adopts the 80 GL/a peak flow as a conservative measure to predict the spatial extent of the environmental mixing zone.

Scenarios 2 and 3 are conservatively higher estimates provided by GEMCO to inform the diffuser design, to ensure it performs adequately in the event that future mining operations require an increase in discharge above the 80 GL/a estimate, for which approval is currently being sought.

Ambient current speeds for the near-field modelling inputs were defined as 0.13 m/s, which is moderately low for the site (30th percentile of all measured current speeds, Figure 3).

3.3 Diffuser concept design

Concept design elements of the diffuser on the basis of UM3 near-field modelling are tabulated in Table 2. One preliminary concept design of a multi-port diffuser has been developed to achieve adequate environmental performance in terms of near-field dilution across the three defined flow scenarios. Further commentary on the design elements is provided in Table 2.

Table 2 Conceptual diffuser details

Parameter	Scenario 1	Scenario 2	Scenario 3	Comment
Flow rate (GL/a)	60	112.5	150	Scenarios for assessment defined by GEMCO
Flow rate (m^3/s)	1.90	3.57	4.76	
Number of ports	30			Port sizing and spacing designed to minimise merging of plumes from neighbouring ports. Number of ports and diffuser length selected to fit within available spatial constraints (i.e. multi-port diffuser not extending past 10 m contour). Outlet diameters selected to give exit velocities that promote momentum (velocity) induced near-field mixing in the immediate vicinity of the outlet.
Diffuser length (m)	145			
Port spacing (m)	5			
Port Diameter (m)	0.15			
Multi-Port Diffuser Depth Range (m)	7.5-9.5 (8.5 average)			Diffuser located on seafloor between 8-10 m depth contour, with 0.5 m port elevation above seabed
Diffuser height above seabed (m)	0.5			
Port Discharge Vertical Angle	10°			Slightly upward discharge angle to avoid interaction of the plume with seabed, but yet maintain sufficient water depth above the plume when it transitions from momentum (velocity) induced mixing to buoyancy (rising plume to surface) driven mixing.
Port Discharge Horizontal Angles	315°/135° alternating			Alternating north-west/south-east discharge angles that are aligned with the prevailing site current directions to minimise plumes emanating from different ports interacting and merging (plume merging reduces near-field mixing efficiency).
Port Exit Velocity (m/s)	3.6	6.7	9.0	Elevated exit velocities achieved through selection of port diameters to maximise turbulent dilution near diffuser for near-field dilution

3.4 Water quality objectives

The Water Quality Objectives (WQOs) to be achieved at the edge of the mixing zone for key parameters of concern in the excess mine water discharge have been developed in consideration of the following data:

– Ambient water quality data:
  - Available water quality data of the marine receiving environment from GEMCO's marine monitoring program as reported by Indo-Pacific Environmental (IPE, 2023a). The 50th percentile (median) of IPE (2023a) data has been adopted as the ambient marine water quality concentration for each analyte.

  - Additional monthly marine water quality data for nutrients and salinity at a marine reference site ~800 m south of the port facility was available from GEMCO's wastewater discharge monitoring program related to the treated effluent discharge. These nutrient and salinity data span from March 2015 to July 2023 and September 2022 to July 2023, respectively.
  - It is noted that the median nitrate and phosphate measurements from the GEMCO wastewater discharge monitoring data at the reference site were below the Limit of Reporting (LOR), as were the majority of all measurements. In these cases, half of the LOR was assumed to represent the ambient concentration.
- Discharge water quality data:
  - Discharge water quality was largely defined by IPE (2023b) to be the 95th percentile of the volume-weighted mixed analyte concentrations on the basis of long-term monthly monitoring by GEMCO at a range of mine pits. This is considered a high (conservative) estimate of the discharge water quality, particularly in the context of the 3D far-field modelling approach that evaluated a continuous discharge at these 95th percentile concentrations for a whole year. Clearly, excess mine water discharge concentrations are likely to be lower than the 95th percentile concentration for the vast majority of the time.
  - For salinity, the discharge water quality was estimated to be 0 PSU (Practical Salinity Units) based on the very low electrical conductivity (EC) measurements.
  - For pH, the volume-weighted approach employed by IPE (2023b) is not suitable due to complex chemical interactions of various factors that occur when mixing solutions of differing pH. An alternative approach for developing pH WQOs was applied as detailed in Section 3.5.
- Marine trigger values (or WQOs) were:
  - Primarily defined by IPE (2023a) as either:
    - The 80th percentile of marine water quality data;
    - Trigger values suggested in the published literature; or
    - Default Guideline Values (DGVs) reported in ANZG (2018) or ANZECC & ARMCANZ (2000).
  - For ammoniacal nitrogen, the 80th percentile of measured data from GEMCO's wastewater discharge monitoring program (reference site) was adopted in lieu of the trigger value reported in IPE (2023a), which did not have this dataset available at the time of reporting.
  - For salinity, the trigger value was selected on the basis of a maximum allowable salinity reduction of 1 PSU below ambient conditions. This was derived as the difference between median and 20th percentile salinity from the CSIRO Atlas of Regional Seas (CARS, 2009), which is a modelling dataset adopted by ANZG (2018) in the derivation of some guideline values for mesoscale marine bioregions. The data from the CARS (2009) node nearest to the Proposal site was extracted to calculate the salinity reduction.

The marine trigger values for aluminium and iron have been updated from those presented in the referral, following the addition of DGVs for these parameters within the ANZG (2018) guidance in December 2025. For aluminium, the trigger value has increased from 24 µg/L (adopted previously) to 37 µg/L (per ANZG, 2018), while for iron, the previously adopted value of 5.4 µg/L, which was defined by IPE (2023a) as the 80th percentile of ambient concentrations, has been increased to 540 µg/L (per ANZG, 2018), which represents a toxicity threshold for 95% level of species protection. As a result, aluminium requires a lower degree of dilution to achieve the trigger value relative to the modelling presented in the referral, while iron no longer requires any dilution, as its concentration within the discharge is an order of magnitude below the trigger value.

The WQOs are expressed as a required dilution factor of the discharge by the ambient marine waters to meet the relevant water quality trigger values. The dilution of the discharged excess mine water by the ambient marine waters is simulated in the 3D far-field modelling assessment to predict the spatial extent of the mixing zone during operation. The dilution factors to define the edge of the mixing zone are calculated as:

$$D_T = \frac{C_O - C_A}{C_T - C_A}$$

where:

- D_T = Target dilution factor.
- C_O = Outlet concentration.

– C_T = Target concentration to achieve the WQO.
– C_A = Ambient concentration.

The calculated dilution targets are summarised in Table 3. The most stringent dilution target is **42-fold** for nitrate, Therefore, achieving a 42-fold dilution of the mine water plume will ensure adequate dilution of all other parameters to meet the respective WQOs. The trigger value for nitrate is not based on marine toxicity, but rather as a nutrient that acts to stimulate ecosystem productivity (e.g. higher algal biomass). Elevated nitrate within the mixing zone is therefore not likely to have direct impacts to marine biota, but may lead to indirect impacts such as higher phytoplankton concentrations. However, this is only likely if the receiving marine environment is poorly flushed and algae remain in the mixing zone with elevated nutrient concentrations for extended periods of time.

The next most stringent dilution target is that of salinity at **35-fold**. Salinity is a more traditional analyte for defining a mixing zone, as it may lead to direct ecological effects on marine biota, particularly benthic primary producers, that are exposed to reduced salinity beyond the natural range.

Of the metals and metalloids, which are potential marine toxicants, the highest dilution requirement is **9-fold** for aluminium.

The mixing zone for 42-fold dilution is therefore described in this study as the zone of **potential indirect effects**, whereas the mixing zone for 35-fold dilution is described as the zone of **potential direct effects**. The mixing zone for 9-fold dilution is described as the zone of **metals and metalloids exposure**.

Table 3 Summary of water quality data and dilution calculations with bold dilution targets indicating those that are assessed in further detail with the far-field modelling.

Analyte	Units	C_A [3]	C_O [4]	C_T [5]	D_T
Aluminium	µg/L	2.5	325.35	37 [6]	**8.4**
Antimony	µg/L	0.25	0.52	270	No dilution required [7]
Arsenic	µg/L	1.5	0.68	12	No dilution required [7]
Cadmium	µg/L	0.1	0.06	0.7	No dilution required [7]
Chromium (Cr VI)	µg/L	0.25	0.59	4.4	No dilution required [7]
Cobalt	µg/L	0.1	0.92	1.0	No dilution required [7]
Copper	µg/L	0.5	1.81	1.3	No dilution required [7]
Iron	µg/L	2.5	44.28	540	No dilution required [7]
Lead	µg/L	No data	0.5	4.4	No dilution required [7]
Manganese	µg/L	1.8	292.08	300	No dilution required [7]
Mercury	µg/L	No data	0.05	0.1	No dilution required [7]
Nickel	µg/L	0.25	2.02	6	No dilution required [7]
Silver	µg/L	0.05	0.5	1.4	No dilution required [7]
Thallium	µg/L	No data	0.5	17	No dilution required [7]
Tin	µg/L	2.5	0.73	10	No dilution required [7]
Vanadium	µg/L	No data	5	100	No dilution required [7]
Zinc	µg/L	2.5	20.16	8	2.2
Rare-earth elements	µg/L	0 [8]	4.25	0.5	7.5
>C10 – C40 Fraction (sum)	µg/L	0 [8]	52.37	50	No dilution required [7]
Ammoniacal Nitrogen	µg/L	50 [9]	457.54	142 [10]	3.4
Nitrate Nitrogen	µg/L	5 [11]	308.25	12.15	**41.4**
Total Nitrogen	µg/L	500 [9]	317.18	1,000 [10]	No dilution required [7]
Phosphate	µg/L	5 [11]	2.87	9.31	No dilution required [7]
Total Phosphorus	µg/L	60 [9]	5.34	100 [10]	No dilution required [7]
Salinity	PSU	35.62 [9]	0	34.62 [12]	**34.6**

[3] Ambient concentration C_A is defined by IPE (2023a) unless otherwise specified by subsequent footnotes.
[4] Outlet concentration C_O is defined by IPE (2023b) unless otherwise specified by subsequent footnotes.
[5] Trigger value C_T is defined by IPE (2023a) unless otherwise specified by subsequent footnotes.
[6] Trigger value has adopted the ANZG (2018) DGV for 95% species protection rather than 24 µg/L suggested by IPE (2023a). The ANZG value was published in December 2025, after the IPE (2023a) study was carried out.
[7] No dilution require when outlet concentration C_O is already below the trigger value C_T
[8] Assumed zero concentration of rare earth elements and hydrocarbons in ambient environment.
[9] Calculated as 50th percentile of GEMCO wastewater discharge monitoring reference site data.
[10] Calculated as 80th percentile of GEMCO wastewater discharge monitoring reference site data.
[11] All ambient measurements from GEMCO wastewater discharge monitoring reference site data were below LOR (10 µg/L). Adopted half LOR for C_A.
[12] Using salinity reduction of 1 PSU from ambient on basis of difference between median and 20th percentile salinity from CARS (2009)

3.5 WQO for pH

Development of WQOs for pH required additional data (namely alkalinity) to predict the pH of mine water when mixed from various stand-alone storages within the mine site.

GEMCO supplied additional pH and alkalinity data to GHD and Indo-Pacific Environmental (IPE). IPE (2023) produced a memorandum summarising the statistical spread of pH readings collected in the marine environment throughout multiple GEMCO monitoring campaigns, as well as a statistical summary of mine water pH.

GHD has utilised the updated pH data (IPE, 2023c), along with recent alkalinity measurements to determine the number of dilutions of discharged mine water required to achieve the adopted pH water quality trigger.

3.5.1 Summary of pH and alkalinity data

IPE (2023c) provides a summary of the pH data collected by GEMCO, including 111 *in situ* readings taken across 20 mine quarries and 283 *in situ* readings compiled from GEMCO's marine monitoring programs for the port and wastewater discharge.

The following values were adopted for the pH mixing zone assessment:

– The median pH of the marine monitoring data (**pH 8.05**) was adopted for the ambient marine environment.
– The discharge pH was calculated by IPE (2023c) as the volume-weighted 5th percentile pH values from the mine quarry measurements. The approach used projected mine water discharge flow rates from each quarry provided by GEMCO for financial years 2025-2031 to determine volume-weighted (or flow-weighted) pH values for the mixed discharge from all mine quarries. A 5th percentile pH was produced for each year of 2025-2031. The average of the 5th percentile volume-weighted pH data for each year (**pH 5.37**) was adopted as a conservative value to represent mine water discharge for this assessment. The average was calculated by first converting the pH values for each year to hydrogen ion concentrations, taking the average, then converting back to pH. This approach is necessary to account for the logarithmic pH scale.
– The marine water quality trigger for pH was defined as the 20th percentile of marine water quality data (**pH 8.00**), as aligned with the approach adopted for salinity and recommended in ANZG (2018). The relatively low pH of the mine water discharge (pH 5.37) must be increased through dilution and buffering processes with ambient seawater (pH 8.05) to at least pH 8.00 in order to satisfy this water quality objective.

Alkalinity data provided by GEMCO to GHD included the following:

– Monthly marine monitoring data from the wastewater discharge monitoring program (reference site in the receiving environment) totalling 24 measurements spanning January 2022 to November 2023.
– Measurements taken during October 2023 from the marine monitoring program across 41 locations.
– 89 measurements from 24 mine quarries spanning July to November 2023.

Representative alkalinity values were defined as follows:

– Mine water discharge was defined as the average alkalinity from quarry measurements (**3 mg/L** as $CaCO_3$).
– The alkalinity of the receiving marine environment was defined as **119 mg/L** (as $CaCO_3$) on the basis of the average from the wastewater discharge monitoring program data, which spanned almost two complete years. The data from the marine monitoring program for the port, which contained a large number of measurements spanning a short period in October 2023, was excluded so as not to introduce a seasonal bias to the data.

3.5.2 pH modelling

Adopting the pH and alkalinity conditions described in Section 3.5.1, water quality modelling was undertaken using the PHREEQC software, version 3.7.3 (Parkhurst and Appelo, 2013). PHREEQC is an industry standard software for simulating chemical reactions and transport processes in natural or polluted water, in laboratory experiments, or in industrial processes. Importantly, PHREEQC includes algorithms for calculating the water quality resulting from the mixing of two pre-defined solutions, with sufficient complexity in the model to account for pH transformations, including pH buffering, when mixing two solutions.

The key inputs to PHREEQC are summarised in Table 4. Other properties defined for ambient marine water adopted the default values for seawater outlined in the PHREEQC user manual. Where inputs are not specifically defined, PHREEQC calculates an extensive set of ionic compositions of each solution.

Table 4 Summary of key inputs to PHREEQC

Parameter	Mine water discharge	Ambient marine water	Basis
pH	5.37	8.05	Section 3.5.1
Alkalinity (mg/L as $CaCO_3$)	3	119	Section 3.5.1
Temperature (°C)	28	28	Typical air temperature (for mine water) and average ocean temperature at Groote Eylandt from CARS (2009)
Density (kg/m^3)	1,000	1,023	Calculated on basis of salinity and temperature

PHREEQC was used to assess various mixing ratios of mine water and ambient seawater to determine the minimum dilution required to achieve the pH water quality objective (pH ≥ 8.00). For the adopted input conditions, a minimum **dilution ratio of 28** results in a mixed pH of 8.001, marginally higher than the pH water quality objective. This dilution target is below the calculated targets for nitrate (dilution target of 42 for potential indirect effects) and salinity (dilution target of 35 for potential direct effects), thereby indicating that any potential environmental effects related to pH will be abated (via dilution) closer to the point of discharge compared to those related to nitrate and salinity.

3.6 WQO for suspended solids/turbidity

The mine water discharge may at times contain elevated suspended solids concentrations or high turbidity, which has the potential to impact on benthic communities via two impact pathways; deposition that smothers seagrass or coral communities, or sustained presence of suspended solids within the water column that cause high turbidity, reducing the amount of light reaching benthic primary producer receptors. As suspended particles behave differently to dissolved analytes, whereby they can settle out of suspension and be remobilised at a later time via resuspension and sediment transport, assessing potential impacts via dilution targets (as defined in section 3.4) may not adequately consider all potential outcomes. Although the initial modelling presented in the referral indicated ample dilution would occur to rapidly reduce risks associated with suspended solids, updated, modelling of suspended solids was carried out directly, separately from the dilution modelling, to address one of the public comments received from the Anindilyakwa Land Council.

Turbidity, an optical measurement of water, is extremely complex to model directly. The Suspended Sediment Concentration (SSC) however can be modelled as suspended particles and also provide a suitable analogue for assessing potential turbidity impacts.

Much of the scientific literature on the impacts of turbidity/SSC within the marine environment focusses on dredging projects, as this is a key risk of such activities. Therefore, the assessment of impacts from the discharge of TSS in the mine water discharge has followed guidance from the Western Australian Marine Science Institute's (WAMSI's) Dredge Science Node (DSN), as well as the WA EPA's (2021) *Technical Guidance – Environmental impact assessment of marine dredging proposals*, which is also heavily informed by the findings of the DSN. The outputs from the DSN are considered to be leading practice technical guidance for marine dredging by the NT EPA, as noted in the *Draft Marine Dredging Guideline* (NT EPA, 2023). Recent dredging proposals submitted to the NT EPA have also aligned with the WA EPA guidance, including INPEX (2022) and KBR (2023). Adoption of this guidance to assess the risks associated with the mine water discharge, which is not expected to have sustained high SSC or generate plumes on the same scale as a dredging project, is a highly conservative approach, but has been applied nonetheless to ensure a thorough assessment.

Specifically, the guidance recommends establishment of a spatially-based zonation scheme to assess the extent, severity and duration of impacts to benthic habitats associated with proposed dredging activities. WA EPA (2021) defines three impact zones, namely:

– **Zone of High Impact (ZoHI)** is the area where serious damage to benthic communities is predicted or where impacts are considered to be irreversible. The term serious damage means 'damage to benthic communities and/or their habitats that is effectively irreversible or where any recovery, if possible, would be unlikely to occur for at least 5 years'. The loss of the benthic communities and/or habitats within these zones should be considered irreversible, unless a defensible case for recovery of the impacted benthic communities and habitats can be presented.

– **Zone of Moderate Impact (ZoMI)** is the area within which predicted impacts on benthic organisms are sub-lethal, and/or the impacts are recoverable within a period of 5 years. This zone abuts, and lies immediately outside of, the ZoHI. The outer boundary of this zone is coincident with the inner boundary of the next zone, the Zone of Influence.
– **Zone of Influence (ZoI)** is the area within which changes in environmental quality associated with suspended sediment plumes are predicted and anticipated, but where these changes would not result in a detectable impact on benthic biota (e.g. a reduction in biomass). These areas can be large, but at any point in time the plumes are likely to be restricted to a relatively small portion of the ZoI.

The benthic habitats within the receiving waters of Milner Bay include seagrass and coral communities. These organisms are adapted to a highly variable light environment resulting from natural fluctuations in turbidity, depth and cloud cover. Thus, short term changes in turbidity resulting from the mine water discharge are not expected to significantly impact the health of seagrass or coral communities. Instead, physiological impacts may arise if reductions in light are maintained over longer periods of days to weeks.

The impact zone criteria of WA EPA (2021) have been applied in varying ways in recent Northern Territory dredging projects, as summarised below:

– The ZoHI was classified by INPEX (2022) and KBR (2023) as the area of direct habitat loss within the dredging and disposal zones.
– The ZoMI was classified by INPEX (2022) as the areas where SSC exceeds tolerance limits for coral and seagrass ranging from 10.7 to 64.2 mg/L for 10% of the time, or the sedimentation depth exceeds 15 mm for corals and 40 mm for seagrass. KBR (2023) defines the ZoMI as the areas where SSC exceeds 23 mg/L for 10% of the time.
– The ZoI was classified by INPEX (2022) as the area where SSC exceeds tolerance limits for coral and seagrass ranging from 10.7 to 64.2 mg/L for 5% of the time, or the sedimentation depth exceeds 3 mm. KBR (2023) defines the ZoI as the areas where SSC exceeds 10 mg/L for 10% of the time.

For this study, a more conservative approach to defining impact thresholds for SSC is adopted. The baseline data established in Section 2.5 has a relatively low range of SSC in comparison to the thresholds adopted by INPEX (2022) and KBR (2023), with a median of 3.3 mg/L, an 80th percentile of 5.6 mg/L, 95th percentile of 8.0 mg/L and a maximum of 20 mg/L. This study therefore adopts the 95th percentile (8.0 mg/L) as the ZoHI threshold and the 80th percentile (5.6 mg/L) as the ZoMI threshold, as these values are at the upper range of measured data from the site. Additionally, to align with the definition of the ZoI, an increase in SSC of 1 mg/L is considered the smallest change that would be detectable by typical laboratory analyses of water samples.

With these values defined, it is also important to consider the duration/frequency of exposure that is biologically relevant to the seagrass and coral habitats. Appendix A of WA EPA (2021) outlines a range of averaging periods appropriate for assessing SSC impacts to corals and seagrass. For corals, 'possible effects' may occur within the ZoMI if turbidity exceeds 6.5 NTU over a 14-day averaging window, which is roughly aligned with the adopted ZoMI threshold of 5.6 mg/L (~6.1 NTU when converted using the relationship defined in Section 2.5), while averaging periods of 10 days and 20 days are suggested for 'possible' and 'probable' impacts, respectively, within the ZoHI when turbidity exceeds 38 NTU (a much higher threshold than the ZoHI value adopted for this study of 8.0 mg/L or ~8.7 NTU). Therefore, a 14-day averaging window is considered appropriate for assessing impacts to corals for the ZoHI as well as the ZoMI. Similarly, 14-day averaging windows are also suggested within Appendix A of WA EPA (2021) for assessing impacts to seagrass.

The final consideration regarding suspended sediment plumes is the potential for sedimentation that may impact benthic communities. INPEX (2022) adopts ZoMI thresholds of 15 mm and 40 mm deposition thicknesses for corals and seagrass, respectively, and 3 mm as a ZoI threshold. WA EPA (2021) suggests 40 mg/cm^2/d over a 20-day averaging period for 'probable effects' within the ZoHI for corals (equivalent to ~44 mm deposition thickness for weakly consolidated sediments deposited at a density of 180 kg/m^3), and 40 mm as a 'no observable effect' threshold within the ZoMI for seagrass. To remain conservative, lower-range values of 3 mm for the ZoI and 15 mm for the ZoMI are adopted, which align with INPEX (2022).

The final adopted threshold criteria applied in this study are summarised in (Table 5). To align with the modelling approach, which did not model ambient SSC, the SSC thresholds are expressed as ΔSSC (i.e. the change relative to ambient conditions). The ZoMI and ZoHI thresholds have therefore been modified by subtracting the median SSC (3.3 mg/L) to assess the allowable increase above the median.

Table 5 Summary of threshold criteria adopted for sediment dispersion assessment

Zone	ΔSSC	Sedimentation thickness
Zone of Influence (ZoI)	Any area where modelled 95th percentile ΔSSC > 1 mg/L	3 mm
Zone of Moderate Impact (ZoMI)	Any area where modelled 14-day average ΔSSC > 2.4 mg/L	15 mm
Zone of High Impact (ZoHI)	Any area where modelled 14-day average ΔSSC > 4.7 mg/L	Not assessed

3.6.1 Discharge quality

The SSC of the mine water discharge was defined by IPE (2023a) as 90 mg/L, adopting the 95th percentile of measurements from the mine quarry data[13]. For reference, the 95th percentile (volume-weighted) of turbidity in the mine quarry water was defined by IPE (2023b) at 120 NTU, though this was not explicitly modelled.

3.7 Sediment quality objectives

As the suspended solids discharged from the mine quarries may contain particulate metals, an additional assessment of sediment quality has been carried out to determine the risk of exceeding sediment quality guidelines within the marine environment from the deposition of discharged sediments onto the seabed. This assessment has been carried out in response to the NT EPA request for additional information regarding the potential for biomagnification and bioaccumulation of metals and metalloids in the marine environment, which may affect the sediments in addition to the water quality.

ANZG (2018) default guideline values for toxicants in sediments are expressed in units of mg of toxicant per kg of sediment. These guideline values for the toxicants noted to be present within the mine water are outlined in Table 6, and include metals and metalloids, as well as hydrocarbons (the C10-C40 hydrocarbon fractions have been assessed against the ANZG Total Petroleum Hydrocarbons [TPH] threshold).

For this assessment, it is conservatively assumed that all toxicants within the discharge are present as suspended particles rather than dissolved, thus having the greatest potential to settle onto the seabed and accumulate at toxic concentrations.

To compare the guidelines against the modelled outcomes, it is necessary to calculate the limit of sediment deposition (in g/m^2) that could occur before each guideline value would be exceeded. These calculated deposition limits are presented in Table 6, and adopted the following assumptions:

- The seabed has a typical sediment (dry) density of 1,500 kg/m^3, which assumes a nominal porosity of 40% (typical of coastal environments).
- The TSS load in the discharge is 90 mg/L. Dividing the discharge concentration of each toxicant by this total TSS load gives the proportion (by mass) of the toxicant within the suspended solids. The remaining suspended solids not comprised of toxicants are anticipated to be benign sediments from the mine site.
- The ANZG DGVs are expressed in terms of a mass-concentration (mg/kg), whereas model outputs are given as areal concentrations (g/m^2). As such, this assessment focusses on the upper 10 cm of the seabed sediments, assuming sediment accumulation is mixed evenly within this layer. Given the assumed sediment density of 1,500 kg/m^3, one square meter of sediments 10 cm thick (0.1 m^3) would have a total mass of 150 kg/m^2. The sediment DGV is multiplied by this total sediment mass and divided by the proportion of toxicant within the sediments to calculate the maximum allowable sediment deposition.

[13] For turbidity, the volume-weighted approach of IPE (2023b) was adopted, while for TSS, the concentration was defined simply as the 95th percentile of all mine quarry samples.

As shown in Table 6, across all sediment toxicants assessed, the lowest (i.e. most stringent) of the maximum allowable deposition values is 27,000 g/m^2 (silver). Exceeding this deposition value would cause the silver concentration within the upper 10 cm of seabed to exceed the DGV of 1 mg/kg, on the basis of the above calculations and assumptions.

Table 6 Sediment quality guidelines and calculated maximum allowable sediment deposition in upper 10 cm of seabed to achieve the guidelines

Sediment toxicant	Discharge Concentration (µg/L)	Sediment DGV (mg/kg)	Proportion of toxicant in TSS ($\%_{mass}$)	Maximum allowable sediment deposition in upper 10 cm (g/m^2)
Antimony	0.52	2	0.0006%	51,923
Arsenic	0.68	20	0.0008%	397,059
Cadmium	0.06	1.5	0.0001%	337,500
Chromium (Cr VI)	0.59	80	0.0007%	1,830,508
Copper	1.81	65	0.0020%	484,807
Lead	0.5	50	0.0006%	1,350,000
Mercury	0.05	0.15	0.0001%	40,500
Nickel	2.02	21	0.0022%	140,347
Silver	0.5	1	0.0006%	27,000
Zinc	20.2	200	0.0224%	133,929
>C10 – C40 Fraction (assessed as TPH)	52.4	280	0.0582%	72,179

3.8 Consideration of treated effluent quality

To account for potential cumulative effect that may arise from the mine water discharge plume interacting with the discharged treated effluent within Milner Bay (and in response to the NT EPA request for an assessment of potential cumulative impacts), the treated effluent was modelled with the water quality outlined in Table 7, defined as the 95th percentile of treated effluent monitoring data provided by GEMCO. Only the parameters common to the mine water discharge and the treated effluent were considered, as these parameters have the potential to generate cumulative impacts within the marine environment that may exceed the influence of either discharge operating individually.

Table 7 Water quality data measured at the STP outlet

Analyte	Units	Samples	95th Percentile
>C10 - C40 Fraction (sum)	µg/L	46	1,455
Ammonia	µg/L	47	18,630
Aluminium	µg/L	1	46
Copper	µg/L	46	56
Iron	µg/L	1	28
Manganese	µg/L	46	806
Nitrate as N	µg/L	47	7,714
Phosphate as P	µg/L	45	6,734
Total Nitrogen as N	µg/L	47	25,610
Total Phosphorus as P	µg/L	47	8,300
Turbidity - Field	NTU	46	80
Zinc	µg/L	46	105

3.9 Far-field model development

3.9.1 Far-field concept

The far-field describes the region beyond the near-field whereby plume transport is driven by ambient currents (generated by tides and winds) and vertical circulation (generated by waves). Both tidal and wind-induced currents are included within the modelling framework, as well as the influence of waves (as described in Section 2.3).

3.9.2 Model platform

Far-field modelling was undertaken with the three-dimensional (3D) MIKE3 FM (flexible mesh) hydrodynamic model to simulate wind and tide-induced currents. MIKE 3 FM was developed by the Danish Hydraulic Institute (DHI) and is an industry standard for 3D hydrodynamic (HD) 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 by a sigma coordinate (fixed number of vertical layers throughout the model domain that vary in thickness according to the depth) or a combined sigma and z-level (allows inclusion of layers with fixed widths) configuration. 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. variations in water levels and currents at the open boundaries, winds acting on the sea surface, heat exchange across the model domain and point sources including outfalls/diffusers).

Additionally, wave modelling was carried out with the MIKE 21 (two-dimensional) Spectral Wave (SW) model.

Outputs from the hydrodynamic and wave models were provided as inputs into the following additional MIKE modules:

– EcoLab, which was used to simulate the dispersion of dissolved analytes configured as conservative (i.e. non-decaying) numerical tracers
– Mud Transport (MT), which was used to simulate the dispersion, settling, deposition and resuspension of suspended sediments within the mine water and treated effluent discharge plumes.

3.9.3 Model domain

3.9.3.1 Hydrodynamic model

The model mesh and bathymetry are presented in Figure 10 (entire domain), Figure 11 (high resolution area surrounding the Proposal site) and Figure 12 (Milner Bay Wharf and post-dredge survey data locality).

The resolution of the hydrodynamic model mesh ranges from ~15 km at the offshore model boundaries to ~20-30 m in the proposed area of the diffuser. The bathymetry was developed with the following data:

– Neptune 0.25 m resolution survey of the Milner Bay Wharf area.
– September 2022 0.25 m resolution post-dredge bathymetry survey of the GEMCO Tug Berth.
– DHI’s MIKE C-Map nautical chart information in all areas where no other data was available.

The above data was collated and processed, ensuring that all surfaces have the same horizontal (GDA 2020 / MGA zone 53) and vertical datum.

The vertical domain in the 3D model was configured as follows:

– Sigma coordinate system of the 4 layers in the upper section of the water column extending to a depth of 12 m below MSL. These layers expand and contract in response to tidal and non-tidal water level variations.
– At depths greater than the sigma domain (i.e. depths greater than 12 m below MSL), a fixed coordinate (z-level) system of 7 lower layers is used. Layer thicknesses in the z-level domain, from top to bottom, are 3 m, 5 m, 5 m, 5 m, 10 m, 10 m and 20 m thick.

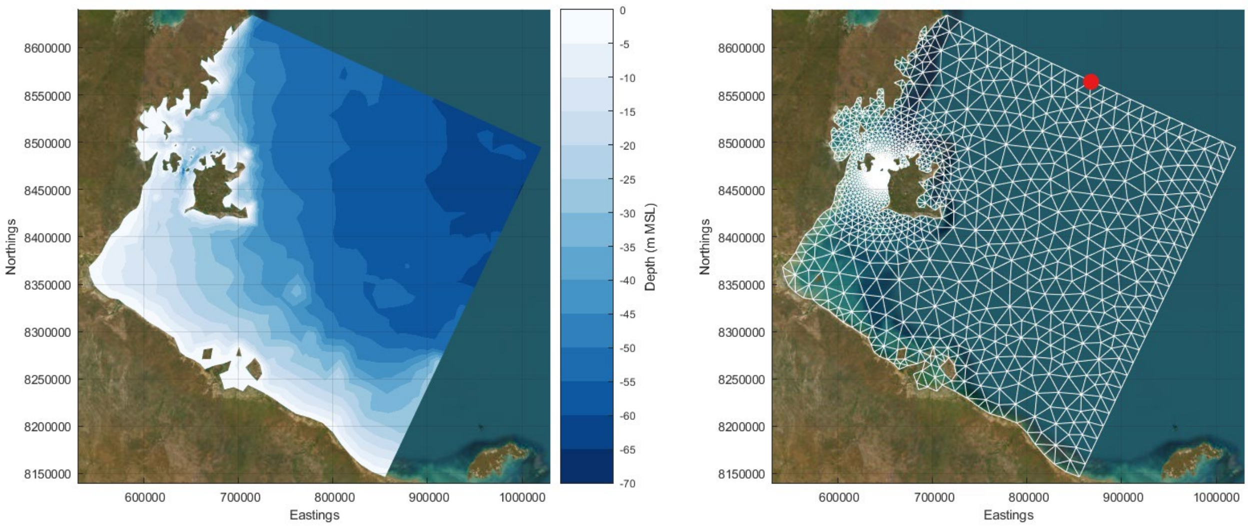


Figure 10 ***Hydrodynamic model bathymetry (left) and mesh (right) of the entire model domain with red dot demarking location of open ocean boundary inputs presented in Section 3.9.5.***

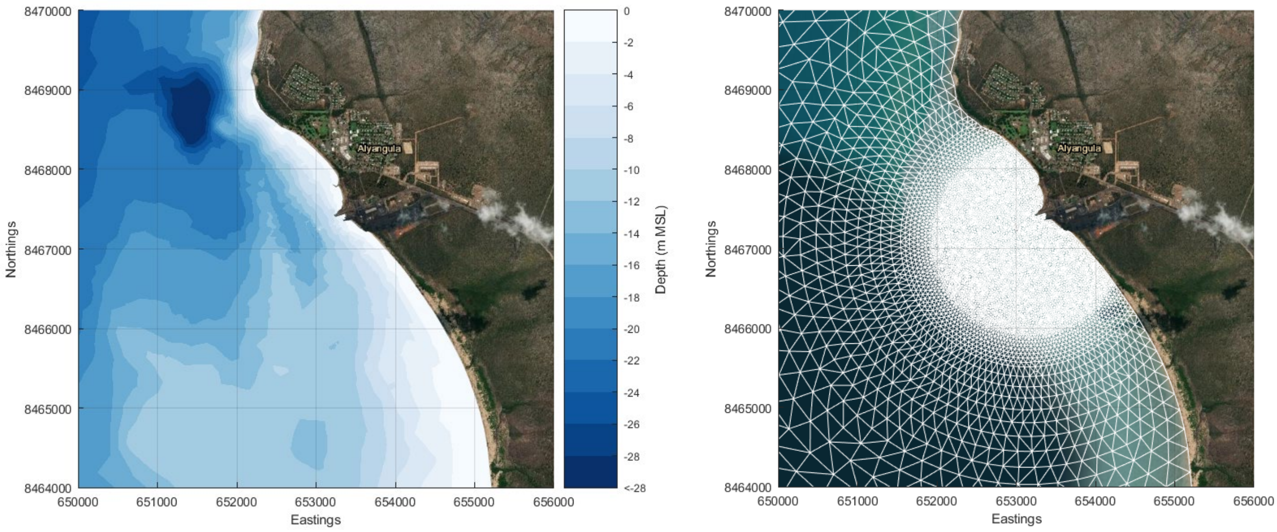


Figure 11 ***Hydrodynamic model bathymetry (left) and mesh (right) in the diffuser locality.***

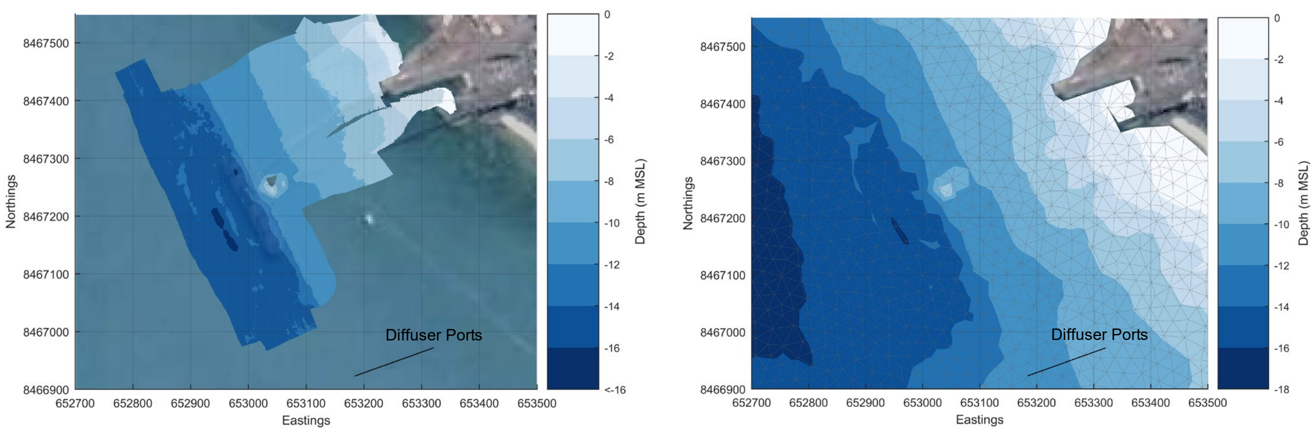


Figure 12 ***Survey data (left) and hydrodynamic model mesh/bathymetry (right) at the Milner Bay Wharf locality.***

3.9.3.2 Wave model

The same bathymetry data sources described in Section 3.6.3.1 were used to generate a coarser mesh for the two-dimensional wave model. The coarse mesh and bathymetry are presented in Figure 13 for the high-resolution area surrounding the Proposal site.

The resolution of the hydrodynamic mesh ranges from approximately 15 km at the offshore model boundaries to around 100 m in the proposed diffuser area.

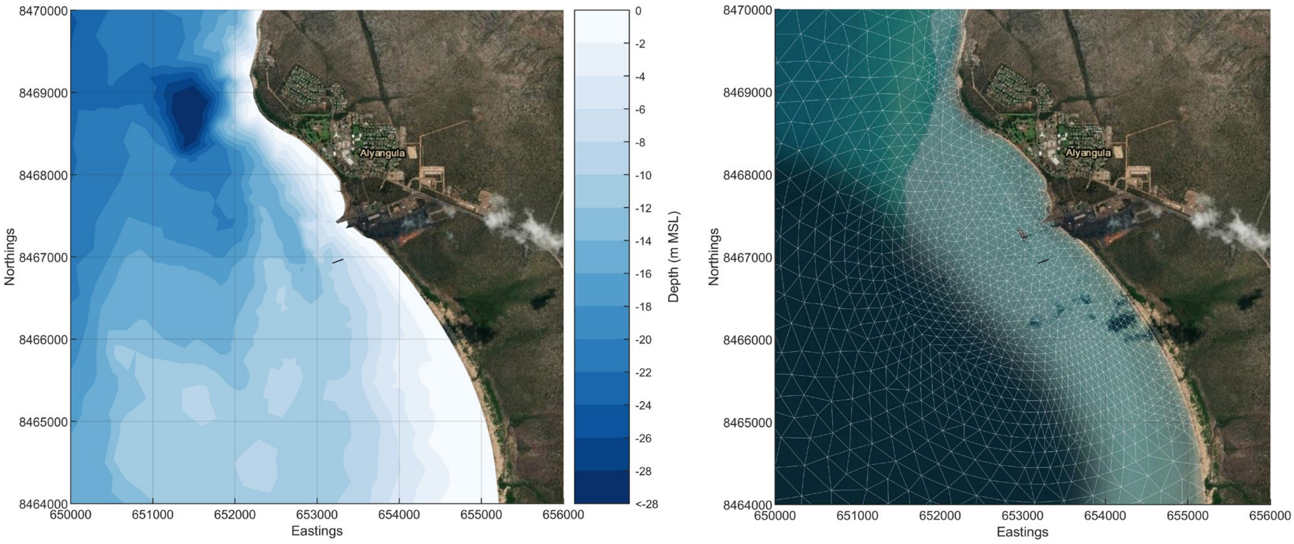


Figure 13 ***Wave model bathymetry (left) and mesh (right) in the diffuser locality (coarse mesh).***

3.9.4 Simulation period

To account for seasonally varying met-ocean conditions at the site, the hydrodynamic model was run for a one-year period. This requires the selection of a representative year which reflects the long-term average conditions of the system, without being skewed by extreme events or anomalies.

The year of 2022 was deemed attractive due to the abundance of model validation data (measured water levels and currents) during this period. It was therefore necessary to determine how the metocean conditions of this period compare against long-term conditions.

As detailed in Section 2.3, the site is located within a highly sheltered environment with limited wave energy. Tidal forcing is the dominant driver of mixing at the site, with the influence of winds and waves being secondary. Tidal patterns are predictable and similar when compared between years, therefore consideration of tides is not critical to the assessment of the representative year, despite tides being the dominant force. Therefore, a comparison of the wave conditions of 2022 against the long-term average conditions was carried out to determine whether this secondary forcing is well presented by the simulation period.

An exceedance plot for the significant wave height and wave flux energy is shown in Figure 14. Both plots show that the simulation period (2022) tends to sit within the range of longer-term wave conditions throughout 2015-2024, though it is somewhat skewed towards lower wave heights, with a median of significant wave height of 0.6 m compared to the long-term median of ~0.7 m. However, the long term range in typical wave heights (generally up to 2.5 m) is well represented during 2022. The year 2022 can be considered a slightly conservative year for the purpose of this study, as lower wave heights and energy generally result in lower rates of plume mixing/dilution. A wave rose comparison is shown in Figure 15, which also demonstrates reasonable alignment to the long-term wave patterns.

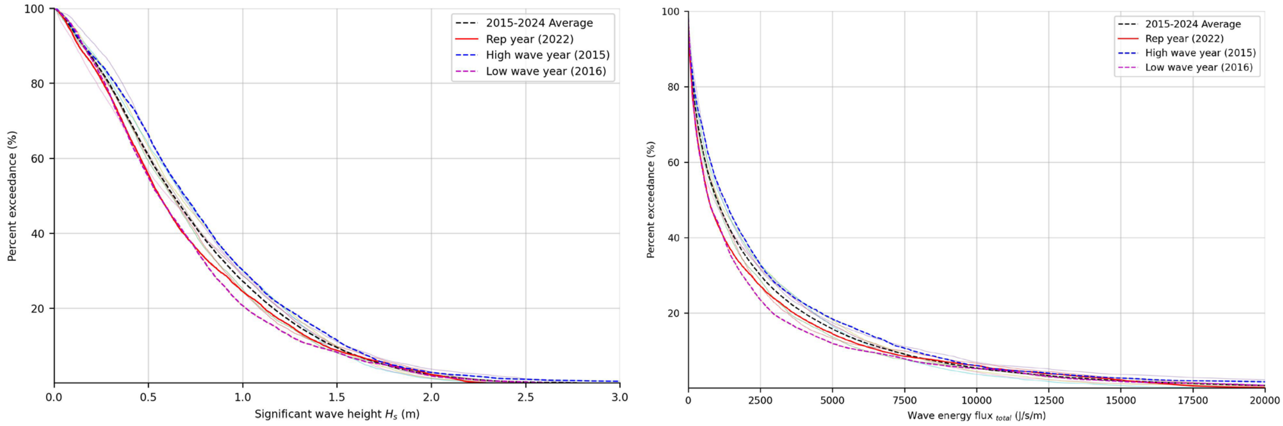


Figure 14 ***Percent exceedance of significant wave height (left) and wave energy (right) for the long-term average and selected simulation year (2022)***

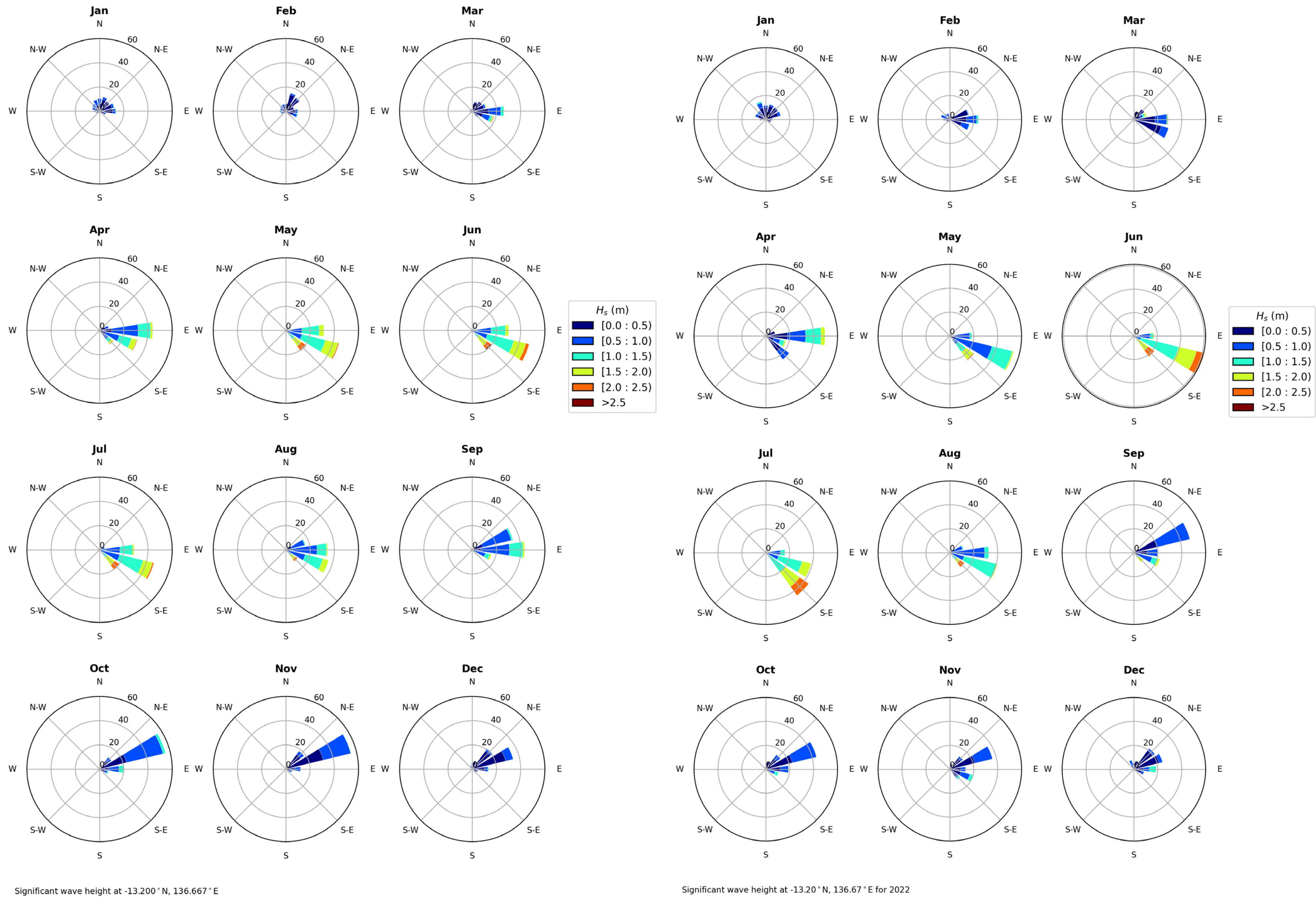


Figure 15 ***Significant wave height rose for each month for the long-term average (left) and simulation year of 2022 (right)***

3.9.5 Open ocean boundary inputs

Model inputs of spatially varying water levels were from a combination of astronomical tides from the global tide model TPXO9 (Egbert and Erofeeva, 2002) and non-astronomical water levels from the Hybrid Coordinate Ocean Model (HYCOM) at 1/12° horizontal resolution and 3-hourly temporal resolution (Chassignet *et al.*, 2007). Further, horizontally, vertically and temporally varying currents applied at the model open boundaries were from the combined oceanographic HYCOM and tidal TPXO9 currents.

Examples of the model's offshore inputs at the middle of the northern open boundary (point shown in Figure 10) are illustrated for water levels in Figure 16, v-currents (north-south) and u-currents (east-west currents) in Figure 17, and temperatures and salinities in Figure 18.

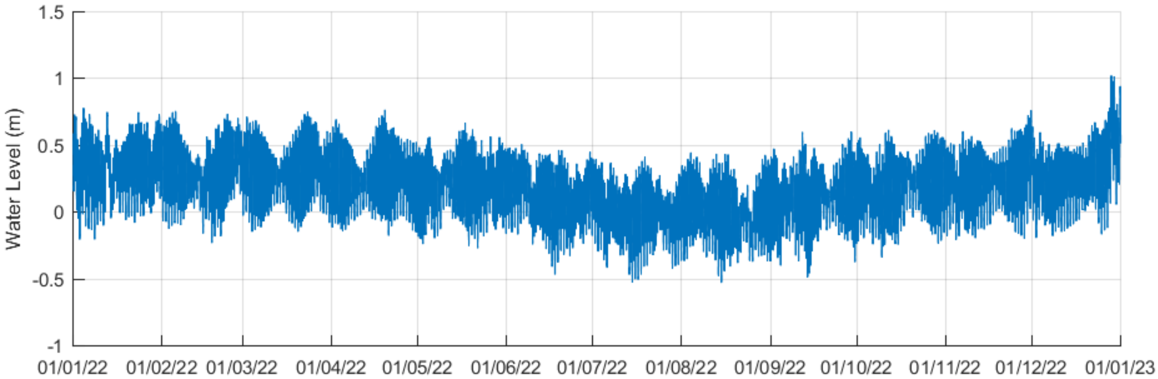


Figure 16 ***Water levels at a middle location along the northern open ocean boundary from 1 January 2022 through 1 January 2023.***

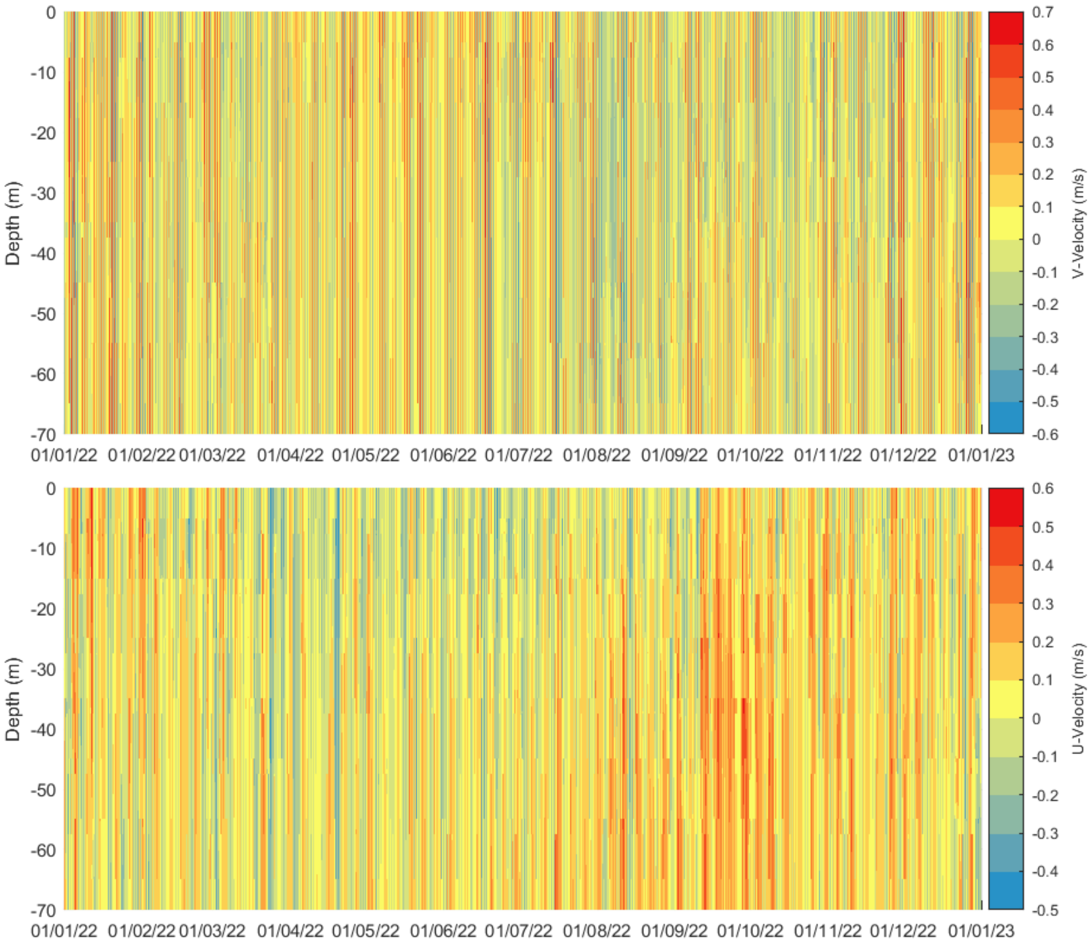


Figure 17 ***V- (upper) and U- (lower) currents at a middle location along the northern open ocean boundary from 1 January 2022 through 1 January 2023.***

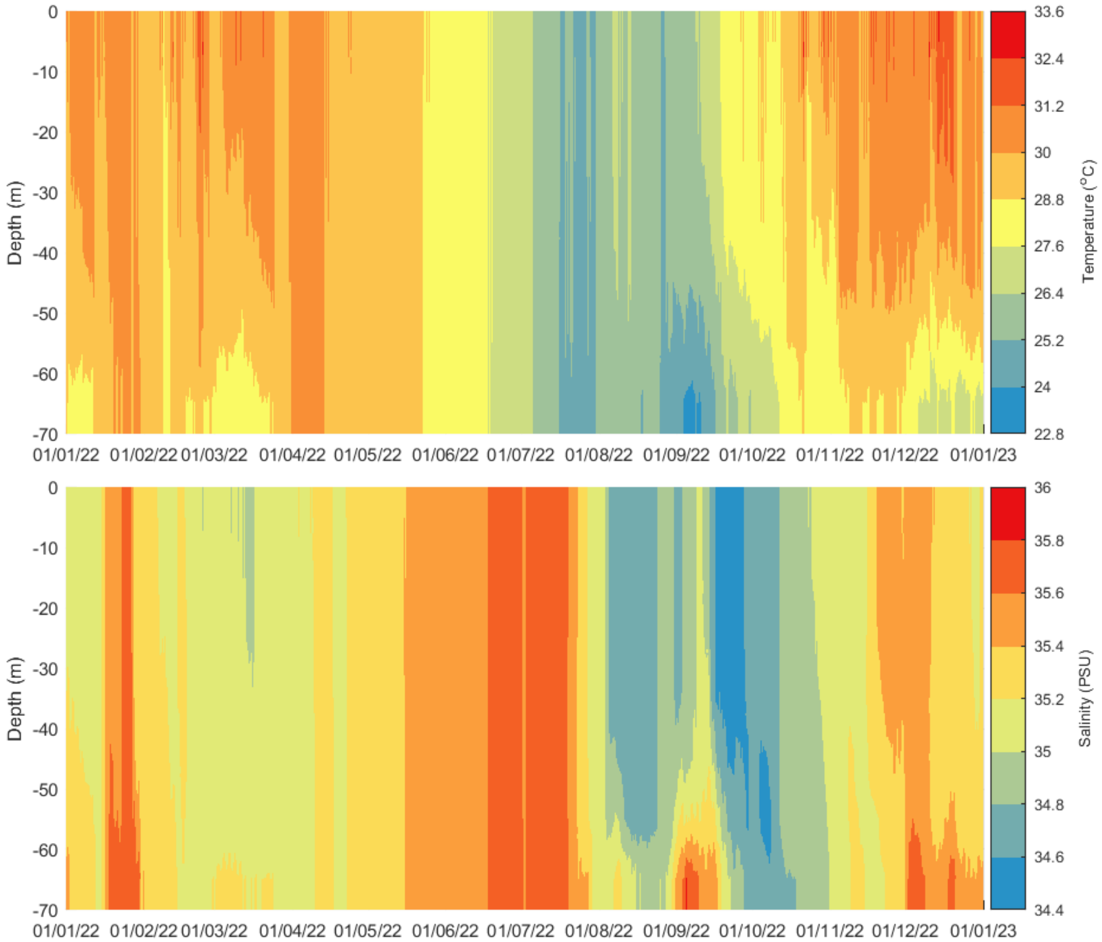


Figure 18 ***Temperatures (upper) and salinities (lower) at a middle location along the northern open ocean boundary from 1 January 2022 through 1 January 2023.***

For the 2D wave model, water levels from TPXO9 combined with HYCOM, as previously described, were applied to at the open boundary. Deepwater wave parameters (including significant wave height, peak wave period, mean wave direction and directional spreading) were extracted from the CSIRO CAWCR wave hindcast aggregated collection dataset (Durrant *et al.*, 2019). The CAWCR wave hindcast was generated using NOAA's WaveWatch III model on a global grid with 0.4° resolution, refined to a resolution of 4 arc minutes (0.066°) within Australia and the Pacific region.

Examples of the model's offshore wave parameter inputs at the middle of the northern open boundary are illustrated for year 2022 in Figure 19.

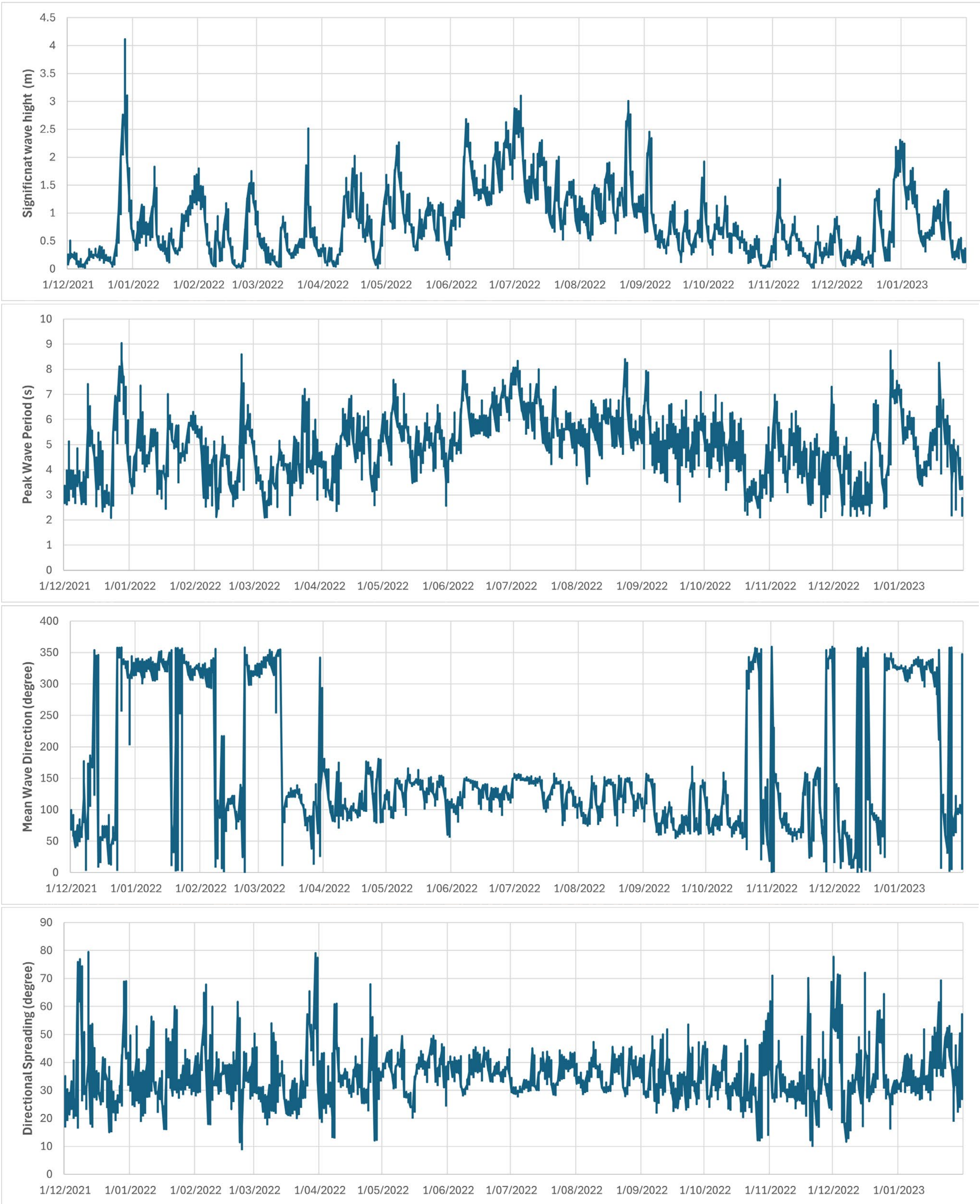


Figure 19 *CAWCR Wave parameters at a middle location along the northern open ocean boundary from 1 January 2022 through 1 January 2023.*

3.9.6 Wind forcing

Spatially varying CFSv2 wind was applied to the seas surface of the model. Wind speeds and directions from the CFSv2 dataset at Groote Eylandt are illustrated in Figure 20 for the year of 2022 (representative year selected for this study). For the 2D wave model, spatially varying winds were sourced from the ERA5 model to align with previous wave modelling works carried out by GHD for another project.

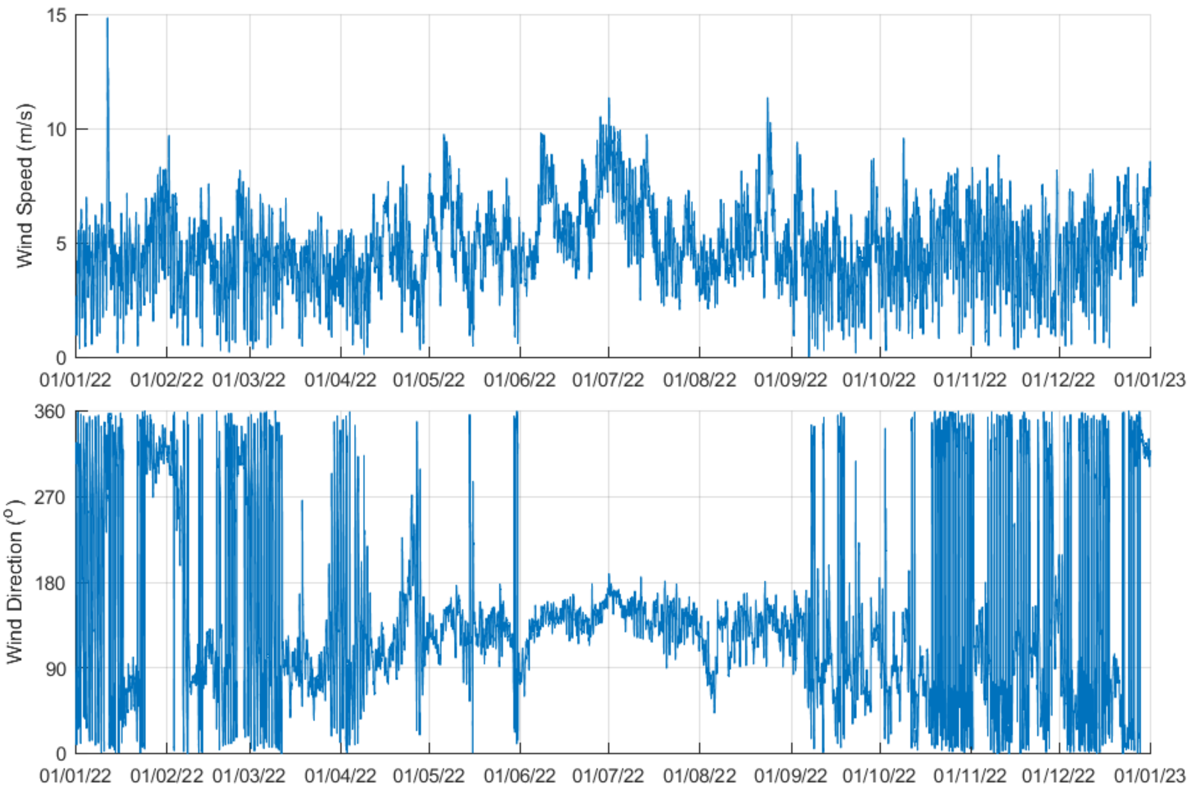


Figure 20 CFSv2 simulated wind at Groote Eylandt from 1 January 2022 to 1 January 2023.

3.9.7 Ocean temperature and salinity forcing

Spatially and temporally varying ocean temperature and salinity data from HYCOM were applied to the offshore boundary of the 3D hydrodynamic model. These parameters are important for establishing realistic density structures which influence plume stratification, mixing, buoyancy, and circulation, and have been illustrated previously in Figure 18.

3.9.8 Heat exchange processes

Heat exchange was included in the 3D model configuration to account for the transfer of heat between the water surface and atmosphere via evaporation, convection and solar radiation (longwave and shortwave). The inputs for the heat exchange module were derived from CFSv2 and included the shortwave radiation flux, air temperature, relative humidity and clearness coefficient (a measure of the proportion of cloud cover).

3.9.9 Discharge

The concept design of the multi-port diffuser from the near-field modelling assessment was configured into the 3D far-field model. The discharge scenario of 80 GL/a was simulated spanning the entire year of 2022 as summarised in Table 2. As noted in Section 3.2.2, Scenario 1 for the far-field assessment has an increased discharge (80 GL/a) relative to the near-field assessment to conservatively account for likely shorter-term peak flow rates that may occur throughout the year.

Table 8 Diffuser configuration and flow rates incorporated into the 3D far-field model.

Parameter	Far-field Scenario 1
Flow rate (GL/a)	80
Flow rate (m^3/s)	2.54
Number of ports	30
Diffuser length (m)	145
Port spacing (m)	5
Outlet Diameter (m)	0.15
Outlet Depth (m)	7.5-9.5 (8.5 average)
Outlet height above seabed (m)	0.5
Discharge Vertical Angle	10°
Discharge Horizontal Angle	315°/135° alternating
Exit Velocity (m/s)	4.8

Additionally, the discharge of treated effluent was included in the model to understand potential cumulative impacts from the two discharges operating concurrently. The configuration of this outlet is detailed in Table 9.

Table 9 STP outlet configuration and flow rates incorporated into the 3D far-field model.

Parameter	Far-field Scenario 1
Flow rate (GL/a)	0.35
Flow rate (m^3/s)	0.011
Number of ports	1
Outlet height above seabed (m)	0.5

3.9.10 Sediment dispersion modelling

Simulation of the dispersion of suspended sediments within the mine water and treated effluent discharges was undertaken with the DHI MIKE Mud Transport (MT) module. MIKE MT utilises the MIKE 3 FM hydrodynamic simulation outputs as inputs, along with waves from MIKE21 SW. MIKE MT simulates the fate of particles due to settling and resuspension.

The inputs into the MIKE MT model include sediment concentrations within the simulated discharges as well as particle settling velocities. Data provided by the GEMCO demonstrates that suspended solids are present in both the treated effluent and mine water discharges. However, as no details on the particle size distribution (PSD) were available, the diameters of the particles were assumed. It is expected that only clay and silt-sized particles (i.e. 'fines') are present in the discharge with larger particles assumed to have been removed by the STP and undergone settling within the mine storage pits prior to discharge.

The settling velocities of the sediment particles were calculated on the basis of grain diameters with the relationships of Cheng (1997). The associated properties of the particles are presented in Table 10, whereby it was assumed that the particle size distribution was equal across the five Wentworth grain classes considered in this investigation.

Table 10 Settling velocity and distribution of sediments

Wentworth Grain Classification	Nominal diameter (µm)	PSD (% volume)	Settling velocity (m/s)
Clay (0-4 um)	2	20	2.33E-06
Very Fine Silt (4-8 um)	6	20	2.10E-05
Fine Silt (8-16 um)	12	20	8.38E-05
Medium Silt (16-32 um)	23.5	20	3.20E-04
Coarse Silt (32-63 um)	46.5	20	1.23E-03

3.9.11 Far-field model verification

Verification of the model performance utilised the following quantitative indices to compare the simulation with the measurements:

– **Percentile probability distributions** of simulated and measured data. This is a graphical comparison of the statistical spread of the data for a parameter at a particular location (e.g. current speed range at the ADCP site) between the simulation and measurements. This comparison enables quantification of the percentage of time that the model is under- or over-predicting the measured data.

– **Mean Absolute Error (MAE).** A quantitative measure of the absolute differences between the simulation and measurements. Low values of MAE represent good model performance. This metric is easily interpreted and a more natural measure than the commonly used root-mean-squared error, as it is less influenced by extreme values (i.e. outliers or ‘noise’ in the measured data) (Willmott 1982).

  The **MAE** is calculated as:

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

  where:

  - P_i = Predicted value at comparison time i
  - O_i = Observed value at comparison time i
  - n = Number of comparison measurements

– **Index of Agreement (IOA).** IOA is a quantitative measure of the average differences between predicted and observed values relative to the range of values in the observation data (Willmott 1982). It is bounded between the values of 0 and 1, with values close to 0 describing large relative differences (i.e. poor validation) and values close to 1 describing small relative differences (i.e. good validation). Willmott et al. (1985) suggests that IOA values meaningfully greater than 0.5 represent good model validation, with values approaching 1 representing excellent validation. The **IOA** is calculated as:

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

  where, further to the definitions for MAE:

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

The quantitative model skill measures of MAE and IOA are not applicable to directional parameters (e.g. current direction) as these equations are not designed for data defined on a circular scale.

3.9.12 Modelling scenarios

3.9.12.1 Far-field modelling scenarios

A total of three simulations were evaluated in the far-field modelling assessment as summarised in Table 11, which include a baseline simulation for model verification and two operational discharge scenarios of 80 GL/a without and with wave effects.

Each simulation period included a one-week simulation spin-up time to allow the models with static starting conditions to reach a representative dynamic state.

Table 11 Simulation scenarios

Scenario	Simulation Period
Baseline simulation (for model verification)	January 2022 to December 2022
Scenario 1: Estimate of likely short to medium-term discharge rates based on current operations (80 GL/a to account for peak flows) with no wave modelling	January 2022 to December 2022
Scenario 2: Aligned with scenario 1 with inclusion of wave modelling	January 2022 to December 2022

3.9.12.2 Flushing simulations

As an additional assessment to contextualise the mixing zone predictions, simulations were carried out to characterise the flushing of the nearshore receiving waters. The flushing rate is evaluated through calculation of the e-folding flushing time. The e-folding flushing time is the duration for ~63% of a water body's volume to exchange with adjacent ambient waters until ~37% (1/e) of the original volume remains. Numerically, this is estimated by fitting an exponential curve of the form $C_t=e^{-kt}$ to a conservative tracer concentration (C_t) over time (t). The inverse of the fitted exponent (1/k) is the e-folding flushing time scale.

The e-folding time was determined for the 'control volume' of the near-shore waters encompassing the predicted mixing zones, which was defined as an area extending approximately to the 12 m depth contour, and ~5 km northward and southward from the Proposal site, as depicted in Figure 21. This control volume is 'seeded' with a numerical tracer at the start of the flushing assessment to track the exchange of waters between the control volume and surrounding marine environment.

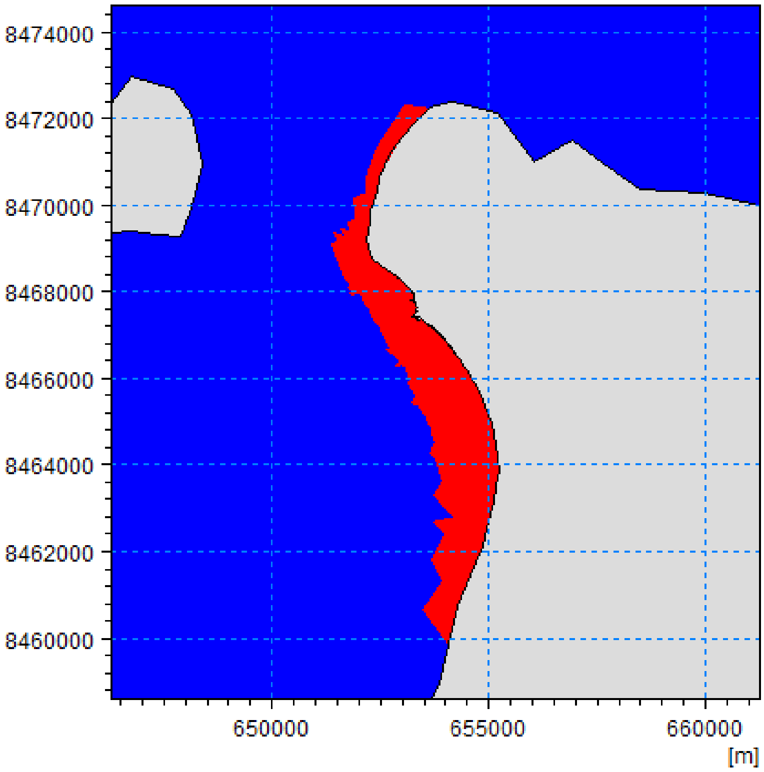


Figure 21 Control volume (red area) assessed for flushing simulations.

The e-folding time is presented in two ways, namely:

– A 'bulk' volumetric e-folding flushing time for ~63% of the volume to exchange with adjacent waters.
– Spatial e-folding flushing times are presented by calculated the individual e-folding time for each model cell, yielding contours of flushing times demonstrating the spatial variability in localised flushing rates within the control volume.

An example depicting the calculation of the bulk volumetric e-folding time is shown graphically in Figure 22 for a control volume that flushes in 1.44 days.

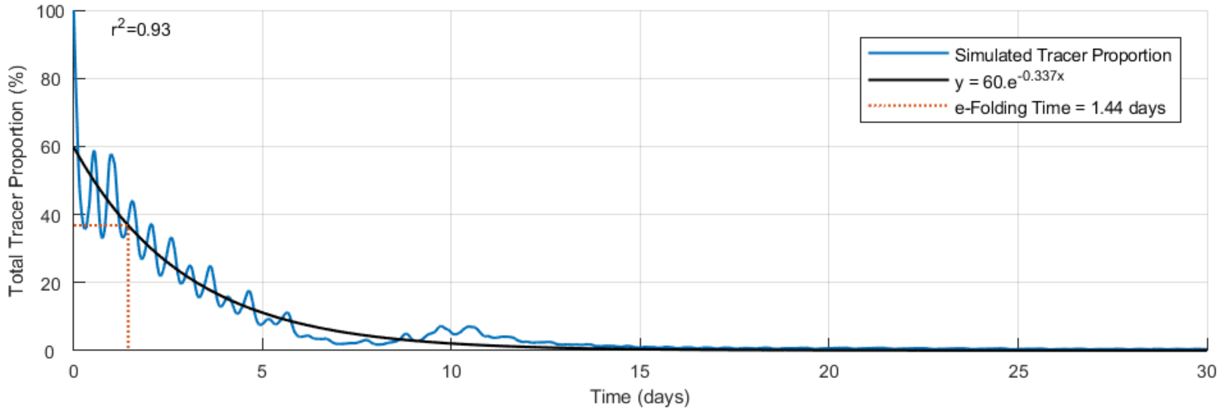


Figure 22 ***Example calculation of the bulk e-folding flushing time.***

To contextualise the results of the flushing assessment, the e-folding time estimates are compared with the PIANC (2008) guidance for marinas, which states an e-folding time of four days (eight tidal cycles) to represent “good” flushing, with flushing between four and ten days classified as “fair” and “poor” for flushing times exceeding ten days. The purpose of the evaluation for marinas is to avoid water quality issues related to stagnation (e.g. eutrophication).

Since flushing can typically be approximated as an exponential reduction, whereby the majority of exchange from the control volume occurs rapidly, the e-folding flushing rate can be highly sensitive to the met-ocean conditions encountered at the start of the assessment. In order to incorporate a range of conditions in the flushing assessment, ten flushing simulations were run with start dates targeting a range of tidal states and wind conditions as summarised in Table 12. The met-ocean conditions during the start dates of the flushing scenarios are further depicted in Figure 23.

Table 12 ***Flushing modelling simulations***

Simulation Number	Description of starting conditions	Start Date/time	End Date/time
1	Spring flooding tide under low wind	1/01/2022 6:00	31/01/2022 6:00
2	Neap low slack tide under low wind	6/02/2022 2:00	8/03/2022 2:00
3	Spring low slack tide under moderate wind	15/03/2022 21:00	14/04/2022 21:00
4	Spring flooding tide under moderate wind	23/04/2022 0:00	23/05/2022 0:00
5	Neap low slack tide under moderate wind	25/05/2022 7:30	24/06/2022 7:30
6	Neap ebbing tide under high wind	5/07/2022 7:30	4/08/2022 7:30
7	Spring flooding tide under moderate wind	8/08/2022 16:00	7/09/2022 16:00
8	Neap low slack tide under low wind	12/09/2022 0:00	12/10/2022 0:00
9	Neap low slack tide under high wind	24/10/2022 9:00	23/11/2022 9:00
10	Spring low slack tide under low wind	27/11/2022 3:30	27/12/2022 3:30

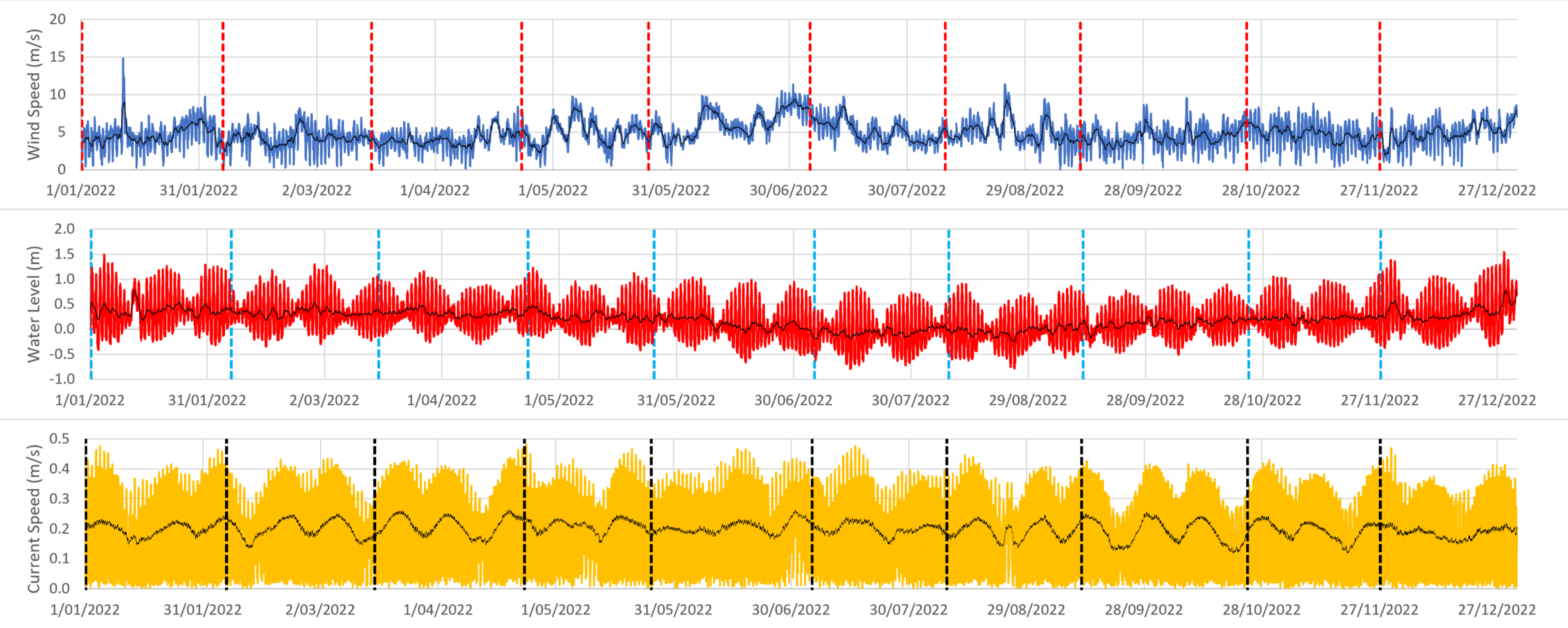


Figure 23 *Time series of wind speeds (top), water levels (middle) and current speeds (bottom) over the 1-year duration hydrodynamic simulation with the 24-hour running mean (black line) and vertical dashed lines representing the start date and time of the accompanying 10 flushing simulations.*

4. Results

4.1 Near-field modelling

The UM3 near-field modelling was undertaken for the scenarios outlined in Table 2 of Section 3.2 with ambient current speeds of 0.13 m/s. Predicted near-field plume trajectories and dilutions are displayed in Figure 24 and Figure 25, respectively.

The UM3 modelling indicates that the average plume dilutions (average dilution through a cross-section of the plume) are predicted to exceed the dilution targets of 42-fold (potential indirect effects) and 35-fold (potential direct effects). However, the plume centreline dilution (dilution in the centre of the plume) remains below these targets for all scenarios. This indicates that additional far-field mixing would be required to achieve the adopted dilution targets.

Furthermore, the UM3 assessment has the limitation of only assessing one steady-state condition (i.e. one ambient current speed) for each scenario. In this manner, the UM3 model is unable to account for the dynamic effects of long-term build-up of discharged mine waters within the receiving environment, which may reduce the dilution efficiency and further extend the mixing zone. Additional assessment of the mixing zone with the 3D far-field modelling was therefore required in order to provide higher confidence predictions of the mixing zone's spatial extent.

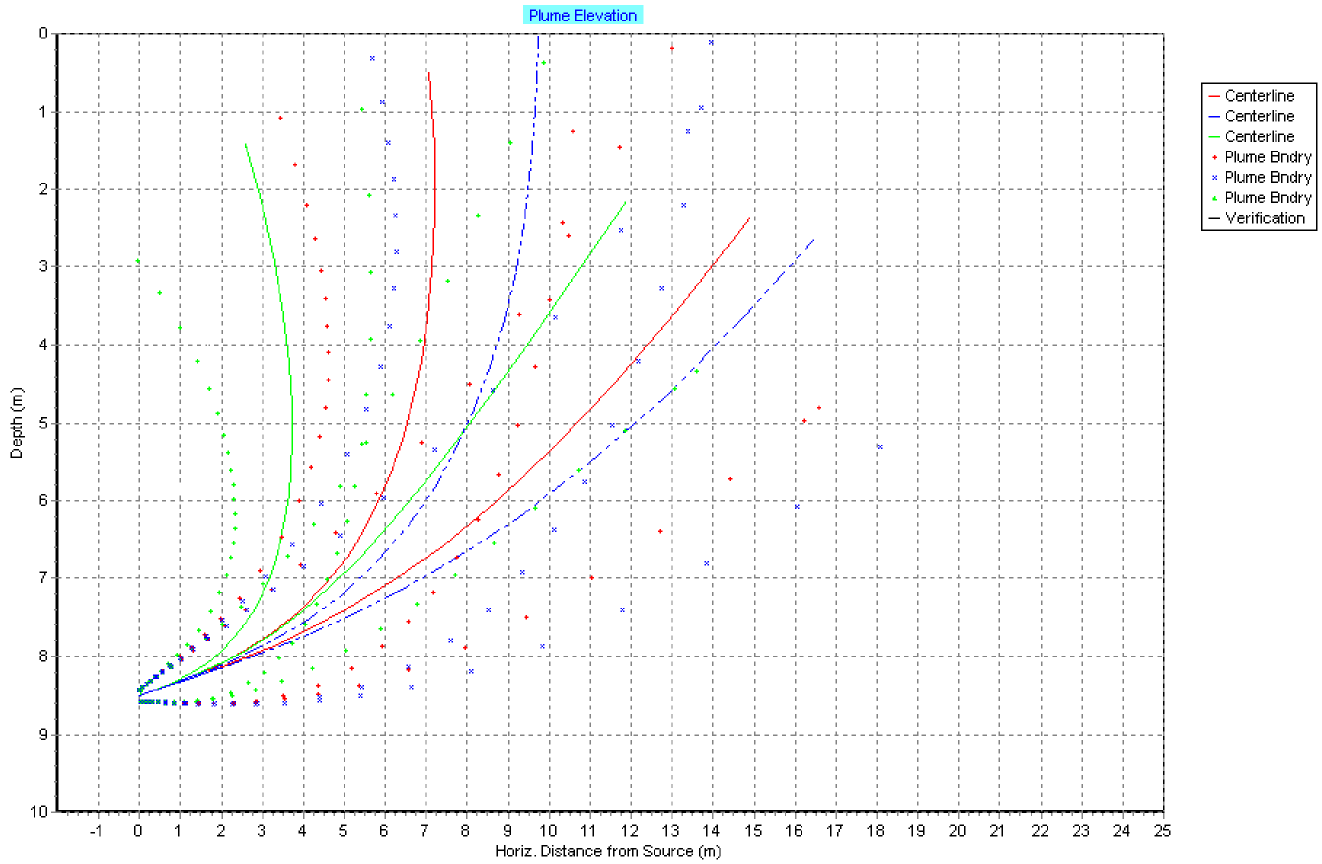


Figure 24 *UM3 prediction of near-field plume trajectory for near-field scenarios 1 (green), scenario 2 (red) and scenario 3 (blue). The two sets of lines for each scenario indicate the plumes from ports discharging with and into the currents.*

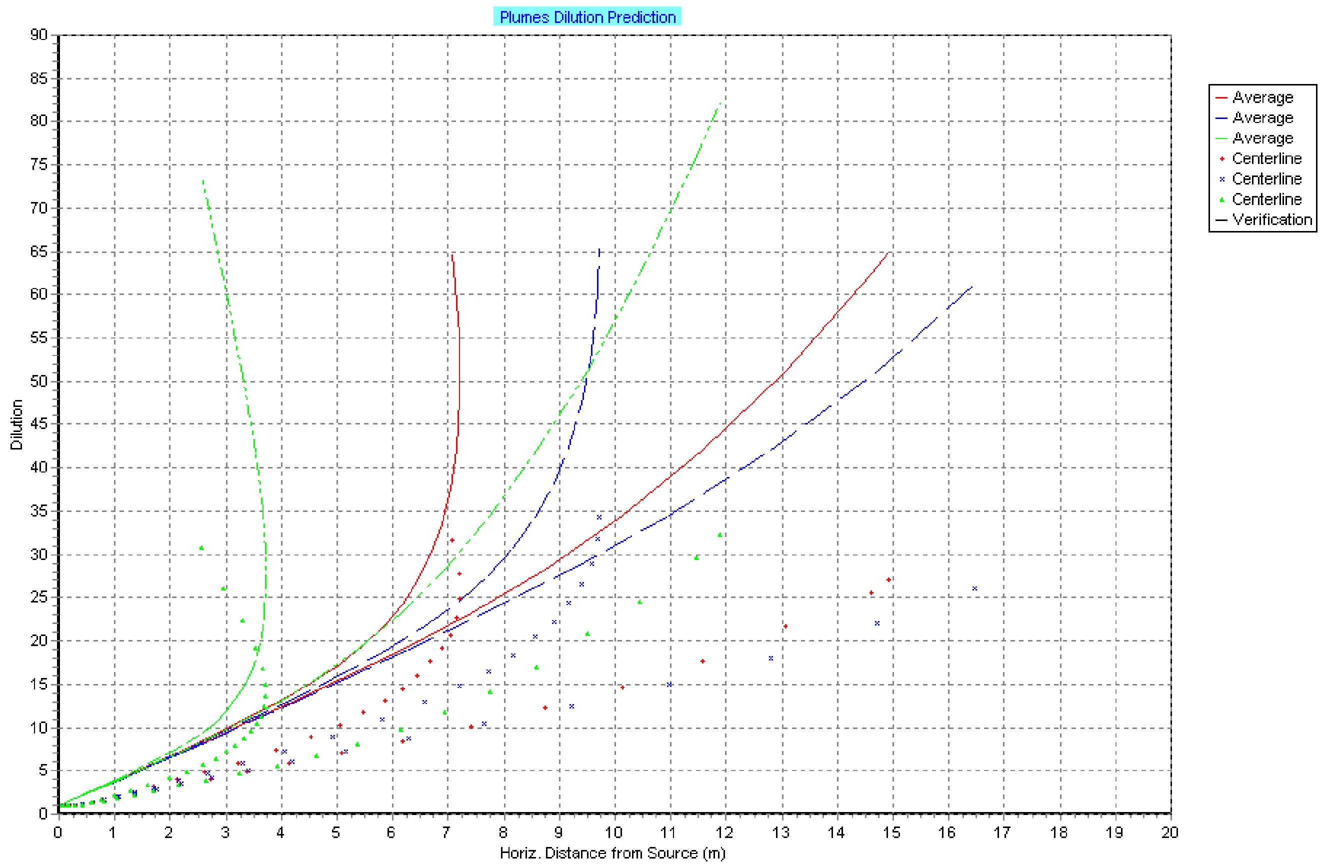


Figure 25 *UM3 prediction of near-field plume dilution for near-field scenarios 1 (green), scenario 2 (red) and scenario 3 (blue). The two sets of lines for each scenario indicate the plumes from ports discharging with and into the currents.*

4.2 Far-field model verification

4.2.1 Hydrodynamic model

The far-field hydrodynamic model performance was verified via comparison of the model predictions to water levels downloaded from Bureau of Meteorology (BoM station 14406 – Groote Eylandt at 136.4158°E, 13.86°S) and current measurements supplied by GEMCO. The water level measurements span the entire year of 2022 at Groote Eylandt station, while the current speed measurements used for model verification ranged from 01 February 2022 to 01 June 2022 at the ADCP site (shown in Figure 1). It is noted that the ADCP data provided had only one current speed reported for each timestep. GEMCO was not able to ascertain the depth at which this measurement was recorded. Therefore, it was assumed to be a depth-averaged value, and the model results were depth-averaged accordingly for the comparison.

Quantitative measurements of model skill for water level and current speeds are presented in Table 13. The quantitative measurements include the index of agreement (IOA) and the mean absolute error (MAE) (Willmott, 1982). Willmott *et al.* (1985) suggests that IOA values meaningfully greater than 0.5 represent good model performance with values approaching 1 representing excellent performance.

Based on the quantitative indices, water levels are deemed to be extremely well represented by the model, achieving an excellent IOA score of 0.97, with an MAE of 0.11 m (Table 13). Simulated current speeds between February 2022 to June 2022 also achieved a very high IOA score of 0.91 (Table 13) with a low MAE of 6 cm/s when compared to the measured data. Additionally, the linear regression of measured versus simulated current speeds indicates a reasonable correlation (r^2=0.76), a slope similar to the 1:1 line and a marginal offset of -4 cm/s in simulated currents compared to the measurements. This indicates currents are typically underestimated by a small degree (4 cm/s compared to a range of 60 cm/s)

Qualitative comparisons of the simulated and measured water level (Figure 26), current speed (Figure 27) and current direction (Figure 28) also indicate a high degree of model skill in replicating the measured data. A comparison over a shorter time period (February 2022) is presented in Figure 29 to highlight additional detail.

Based on the outcomes of the verification assessment, the model is deemed fit-for-purpose for simulating the mixing zone of the far-field discharge scenario.

Table 13 ***Index of agreement and mean absolute errors of simulated water level and depth averaged current speeds for 2022.***

Location	Parameter	Period	IOA	MAE
BOM Groote Eylandt Station	Water Level	January 2022 to December 2022	0.97	0.11 m
Depth Average (ADCP site)	Current speed	February 2022 to May 2022	0.91	0.06 m/s

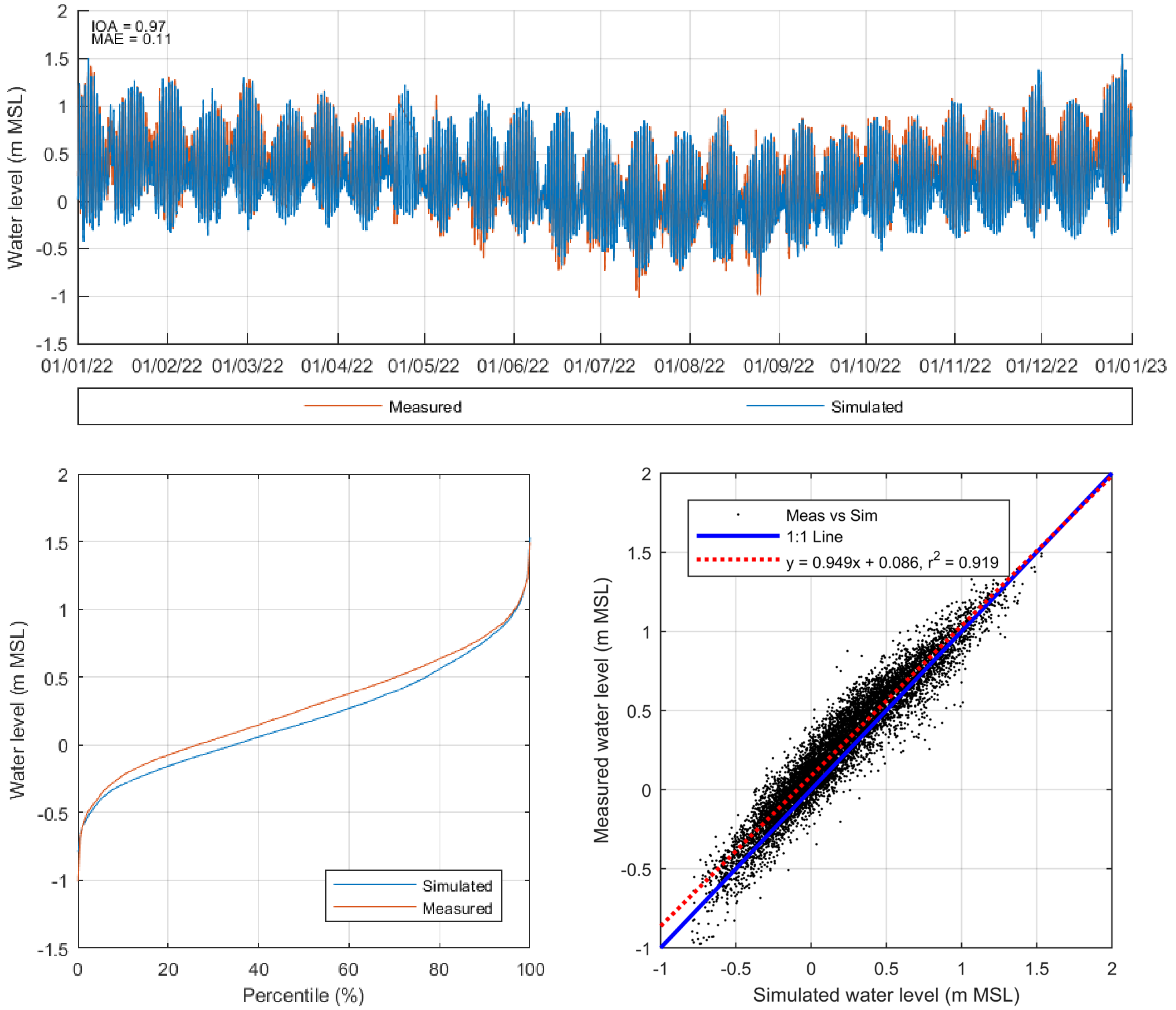


Figure 26 ***Comparison of simulated and measured water level during January 2022 and December 2022 (top panel: time series, bottom left panel: percentile distribution, bottom right panel: measured vs simulated water level with linear regression fit).***

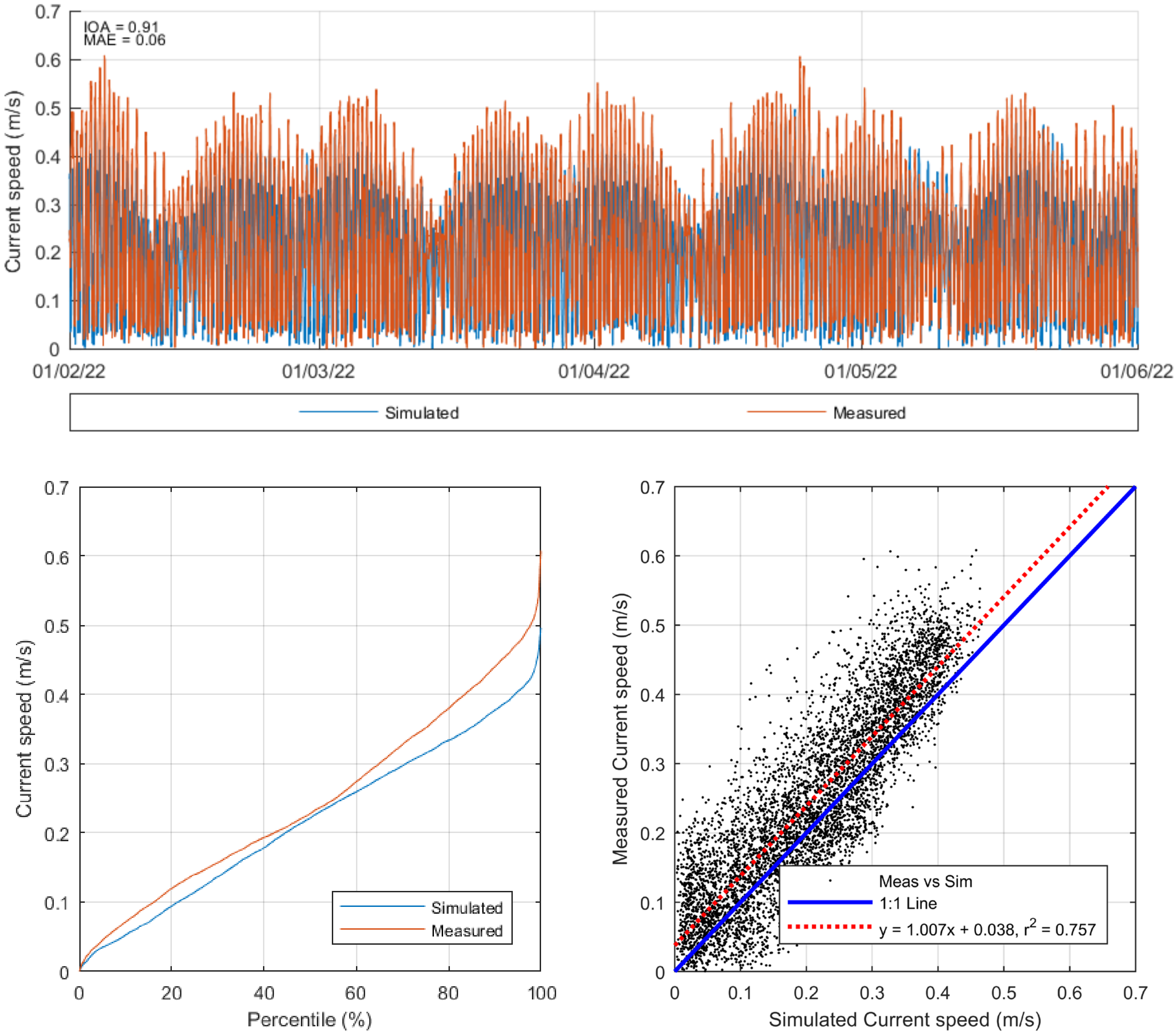


Figure 27 ***Comparison of simulated and measured current speed during February 2022 and May 2022 (top panel: time series, bottom left panel: percentile distribution, bottom right panel: measured vs simulated water level with linear regression fit).***

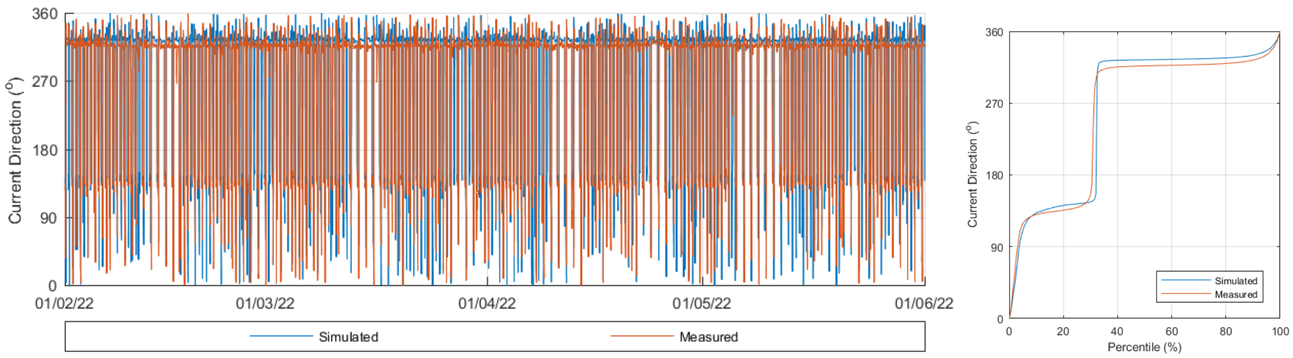


Figure 28 ***Comparison of simulated and measured current direction during February 2022 and May 2022 (left panel: time series, right panel: percentile distribution).***

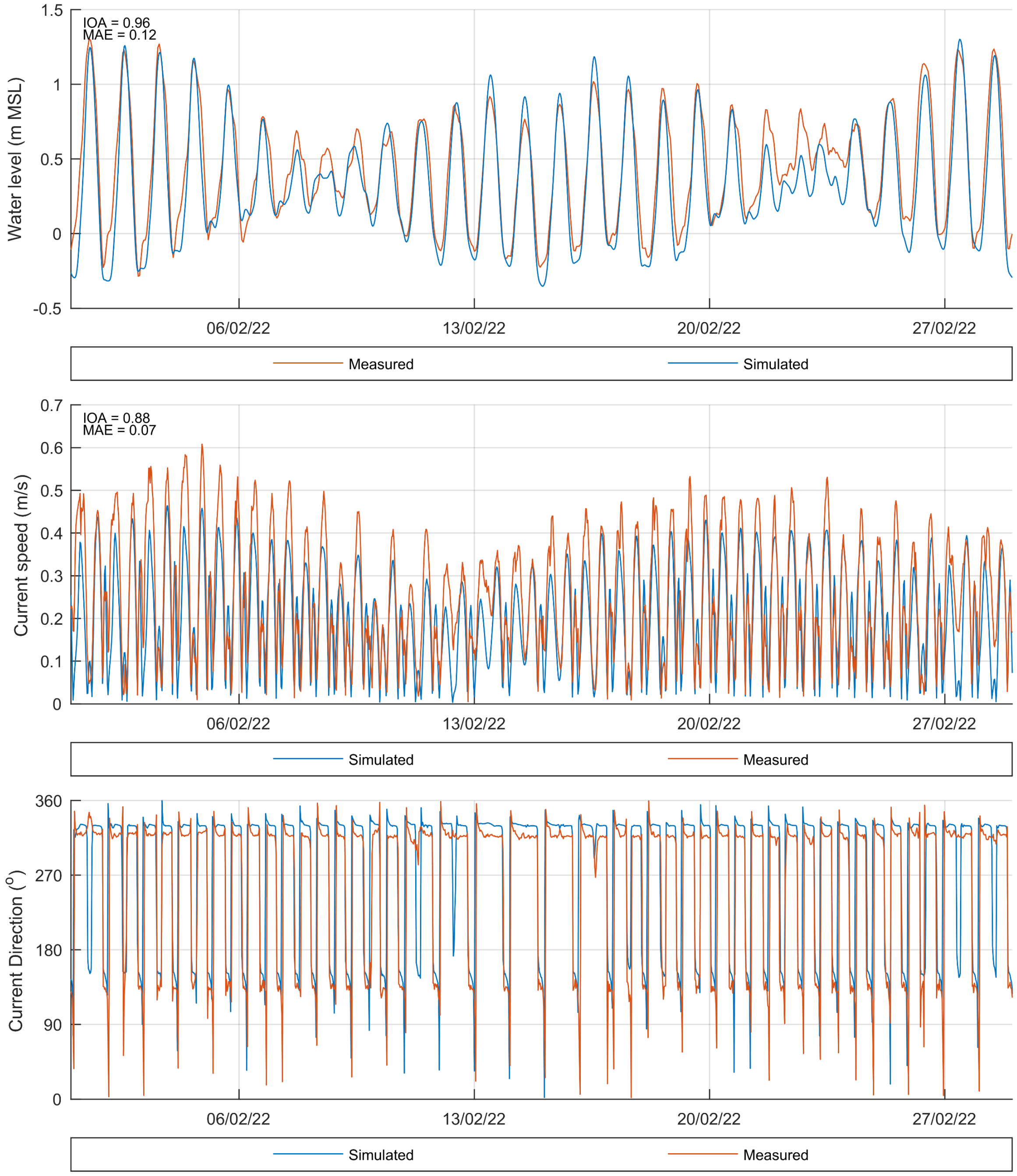


Figure 29 ***Comparison of simulated and measured water levels (top), current speed (middle) and current direction (bottom) for February 2022.***

4.2.2 Wave model

The spectral wave model was validated against measured data provided by GEMCO. Wave characteristics were measured by an ADCP device located at 136.4175ºE, 13.8632ºS (as shown in Figure 1, GEMCO Aquadopp). This data was collected in two periods:

- 18 November 2023 to 6 February 2024
- 12 February 2024 to 4 April 2024

The second time period captures the impact of Cyclone Megan, which passed the island as a category 3 cyclone. This is considered a rare occurrence and therefore does not reflect the yearly average wave conditions the model aims to represent. As such, the second time series has been omitted from the validation.

The simulated significant wave height, peak wave period and mean wave direction are compared against measured ADCP data. The results are shown in Table 14, and Figure 30 to Figure 32.

In general, the model represents the significant wave height well, achieving an IOA of ≥0.88 and MAE of ≤0.08 m. The percentile distribution plot of the significant wave height (Figure 33) shows that the simulated results tend to marginally underpredict the observed measurements. In this case, the underestimation indicates that the model is more conservative, as lower wave heights generate less mixing and dilution.

The peak wave period shows reasonable agreement with an IOA of ≥0.59. The comparison plot (Figure 31) shows that the simulated data aligns well with the general trend of the measured data. The measured and simulated peak wave periods are typically below 5 s, representative of wind-generated seas rather than swells that are generated within the open ocean and have longer wave periods. This aligns with the sheltered nature of the Proposal site which is protected from swells but may be exposed to seas generated from the west.

Finally, the simulated mean wave directions are well aligned to the measurements, with seas from the west-northwest being dominant at the site.

Based on the outcomes of the validation assessment, the spectral wave model is deemed fit-for-purpose for application in this assessment.

Table 14 ***Index of Agreement and Mean Absolute Error of wave characteristics compared to ADCP data***

Parameter	Index of Agreement	Mean Absolute Error
Significant wave height (m)	0.88	0.08
Peak wave period (s)	0.59	0.64

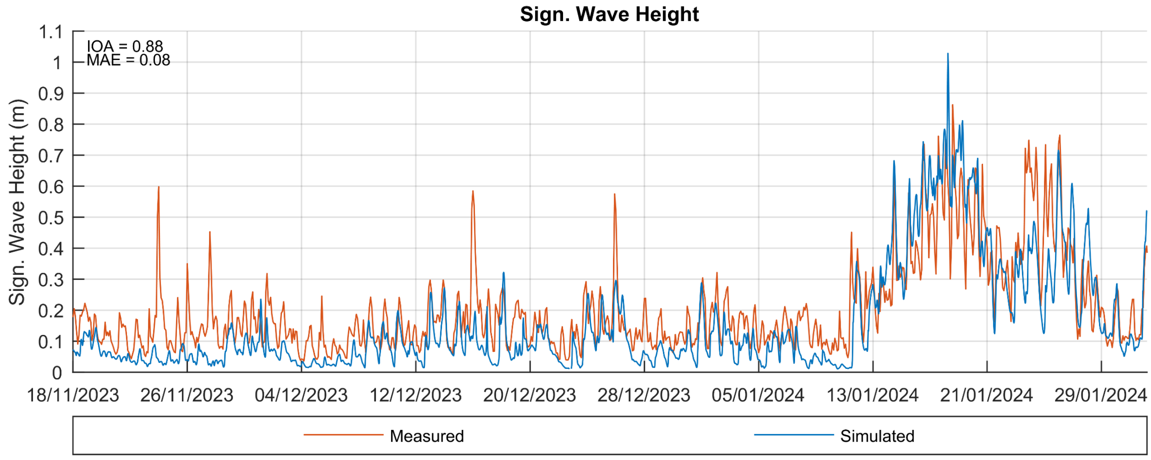


Figure 30 ***Comparison of simulated and measured significant wave heights.***

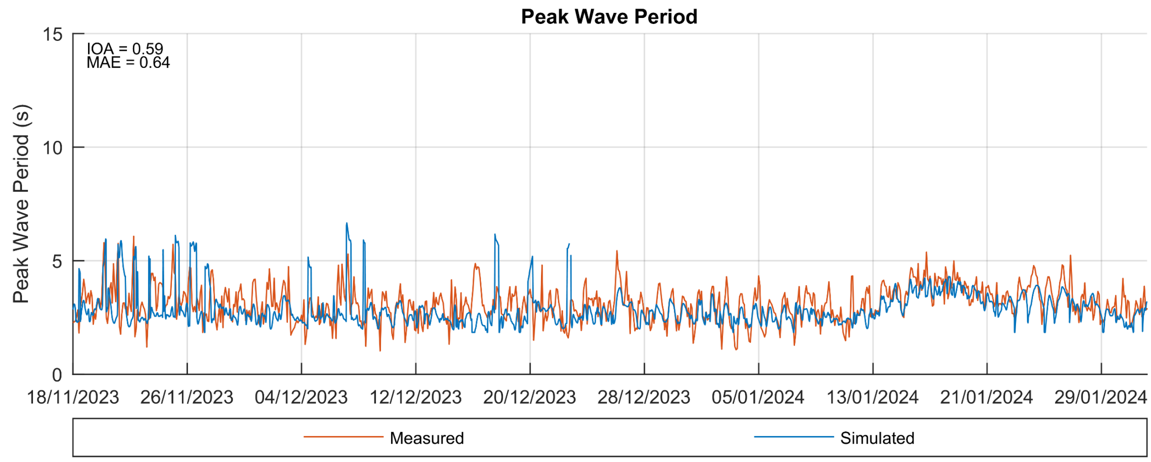


Figure 31 ***Comparison of simulated and measured peak wave periods.***

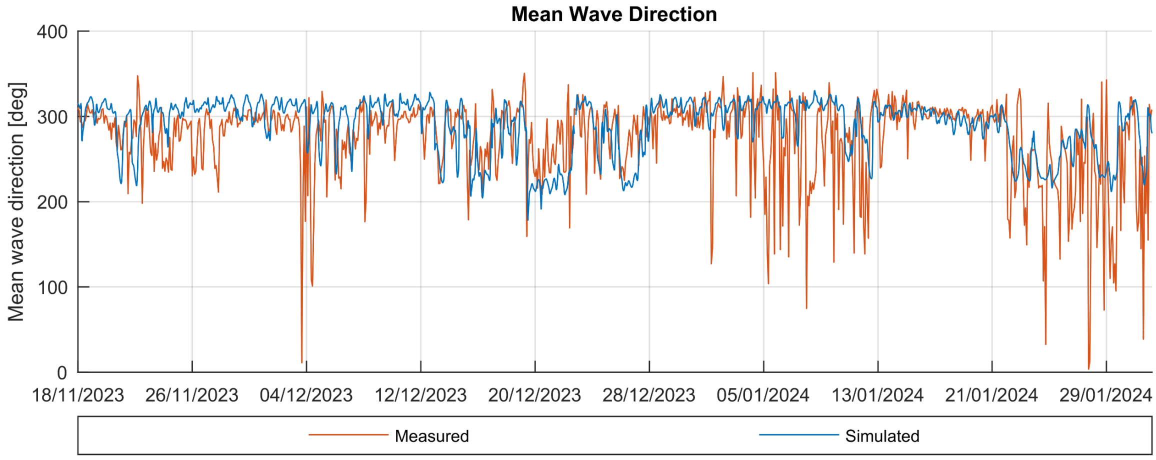


Figure 32 ***Comparison of simulated and measured mean wave direction.***

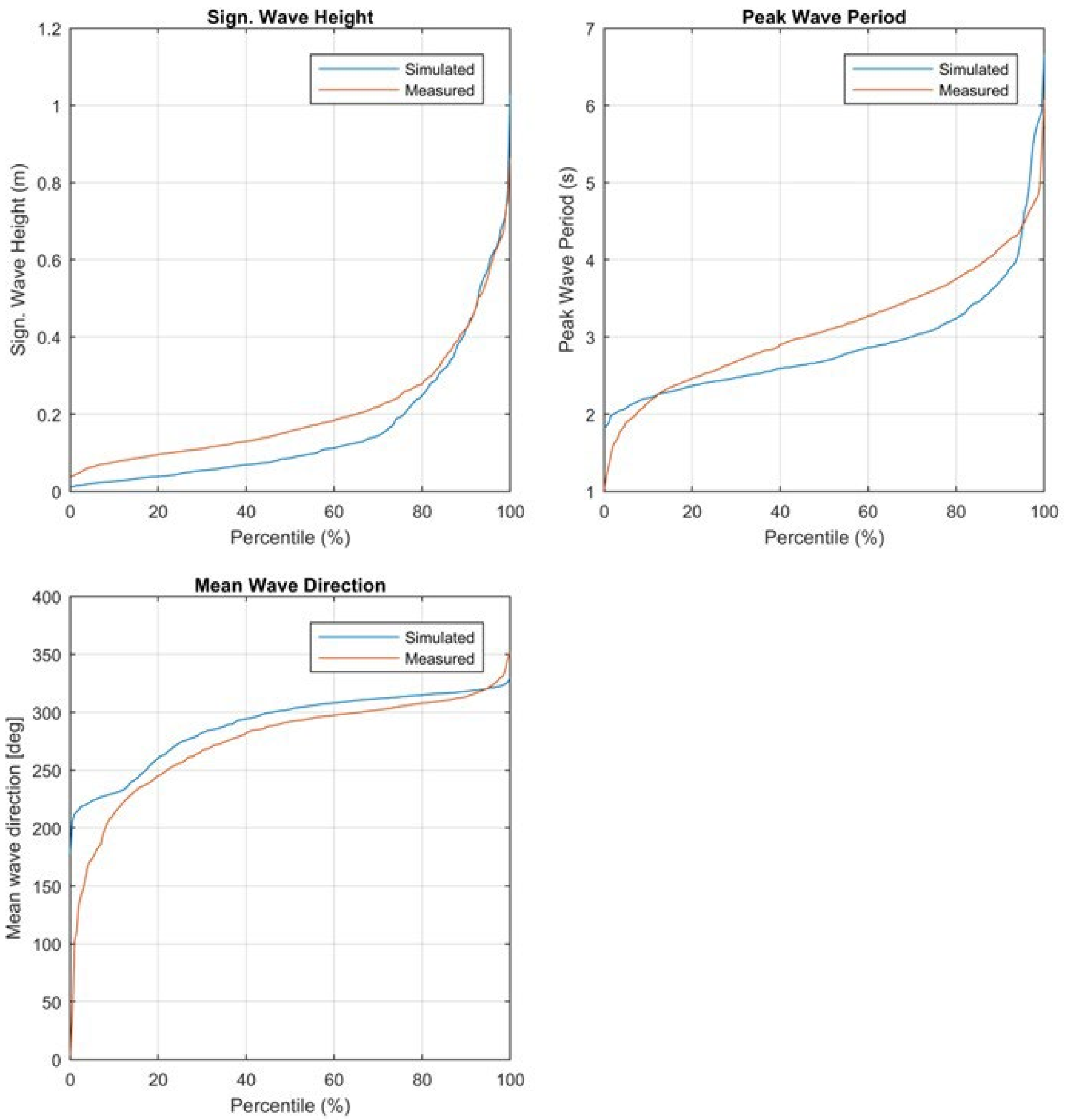


Figure 33 ***Simulated and measured percentile distributions for the significant wave height, peak wave period and mean wave distribution.***

4.3 Wave results

Spatial contours of significant wave height statistics are presented in Figure 34 for the 5th percentile, median (50th percentile) and 95th percentile of significant wave height. At the diffuser location, 5th percentile, median and 95th percentile significant wave heights are approximately 0.05 m, 0.1 m and 0.3 m, respectively, demonstrating calm, sheltered conditions occur at this location for the vast majority of the time.

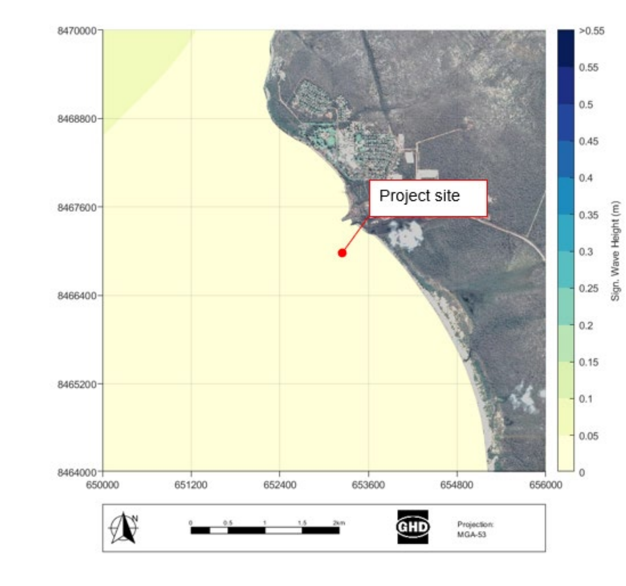
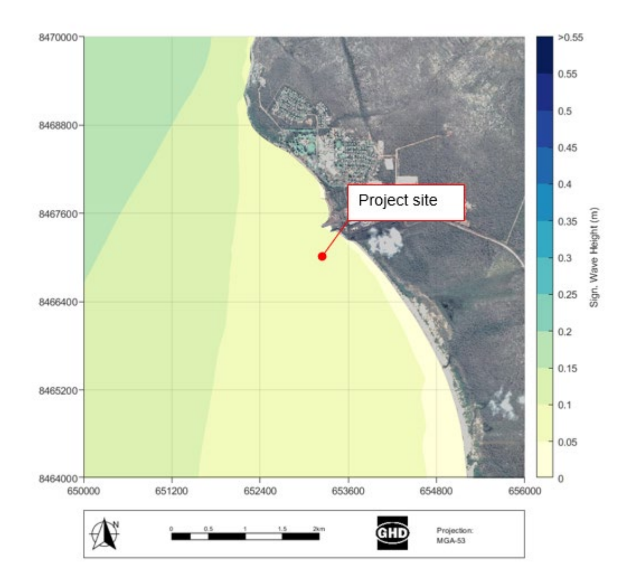
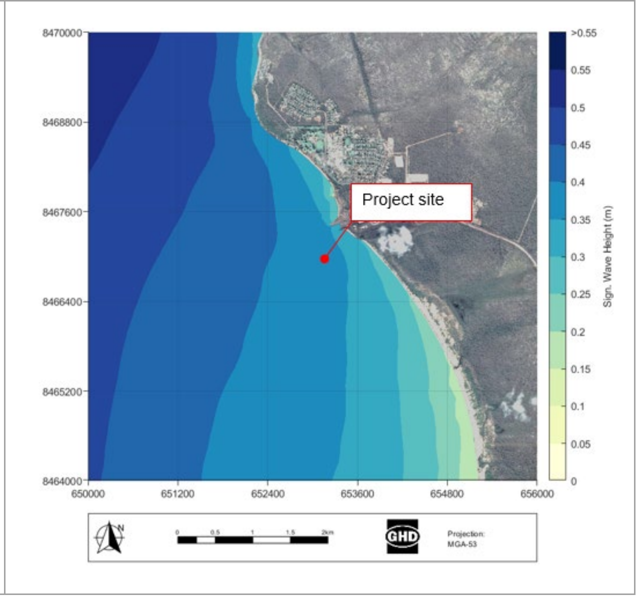
5th percentile	50th percentile (median)	95th percentile
		

Figure 34 *5th percentile (left),* **median (middle) and 95th percentile (right) of depth-averaged significant wave height.**

4.4 Hydrodynamic results

Spatial contours of current speed statistics are presented in Figure 37 for the 5th percentile, median (50th percentile) and 95th percentile of depth-averaged currents. At the diffuser location, 5th percentile, median and 95th percentile current speeds are approximately 0.02 m/s, 0.3 m/s and 0.4 m/s, respectively. Low current speeds likely occur primarily during flood tides, whereby the Proposal site is largely sheltered from the jet of southward currents that form through the span between Connexion Island and Groote Eylandt (Figure 35). In contrast, northward currents that primarily occur during ebb tides sweep past the Proposal site before becoming constricted in the span between the islands (Figure 36). Given the large estimated discharge rate of mine water (80 GL/a), plume dilution rates will largely be driven by the flushing rate of the near-shore waters, which is elevated during periods of northward currents compared to southward currents.

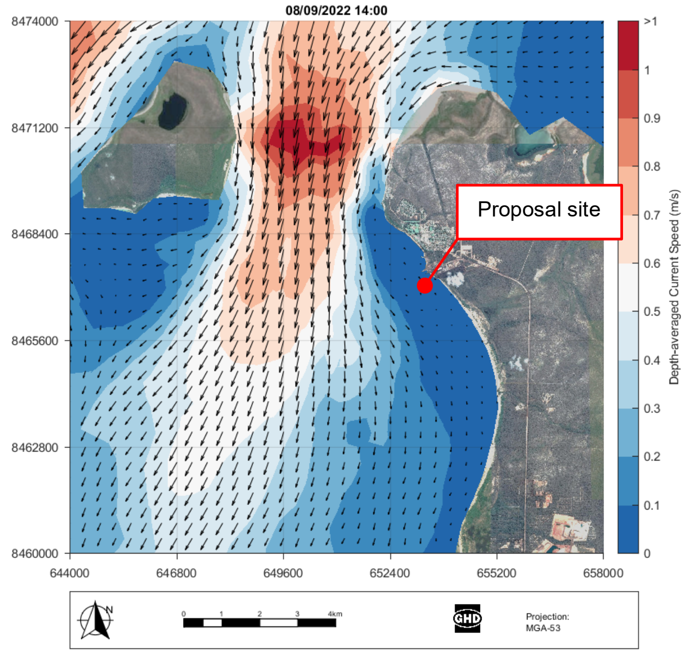


Figure 35 Example snapshot of southward currents during flood tide.

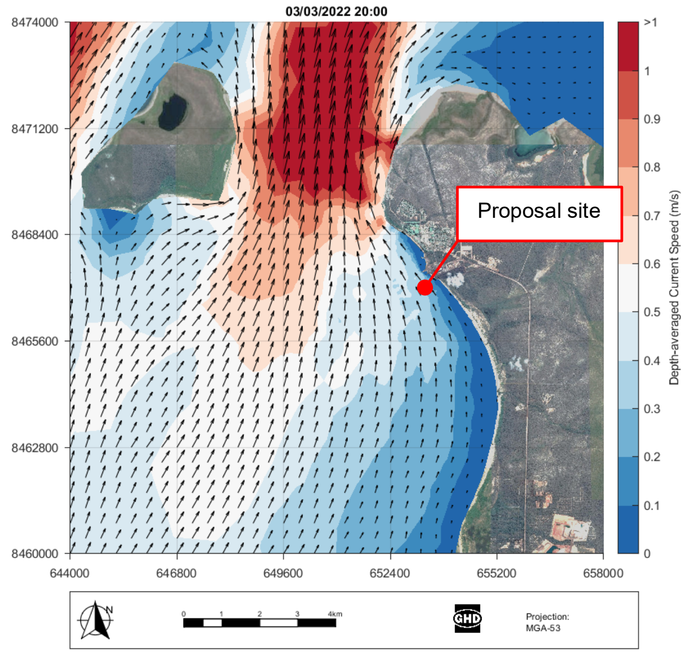


Figure 36 Example snapshot of northward currents during ebbing tide.

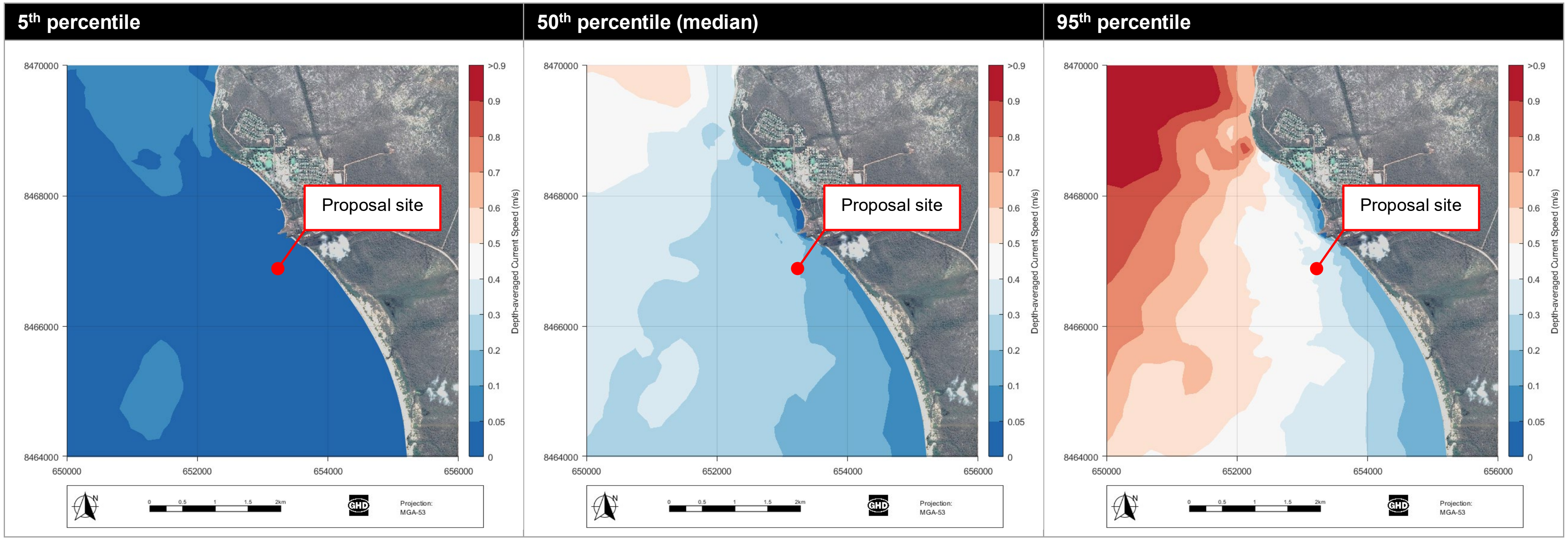


Figure 37 *5^{th} percentile (left), median (middle) and 95^{th} percentile (right) of depth-averaged current speeds at the Proposal site.*

4.5 Mixing zone predictions

The extent of the mixing zone for the operational discharge scenario has been defined as the 1st percentile of dilution. Due to a range of compounding conservative assumptions adopted in this study (flow rates and discharge concentrations both highly conservative), presenting the minimum dilution is anticipated to significantly overestimate the spatial scale of the mixing zone as compared to the more probable discharge conditions. Adopting the 1st percentile dilution is a means of reducing this over-estimate while still remaining conservative.

The mixing zone prediction (for surface waters) is presented in Figure 38 for the simulation that excluded waves. The following summarised outcomes are predicted:

- Plume trajectories are generally predicted to be northwest and southeast, aligned with the coastline and the predominant directions of the tidal currents.
- Due to the buoyant nature of the discharge, the plume is primarily constrained to the surface waters and did not result in dilution rates below the adopted dilution targets at the seabed.
- The outer extent of the surface mixing zone for **potential indirect effects** (42-fold dilution target related to nitrate enrichment) is predicted to extend ~650 m north and ~550 m southeast from the diffuser.
- The outer extent of the surface mixing zone for **potential direct effects** (35-fold dilution target related to salinity reduction) is predicted to extend ~400 m north-northwest and ~350 m southeast from the diffuser.
- There was no predicted mixing zone for **metals and metalloids exposure** (9-fold dilution for aluminium), indicating that adequate dilution occurs within the spatial scale of one model cell (~20 m) for metals and metalloids to reduce below environmental threshold limits.

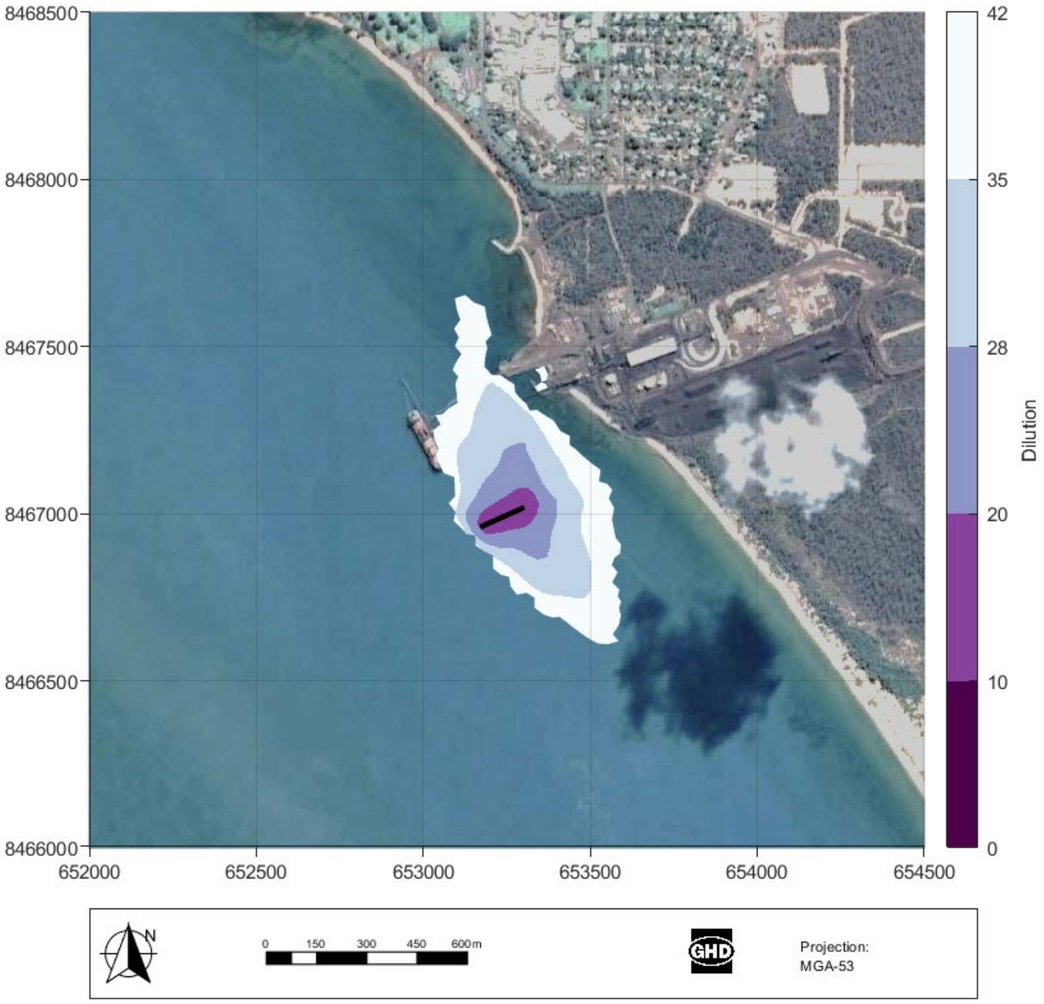


Figure 38 ***Predicted surface mixing zone for various dilution targets for far-field Scenario 1 (80 GL/a), with the zone of potential indirect effects represented by the 42-fold dilution contour and the zone of potential direct effects represented by the 35-fold dilution contour.***

The mixing zone prediction for surface waters with the inclusion of waves is presented in Figure 39. Compared to the size of the mixing zone where the wave action was not considered (Figure 38), the mixing zone has slightly reduced in size:

– The outer extent of the surface mixing zone for **potential indirect effects** (42-fold dilution target related to nitrate enrichment) is predicted to extend ~630 m north and ~460 m southeast from the diffuser.
– The outer extent of the surface mixing zone for **potential direct effects** (35-fold dilution target related to salinity reduction) is predicted to extend ~400 m north-northwest and ~300 m southeast from the diffuser.
– There remains no predicted mixing zone for **metals and metalloids exposure**.
– There remains no predicted mixing zone at the seabed for any of the assessed dilution targets due to the buoyant nature of the plume.

Hence, inclusion of waves within the modelling has marginally improved the outcomes by introducing additional dilution (via vertical circulation), though the effect is minor due to the sheltered wave climate at the site.

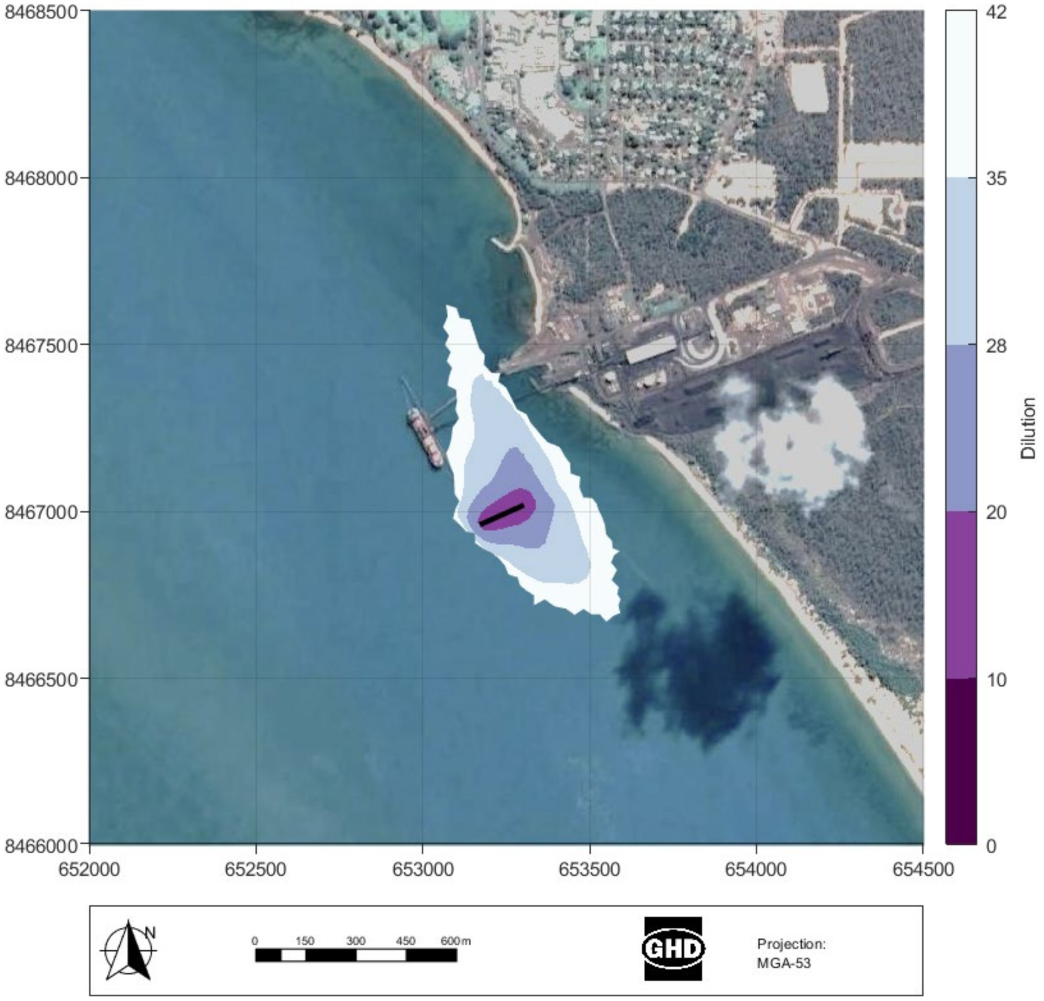


Figure 39 ***Predicted surface mixing zone for various dilution targets for far-field Scenario 2 (including wave action), with the zone of potential indirect effects represented by the 42-fold dilution contour and the zone of potential direct effects represented by the 35-fold dilution contour.***

4.5.1 Treated effluent plume interaction

The treated effluent outlet north of the diffuser ports is located within the predicted nitrate and salinity mixing zone generated by the mine water discharge diffuser, and therefore the two discharges have the potential to create cumulative impacts. To understand a potential cumulative impact between the mine water and treated effluent discharge, the concentrations of water quality parameters common to both outlets were modelled. These parameters are identified in Section 3.7.

Generally, while some of the concentrations from the treated effluent discharge are relatively high compared to the mine water discharge, the flow is relatively small (0.011 m^3/s for the treated effluent discharge versus 2.54 m^3/s for the mine water discharge), resulting in limited interaction between the nutrients in the two plumes due to the high degree of treated effluent dilution that occurs.

Contour plots for the 50^{th}, 95^{th} and 99^{th} percentile of various water quality parameters are presented in Figure 40 (nitrate) and Figure 41 (salinity), comparing the mixing zones of the treated effluent and mine water discharge individually, as well as the combined cumulative impact from both operating simultaneously. Other parameters as listed in Section 3.7 were also assessed, but are not presented because the outcomes were either one of the following:

- No mixing zone was predicted at either discharge location when operating individually or in parallel.
- A small mixing zone was predicted for the STP outlet operating individually, but it was not influenced by the inclusion of the mine water discharge.

For nitrate (Figure 40), both discharge locations generate plumes when operating individually, with both the 95^{th} and 99^{th} percentile extent of the mine water discharge plume overlapping with the treated effluent discharge point under certain conditions. When operating in parallel, the plume footprints combine and a marginal lengthening of the 95^{th} and 99^{th} percentile plumes toward the north is predicted (relative to the mine water discharge operating individually). The 95^{th} percentile extent of nitrate exceeding the threshold is predicted to extend a further ~80 m northward due to the cumulative effect of the STP outlet, while the 99^{th} percentile extends an additional ~140 m northward.

For salinity (Figure 41), while the 99^{th} percentile extent of the low salinity plume (i.e. 1^{st} percentile of salinity) extends from the mine water discharge diffuser across the STP outlet under rare conditions, there is no change in the shape or extent of the mixing zone when assessed cumulatively with the STP outlet. This is due to the low flow rate and high level of dilution achieved for the STP outlet, which on its own does not generate an individual mixing zone at the point of discharge.

In summary, for the majority of water quality analytes, no cumulative impacts are predicted when operating the mine water and the STP outlets in parallel. There is some potential for a minor increase in the nitrate mixing zone when assessed cumulatively, however this is anticipated to occur only rarely, and was predicted on the basis of highly conservative assumptions that include both discharges continuously operating at high flow rates for a full year, with sustained high nitrate concentrations reflecting 95^{th} percentile discharge concentrations.

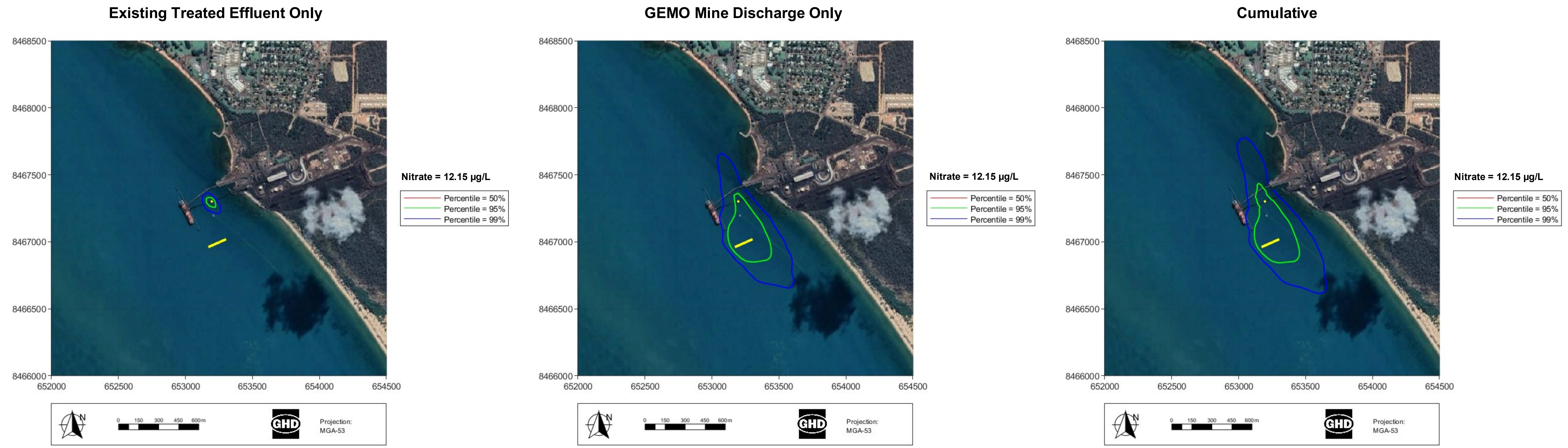


Figure 40 *Contour plot for the 50th, 95th and 99th percentile extents of where the target value of nitrate is achieved for the existing treated effluent discharge (left), GEMCO mine discharge only (middle) and cumulative extent of both discharges operating concurrently (right). Yellow indicates the location of the diffuser ports (line) and the STP outlet (point).*

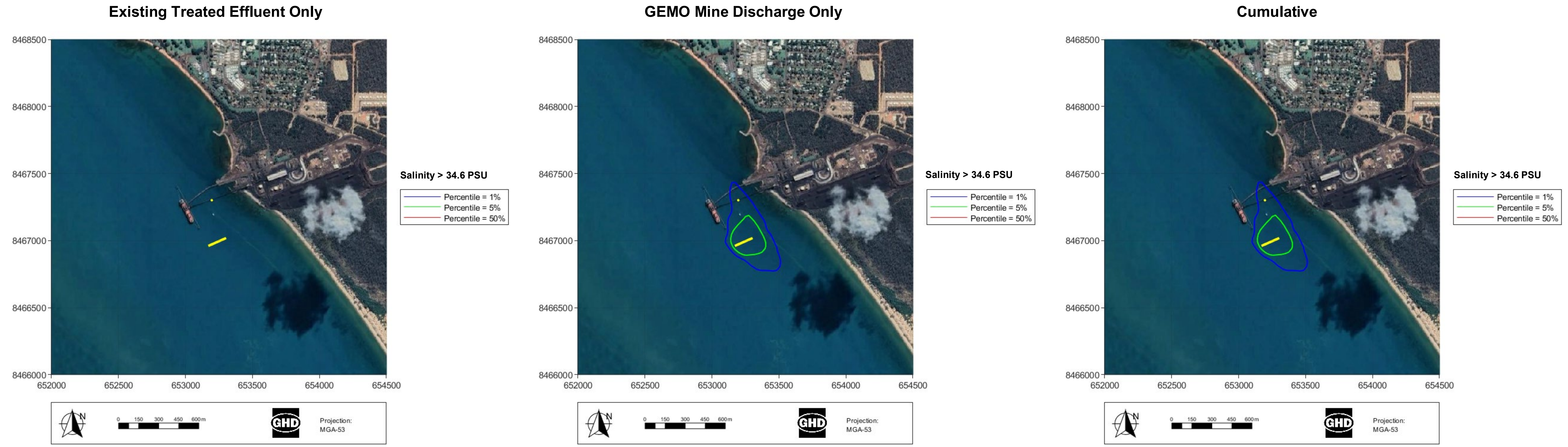


Figure 41 *Contour plot for the 50th, 95th and 99th percentile extents of where the target value of salinity is achieved for the existing treated effluent discharge (left), GEMCO mine discharge only (middle) and cumulative extent of both discharges operating concurrently (right). Yellow indicates the location of the diffuser ports (line) and the STP outlet (point).*

4.6 Sediment dispersion

4.6.1 Suspended sediments

The spatial extents of ΔSSC (the increase in SSC relative to ambient) are displayed in Figure 42 for the median (50th percentile) and 95th percentile depth-averaged concentrations. Depth-averaged outputs are considered appropriate for evaluating potential impacts from SSC, because the impact of SSC on the attenuation of light reaching benthic habitats at the seabed occurs throughout the entire water column. Further, the 95th percentile is presented to represent the upper range of ΔSSC, in alignment with the ZoI threshold (95th percentile ΔSSC >1 mg/L).

Additionally, the extents of the ZoI, ZoMI and ZoHI are presented in Figure 43, assessed against the ΔSSC criteria outlined in Table 5.

The SSC modelling included both the mine water and the treated effluent discharges, so it represents a cumulative impact assessment. Additionally, waves were also included in these simulations, which generate bed shear stress (along with ambient currents) that can remobilise deposited sediments back into the water column or prevent deposition from occurring under energetic wave conditions.

The following modelled outcomes were predicted:

- The median depth-averaged SSC throughout the entire simulated was not predicted to exceed 1 mg/L above ambient conditions. Therefore, on average, increases in SSC are predicted to be negligible and are unlikely to be observable by the human eye.
- The 95th percentile depth-averaged SSC was predicted to exceed 1 mg/L above ambient conditions at distances of up to ~1,250 m northward and ~220 m to the south-east of the diffuser. Concentrations of 2-3 mg/L were predicted within ~100 m of the diffuser, and up to 2-4 mg/L were predicted to occur within the enclosed waters inside two breakwaters located at the port (Alyangula boat ramp) and ~300 m north of the port. The accumulation of suspended sediments within the breakwaters is a result of a range of factors:
  - The model depths within these areas are shallow, typically 1-1.5 m below MSL.
  - The model resolution of ~20 m is not tailored to accurately representing the depths or current patterns within these areas.
  - Predicted current speeds within these enclosed waters are very low, with 95th percentile currents speeds of <5 cm/s (Figure 37). This results in poor flushing of the areas within the breakwaters.
  - However, the wave model used a coarser spatial resolution of ~100 m in these areas, which was appropriate for the open coastal waters but necessitated the removal of the small breakwater structures from the wave model.
  - As a result, currents are very low, however simulated waves within these areas are unimpeded by the breakwaters. Therefore, suspended sediments that enter these areas are likely to settle out of suspension due to the stagnant currents, but can be resuspended by moderate wave events that occur, and remain within the area (due to poor flushing) for extended periods. In reality, both currents and waves would be low due to sheltering, so these zones would likely experience sediment deposition with very minimal resuspension. Therefore, the predicted higher sediment concentrations within these areas is determined to be an artefact of the model configuration, which was not tailored to specifically assess dynamics within these breakwater zones, rather than a credible model prediction.
- The ZoI (Figure 43) encompasses the same extent as the 95th percentile ΔSSC >1 mg/L described above. Localised areas of ZoMI are predicted within the breakwater regions, however again, these are not considered realistic predictions. Importantly, no ZoMI or ZoHI related to suspended sediments is predicted to occur in the vicinity of the mine water discharge diffuser.
- There is no significant increase in SSC predicted at the STP outlet location. Therefore, cumulative impacts are considered negligible.

4.6.2 Deposition

Modelled deposition is presented in Figure 44, showing the maximum deposition thickness exceeding the ZoI threshold of >3 mm (per Section 3.6), and in Figure 45, showing the maximum net deposition accumulation expressed in grams per square metre (g/m^2) that occurred throughout the one year simulation. The deposition thickness figure allows direct comparison to the ZoI and ZoMI thresholds, while the deposition accumulation figure allows for comparison against the sediment toxicant guidelines as described in Section 3.7, and the potential for bioaccumulation.

The following outcomes related to sediment deposition were predicted:

– Maximum deposition thicknesses exceeded the ZoI threshold of 3 mm only within highly localised deposition zones situated at the end of the Milner Bay jetty structure. The maximum deposition thickness within these zones was less than 8 mm, which is well below the ZoMI threshold of 15 mm. Therefore, no moderate impacts to benthic communities were predicted to occur on the basis of sediment deposition.

– Maximum net deposition accumulation throughout the simulation exceeding 100 g/m^2 (a nominal low value) occurred within localised and largely incongruent areas up to 2.5 km north-westward and ~1.2 km southward from the diffuser. The maximum localised net deposition was ~1,500 g/m^2 at the end of the jetty structure (aligned with the areas of maximum deposition thickness). This deposition accumulation is a factor of 18 lower than the most stringent deposition limit for silver (27,000 g/m^2). In other words, 18 years' worth of simulated deposition would need to occur, without any significant sediment erosion events or biological uptake of silver from the sediments, before silver will accumulate to toxic levels within the sediment. Further, in the unlikely event that this were to occur, the model predictions indicate that toxic levels of silver within seabed sediments would occur only in localised zones at the end of the jetty structure, which is already a disturbed environment due to the presence of the port and shipping activities.

– It is further highlighted that the following highly conservative assumptions were applied in relation to the sediment dispersion modelling:

  - Sediment concentrations within the discharge were sustained at the 95^{th} percentile of measured mine quarry data for the entire one-year simulation.
  - The discharge rate was sustained at 80 GL/a whereas the anticipated annual flow rate is 60 GL/a.
  - For the sediment toxicant assessment, all measured toxicants were assumed to be entirely comprised of suspended particles that could potentially accumulate on the seabed. In reality, a significant proportion of the toxicants may be present as dissolved contaminants.

On the basis of the above outcomes, the risk of impacts to sediment quality from deposition of sediments discharged through the diffuser is considered to be negligible.

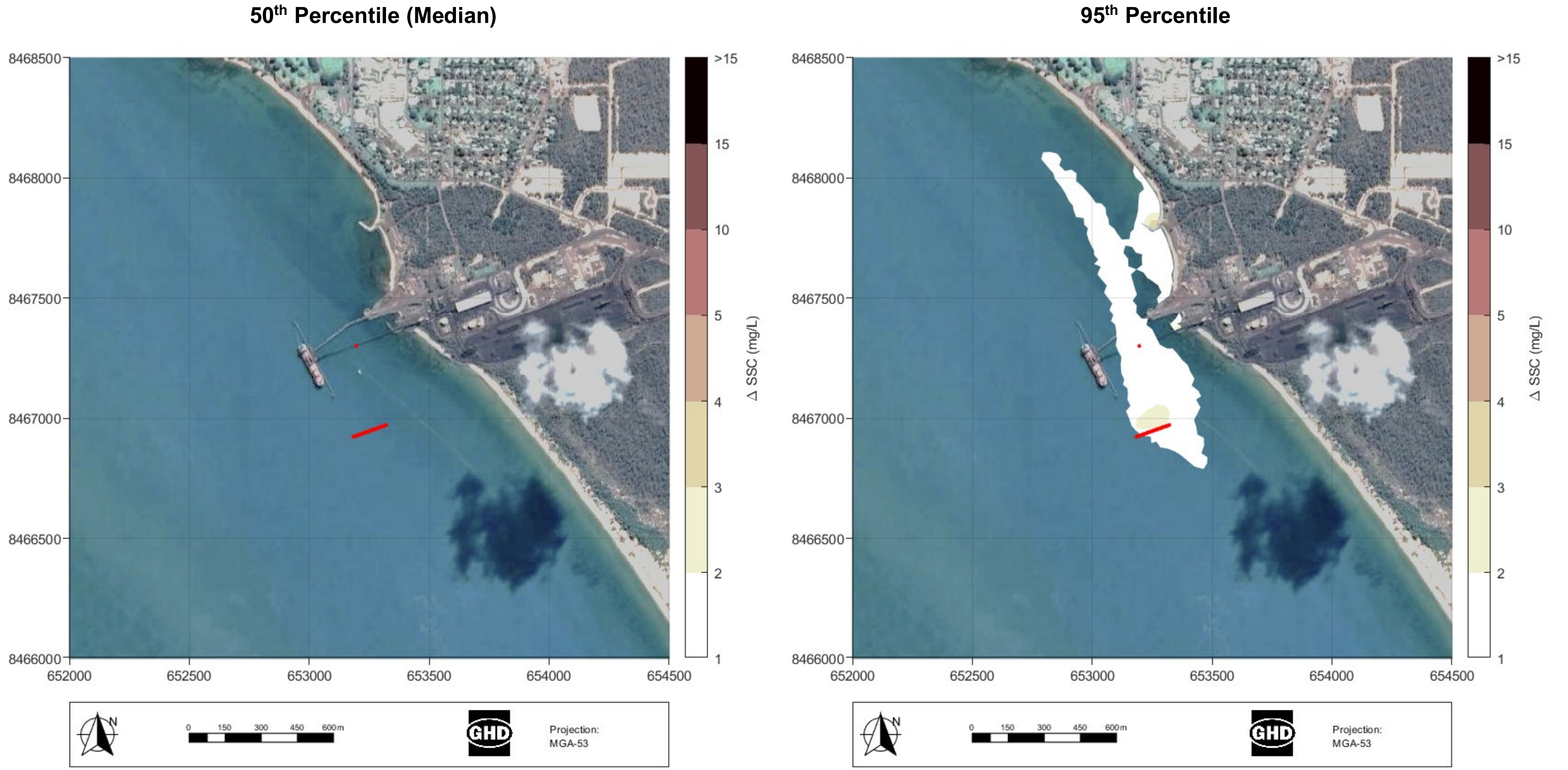


Figure 42 50th percentile (left) and 95th percentile (right) contours of predicted depth-averaged ΔSSC (above ambient) for far-field Scenario 2 (including wave action)

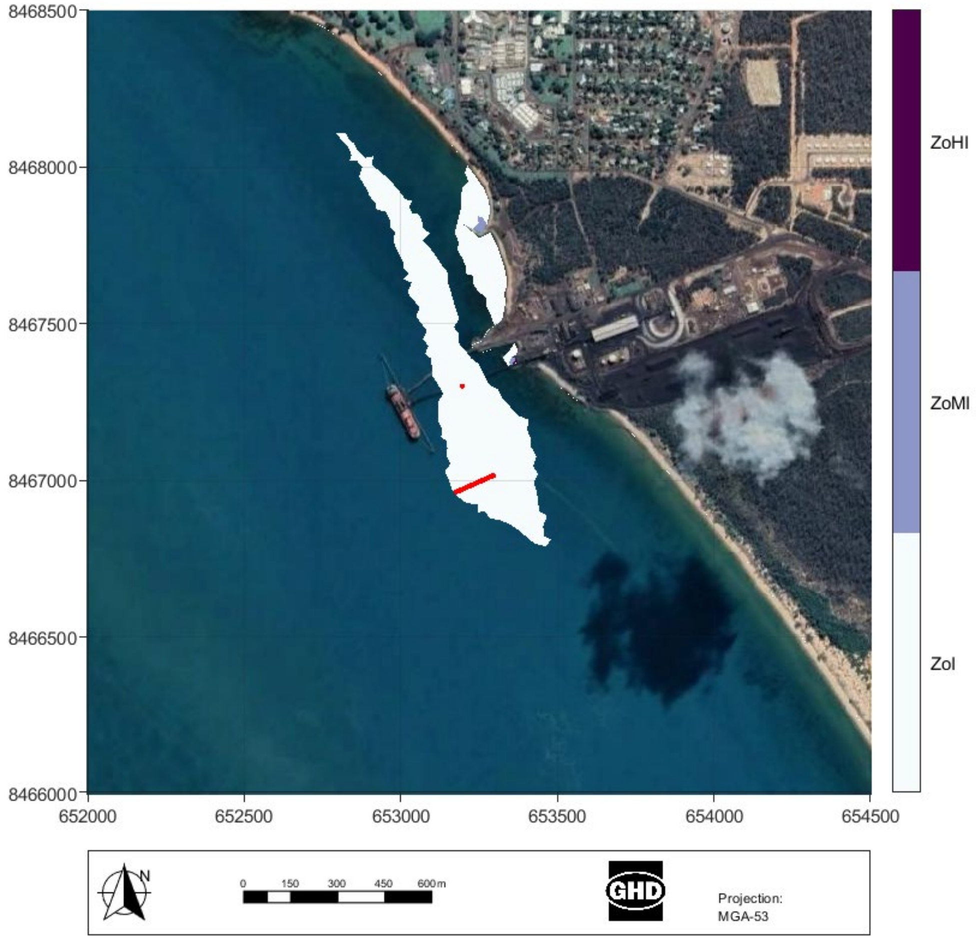


Figure 43 ***Predicted extents of ZoI, ZoMI and ZoHI related to SSC***

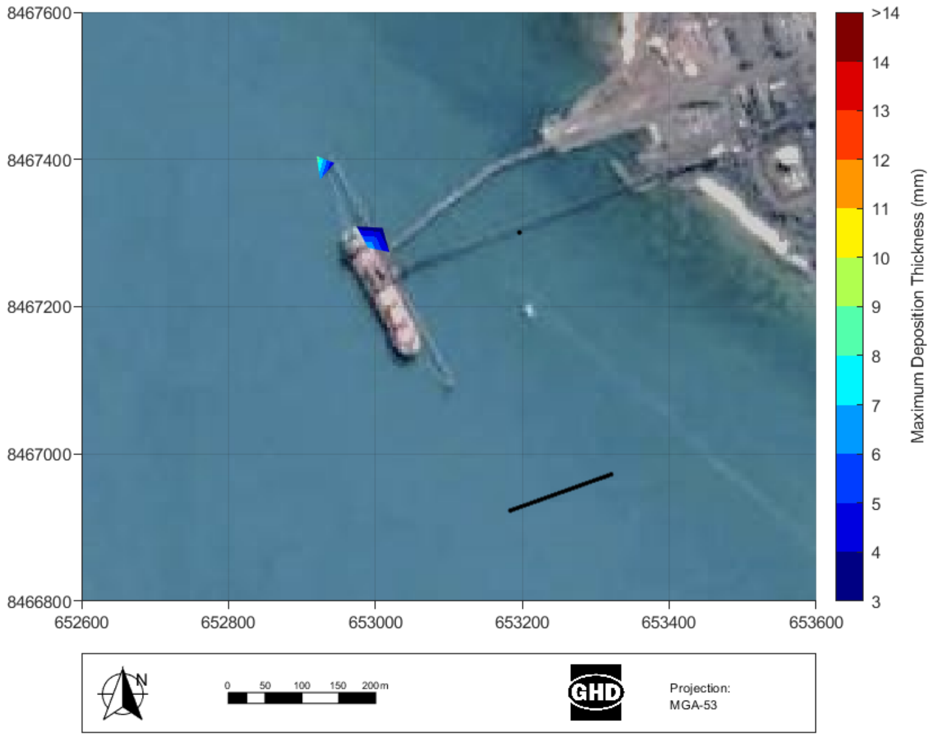


Figure 44 ***Maximum deposition thicknesses exceeding the ZoI threshold of 3 mm, with STP outlet and diffuser ports shown in black***

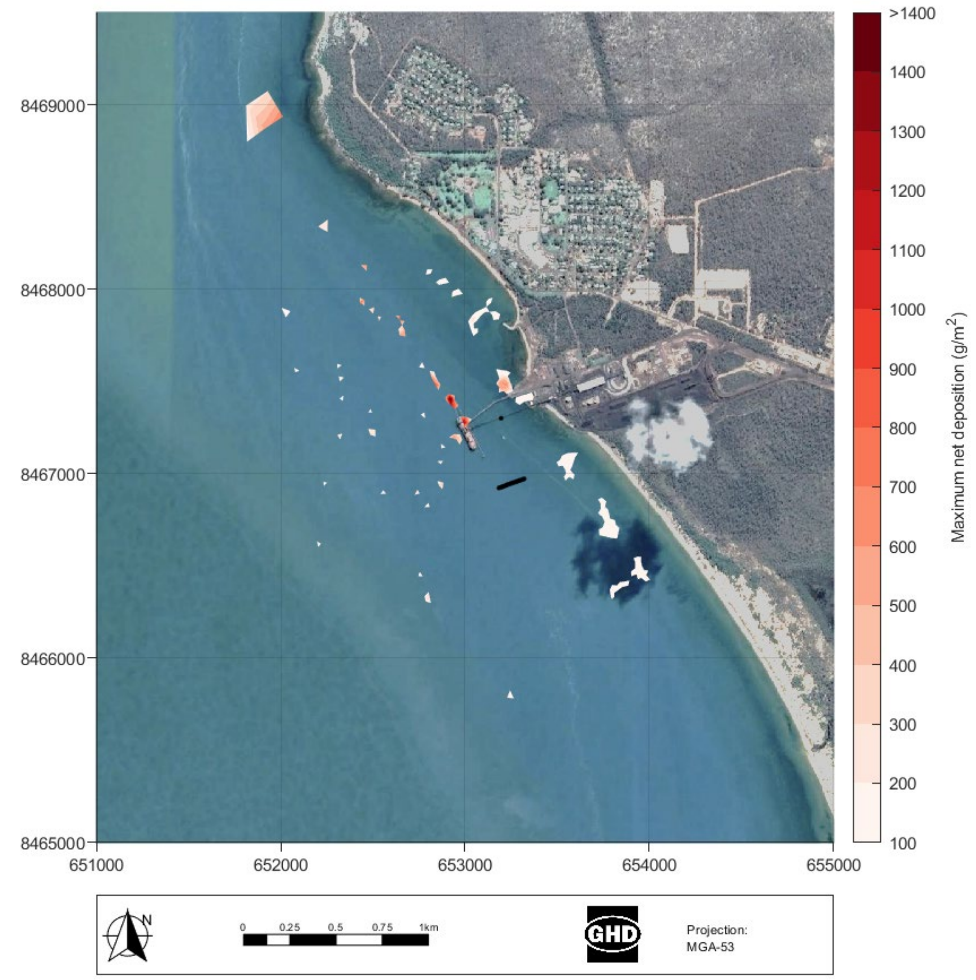


Figure 45 ***Maximum net deposition accumulation***

4.7 Potential for bioaccumulation of metals/metalloids

Following review of the referral report, the NT EPA requested additional information to assess the potential for biomagnification and bioaccumulation of metals and metalloids present in the discharge. Additional modelling has been carried out, with the following updates being presented in this report:

- The zone of potential metals and metalloids exposure (within the water column) has been explicitly defined in this report (Section 4.5), and was predicted to be localised to within less than 20 m distance from the diffuser (i.e. adequate dilutions were achieved within the spatial scale of one model cell).
- An assessment of the potential for deposited metal/metalloid solids from the mine discharge to accumulate to toxic levels within the seabed has also been carried out (Section 4.6.2), concluding that 18 years of sustained sediment deposition at the modelled rates would be required before a metal/metalloid (silver) accumulates to toxic levels within the sediments, and assuming no losses via biological uptake or large erosion events occur in this time. Further, the areas of toxicity under this unlikely scenario would be localised to the western end of the Milner Bay jetty structure, which is already a disturbed environment due to the port and shipping operations.

These assessments cover both exposure pathways that could introduce metals and metalloids into the food chain, i.e. uptake from the water column and uptake from the sediments. In this study, the risk of exposure at toxic levels is considered highly unlikely for metals/metalloids within the water column (due to the low dilution targets required and the high level of dilution predicted) and within the sediments (due to the low deposition rates predicted).

While bioaccumulation/biomagnification can occur with sub-toxic levels of metals/metalloids, the processes of uptake and accumulation within successive trophic levels are highly complex and difficult to predict with any certainty. Due to the negligible presence of metals/metalloids in the marine environment predicted by the modelling, it is deemed appropriate considering the NT *Environment Protection Act 2019* ‘Principle of proportionality’ to classify the risk of bioaccumulation/biomagnification of metals and metalloids as low, without the need for further complex and uncertain predictions to be presented.

4.8 Flushing

Flushing was assessed for ten scenarios as described in Section 3.9.12.2.

4.8.1 Spatial e-folding flushing rates

Contour plots of spatially varying flushing rates within the nearshore control volume are presented in Figure 46-Figure 47. The northern portion of the control volume that extends into the span between Connexion Island and Groote Eylandt is rapidly flushed in all cases, whereas for some of the scenarios the location-specific flushing rate of the Proposal site is longer (up to ~3 days in the worst-case scenario of 6 Feb 2022). Spatially varying flushing rates however were faster than the PIANC (2008) limit for “good” flushing of four days, indicating flushing rates are adequate to avoid potential issues related to stagnation (e.g. eutrophication related to long-duration exposure to elevated nutrients).

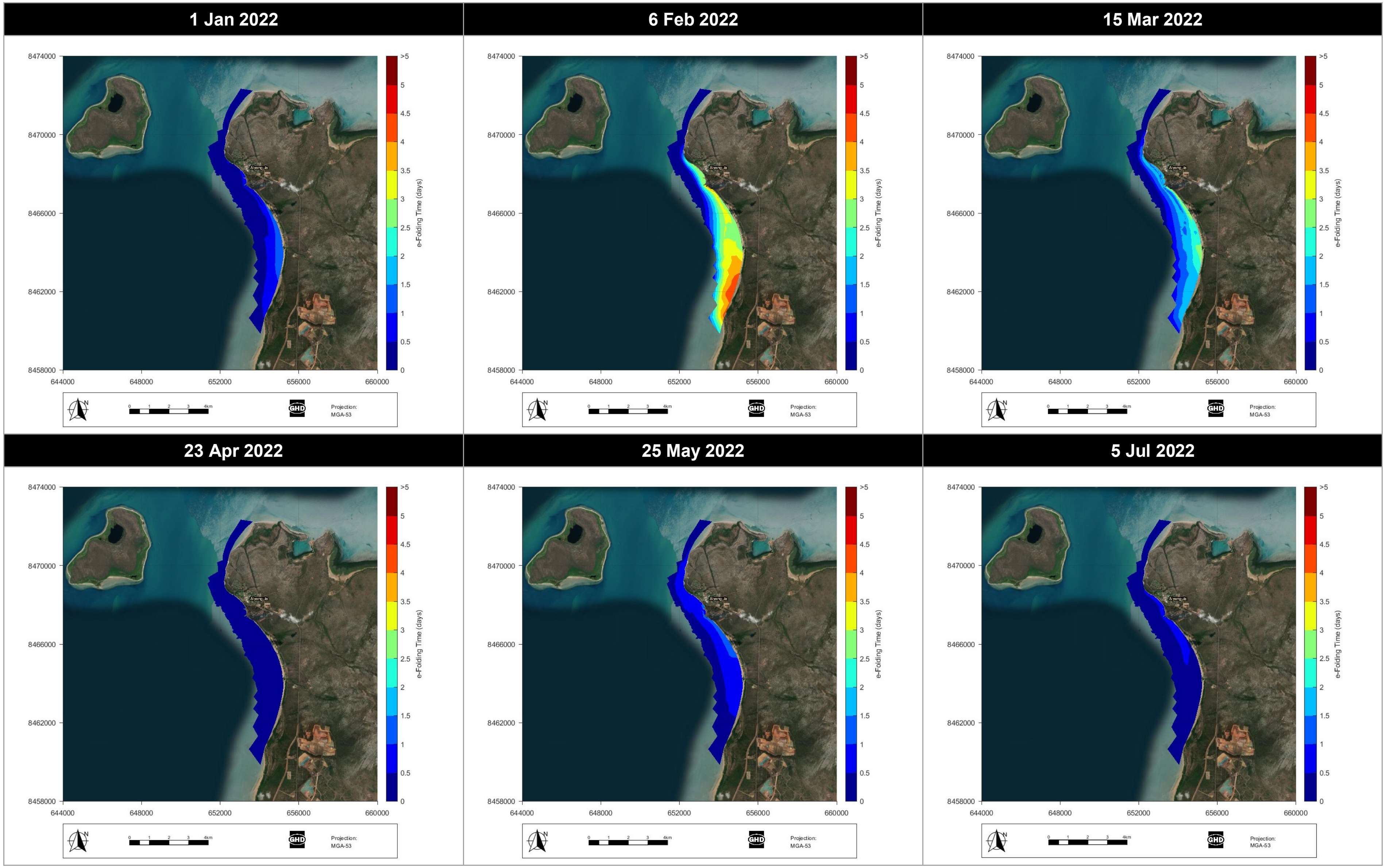


Figure 46 *Spatial e-folding flushing times for simulations beginning 1 Jan 2022 (top-left), 6 Feb 2022 (top-middle), 15 Mar 2022 (top-right), 23 Apr 2022 (bottom-left), 25 May 2022 (bottom-middle) and 5 Jul 2022 (bottom-right).*

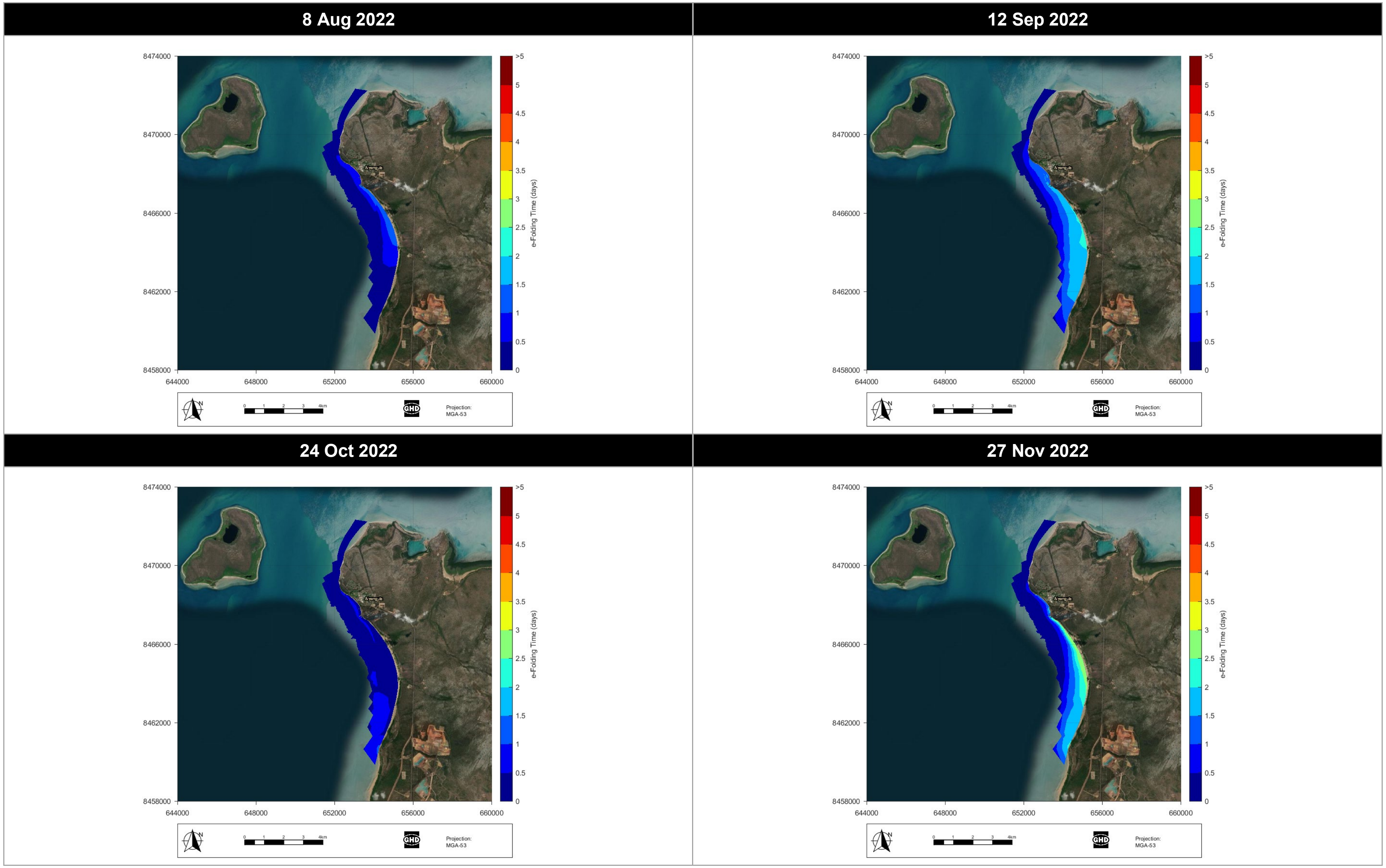


Figure 47 Spatial e-folding flushing times for simulations beginning 8 Aug 2022 (top-left), 12 Sep 2022 (top-right), 24 Oct 2022 (bottom-left) and 27 Nov 2022 (bottom-right).

4.8.2 Volumetric e-folding flushing

The volumetric flushing rates for the whole control volume are summarised for each scenario in Table 15 and Figure 48, with time-series of tracer exchange rates further for each scenario further presented in Figure 49-Figure 51.

The control volume is generally very rapidly flushed, with e-folding timescales averaging ~16 hours, and ranging from 6 hours at a minimum to ~35 hours maximum. Again, the flushing rate of the nearshore waters in all cases was faster than the PIANC (2008) limit for “good” flushing of four days. The high degree of flushing is therefore expected to mitigate any potential water quality issues related to stagnation such as eutrophication, even in the event of increased nutrient concentrations from the discharge.

Table 15 Simulated flushing times for the ten (10) simulations.

Simulation Number	Start Date/time	e-folding time (days)	e-folding time (hours)
1	01/01/2022 06:00	0.42	10.1
2	06/02/2022 02:00	1.44	34.6
3	15/03/2022 21:00	1.06	25.4
4	23/04/2022 00:00	0.28	6.7
5	25/05/2022 07:30	0.68	16.3
6	05/07/2022 07:30	0.25	6.0
7	08/08/2022 16:00	0.44	10.6
8	12/09/2022 00:00	0.94	22.6
9	24/10/2022 09:00	0.49	11.8
10	27/11/2022 03:30	0.62	14.9
Average		**0.66**	**15.9**

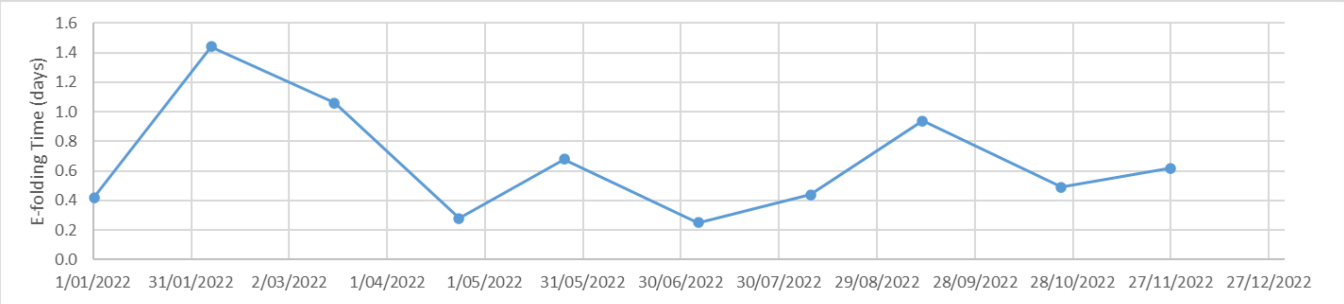


Figure 48 Time series of simulated flushing times of the ten (10) simulations.

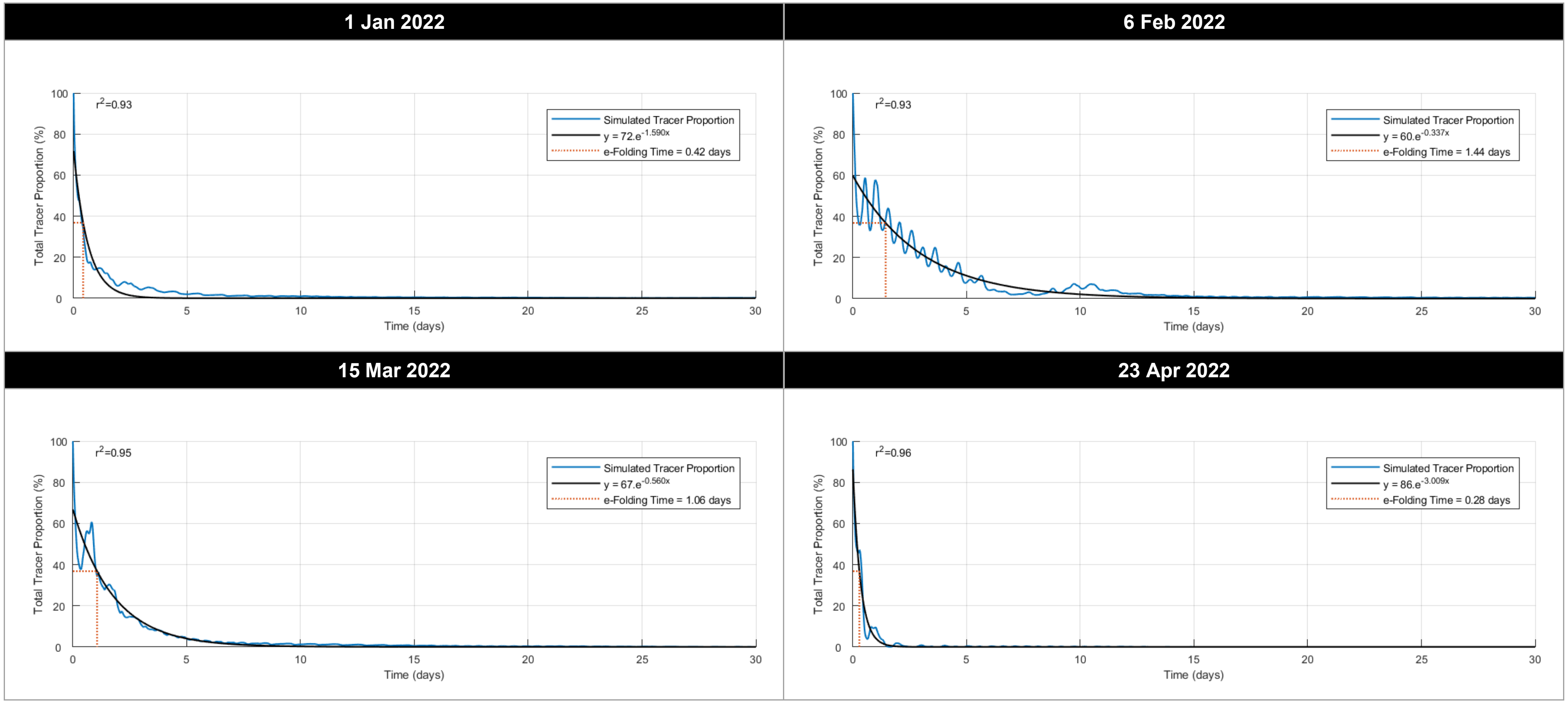


Figure 49 ***Volumetric e-folding flushing times for simulations beginning 1 Jan 2022 (top-left), 6 Feb 2022 (top-right), 15 Mar 2022 (bottom-left) and 23 Apr 2022 (bottom-right).***

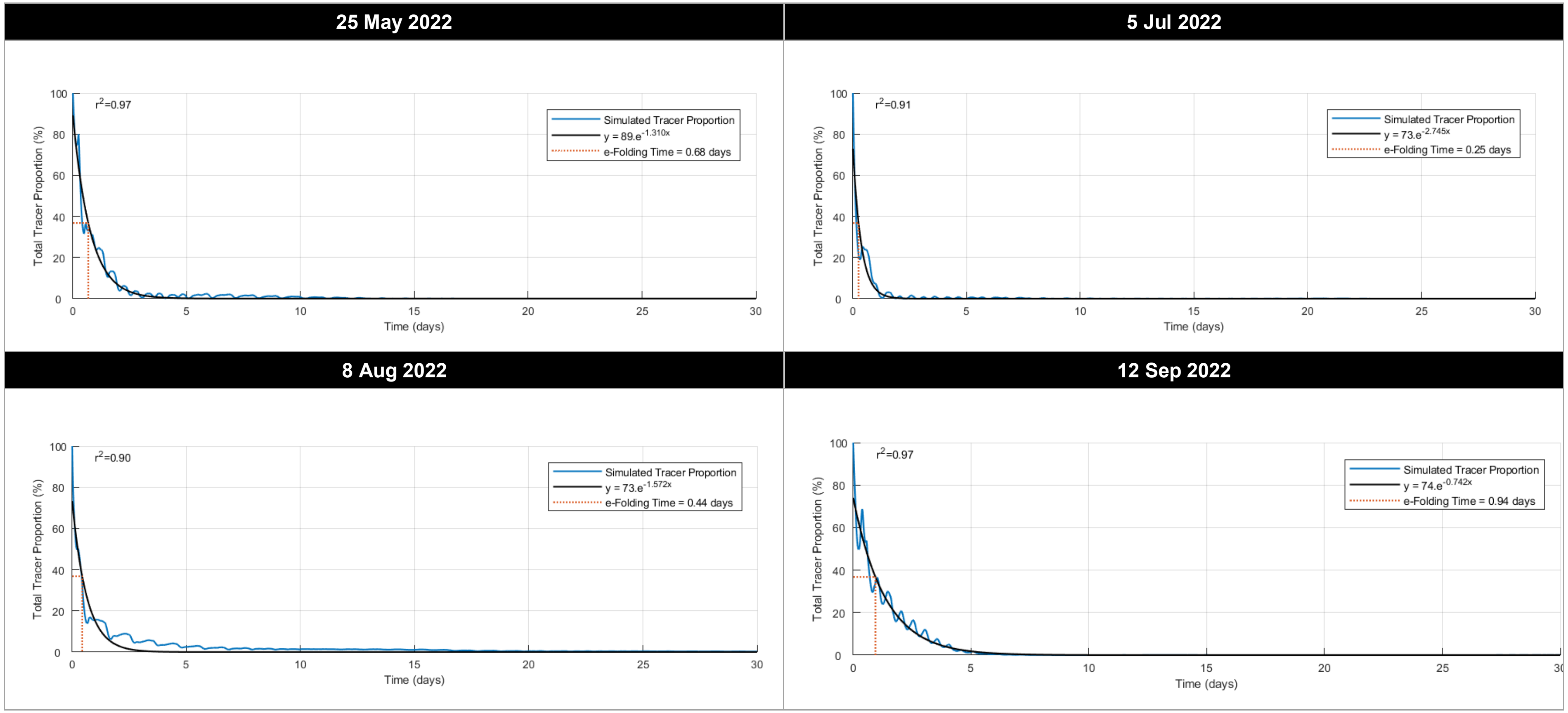


Figure 50 ***Volumetric e-folding flushing times for simulations beginning 25 May 2022 (top-left), 5 Jul 2022 (top-right), 8 Aug 2022 (bottom-left) and 12 Sep 2022 (bottom-right).***

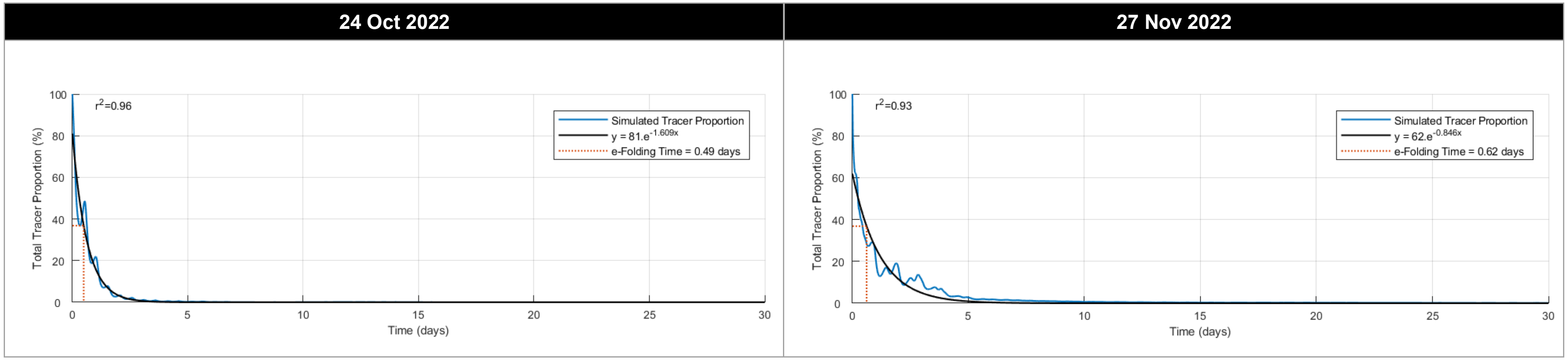


Figure 51 ***Volumetric e-folding flushing times for simulations beginning 24 Oct 2022 (left) and 27 Nov 2022 (right).***

5. Conclusions

This study has covered the following scope:

– Preliminary design of a marine multi-port diffuser that achieves elevated rates of near-field dilution for the range of discharge scenarios assessed.
– Definition of WQOs and associated dilution targets, as well as impact thresholds for suspended sediments, sediment deposition and sediment quality.
– Far-field mixing zone modelling for a discharge scenario of 80 GL/a, including the influence of waves.
– A cumulative impact assessment of the mine water discharge in parallel with the treated effluent discharge.
– Modelling of the dispersion, deposition and resuspension of suspended sediments discharged via the proposed diffuser and existing STP outlet.
– An assessment of the potential for bioaccumulation of metals/metalloids.
– Flushing modelling of the near-shore coastal waters encompassing the mixing zone.

Based on conservative assumptions of discharge quality, the two analytes requiring the highest level of dilution were nitrate and salinity. Dilution targets of 42-fold for the mixing zone of **potential indirect effects** related to nitrate stimulation, and 35-fold for the mixing zone for **potential direct effects** related to salinity reduction have been defined for this study. The indirect effects are only likely to represent a risk if the receiving marine environment is not flushed rapidly enough, resulting in prolonged exposure to elevated nitrate concentrations for algae that drift through the mixing zone that may potentially stimulate algal growth and lead to algal blooms. Further, potential direct effects related to salinity reduction are only expected to yield ecological impacts when occurring at the seabed in the presence of benthic primary producers (seagrass or corals) that are unable to escape the plume. Additionally, a 9-fold dilution target for the mixing zone for **potential metals/metalloids exposure** (within the water column) related to dissolved aluminium was also defined.

Simulation of an operational discharge of 80 GL/a in the far-field model with the adopted 145 m long diffuser design yielded the following outcomes:

– The outer extent of the surface mixing zone for **potential indirect effects** (42-fold dilution target related to nitrate enrichment) is predicted to extend ~650 m north and ~550 m southeast from the diffuser. With the inclusion of waves within the modelling, the predicted distances reduce to ~630 m north and ~460 m southeast from the diffuser. When assessed cumulatively with the treated effluent discharge, the 99^{th} percentile extent of the nitrate mixing zone is predicted to increase marginally along an elongated zone extending a further ~140 m northward.
– The outer extent of the surface mixing zone for **potential direct effects** (35-fold dilution target related to salinity reduction) is predicted to extend ~400 m north-northwest and ~350 m southeast from the diffuser. With waves, the predicted distances reduce to ~400 m north-northwest (i.e. similar) and ~300 m southeast from the diffuser. No observable difference in the 99^{th} percentile extent of the salinity mixing zone was predicted from the cumulative assessment including the treated effluent discharge.
– There was no predicted mixing zone for **metals and metalloids exposure** (9-fold dilution for aluminium), meaning the dilution target was predicted to be achieved within the spatial scale of one model cell (i.e. <20 m distance from the diffuser). This outcome was similar both with and without waves.
– There was no predicted mixing zone at the seabed due to the buoyant nature of the plume.

The sediment dispersion modelling incorporated suspended solids within the treated effluent discharge as well as the mine water discharge, and yielded the following outcomes:

– The ZoI, where changes in SSC are anticipated but not expected to impact on benthic communities, was predicted to extend up to ~1,250 m northward and ~220 m to the south-east of the diffuser. Highly localised zones of deposition exceeding the ZoI threshold were predicted to occur only at the end of the Milner Bay jetty structure.
– No ZoMI or ZoHI related to suspended sediments is predicted to occur in the vicinity of the mine water discharge diffuser. Additionally, deposition thicknesses exceeding the ZoMI threshold were not predicted. As

such, impacts to benthic communities resulting from suspended sediment loads within the discharge or subsequent deposition are not anticipated to occur.

- The predicted maximum net deposition was a factor of 18 lower than the most stringent deposition limit (for silver). In other words, 18 years' worth of simulated deposition would need to occur, without any significant sediment erosion events or biological uptake of silver from the sediments, before silver will accumulate to toxic levels within the sediment, and this would occur only within localised zones at the end of the jetty structure. As such, the risk of impacts to sediment quality from deposition of sediments discharged through the diffuser is considered to be negligible.

Further, the potential for bioaccumulation of metals/metalloids is considered low, given the very low predicted risks of exposure related to metals/metalloids within the water column and within the sediments as described above.

Additionally, the flushing assessments predicted that the near-shore receiving waters encompassing the mixing zone are rapidly flushed, with e-folding timescales averaging 16 hours, and ranging from 6 hours at a minimum to 35 hours maximum. The PIANC (2008) standard for marinas states e-folding times of less than four days represent good flushing.

The modelling outcomes indicate that negative ecological effects from the mine water discharge to the receiving marine environment are unlikely due to the following reasons:

- Potential indirect effects due to nitrate stimulation causing algal blooms are unlikely to occur within an environment that flushes so rapidly (typically on the order of hours). The residence time of algal colonies drifting through the mixing zone is generally not long enough for algal stimulation to result in the formation of algal blooms.
- Potential direct effects due to salinity reductions are of primary concern for benthic primary producers (e.g. seagrasses) at the seabed that cannot escape the plume. The mixing zone for potential direct effects does not impinge on the seabed.
- Impacts to benthic communities related to the discharge of suspended sediments were not predicted.
- No zones of exposure to metals/metalloids within the water column or sediments were predicted by the modelling assessment, and as such the risk of bioaccumulation of metals/metalloids is also considered to be low.

The predictions presented in this study are considered conservative for the following reasons:

- The discharge of 80 GL/a defined by GEMCO represents the assumed peak flow. The discharge rate in the model was held constant over a one-year duration simulation and therefore overestimates the likely discharge volumes on an annual timescale, which during operations are expected to average 60 GL/a.
- Concentrations of analytes within the discharge were generally defined as the 95th percentile of historical measurements from the site and therefore are over-estimates of loads for the majority of the time.
- Though the hydrodynamic model was verified with measured currents that were well reproduced, current speeds are marginally under-estimated. This resultant reduction in the simulated flushing of the nearshore environment relative to actual conditions therefore likely represents an over-prediction of the mixing zone spatial extent in general due to less volumetric dilution.
- All water quality analytes assessed (with the exception of pH and suspended solids) were treated as numerically conservative tracers, neglecting transformative processes (degradation, decay, biological uptake) that may otherwise occur for some analytes and will lead to lower concentrations during operations than those simulated here. In general, this assumption will over-estimate the spatial extent of the mixing zone.

On the basis of these outcomes, the discharge scenario assessed in this study is considered to pose a suitably low level of environmental risk.

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Appendix B

Updated significant impact assessments

B-1 Australian humpback dolphin

Biology and ecology

Australian humpback dolphins are listed as vulnerable, migratory, and cetacean under the EPBC Act, and are not listed as threatened under the TPWC Act. This species occurs in coastal and island waters from Shark Bay in Western Australia to the Queensland-New South Wales border. The Australian humpback dolphin can be differentiated by other *Sousa* species by its darker colouration, triangular dorsal fin which is lower and wider at the base, and white scarring and dark flecks on adults (DCCEEW, 2025b).

Occurrence and habitat

Australian humpback dolphins have been confirmed present within the Project area; however, this is likely transient movement through the open water to coastal inshore regions.

In Australia, the Australian humpback dolphins are typically found in shallow coastal waters about 5-15 m deep and within 20 km of the coast, in turbid, inshore waters less than 2 km from the coast, and in embayments and estuaries (DCCEEW, 2025b). This species utilises a wide range of near-shore habitats, and there appears to be a high adaptability of this species to local environment characteristics (Parra and Cagnazzi 2016). Due to the generalist and opportunistic feeding preferences of this species, it is considered that there is suitable migratory and foraging habitat throughout the Project area.

Important populations

Important populations of the Australian humpback dolphin include (but not limited to) those inhabiting coastal waters of (DCCEEW, 2025):

- North West Cape, Western Australia
- Cygnet Bay, Western Australia
- Darwin region: Bynoe Harbour, Darwin Harbour and Shoal Bay, Northern Territory
- Port Essington, Northern Territory
- Aurukun to Weipa, Cape York, Queensland
- Townsville region: Cleveland Bay and Halifax Bay, Queensland
- Capricorn Coast, Queensland
- Curtis Coast, Queensland
- Great Sandy Strait, Queensland
- Moreton Bay, Queensland.

No important populations have been identified around Groote Eylandt.

Habitat critical to survival

Habitat critical to the survival of the species is defined as shallow (≤15 m depth) inshore coastal waters and estuarine habitats within sub-tropical and tropical zones of Australia up to 20 km from a coastline or land body, such as an island group, with sand banks, mud flats, seagrass, rock and/or reef substrate. Within this range, sites with a high density of teleost fish, cephalopods and bivalves are considered potential important foraging habitat (DCCEEW, 2025b).

Nature and extent of impact

Potential impacts to Australian humpback dolphins as a result of the proposed works for the Proposal, include the following:

- Disturbance to migratory pathways from noise and vibration
- Impacts and injury or mortality to individuals due to vessel strikes or interactions
- Degradation of water quality that could impact on foraging or other behaviours, or in extreme cases causes physiological harm.

The extent of impact is restricted to the Proposal area as defined in Table 4 of the SER.

Key threats

Key threats to Australian snubfin dolphins have been identified as:

– Habitat loss and degradation
– By-catch
– Water pollution
– Underwater noise
– Floods
– Vessel traffic
– Overfishing of prey resources
– Wildlife tourism.

Whilst some of the activities proposed align with key threats for the species, the pipeline corridor being installed for the Proposal would not be considered a threat to the Australian humpback dolphin, as it covers a small area (2 ha) located adjacent to the existing wharf. This area does not constitute quality habitat, primarily consisting of open sandy seabed outside of the continental shelf. No other key threats are relevant to the proposed Proposal.

Overall, with the mitigation measures proposed the Proposal will not have an influence on any of the key threats to this species.

Significant impact assessment

The Proposal occurs within known migratory and potential foraging habitat for the Australian humpback dolphin. These dolphins have historically been observed in the area during standard operations and there have been no reported impacts to this species. All potential impacts will be managed through avoidance and mitigation controls.

To determine if the Proposal is likely to have a significant impact on Australian humpback dolphins, a significant impact assessment in accordance with the Commonwealth's *Significant Impact Guidelines 1.1* has been undertaken in Table B.1. The significant impact assessment is based on the extent of impact to the species within the Project area.

Due to the lack of significant residual impacts associated with the Proposal, a significant impact on Australian humpback dolphins is not considered likely to occur.

Table B.1 Significant impact assessment – Australian humpback dolphin

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Lead to a long-term decrease in the size of an important population	**Not likely** No important populations of Australian humpback dolphins have been identified within Groote Eylandt. There are also no known aggregations of Australian humpback dolphins in the Project area or around Groote Eylandt in general. The few individuals identified within the Project area on NR Maps and Atlas of Living Australia are likely transient individuals migrating through the open water to estuarine and coastal habitats in the wider region. Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. Therefore, it is unlikely the Project will lead to a long-term decrease in the size of an important population of the species.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Reduce the area of occupancy of an important population	**Not likely** Occurrences of this species listed on the Atlas of Living Australia and NR Maps are limited to a few individuals in the Project area and these are likely transient individuals migrating to estuarine and coastal habitats in the wider region. Suitable migratory and foraging habitat has been identified throughout the Project area due to their generalist and opportunistic feeding preferences, however direct impacts to the species and its main habitat will be avoided or mitigated. Only a small portion of open sandy seabed will be removed (2 ha), and this is located inshore next to existing infrastructure and would not impede on movement or occupancy to other suitable habitats. Therefore, the Proposal will not reduce the area of occupancy of this species.
Fragment an existing important population into two or more populations	**Not likely** There are no important populations of Australian humpback dolphins within the Groote Eylandt region and no known aggregations of the species have been identified in the Project area or around Groote Eylandt. Historical occurrences are limited, and these are likely to be transient individuals. Direct and indirect impacts to the species will be avoided, mitigated or managed, and are not expected to interfere with the movement of this species throughout the Project area. Therefore, the Proposal is unlikely to fragment an important population into two or more populations.
Adversely affect habitat critical to the survival of a species	**Not likely** Habitat critical to the survival of the species is defined as shallow (≤15 m depth) inshore coastal waters and estuarine habitats within sub-tropical and tropical zones of Australia up to 20 km from a coastline or land body. This includes an island group, with sand banks, mud flats, seagrass, rock and/or reef substrate (DCCEEW, 2025b). Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. While a small reduction of open sandy seabed habitat (2 ha) will occur from installation of the pipeline, this habitat is not considered to be of high quality/importance for these species. Therefore, the Proposal is not likely to adversely affect critical habitat to the survival of the species.
Disrupt the breeding cycle of an important population	**Not likely** There are no known aggregations of Australian humpback dolphins in the Project area or around Groote Eylandt. Occurrences of this species listed on the Atlas of Living Australia and NR Maps are limited to a few individuals in the Project area and these are likely transient individuals migrating to estuarine and coastal habitats in the wider region. Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. Therefore, it is unlikely the Proposal will disrupt the breeding cycle of an important population.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	**Not likely** Important habitat is defined as shallow (≤15 m depth) inshore coastal waters and estuarine habitats within sub-tropical and tropical zones of Australia up to 20 km from a coastline or land body. Suitable foraging and migratory habitat may be present throughout the Project area. However, only a small portion of open sandy seabed will be removed (2 ha), and this is located inshore next to existing infrastructure and would not impede on movement or occupancy to other suitable habitats. This would not be quality habitat for foraging due to the lack of dense seagrasses and reef substrate in which higher densities of prey species would be found. Indirect impacts have the potential to cause disturbance due to alteration of fauna movement from construction activities and associated noise and vibration, as well as reducing water quality in the form of sediment plumes during construction or operation. Impacts will be managed through avoidance (i.e. construction halted when an individual is spotted within the shutdown zone) and standard practice mitigation controls including implementation of a CEMP and OEMP, including an adaptive management plan for water quality. During construction and operation, vessels will be operating under speed limits no greater than 6 knots. These speeds are considered suitable for minimising the potential for direct impact to marine fauna and reducing the potential for mortality. As such, the Proposal is unlikely to substantially modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	**Not likely** The potential introduction of invasive marine species (IMS) during the Proposal will be managed via adherence to Australian quarantine requirements and port biosecurity management plans. As the Project area does not constitute quality habitat, the species are also expected to occur in the Proposal as transient visitors only which further reduces the risk of IMS transmission to the species.
Introduce disease that may cause the species to decline	**Not likely** There are no known introduced diseases that have caused the decline of marine mammals in Australia. The risk of disease introduction will be mitigated by following standard industry procedures. It is considered unlikely the Project will have the potential to introduce disease to the extent that dolphin populations will decline, and the residual risk of introduced disease is considered to be low.
Interfere substantially with the recovery of the species	**Not likely** Whilst the proposed activities are aligned with key threats to this species, the potential for impact is considered low with the application of identified mitigation measures. Indirect impacts have the potential to cause disturbance due to alteration of fauna movement from construction activities and associated noise and vibration, as well as reducing water quality in the form of sediment plumes during construction or operation. Impacts will be managed through avoidance (i.e. construction halted when an individual is spotted within the shutdown zone) and standard practice mitigation controls including implementation of a CEMP and OEMP, including an adaptive management plan for water quality. During construction and operation, vessels will be operating under speed limits no greater than 6 knots. These speeds are considered suitable for minimising the potential for direct impact to marine fauna and reducing the potential for mortality. Therefore, the Proposal is unlikely to substantially interfere with the recovery of the species.

B-2 Australian snubfin dolphin

Biology and ecology

Australian snubfin dolphins are listed as vulnerable, migratory, and cetacean under the EPBC Act and are not listed as threatened under the TPWC Act. This species occurs in coastal and island waters from the Exmouth Gulf in Western Australia across the northern coastline, and along the east coast as far south as the Brisbane River in Queensland. The Australian snubfin dolphin has a broadly rounded head with a straight mouthline, and no signs of a beak. The dorsal fin is small and situated on the back half of the body, and the broad paddle-like flippers make it extremely mobile (DCCEEW, 2025a). This species comes to the surface to breathe; however, unlike most dolphins, the Australian snubfin dolphin has a u-shaped blowhole that opens to the front.

Occurrence and habitat

Australian snubfin dolphins have been confirmed present within the Project area; however, this is likely transient movement through the open water to inshore areas.

In Australia, the Australian snubfin dolphins have almost exclusively been recorded in coastal and estuarine environments. They typically occur in waters less than 15 m deep, within 20km from freshwater outflows and within 10 km from the coast. This species prefers protected coastal waters close to river and creeks mouths, and seagrass beds where they can forage for food; primarily small-bodied fish (DCCEEW, 2025a). There was no suitable foraging habitat recorded in the Project area as there was a lack of dense seagrass meadows, and river and creek mouths are located elsewhere, such as Angurugu River. There is suitable migratory habitat throughout the Project area.

Important populations

Important populations of the Australian snubfin dolphin include (but are not limited to) those inhabiting coastal waters of (DCCEEW, 2025a):

– Roebuck Bay, Western Australia
– Cygnet Bay, Western Australia
– Darwin region: Bynoe Harbour, Darwin Harbour and Shoal Bay, Northern Territory
– Port Essington, Northern Territory
– South Western Gulf of Carpentaria, Northern Territory
– Princess Charlotte Bay, Queensland
– Townsville region: Cleveland Bay and Halifax Bay, Queensland
– Gladstone region: Fitzroy River, Port Alma, and Keppel Bay, Queensland.

Habitat critical to survival

Habitat critical to the survival is defined as shallow (≤20 m depth) inshore coastal waters and estuarine habitats up to 10 km from a coastline and/or 20 km from a freshwater outflow such as creeks and river mouths within sub-tropical and tropical zones of Australia. Within this range, sites with a high density of teleost fish and cephalopods, such as mangroves and seagrass meadows, are considered potential important foraging habitat (DCCEEW, 2025a).

Nature and extent of impact

Potential impacts to Australian snubfin dolphins as a result of the proposed works for the Proposal, include the following:

– Disturbance to migratory pathways from noise and vibration
– Impacts and injury or mortality to individuals due to vessel strikes or interactions
– Degradation of water quality that could impact on foraging or other behaviours, or in extreme cases causes physiological harm.

The extent of impact is restricted to the Project area as defined in Table 4 of the SER.

Key threats

Key threats to Australian snubfin dolphins have been identified as:

– Habitat destruction and degradation
– Incidental capture in gillnets
– Traditional hunting by Indigenous Australian communities
– Live capture for oceanariums.

The pipeline corridor being installed for the Proposal would not be considered a threat to the Australian snubfin dolphin, as it covers a small area (2 ha) located adjacent to the existing wharf. This area does not constitute quality habitat, primarily consisting of open sandy seabed outside of the continental shelf. No other key threats are relevant to the Proposal.

Overall, the Proposal will not have an influence on any of the key threats to this species.

Significant impact assessment

The Proposal occurs within known migratory habitat for the Australian snubfin dolphin but is not considered to be significant foraging habitat. These dolphins have historically been observed in the area during standard operations and there have been no reported impacts to this species. All potential impacts will be managed through avoidance and mitigation controls.

To determine if the Proposal is likely to have a significant impact on Australian snubfin dolphins, a significant impact assessment in accordance with the Commonwealth's *Significant Impact Guidelines 1.1* has been undertaken in Table B.2. The significant impact assessment is based on the extent of impact to the species within the Project area.

Due to the lack of significant residual impacts associated with the Proposal, a significant impact on Australian snubfin dolphins is not considered likely to occur.

Table B.2 Significant impact assessment – Australian snubfin dolphin

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Lead to a long-term decrease in the size of an important population	**Not likely** An important population has been identified in the southwestern part of the Gulf of Carpentaria, NT. Groote Eylandt is located in the mid-west part of the Gulf of Carpentaria and there are no known aggregations of Australian snubfin dolphins in the Project area or around Groote Eylandt. Occurrences of this species listed on the Atlas of Living Australia and NR Maps are limited to a few individuals in the Project area and these are likely transient individuals migrating to estuarine and coastal habitats in the wider region. Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. Therefore, it is unlikely the Proposal will lead to a long-term decrease in the size of an important population of the species.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Reduce the area of occupancy of an important population	**Not likely** Previous records of the Australian snubfin dolphin are limited and are likely to be transient individuals migrating to estuarine and coastal habitats in the wider region. There is also no suitable foraging habitat identified in the Project area due to the lack of dense seagrass meadows and river and creek mouths located elsewhere. Only a small portion of open sandy seabed will be removed (2 ha), and this is located inshore next to existing infrastructure and would not impede on movement or occupancy to other suitable habitats. Therefore, the Proposal will not reduce the area of occupancy of this species.
Fragment an existing important population into two or more populations	**Not likely** Although there is an important population in the southwestern part of the Gulf of Carpentaria, NT, Groote Eylandt is located in the mid-west section of the Gulf. It is unlikely an important population would be situated around Groote Eylandt, as there are no known aggregations of the species in the Project area or around Groote Eylandt; and historical occurrences are limited. These are likely to be transient individuals. Direct and indirect impacts to the species will be avoided, mitigated or managed and are not expected to interfere with the movement of this species throughout the Project area. Therefore, it is unlikely the Proposal will fragment an existing population into two or more populations.
Adversely affect habitat critical to the survival of a species	**Not likely** Habitat critical to the survival is defined as shallow (≤20 m depth) inshore coastal waters and estuarine habitats up to 10 km from a coastline and/or 20 km from a freshwater outflow such as creeks and river mouths within sub-tropical and tropical zones of Australia. Important foraging habitat include mangroves and seagrass meadows (DCCEEW, 2025a). The pipeline corridor being installed for the Proposal would not be considered a threat to the species, as it covers a small area (2 ha) located adjacent to the existing wharf. This area does not constitute quality habitat, due to the lack of dense seagrass meadows. It primarily consists of open sandy seabed outside of the continental shelf. River and creek mouths are also located outside the Project area. The Project area comprises open ocean waters and developed port areas, which would only constitute temporary migratory habitat. Therefore, the Proposal is not expected to adversely affect habitat critical to the survival of the species.
Disrupt the breeding cycle of an important population	**Not likely** There are no known aggregations of Australian snubfin dolphins in the Project area or around Groote Eylandt. Occurrences of this species listed on the Atlas of Living Australia and NR Maps are limited to a few individuals in the Project area and these are likely transient individuals migrating to estuarine and coastal habitats in the wider region. Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. Therefore, it is unlikely the Proposal with disrupt the breeding cycle of an important population.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	**Not likely** The Project area comprises open ocean waters and developed port areas, which would only constitute temporary migratory habitat. River and creek mouths are located outside the Project area, and there is no suitable foraging habitat identified in the Project area due to the lack of dense seagrass meadows Indirect impacts have the potential to cause disturbance due to alteration of fauna movement from construction activities and associated noise and vibration, as well as reducing water quality in the form of sediment plumes during construction or operation. Impacts will be managed through avoidance (i.e. construction halted when an individual is spotted within the shutdown zone) and standard practice mitigation controls including implementation of a CEMP and OEMP, including an adaptive management plan for water quality. During construction and operation, vessels will be operating under speed limits no greater than 6 knots. These speeds are considered suitable for minimising the potential for direct impact to marine fauna and reducing the potential for mortality. As such, the Proposal is unlikely to substantially modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	**Not likely** The potential introduction of IMS during the Proposal will be managed via adherence to Australian quarantine requirements and port biosecurity management plans. As the Project area does not constitute quality habitat, the species are also expected to occur in the Proposal as transient visitors only which further reduces the risk of IMS transmission to the species.
Introduce disease that may cause the species to decline	**Not likely** There are no known introduced diseases that have caused the decline of marine mammals in Australia. The risk of disease introduction will be mitigated by following standard industry procedures. It is considered unlikely the Proposal will have the potential to introduce disease to the extent that dolphin populations will decline, and the residual risk of introduced disease is considered to be low.
Interfere substantially with the recovery of the species	**Not likely** Whilst the proposed activities are aligned with key threats to this species, the potential for impact is considered low with the application of identified mitigation measures. Indirect impacts have the potential to cause disturbance due to alteration of fauna movement from construction activities and associated noise and vibration, as well as reducing water quality in the form of sediment plumes during construction or operation. Impacts will be managed through avoidance (i.e. construction halted when an individual is spotted within the shutdown zone) and standard practice mitigation controls including implementation of a CEMP and OEMP, including an adaptive management plan for water quality. During construction and operation, vessels will be operating under speed limits no greater than 6 knots. These speeds are considered suitable for minimising the potential for direct impact to marine fauna and reducing the potential for mortality. Therefore, the Proposal is unlikely to substantially interfere with the recovery of the species.

B-3 Whale Shark

Biology and ecology

Whale sharks are listed as vulnerable and migratory under the EPBC Act and are not listed as threatened under the TPWC Act. The species has a global distribution in tropical and warm temperature waters, mainly occurring off the Northern Territory, northern Western Australia and Queensland in Australia. However, there are isolated records of the species off New South Wales, Victoria and South Australia. Whale sharks have a flattened, broad head with a large, wide mouth. Their streamlined body has a distinctive pattern consisting of white spots between pale vertical and horizontal stripes on a greyish, bluish or brownish top. They also have five large gill-slits, allowing them to extract oxygen from the water to breathe (TSSC, 2015).

Occurrence and habitat

Eight juvenile whale sharks have been observed off Groote Eylandt in November 2025, and one has been historically recorded near the Study area. Seasonal aggregations of whale sharks occur due to localised seasonal pulses of food productivity. These occur at Ningaloo Reef, Western Australia (March to July), off the coast of Christmas Island (December to January) and in the Coral Sea (November to December). The northern part of the Western Australian coast is an important migration route from July to November (TSSC, 2015).

The Whale Shark is an oceanic and coastal, tropical to warm-temperate pelagic shark. It is often seen far offshore but can also come inshore and sometimes enters lagoons of coral atolls. The whale shark is generally encountered close to or at the surface, in areas where the surface temperature is 21–25 °C, preferably with cold water (<17 °C) upwelling into it, and salinity between 34 to 34.5 parts per thousand (ppt) (Pogonoski et al., 2002).

Important populations

There are no described important populations for the whale shark. Data on the global population size is unavailable, however, populations in the Ningaloo Marine Park are estimated to be between 300 to 500 individuals (Meekan et al., 2006). No important populations have been identified around Groote Eylandt.

Habitat critical to survival

Habitat critical to survival of the species is not defined but assumed to be tropical and warm temperate oceanic and coastal waters with temperature between 21–25 °C and salinity between 34 to 34.5 ppt.

Nature and extent of impact

Potential impacts to whale sharks as a result of the proposed works for the Proposal, include the following:

- Disturbance to migratory pathways from noise and vibration
- Impacts and injury or mortality to individuals due to vessel strikes or interactions
- Degradation of water quality that could impact on foraging or other behaviours, or in extreme cases causes physiological harm.

The extent of impact is restricted to the Project area as defined in Table 4 of the SER.

Key threats

Key threats to whale sharks have been identified as:

- Boat strikes
- Commercial fishing
- Illegal, unreported and unregulated fishing
- Habitat disruption from mineral exploration, production and transportation.
- Tourism
- Climate change
- Predation of juvenile whale sharks.

Significant impact assessment

To determine if the Proposal is likely to have a significant impact on whale sharks, a significant impact assessment in accordance with the Commonwealth's *Significant Impact Guidelines 1.1* has been undertaken in Table B.3. The significant impact assessment is based on the extent of impact to the species within the Project area.

Due to the lack of significant residual impacts associated with the Proposal, a significant impact on whale sharks is not considered likely to occur.

Table B.3 Significant impact assessment – Whale shark

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Lead to a long-term decrease in the size of an important population	**Not likely** An important population has not been identified around Groote Eylandt. Eight juvenile whale sharks have recently been spotted off Groote Eylandt, and one has historically been recorded near the Study Area. This species typically occurs in deeper waters and would be unlikely to occur inshore where there is less suitable habitat (no deep upwellings or known seasonal aggregations of plankton). These known occurrences are likely transient individuals migrating to deep water habitats surrounding the island. Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. Therefore, it is unlikely the Proposal will lead to a long-term decrease in the size of an important population of the species.
Reduce the area of occupancy of an important population	**Not likely** Occurrences of the species near Groote Eylandt are likely to be transient individuals migrating to deeper water habitats. There is also no suitable foraging habitat identified in the Project area due to the lack of cold upwelling areas. Only a small portion of open sandy seabed will be removed (2 ha), and this is located inshore next to existing infrastructure and would not impede on movement or occupancy to other suitable habitats. Therefore, the Proposal will not reduce the area of occupancy of this species.
Fragment an existing important population into two or more populations	**Not likely** There are no known important populations of whale sharks in the Project area or around Groote Eylandt. Eight juvenile whale sharks have been recently observed off Groote Eylandt, and one previously recorded near the Study area. These are likely to be transient individuals. Direct and indirect impacts to the species will be avoided, mitigated or managed and are not expected to interfere with the movement of this species throughout the Project area. Therefore, it is unlikely the Proposal will fragment an existing population into two or more populations.
Adversely affect habitat critical to the survival of a species	**Not likely** Habitat critical to the survival of the whale shark has not been defined. However, this species is an oceanic and coastal pelagic shark inhabiting tropical to warm temperature areas with surface temperatures of 21-25 ^{o}C. This species is often seen offshore and aggregate deep cold upwelling areas with high productivity. The pipeline corridor being installed for the Proposal would not be considered a threat to the species, as it covers a small area (2 ha) located adjacent to the existing wharf. This area does not constitute quality habitat, as the species due to the lack of upwelling areas and deeper waters. The Project area comprises open ocean waters and developed port areas, which would only constitute temporary migratory habitat. Therefore, the Proposal is not expected to adversely affect habitat critical to the survival of the species.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Disrupt the breeding cycle of an important population	**Not likely** There are no known important populations of whale sharks in the Project area or around Groote Eylandt. Eight juvenile whale sharks have been recently observed off Groote Eylandt, and one previously recorded near the Study Area. However, these are likely transient individuals migrating to more suitable habitat within the wider region. Direct impacts to the species and its main habitat will be avoided or mitigated. Indirect impacts will be controlled via detailed management plans and are not expected to interfere with the mobility of this species throughout the Project area. Therefore, it is unlikely the Proposal with disrupt the breeding cycle of an important population.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	**Not likely** The Project area comprises open ocean waters and a developed port area, which would only constitute temporary migratory habitat. Suitable upwelling areas are not present within the Project area. Indirect impacts have the potential to cause disturbance due to alteration of fauna movement from construction activities and associated noise and vibration, as well as reducing water quality in the form of sediment plumes during construction or operation. Impacts will be managed through avoidance (i.e. construction halted when an individual is spotted within the shutdown zone) and standard practice mitigation controls including implementation of a CEMP and OEMP, including an adaptive management plan for water quality. During construction and operation, vessels will be operating under speed limits no greater than 6 knots. These speeds are considered suitable for minimising the potential for direct impact to marine fauna and reducing the potential for mortality. As such, the Proposal is unlikely to substantially modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	**Not likely** The potential introduction of IMS during the Proposal will be managed via adherence to Australian quarantine requirements and port biosecurity management plans. As the Project area does not constitute quality habitat, the species are also expected to occur in the Proposal as transient visitors only which further reduces the risk of IMS transmission to the species.
Introduce disease that may cause the species to decline	**Not likely** There are no known introduced diseases that have caused the decline of whale sharks in Australia. The risk of disease introduction will be mitigated by following standard industry procedures. It is considered unlikely the Proposal will have the potential to introduce disease to the extent that whale shark populations will decline, and the residual risk of introduced disease is considered to be low.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	Assessment
Interfere substantially with the recovery of the species	**Not likely** Whilst the proposed activities are aligned with one of the key threats to this species (boat strike), the potential for impact is considered low with the application of identified mitigation measures. Indirect impacts have the potential to cause disturbance due to alteration of fauna movement from construction activities and associated noise and vibration, as well as reducing water quality in the form of sediment plumes during construction or operation. Impacts will be managed through avoidance (i.e. construction halted when an individual is spotted within the shutdown zone) and standard practice mitigation controls including implementation of a CEMP and OEMP, including an adaptive management plan for water quality. During construction and operation, vessels will be operating under speed limits no greater than 6 knots. These speeds are considered suitable for minimising the potential for direct impact to marine fauna and reducing the potential for mortality. Therefore, the Proposal is unlikely to substantially interfere with the recovery of the species.

B-4 References

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Appendix C

Updated noise and vibration assessment

Technical Memorandum

January 28, 2026

To	Will Longworth
Copy to	Sabine Walker; Anna Boden; Brioni Armstrong
From	Matthijs Oosterlaken
Project Name	GEMCO Excess Water Disposal project
Project No.	12624084
Subject	Noise and Vibration memorandum to support SER

1. Introduction

Groote Eylandt Mining Company (GEMCO) proposes the development of the Excess Water Disposal project (the Proposal). This involves installing and operating a marine outfall pipeline, which will run from a quarry on the existing GEMCO mineral lease (ML), along the Rowell Highway, through to an ocean outfall, located adjacent to their existing port facility at Milner Bay.

The Proposal has the potential to generate noise and vibration emissions during construction of the pipeline and the outfall structures, and during operation of pumps and generators. A Noise and Vibration Impact Assessment report has previously been prepared by GHD to assess the potential airborne and underwater noise and vibration impacts from the construction and operation of the Proposal, and to provide mitigation and management measures for potential impacts.

1.1 Purpose of this Memorandum

The purpose of this technical memorandum is to provide an overview of the updates to the Noise and Vibration Impact Assessment report regarding underwater noise impacts from the potential use of impact piling during construction and cumulative noise impacts from shipping. A revision to the construction methodology identified impact piling may be required in addition to vibratory piling. The cumulative noise assessment on shipping was undertaken in response to the submission by the NT Department of Lands, Planning and Environment (DLPE) on the referral.

1.2 Scope and limitations

This technical memorandum has been prepared by GHD for GEMCO and may only be used and relied on by GEMCO for the purpose agreed between GHD and GEMCO as set out in section 1.1 of this technical memorandum.

GHD otherwise disclaims responsibility to any person other than GEMCO arising in connection with this technical memorandum. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this technical memorandum were limited to those specifically detailed in the technical memorandum and are subject to the scope limitations set out in the technical memorandum.

The opinions, conclusions and any recommendations in this technical memorandum are based on conditions encountered and information reviewed at the date of preparation of the technical memorandum. GHD has no responsibility or obligation to update this technical memorandum to account for events or changes occurring subsequent to the date that the technical memorandum was prepared.

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GHD has prepared this technical memorandum on the basis of information provided by GEMCO and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the technical memorandum which were caused by errors or omissions in that information.

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2. Underwater noise

The Proposal will involve the construction of a sheet pile walled coffer dam from the foreshore to beyond the extent of the surf zone, which is anticipated to result in elevated underwater noise levels, specifically during the vibratory or impact piling and trenching works associated with the construction of the corridor and installation of the piles.

Underwater noise sources can be broadly classified as either impulsive or non-impulsive (continuous). The US National Marine Fisheries Service (NMFS) (2024) provides the following definitions:

– *Impulsive - Sounds that are typically transient, brief (less than 1 second), broadband and consist of high peak sound pressure with rapid rise time and rapid decay. Impulsive noise sources can be single pulse (e.g. single explosion, impact pile strike, sonar ping, etc.) or multiple pulses (serial explosions, multiple pile strikes, etc.)*
– *Non-impulsive - Sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have a high peak sound pressure with rapid rise and decay times. Examples of non-impulsive noise sources include ship passbys, rock dumping, drilling, etc.*

Impulsive noise sources have sound characteristics that make them more injurious to marine fauna than non-impulsive sources. Activities associated with the Proposal have the potential to release both impulsive (i.e. impact piling) and continuous (e.g. shipping) noise sources.

To assess the impacts to marine fauna, the following guidance documents have been used:

– *Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects* (Southall et al., 2019).
– *Underwater Piling and Dredging Noise Guidelines* (South Australia, 2023).

Section 2.1 outlines the noise exposure criteria for impulsive and continuous noise sources for marine mammals, fish and marine turtles.

2.1 Noise exposure criteria

2.1.1 Marine mammals

The criteria for impulsive and continuous sources for the identified functional hearing groups are reproduced in Table 1, where Permanent Threshold Shift (PTS) criteria represent the likelihood of permanent threshold shifts and Temporary Threshold Shift (TTS) criteria represent the likelihood of temporary threshold shifts, if noise exposure exceeds these values over a 24-hour period. It should also be noted that these criteria are frequency weighted to the functional hearing group, analogous to the A-weighting developed for the human ear. Details of these weighting functions are provided in Southall et al. (2019).

Table 1 Physiological noise criteria for impulsive and continuous sources (Southall et al., 2019).

Functional hearing group	Noise criteria	Continuous sources (vibratory piling and trenching) SEL_{24hr} dB re 1μPa²·S	Impulsive sources (impact piling)	
			Peak SPL, dB re 1μPa	SEL_{24hr}, dB re 1μPa²·s
High-frequency cetaceans (Majority of toothed whales) (HF)	Physiological (TTS)	178	224	170
	Physiological (PTS)	198	230	185
Sirenians (dugong) (SI)	Physiological (TTS)	186	220	175
	Physiological (PTS)	206	226	190
Notes: Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS)				

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In an applied construction noise management context, the TTS criteria are used in preference to PTS criteria as these are more stringent and therefore minimise the risk of irreversible auditory damage to marine mammals.

2.1.2 Fishes and marine turtles

Rather than categorising by individual species, Popper et al. (2024) classify fish and sea turtles into groups based on their anatomy and available hearing data for similar fish and sea turtles with comparable anatomical features:

– Fishes with no swim bladder or other gas chamber (e.g. dab and other flatfish): These fish only detect particle motion and are less susceptible to pressure-related injuries.
– Fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g. Atlantic salmon): These fish base their hearing only on particle motion but are susceptible to pressure-related injuries.
– Fishes with swim bladder in which hearing involves a swim bladder or other gas volume (Atlantic cod, herring and relatives, etc.): These fish detect sound pressure and particle motion and are susceptible to pressure-related injuries.
– Fish eggs and larvae: These are categorised separately due to their increased vulnerability and reduced mobility. There are very few peer-reviewed studies on how eggs and larvae respond to human-made sounds.
– Sea turtles: Sea turtles likely detect sound through bone conduction, which restricts hearing to low frequencies as higher frequencies are dampened by bone. For instance, the leatherback turtle (*Dermochelys coriacea*) has a recorded hearing range between 50 Hz and 1,200 Hz, with peak sensitivity between 100 Hz and 400 Hz.

The noise exposure criteria for impulsive and continuous sounds for the fish groups and sea turtles are shown in Table 2.

Table 2 Noise exposure criteria – fishes and sea turtles (Popper et al., 2024)

Type of animal	Source character	Mortality and potential mortal injury	Impairment			Behaviour
			Recovery injury	TTS	Masking	
Fish: no swim bladder (particle motion detection)	Impulsive	>219 dB SEL_{cum} >213 dB Pk SPL	>216 dB SEL_{cum} >213 dB Pk SPL	186 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	Continuous	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (particle motion detection)	Impulsive	>210 dB SEL_{cum} >207 dB Pk SPL	>203 dB SEL_{cum} >207 dB Pk SPL	186 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Low
	Continuous	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder involved in hearing	Impulsive	>207 dB SEL_{cum} >207 dB Pk SPL	>203 dB SEL_{cum} >207 dB Pk SPL	186 dB SEL_{cum}	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate

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Type of animal	Source character	Mortality and potential mortal injury	Impairment			Behaviour
			Recovery injury	TTS	Masking	
(primarily pressure detection)	Continuous	(N) Low (I) Low (F) Low	170 dB SPL RMS for 48h	158 dB SPL RMS for 48h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	Impulsive	>210 dB SEL_{cum} >207 dB Pk SPL	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
	Continuous	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) High	(N) Moderate (I) Moderate (F) Low
Sea turtles	Impulsive	237 dB Pk SPL	204 dB SEL_{cum} 232 dB Pk SPL	189 dB SEL_{cum} 226 dB Pk SPL	(N) High (I) High (F) Moderate	175 dB SPL RMS
	Continuous	237 dB SEL_{cum}	220 dB SEL_{cum}	200 dB SEL_{cum}	(N) High (I) High (F) Moderate	175 dB SPL RMS

Notes: rms sound pressure levels (SPL RMS) dB re 1 µPa. All criteria are presented as sound pressure even for fish without swim bladders since thresholds, modelling and monitoring methods for peak particle motion sensitivity are still an active area of research. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Within the tables, where data exist that can be used to suggest provisional guidelines, received signal levels are reported in appropriate forms (e.g. SPL L_{rms}). Where insufficient data exist to make a recommendation for guidelines, a subjective approach is adopted in which the relative risk of an effect is placed in order of rank at three distances from the source – near (N), intermediate (I), and far (F) (top to bottom within each cell of the table, respectively). In general, "near" might be in the tens of metres from the source, "intermediate" in the hundreds of metres, and "far" in the thousands of metres. The relative risk of an effect is then rated as being "high," "moderate," and "low" with respect to source distance and functional hearing group. The rating for effects in these tables is highly subjective and represents consensus within the working group that produced the guidelines.

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3. Underwater noise impacts

3.1 Shipping (continuous source)

Given the ocean outfall construction works occur near the existing GEMCO jetty and the marine traffic in close proximity to this jetty is relatively high density, sound pressure level noise descriptors (i.e., RMS SPL and Pk SPL) are not expected to increase significantly.

However, the cumulative sound exposure level noise descriptor (typically assessed/measured over a 24-hour period) could increase depending on the following factors:

1. The composition, speed and frequency of vessel movements associated with the Proposal in the Port
2. The composition, speed and frequency of existing vessel movements in the Port
3. The propeller design, hull design and selection of onboard machinery for vessels described in 1) and 2), and
4. The proximity of a given receptor location to the vessel routes described in 1) and 2).

Depending on the size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 µPa at 1 m with main frequencies from 1 to 500 Hz (McCauley 1994; NRC 2003). Especially at low frequencies between 5 to 100 Hz, vessel traffic is a major contributor to noise in the world's oceans, and under the right conditions, these sounds can propagate hundreds of kilometres thereby affecting very large geographic areas (Pidcock et al., 2003).

Typical Source Levels (SL) of vessels from the ECHO measurement dataset (MacGillivray, A. & Z. Li., 2018 and MacGillivray, 2021) can be seen in Figure 1. The existing jetty is used by bulk-type vessels, which radiate broadband sound levels between 177 and 188 dB re 1 µPa at 1 m (McKenna, Ross, Wiggins, & Hildebrand, 2012) while in transit. While berthed, the vessels would also radiate sound originating from the on-board engine and generator to power the vessel. Sound levels while berthed would be less than during transit due to the lack of propeller movement.

Existing vessels at the GEMCO jetty consist of one tanker per month, one ore carrier about every three days, and two to three barges per week. Construction of the Proposal would require support vessels such as small watercraft, barges and jack-up barges and a pipe-laying vessel. Noise radiated from the small watercraft, barges and jack-up barges is considered minimal, whereas noise from a pipe-laying vessel would be similar to that of trenching activities.

Noise radiated from project-related vessel movements during construction is considered minimal, and is likely to be comparable to, or even less than, the noise generated by existing port traffic. Generally, doubling the number of noise sources results in only a modest increase in overall noise levels. Gradual exposure to continuous noise sources, such as additional shipping vessels during construction of the Proposal, is generally regarded as being less harmful and less likely to startle or stress marine fauna than rapid-onset impulsive noise sources like piling (Hamernik, R. et al, 1993 and Hamernik, R. et al, 2003).

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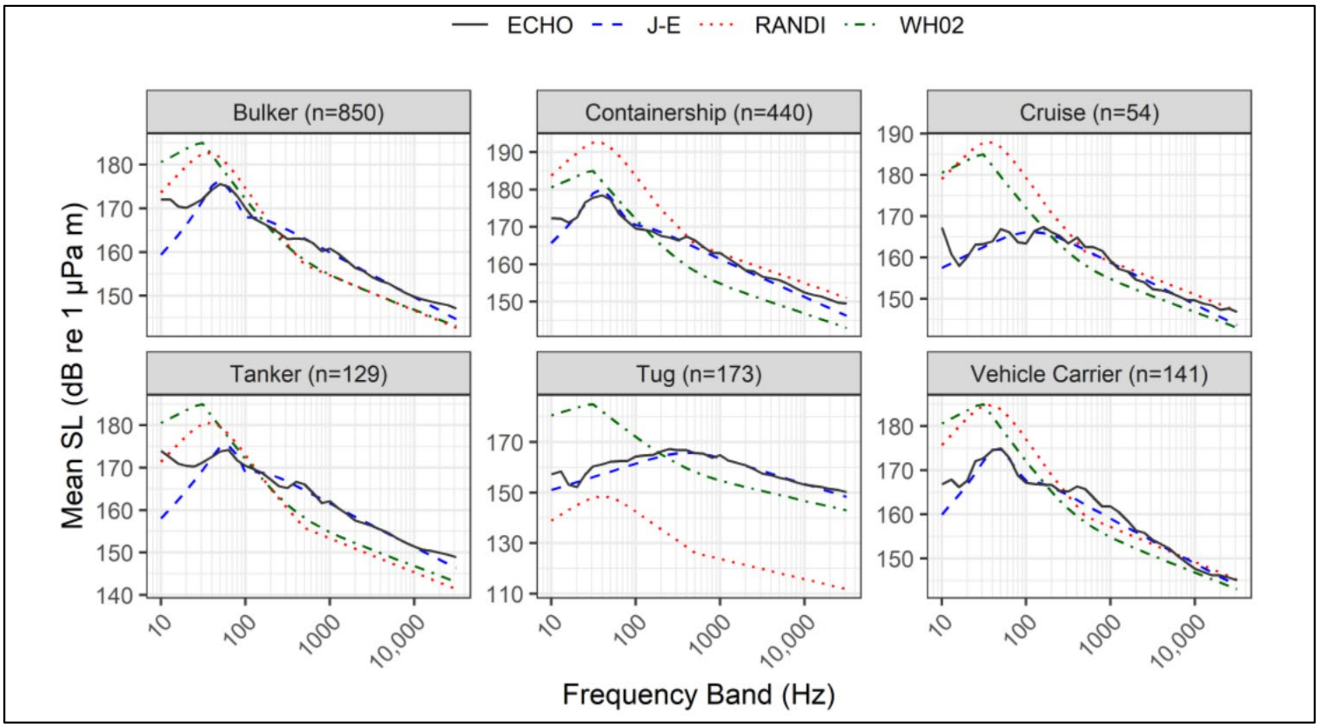

Figure 1 JOMOPANS-ECHO shipping noise model (MacGillivray, 2021)

3.2 Impact piling (impulsive source)

Vibratory piling / use of a vibratory hammer is the preferred piling method. Only where ground conditions prevent the pile from reaching the required depth, impact piling would be used to finish the pile installation. The Proposal would require piles with a diameter of up to 0.61 metre. Impact piling activities, where required, are anticipated to affect marine fauna near the piling activity. It is recommended to implement the mitigation measures detailed in Section 4 to reduce risk of impacts to marine fauna, fishes and sea turtles.

The single strike SEL (SEL_{SS}) and peak sound pressure levels adopted in the Underwater Noise Management Plan (UNMP), which are associated with impact piling activities for the reconstruction of the wharf and ship loader, are presented in Table 3.

Table 3 UNMP adopted impact hammer sound pressure levels (Resonate, 2024)

Pile size	SEL_{ss} at 10m (dB re 1 µPa^2 s)	Peak at 10m (dB re 1 µPa)	Notes
1.2 m diameter wharf piles	184	210	Average of values presented in Table 3 of the UNMP for 0.91m to 1.5m diameter piles

The wharf and ship loader reconstruction activities occurred in the near vicinity of the Proposal site and required impact piling of 1.2 metre diameter steel piles. The predictions as part of the UNMP considered a sound pressure level of 184 dB re 1 µPa^2 s at 10 metres from the source (as detailed in Table 3) and a total of 3,600 hammer blows within a 24-hour period.

For comparison, the Proposal requires piling of steel pipe piles with a diameter of 0.25 and 0.61 metre. Piling would commence using a vibratory hammer, only followed by a hydraulic impact hammer should ground conditions require this. The source level of impact piling a steel pipe pile with a diameter of 0.61 metre is 178 dB re 1 µPa^2 s at 10 metres from the source as per Table 4-1 of the SA Guideline. This is approximately 6 dB lower than the source level of 184 dB re 1 µPa^2 s for a 1.2 metre diameter pile.

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In the worst-case, a similar number of impact hammer blows (3,600) would be required to install the piles for the Proposal. However, as vibratory piling would be started with, the number of impact hammer blows would be reduced significantly.

Considering that the local conditions of the Proposal area would be similar to that of the wharf and ship loader reconstruction activities assessed as part of the UNMP, the lower source level of the impact piling activities, and the likely reduced number of required hammer blows, adopting the predicted distances of the UNMP for this Proposal is considered a conservative approach.

3.2.1 Auditory injuries to marine mammals

Distances to the physiological noise exposure onset criteria are calculated using a practical spreading model. SEL_{24hr} decibels re 1 µPa^2s is a cumulative metric that represents the effect of noise within the construction period based on the assumption that an animal is at fixed position and continuously exposed to a noise source. This is considered an unlikely worst-case scenario since, more realistically, marine animals would not stay in the same location or at the same distance from a sound source for an extended period of time. Therefore, the estimated range to an exceedance of the SEL_{24h} criteria does not mean that any animal travelling within this radius from the source *will* be injured, but rather that it *could* be injured if it remained within that range for the entire duration of the construction activities.

The results are based on an animal's noise exposure to construction activities assuming the various construction durations for trenching and vibratory piling, and various number of pile strikes for impact piling. The estimated range at which a PTS and TTS could occur is based on the minimum distance from the source at which the PTS and TTS onset thresholds are exceeded.

Distances to the physiological noise exposure onset criteria for the identified marine mammal functional hearing groups are shown in Table 4 and are replicated from the UNMP. Based on the predicted distances, the maximum ranges to the PTS/TTS onset threshold criteria can be summarised as:

- TTS onset threshold criteria:
  - High frequency (HF) cetaceans: 253 metres
  - Sirenians (SI): 242 metres.
- PTS onset threshold criteria:
  - High frequency (HF) cetaceans: 87 metres
  - Sirenians (SI): 86 metres.

Table 4 Distance to PTS and TTS threshold levels, metres – marine mammals (impulsive sources) (Resonate, 2024)

Group	Physiological noise exposure onset criteria SEL_{24hr} dB re 1 µPa^2·s	Distance to PTS and TTS threshold levels, metres
Permanent Threshold Shift (PTS)		
HF	185	87
SI	190	86
Temporary Threshold Shift (TTS)		
HF	170	253
SI	175	242

3.2.2 Potential effects to fish and marine turtles

The distances to the mortality and potential mortal injury, recoverably injury and TTS onset criteria ($SEL_{24hr,}$ dB re 1 µPa^2·s) were calculated for fish species and sea turtles. Based on the distances shown in Table 5, which are based on the UNMP, the maximum ranges to the onset threshold criteria can be summarised as:

- TTS onset threshold criteria:

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- Fish with and without a swimming bladder involved in hearing: 1,622 metres
- Sea turtles: 1,023 metres.

– Recovery injury:
  - Fish without a swimming bladder involved in hearing: 92 metres
  - Fish with and without swimming bladder involved in hearing: 676 metres
  - Sea turtles: 580 metres.

– Mortality and potential mortal injury:
  - Fish without a swimming bladder involved in hearing: 86 metres
  - Fish with swimming bladder not involved in hearing: 342 metres
  - Fish with swimming bladder involved in hearing: 542 metres
  - Sea turtles: <10 metres.

Table 5 Distances to physiological noise exposure onset criteria – fishes and sea turtles (Resonate, 2024)

Scenario	Physiological noise exposure onset criteria SEL_{24hr} dB re 1 μPa^2·s	Impact piling, SEL_{24hr}
Mortality and potential mortal injury		
Fish: no swim bladder (particle motion detection)	219	86
Fish: swim bladder is not involved in hearing (particle motion detection)	210	342[1]
Fish: swim bladder involved in hearing (primarily pressure detection)	207	542[1]
Sea turtles	Pk SPL: 237 dB re 1 μPa^2	<10
Recoverable injury		
Fish: no swim bladder (particle motion detection)	216	92
Fish: swim bladder is not involved in hearing (particle motion detection)	203	676[1]
Fish: swim bladder involved in hearing (primarily pressure detection)	203	676[1]
Sea turtles	204	580[1]
Temporary Threshold Shift (TTS)		
Fish: no swim bladder (particle motion detection)	186	1,622
Fish: swim bladder is not involved in hearing (particle motion detection)	186	1,622
Fish: swim bladder involved in hearing (primarily pressure detection)	186	1,622
Sea turtles	189	1,023[1]

Note 1: The UNMP includes predicted distances for fishes without a swim bladder only. As such, distances for fish with swim bladders have been determined by extrapolating the predicted distance in the UNMP to the relevant physiological noise exposure onset criteria using the practical spreading model of 15 log (R/R_{ref}).

Note 2: The mortality and potential mortal injury criteria for sea turtles is limited to a peak sound pressure level.

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4. Mitigation and management measures

Based on the modelling outcomes, it is expected that impacts from trenching and vibratory piling activities will be minor, while impact piling activities have potential to impact marine fauna. It is noted that the preferred method for piling activities is using a vibratory hammer. Only where ground conditions prevent the pile from reaching the required depth with vibratory piling, impact piling will be used until the final depth is achieved.

Where impact piling activities are required, it is recommended that management and mitigation measures are considered for impact piling activities to reduce the risk of noise impacts to marine fauna as far as reasonably practicable. The key mitigation management measures to be considered are:

– Safety zones for marine mammals (Section 4.1)
– Planning of activities (Section 4.2)
– Standard operational procedures for impact piling (Section 4.3).

4.1 Safety zones for marine mammals

Two safety zones would be applied around each noise generating activity location:

– **An observation zone**, within which the movement of marine mammals and marine turtles would be monitored to identify any approach to the shut-down zone where practicable. The observation zone is sized based on a nominal 250 m distance from the outer edge of the shut-down zone.
– **A shut-down zone**, within which the observation of marine mammals and marine turtles would trigger noise-generating activities to cease as soon as reasonably practical. Shut-down zones are sized based on the potential for a TTS.

The zones are not designed to eliminate behavioural reactions to audible noise that do not cause physical injury. It is expected that marine mammals near a loud activity will display avoidance behaviours, reducing the risk of them coming close enough to the source to experience hearing damage (i.e., entering the shut-down zone).

The effects of such temporary displacement are generally not significant unless they repeatedly interfere with critical behaviours like breeding, feeding, and resting, or occur in key areas such as migratory paths, calving or nursery grounds and important feeding zones.

For cumulative SEL 24-hour noise thresholds, these zones are bounded by the worst-case high-frequency cetacean marine mammal group present in the study area. Without additional mitigation measures, the shut-down zone is calculated to be 250 metres, and the observation zone is calculated to be 500 metres for impact piling activities.

An example of the safety zones is illustrated in Figure 2 (SA DIT, 2023).

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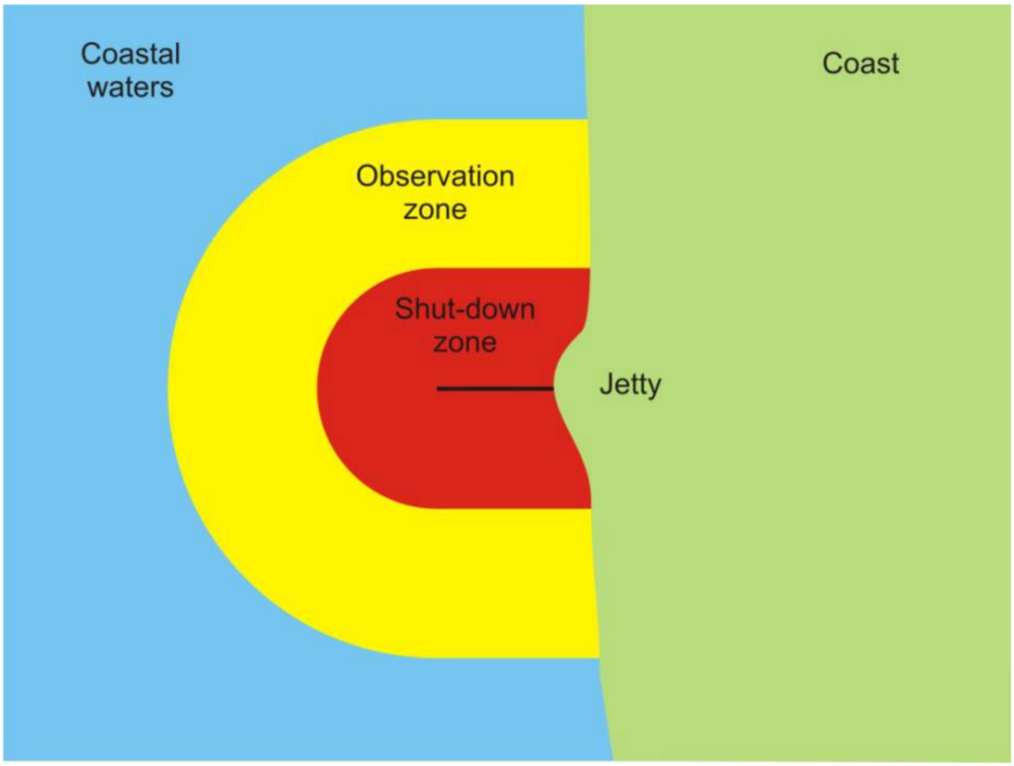

Figure 2 ***Observation and shut-down zones around noise source (SA DIT, 2023)***

4.2 Planning of activities

The following measures pertaining to the planning of impact piling activities should be incorporated into the marine fauna management plan:

– **Timing and duration**: Impact piling activities should avoid periods when marine megafauna are likely to be breeding, calving, feeding, or resting within biologically important habitats in the potential noise impact area.
– **Marine fauna observer (MFO)**: Ensure a suitably qualified MFO (minimum of MFO Level 2 as defined in the SA Guideline[1]) is present during impact piling to oversee and enforce standard operational procedures.
– **Educational materials**: Provide all staff with briefings on environmental regulations, marine mammal (and other relevant marine fauna) identification, and specific environmental obligations. Information about marine mammal concentration areas, migration patterns, and key feeding sites should be identified during planning and used to enhance the effectiveness of marine fauna observation.
– **Contract documentation**: Standard operational procedures and any additional protective measures should be included in the contract documentation for the impact piling rig contractor/operator.

4.3 Standard operational procedures

The following standard operational procedures for impact piling activities are recommended to be incorporated into the marine fauna management plan:

– **Pre-start procedure**: The MFO should visually monitor for marine mammals and other relevant marine fauna from a high vantage point for at least 30 minutes before starting impact piling. This is to ensure the area, especially the shut-down zone, is clear of marine life.
– **Soft-start procedure**: If no marine megafauna is observed, contractors can begin the soft start, gradually increasing piling impact energy over 10 minutes. This procedure is also required after any break in impact piling longer than 30 minutes to alert marine life and allow them to move away. Visual

[1] Marine Fauna Observer, Level 2. A person who has sufficient experience in marine fauna identification and distance estimation.

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observations of marine mammals within the safety zones shall be maintained by the MFO throughout soft starts. The soft start procedure is an added safeguard that can be used to alert marine fauna to the presence of the impact piling rig and enable animals time to move avoid the area to distances where injury is unlikely.

– **Normal operation procedure**: Full impact piling can proceed if no marine mammals are detected during the soft start. Visual monitoring must continue, and the pre-start checks are repeated after significant breaks or visibility issues.
– **Stand-by operations procedure**: If marine megafauna is spotted in the observation zone during operations, the impact piling rig operator must be on stand-by to shut-down the impact piling rig should the mammal enter the shut-down zone.
– **Shut-down procedure**: Impact piling must stop immediately if a marine mammal enters the shut-down zone. Operations can resume with a soft start once the animal leaves the zone or after 30 minutes without sightings, unless visibility is poor, in which case operations remain halted until conditions improve.
– **Compliance and sighting report**: The impact piling contractor is required to keep a detailed record of the procedures employed during operations and information on any marine mammals sighted during the activities and their reaction to the activity. A report on the activity should include location, date, start and completion of the impact piling activities, and information of the impact piling rig (hammer weight, drop height, pile size, number of piles, number of impacts per pile etc.).

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Regards

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Appendix D

Mitigation and management measures

D-1 Overview

The mitigation and management measures in relation to the Proposal are provided below for:

– Marine ecology (refer to Section D-2)
– Terrestrial ecology (refer to Section D-3)
– Noise and vibration (refer to Section D-4)
– Culture and heritage (refer to Section D-5)
– Air quality (refer to Section D-6).

This appendix provides a collation of mitigation and management measures proposed in the Referral Report, as well as those proposed in this SER.

The mitigation measures in Sections D-2 to D-6 will form the CEMP and OEMP. In addition to the CEMP and OEMP, GEMCO standard operating procedures and management plans will be implemented.

The decommissioning of pipeline infrastructure will be included in the GEMCO Closure Plan. If the infrastructure is to be removed, management and mitigation measures proposed for impacts associated with pipeline construction/laying activities will be considered.

D-2 Marine ecology

Impact management and mitigation measures are provided below for potential impacts during construction (Table D.1) and operation (Table D.2) of the Proposal.

Table D.1 Construction marine ecology mitigation measures

Control type	Management and mitigation measure
Minimisation of seabed disturbance	To reduce or eliminate the impact of seabed disturbance, a number of design and management controls will be implemented when possible: – Construction methodology will consider option with least disturbance to seabed area – Engineering controls, such as a silt curtain and sheet piles, will be installed prior to the commencement of excavation and trenching activities: • Sheet piles will be installed for the near shore excavation • Silt curtains will be utilised for placement of material for the working platform and any other seabed disturbance outside the sheet piled coffer dam – Development and implementation of a CEMP to support management of excavation activities – Development and implementation of an ESCP for land-based activities relevant to the marine footprint (such as excavation through the beach zone) – Sediment removed via trenching within the sheet piles will be reinstated. Where reinstatement is not possible sediment will be placed within port's existing onshore dredge spoil ponds. The management of spoil will be included in the CEMP to control the release of sediment/pollutants to surrounding sensitive receptors during transport and storage.
Management of water quality	The following mitigation measures will be implemented to manage the potential for impact associated with altered water quality during construction: – All seabed excavation will be undertaken inside of the cofferdam, or inside of silt curtains – Monitoring of turbidity and underwater light in the receiving environment will be undertaken during construction. This program will include: • Monitoring at the inshore rocky reef area located between the jetty and the marine footprint • Monitoring at the reef/seagrass area to the south of the marine footprint • Monitoring at a suitable far-field reference location • In-situ measurements of turbidity every 15 minutes, with data telemetered to an online platform for visualisation in near real time • Setting of ecologically relevant threshold values for management action. Thresholds will be informed by baseline data and relevant scientific literature, including the outcomes of

Control type	Management and mitigation measure
	the WAMSI DSN referenced in the Draft NT EPA marine dredging guideline, and will consider holistic changes in water quality, encompassing intensity and duration – The implementation of the marine monitoring strategy described in Appendix E – Management actions will be clearly set out in the CEMP for the works and will be linked to threshold values based on a tiered early warning system. Management actions will likely include: • Review of efficacy of installed silt curtains • Modification of trenching works (location, duration, etc) • Temporary cessation of trenching works. The following controls will be adopted in order to manage the potential for the spillage of hydrocarbons, environmentally hazardous chemicals and liquid-waste to the marine environment for all construction methods: – Monitoring for visual contamination in marine waters adjacent to work area (e.g. discolouration or oily sheen) on a daily basis – All chemicals (including environmentally hazardous substances) and hydrocarbons will be stored in closed, secure and appropriately bunded containment – A Safety Data Sheet (SDS) will be available for all chemicals in locations nearby to where the chemicals/wastes are stored – A spill response plan will be included in the CEMP and based on existing Milner Bay spill response procedures – Vessel operators will have an up-to-date Shipboard Oil Pollution Emergency Plan (SOPEP) and Shipboard Marine Pollution Emergency Plan (SMPEP). All shipboard chemical and hydrocarbon spills will be managed in accordance with these plans by trained and competent crew. GEMCO's existing spill management procedures will be adhered to – Spill exercises will be conducted at minimum of every three months and recorded in the vessel log – Spill kit will be located near high-risk spill areas – Spills will be cleaned up immediately, spill kits re-stocked and clean up material contained, and not washed overboard – Contaminated material collected will be contained on board for appropriate onshore disposal – Spill clean-up equipment will be located where chemicals and hydrocarbons are stored and frequently handled (i.e. 'high risk' areas). The quantity of spill recovery materials will be appropriate to the quantity of stored chemicals – Equipment or machinery with the potential to leak oil will be enclosed in continuous bunding or will have drip trays in place where appropriate – All hoses for pumping and transfers will be maintained and checked as per the pump management system (PMS) – On board oily water disposal will be managed in accordance with the *Marine Pollution Regulation 2003*. The vessel operator will record the quantity, time and onshore location of the oily water disposal in the vessel Oil Record Book – The following controls will be implemented for the purposes of mitigating or eliminating the risk of the spillage of hydrocarbon from refuelling of vessels or machinery onboard: • Refuelling operations will be a manned operation. In the event the refuelling pipe is ruptured, fuel bunkering will cease • Spill clean-up equipment will be located where hydrocarbons are stored and frequently handled (i.e. 'high risk' areas) • Refuelling of a vessel will only occur in port and in suitable weather conditions • Dry-break refuelling hose couplings and hose floats will be installed on the refuelling hose assembly.

Control type	Management and mitigation measure
Management of underwater noise and vibrations	The following controls will be implemented for the purposes of minimising or mitigating the impact of underwater noise on marine fauna: – Vessel, trenching and piling machinery will be maintained in accordance with the manufacturer specifications to reduce noise emissions – Pre-start checks of the piling area (including a radius of 15 m around the machinery) will be conducted for marine mammals or marine turtles – Soft starts will be incorporated into all piling activities – During impact piling the mitigation measures detailed below in 'Underwater noise during construction' (refer to Section D-4-2) will be implemented.
Management of marine pests and pathogens	The following controls and processes will be employed wherever practicable in order to mitigate or eliminate the risk of introducing pests: – Vessels will be sourced locally wherever possible – All vessels working on the Project, whether internationally or locally sourced, will adhere to Australian quarantine requirements • The management of ballast water prior to entry to Australian waters must follow AQIS guidelines and compliance requirements in relation to marine pest introduction risk management for any internationally sourced vessel • Vessels landing at the port should adhere to GEMCO's biosecurity inspection procedures including visual inspection for pest animals or plant material • Any additional vehicle, equipment or containers being brought to Groote Eylandt should adhere to the biosecurity inspection procedure requiring a visual inspection • GEMCO's port regulations and guidelines for arriving masters provides for environmental protection from marine pests by stipulating that vessels shall not pump out bilges within Milner Bay port limits, ballast water is not to be discharged onto the wharf and vessels with common ballast and bilge stripping educators must ensure that valves to the bilge system are closed.
Management of fauna interaction	The following controls will be adopted and executed for all construction methods to mitigate or eliminate the risk of collision between vessels and marine fauna: – All vessels utilised for the Proposal will adhere to speed limits within and around the wharf (6 knots) – Operations of vessels will follow the vessel disturbance and vessel strike mitigations outlined by the *Australian Guidelines for Whale and Dolphin Watching* (Commonwealth of Australia, 2017) and the *National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna* (Commonwealth of Australia, 2017). This includes the implementation of the following guidelines: • Reducing vessel speed to as low as is reasonably practical within the Port Limits and adhere to standard speed limits within and around the construction footprint • Caution zone (300 m either side of whales and 150 m either side of dolphins) – vessels must operate at no wake speed in this zone • Caution zone must not be entered when calf (whale or dolphin) is present • No approach zone (100 m either side of whales and 50 m either side of dolphins) – vessels should not enter this zone and should not wait in front of the direction of travel or an animal or pod or follow directly behind • If there is a need to stop, reduce speed gradually • Do not encourage bow riding • If animals are bow riding, do not change course or speed suddenly.

Table D.2 Operations marine ecology mitigation measures

Control type	Management and mitigation measure
Management of water quality due to maintenance activities	As per Table D.1.
Management of water quality from marine discharge	Validation monitoring will be undertaken to validate the outcomes of the marine discharge modelling. Results of the validation monitoring program are to be used to inform the existing GEMCO MEMP and any possible amendments. The following mitigation measures will be implemented to manage the potential for impact associated with altered water quality during operation: – Monitoring of turbidity of water to be discharged. This will comprise in-line monitoring with data available in real time which will inform an adaptive management program. Management actions will be clearly set out in the OEMP for the works and will be linked to turbidity threshold values based on a tiered early warning system. Management actions will likely include: • Review of monitoring data at NH2 quarry • Review of management of water storage (NH2 quarry) • Modification or cessation of excess water discharge. – Monitoring of turbidity and underwater light in the receiving environment will be undertaken during operation. This program will include: • Monitoring at the inshore rocky reef area located between the wharf and the marine footprint • Monitoring at the reef/seagrass area to the south of the marine footprint • Monitoring at a suitable far-field reference location • In-situ measurements of turbidity every 15 minutes, with data telemetered to an online platform for visualisation in near real time • Setting of ecologically relevant threshold values for management action. Thresholds will be informed by baseline data and relevant scientific literature, including the outcomes of the WAMSI dredging science node referenced in the Draft NT EPA marine dredging guideline, and will consider holistic changes in water quality, encompassing intensity and duration – The implementation of the marine monitoring strategy described in Appendix E – Management actions will be clearly set out in the OEMP for the works and will be linked to threshold values based on a tiered early warning system. Management actions will likely include: • Review of monitoring data at NH2 quarry • Review of management of water storage (NH2 quarry) • Modification or cessation of excess water discharge.
Habitat creation	To manage the impacts to created habitat, the following controls will be implemented: – Maintenance of the outfall structure shall seek to avoid slow-moving or cryptic protected species such as syngnathids.
Management of species abundance and diversity	– Validation monitoring of the plume will be undertaken to confirm the Marine Discharge Model predictions associated with plume buoyancy (and therefore no impact to benthic habitats) – Monitoring of benthic primary producer communities will be implemented as described in Appendix E.
Management of marine pests and pathogens	As per Table D.1.
Management of fauna interaction	As per Table D.1.

D-3 Terrestrial ecology

Measures to avoid or mitigate potential impacts to terrestrial ecology are outlined in Table D.3. These measures will be incorporated into a site-specific CEMP to be implemented by GEMCO and respective construction contractors.

Table D.3 Construction mitigation measures for terrestrial ecology

Control type	Mitigation measure
Planning	Prior to the commencement of any activities proposed in relation to the construction of the Proposal, GEMCO will finalise the construction footprint including the: – Layout of infrastructure – Areas to be cleared – Areas to be retained – Temporary clearing (i.e. lay down areas, construction pads, site offices, etc) – Access tracks – Any necessary borrow and/or overburden areas. *Given that the design phase has largely been completed, the majority of these activities have already been completed.* *When finalising the construction footprint (through the detailed design and placement of infrastructure), consideration has been given by GEMCO to minimising the disturbance to native flora and fauna species, as far as practicable by utilising already disturbed areas beside access tracks and the Rowell Highway roadside verge.*
Pre-clearance surveys	Once the final design has been determined and prior to the commencement of construction, pre-clearance surveys will be conducted by a suitably qualified person over the extent of clearing disturbance to limit the potential for impacts to any fauna individual(s): – This survey will target threatened and common fauna species and/or habitat features including hollow bearing trees, burrows, dens, hollow logs, caves, rocky areas i.e. crevices, riparian vegetation, embankments, and any other features which may provide suitable habitat for present fauna – Where pre-clearance surveys identify threatened fauna species that cannot self-disperse, works will cease immediately, and a suitably qualified person will attend site and salvage and translocate the animal/s in question.
Disturbance minimisation	Vegetation clearing will be no wider than is necessary to facilitate the construction of the pipeline and the associated infrastructure, so as to limit the impacts of local flora and fauna – Clearing will be limited as much as possible on the vegetated side of the pipeline alignment, noting there are clearing requirements for fire safety and construction effort – Where possible, the on-ground layout and alignment of the corridor will be micro-sited to avoid native vegetation (i.e. trees) and suitable fauna habitat features (e.g. rock piles, termite mounds, hollow logs, etc) – Trees with hollows will be avoided where possible. This will be captured within the CEMP.
	Clearing, earthworks, and the use of heavy machinery which may cause disturbance will be minimised within 50 m of all watercourses and associated riparian vegetation. – The contractor will clearly demarcate all watercourses and the extent of riparian vegetation (~20 m from watercourse edge) with the intent to limit impacts to freshwater dependent fauna species, including the threatened Mertens' water monitor – Construction works within the extent of riparian vegetation (~20 m from watercourse edge) will be planned so as to occur outside of the Mertens' water monitor mating period (i.e. wet season – December - February) – Minimisation of incursions and limited access to riparian zones by construction personnel – Works to preferentially occur when the watercourse is dry and / or not flowing and erosion and sediment controls implemented – If a temporary waterway barrier is required: • The dimensions of any temporary barrier will be limited to the minimum practicable for the site and purpose • The method of dewatering must not cause fish to become trapped or stranded or have detrimental impacts on the wellbeing of fish

Control type	Mitigation measure
	• If fish salvage is required consultation with an aquatic ecologist on appropriate control measures for the particular situation – Open excavation time in watercourses will be minimised to reduce erosion risks and maintain fauna connectivity across the watercourse (construction within the freshwater habitats will be conducted quickly with underground pipeline installation proposed to be completed, watercourses reshaped to match original grades and flow controls removed (if required) within less than a week per watercourse).
	To limit the potential for disturbance to any EPBC-listed migratory shorebird species at the outfall location to the northern extent of the construction footprint (likely only from around November to March and predominantly during the wet season), clearing works within 300 m of the marine environment will involve an inspection by suitably qualified person to ensure no EPBC-listed migratory shorebirds are utilising the area. If EPBC-listed migratory shorebirds are detected during site inspections, works will only proceed once birds have left the construction footprint.
Trench management	Where any trenching is required during the construction phase, the following will be implemented and incorporated into the CEMP: – The total length of open trench and the length of time any section of trench is open is minimised (e.g. longest trench is 200 m in length, majority of trenches are less than 60m in length and pipelaying is intended to take place immediately after trenching). Open-air trenches will not be left exposed for longer than 48 hours – Trench plugs, ramps and fauna shelter requirements will be considered within the CEMP and implemented as appropriate for each length of trench – Inspections of the entire length of open trenches are undertaken at least once per 24 hour period (ideally immediately post dawn) – If fauna is detected in the trench, advice will be sought from a suitably qualified person with fauna handling experience.
Invasive species management	– To limit the potential for the introduction and establishment of invasive fauna (i.e. cane toad) on Groote Eylandt, any material(s) or machinery brought to the island to support the construction or maintenance of the proposed pipeline will be inspected as part of a biosecurity assessment – Where any invasive fauna species are identified, the individuals will be disposed of and the incident documented.

D-4 Noise and vibration

This section provides mitigation and management measures for:

– Construction noise
– Underwater noise during construction
– Operational noise.

D-4-1 Construction noise

The noise levels at the residential receptors are predicted to be above the recommended ACNLs, and as such GEMCO will apply all feasible and reasonable work practices to meet the recommended ACNLs. The mitigation measures provided in Table D.4 will be implemented where feasible and reasonable by the construction contractor to reduce potential noise impacts at receptors.

Subsequent to the incorporation of the noise mitigation measures, the recommended ACNLs may still be exceeded during standard and non-standard construction hours at the most-affected sensitive receptors. Receptors which are impacted by the construction works of the pipeline alignment would experience noise levels above the ACNLs for a relatively short-term period, as the construction works progress along the alignment. These receptors are anticipated to not be impacted for more than 12 days in a worst-case scenario.

Table D.4 Construction noise and vibration mitigation measures

Control type	Mitigation measures
Work scheduling	Noise generating activities with the potential to impact receptors are to be scheduled during standard GEMCO operational hours (6 am to 6 pm daily)[1]. In particular impact piling activities should be undertaken within standard hours to minimise noise impacts to sensitive receptors. Where no receptors are predicted to be impacted, works could occur outside of the recommended standard construction hours. The Referral Report and accompanying appendices provide an indicative overview of the sections expected to impact sensitive receivers during the worst-case construction activities
	Include an outside standard hour works procedure to minimise the impact of any significant noise and vibration works during construction works outside of the recommended standard hours. This procedure could include, but is not limited to, the following: – Limiting works to low noise generating activities, such as work crews arriving on site, equipment refuelling, safety checks and toolbox talks – Minimise the use of heavy machinery.
Site inductions	Inductions for the work crew will include the specific noise issues and mitigation measures required for the site. The induction will include: – All relevant Proposal specific and standard noise mitigation measures – Relevant licence and approval conditions – Permissible hours of work – Location of sensitive receptors where the recommended assigned construction noise levels may be exceeded – Designated construction employee parking areas – Designated loading/unloading areas and procedures – Site opening/closing times (including deliveries) – Behavioural practices that minimise noise – Avoiding dropping materials from height and avoiding metal to metal contact – Complaints handling process.
Construction Noise and Vibration Management Plan	The Proposal's CEMP will include a Noise and Vibration Management Plan, which will be prepared prior to construction activities commencing.

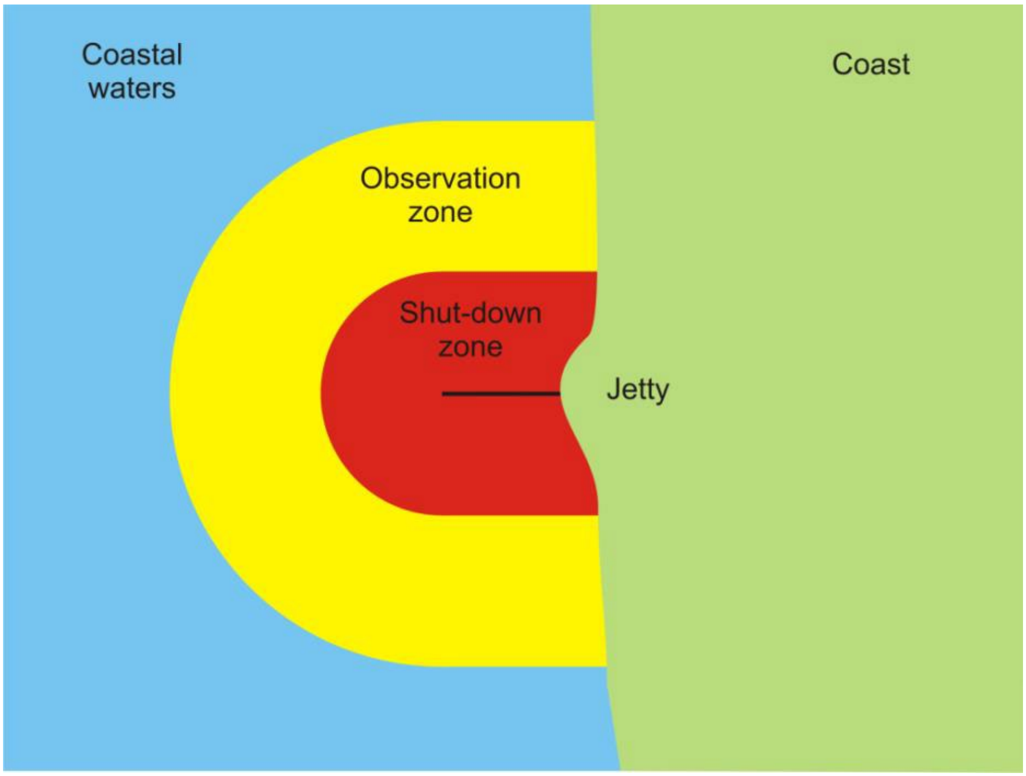
[1] The Referral Report stated, "*Noise generating activities with the potential to impact receptors are to be scheduled during recommended standard construction hours (7 am to 7 pm on Monday to Saturday and 9 am to 6 pm on Sunday).*" An error was made in the Referral Report and has been updated. The updated construction hours reflect the standard work hours already implemented by GEMCO.

Control type	Mitigation measures
Community notification	Notification regarding specific construction activities will be provided to residents and property owners likely to be affected by noise and vibration from the activity. Such notification should be provided prior to the activity commencing (typically one week notice) and should provide the following details: – The reason for the activity – Types of equipment required – The expected hours of operation, including any permitted site preparation works which will occur outside the recommended standard hours – The likely duration and impact of operation at the site and any requirement for subsequent additional works – Contact details for further information and complaints. Check-ins with adjacent residents and property owners regarding construction noise and vibration impacts will be undertaken when construction is occurring in close proximity, where possible.
Consultation	Prior to commencing the construction activities, noise affected residences will be asked about potential concerns they have, and possible solutions will be discussed. During the construction activities the noise affected residences shall be informed of the progress of the works, where possible.
Handling of complaints	The Proposal will establish an effective documented complaints handling process which provides a fair and quick response to valid complaints. A complaint handling process will consider the following: – A dedicated phone line will be provided to enable the community to contact a central project representative – A central point of contact will have the authority to alter mitigation, management and construction activities onsite – A register of complaints will be maintained – Notification of construction project manager within 24 hours of any complaints received or within 24 hours of becoming aware of any noise nuisance caused by construction activities – Internal and external reporting procedures – Complaints will trigger an investigation in which the construction activities at the time of the reported nuisance would be investigated. A noise monitoring program would be undertaken if the investigation determines it is warranted. For example, if multiple complaints are received from multiple receptors, suggesting a pattern of nuisance.
Plant and equipment	Quieter alternative construction methods will be implemented where reasonable and feasible. For example, where impact piling is not required, vibratory piling should be undertaken instead.
	Selecting plant and equipment based on noise and vibration emission levels.
	Ensuring equipment is operated in the correct manner and correctly maintained including replacement of engine covers, repair of defective silencing equipment, tightening of rattling components, repair of leakages in compressed air lines and shutting down of equipment not in use.
	Turning off plant and equipment or throttling them down to a minimum when not in use.
Acoustic screening	Where fixed plant (such as generators) contributes to the received noise levels, acoustic shielding will be considered such as enclosures or barriers.
Reversing alarms	Broadband reversing alarms will be used where reasonable and feasible instead of traditional beeper reversing alarms.
Plant and equipment maintenance	Vehicles, plant and equipment will be regularly maintained and kept in good operational condition.
Number of operational plant and equipment	The number of items of equipment will be reduced to minimise noise impacts during construction works during construction works outside of the recommended hours.

D-4-2 Underwater noise during construction

Key mitigation measures to reduce the risk of noise related impacts on marine fauna from impact piling are identified in Table D.5.

Table D.5 Construction underwater noise mitigation measures

Control type	Mitigation measures
Safety zones for marine mammals and turtles	Two safety zones are to be applied around each noise generating activity location: – **An observation zone**, within which the movement of marine mammals, whale sharks and marine turtles will be monitored to identify any approach to the shut-down zone where practicable. The observation zone is sized based on a nominal 250 m distance from the outer edge of the shut-down zone. – **A shut-down zone**, within which the observation of marine mammals, whale sharks and marine turtles will trigger noise-generating activities to cease as soon as reasonably practical. Shut-down zones are sized based on the potential for a TTS.
	The zones are not designed to eliminate behavioural reactions to audible noise that do not cause physical injury. It is expected that marine mammals near a loud activity will display avoidance behaviours, reducing the risk of them coming close enough to the source to experience hearing damage (i.e., entering the shut-down zone). The effects of such temporary displacement are generally not significant unless they repeatedly interfere with critical behaviours like breeding, feeding, and resting, or occur in key areas such as migratory paths, calving or nursery grounds and important feeding zones. The safety zones can be refined via review of the impact piling operations and modelling assumptions, including: – Confirmation of detailed construction methodologies – Consideration of additional mitigation measures to reduce noise levels. For cumulative SEL 24-hour noise thresholds, these zones are bounded by the worst-case high-frequency cetacean marine mammal group present in the Study area. Without additional mitigation measures, the shut-down zone is calculated to be 250 metres and the observation zone is calculated to be 500 metres for impact piling activities. An example of the safety zones is illustrated in Figure D.1 (SA DIT, 2023).  *Figure D.1 Observation and shut-down zones around noise source (SA DIT, 2023)*

Control type	Mitigation measures
Planning of activities for impact piling	The following measures pertaining to the planning of impact piling activities are to be incorporated into the marine fauna management plan: – **Timing and duration:** Impact piling activities should avoid periods when marine megafauna are likely to be breeding, calving, feeding, or resting within biologically important habitats in the potential noise impact area. – **Marine fauna observer (MFO):** Ensure a suitably qualified MFO (minimum of MFO Level 2 as defined in the SA Guideline) is present during impact piling to oversee and enforce standard operational procedures. – **Educational materials:** Provide all staff with briefings on environmental regulations, marine mammal (and other relevant marine fauna) identification, and specific environmental obligations. Information about marine mammal concentration areas, migration patterns, and key feeding sites should be identified during planning and used to enhance the effectiveness of marine fauna observation. – **Contract documentation:** Standard operational procedures and any additional protective measures should be included in the contract documentation for the impact piling rig contractor/operator.
Standard operational procedures	The following standard operational procedures for impact piling activities are to be incorporated into the marine fauna management plan: – **Pre-start procedure:** Contractors should visually monitor for marine mammals and other relevant marine fauna from a high vantage point for at least 30 minutes before starting impact piling (MFO). This is to ensure the area, especially the shut-down zone, is clear of marine life. – **Soft-start procedure:** If no marine megafauna are observed, contractors can begin the soft start, gradually increasing piling impact energy over 10 minutes. This procedure is also required after any break in impact piling longer than 30 minutes to alert marine life and allow them to move away. Visual observations of marine mammals within the safety zones shall be maintained by the MFO throughout soft starts. The soft start procedure is an added safeguard that can be used to alert marine fauna to the presence of the impact piling rig and enable animals time to move avoid the area to distances where injury is unlikely. – **Normal operation procedure:** Full impact piling can proceed if no marine megafauna are detected during the soft start. Visual monitoring must continue, and the pre-start checks are repeated after significant breaks or visibility issues. – **Stand-by operations procedure:** If marine megafauna are spotted in the observation zone during operations, the impact piling rig operator must be on stand-by to shut-down the impact piling rig should the marine megafauna enter the shut-down zone. – **Shut-down procedure:** Impact piling must stop immediately if a marine megafauna enters the shut-down zone. Operations can resume with a soft start once the animal leaves the zone or after 30 minutes without sightings, unless visibility is poor, in which case operations remain halted until conditions improve. – **Compliance and sighting report:** The impact piling contractor is required to keep a detailed record of the procedures employed during operations and information on any marine megafauna sighted during the activities and their reaction to the activity. A report on the activity should include location, date, start and completion of the impact piling activities, and information of the impact piling rig (hammer weight, drop height, pile size, number of piles, no. of impacts per pile etc.).

D-4-3 Operational noise

Operational noise impacts from the proposed generators and pump stations are not anticipated, and as such specific mitigation measures are not required to be implemented.

D-5 Culture and heritage

The following measures in Table D.6 will be implemented to mitigate risk to heritage for the proposed construction works.

Table D.6 Construction mitigation measures for culture and heritage

Control type	Mitigation measure
Avoidance	Avoidance of known heritage sites at Groote Eylandt identified through previous heritage surveys was achieved through design.
Authority certificate	Apply for an Authority Certificate under the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT).
Consultation	The ALC will be consulted with as part of the Proposal to confirm that the Proposal is executed in line with the guiding principles of the Anindilyakwa IPA Plan of Management (ALC, 2016).
Heritage induction	Heritage induction requirements for relevant personnel undertaking or supervising ground-breaking works. The induction will include the unexpected finds procedure and any sacred site requirements identified on the Authority Certificate.
Disturbance minimisation	No ground disturbing works will take place outside of the approved Project area.

Unexpected finds procedure

The cultural heritage assessment found that the risk of encountering unknown Aboriginal, historic heritage, or natural heritage sites and objects during construction is low. However, if unexpected heritage is identified, the following unexpected finds procedure will be implemented during construction to meet the obligations *under the Heritage Act 2011*. This procedure will be included in the CEMP.

If a suspected cultural heritage place or object is discovered:

1. Refer to the **Discovery of Potential Human Remains** procedure below if the discovery is suspected of being human remains
2. All work within a 50 m radius of the suspected cultural heritage must cease immediately and the area flagged/fenced appropriately to ensure that no further work is undertaken within it
3. The discovery must be reported immediately to the Site Supervisor, who immediately communicates with the Project Manager
4. The Project Manager must notify a Heritage Officer at NT Heritage Branch on 08 8999 5039 or **Heritage.Branch@nt.gov.au**
5. Report in writing as soon as practical, finds that are Aboriginal or Macassan archaeological objects or places, as defined in the *Heritage Act 2011*, to the CEO of the Heritage Branch. The report must include:
   - A description of the place or object
   - Its location (including spatial data)
   - The person who discovered the material's name and address
   - If known by the person – the name and address of the owner or occupier of the place or place where the object is located
6. Work shall not recommence in the vicinity of the find until direction is provided by the Heritage Branch.

If works are to continue within the area of a known/identified archaeological place or object, then an Application to Carry out Works will be submitted to the Northern Territory Heritage Council for consideration. The Minister will (likely) make the final determination on if the object or place can be moved or destroyed. Works cannot recommence within the area until that determination is made.

Unexpected Finds Protocol: Skeletal Remains

If potential human material is identified:

1. All work within a 50 m radius of potentially human material must stop immediately
2. The discovery must be immediately reported to the Site Supervisor who must immediately notify the Northern Territory Police on 131 444. No temporary fencing should be erected unless directed to do so by the Police
3. The Police will take control of the site as a potential crime scene
4. If there are reasonable grounds to believe that the remains are:
    a. A crime scene – the Police will provide direction on the management of the discovery
    b. If remains are Aboriginal ancestral or historical remains rather than a crime scene, the Project Manager should immediately notify:
        i. A Heritage Officer at NT Heritage Branch on 08 8999 5039 or **Heritage.Branch@nt.gov.au**
        ii. As soon as practicable after the discovery, write a report to the CEO of the Heritage Branch. The report must include a description of the place or object; its location; the person's name and address; and if known by the person – the name and address of the owner or occupier of the place or place where the object is located
        iii. Relevant Traditional Owners (Land Councils and Aboriginal Areas Protection Authority) if finds are Aboriginal or Macassan archaeological objects: ALC (08 8996 4999) and AAPA (08 8999 4332)
5. Work is not to recommence in the vicinity of the find until direction is provided by the relevant authorities (Police and Heritage Branch, Northern Territory Government).

Unexpected Finds Protocol: underwater cultural heritage

Underwater cultural heritage is protected under the *Underwater Cultural Heritage Act 2018* which is administered in the Northern Territory by the Heritage Branch. Underwater Aboriginal archaeological places and objects, and wrecks sunk over 75 years ago are automatically protected by this Act. Underwater Cultural Heritage can also be protected as declared heritage under the *Heritage Act 2011*. If new artefacts are found underwater the following steps should be made:

- All work within a 50 m radius of the suspected underwater cultural heritage will cease immediately
- The discovery must be reported immediately to the Site Supervisor, who immediately communicates with the Project Manager
- The Project Manager must notify a Heritage Officer at NT Heritage Branch on 08 8999 5039 or **Heritage.Branch@nt.gov.au**
- Work is not to recommence in the vicinity of the find until direction is provided by the Heritage Branch of the Northern Territory Government.

D-6 Air quality

Proposal relevant mitigation measures proposed to avoid or minimise potential air quality impacts sourced from the IAQM Guidance during construction and operation of the Proposal are listed in Table D.7. These measures are to be implemented where reasonable and practicable in areas of the construction footprint where impacts to sensitive receptors are likely.

It should be noted that existing material stockpiles, which will be utilised are currently managed under the existing MMP, which includes active air quality monitoring adjacent to the northern most construction boundary.

Table D.7 Mitigation measures for construction for air quality

Activity type	Mitigation measure
General site management during construction	Where practicable and feasible, site layout will be planned, so that machinery and dust causing activities are located away from receptors, as far as possible.
	Bulk cement and other fine powder materials are to be delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfill during delivery.
	For smaller supplies of fine powder materials bags are to be sealed after use and stored appropriately to prevent dust.
Track out activities	The use of water-assisted dust sweeper(s) on the access and local roads will be considered, to remove, as necessary, any material tracked out of the site. This may require the sweeper being continually in use.
	Dry sweeping of large areas will be avoided
	Vehicles entering and leaving sites are to be covered to prevent escape of materials during transport.
	On-site tracks and roads will be inspected for integrity and instigate necessary repairs to surface as soon as reasonably practicable.
	All inspections of haul routes and any subsequent action will be recorded in a site logbook.
	There is to be adequate area between the wheel wash facility and the site exit, wherever site size and layout permit.
Earthworks	Earthworks and exposed areas/soil stockpiles will be revegetated to stabilise surfaces as soon as practicable.
	Hessian, mulches or tackifiers will be used where it is not possible to re-vegetate of cover with topsoil, as soon as practicable.
	The cover will only be removed in small areas during work and not all at once.
	Dust suppression will be undertaken, as required, using water sprays water extension agents, soil stabilising polymers or other media on: – Unpaved work areas subject to traffic or wind – Spoil and aggregate stockpiles – During the loading and unloading of dust generating materials – Unpaved access tracks.
	Plant / vehicle movements will be limited to designated access tracks and haul roads.
	Plant and equipment will be switched off when not in use.
	Visual monitoring will be undertaken to confirm implementation measures are effectively managing dust emissions.
General – Complaint management	A stakeholder communications plan that includes community engagement will be developed and implemented before work commences onsite.
	The name and contact details of person(s) accountable for the air quality and dust issues will be displayed on the site boundary. This may be the environment manager/engineer or the site manager.
	All dust and air quality complaints will be recorded, causes identified, and appropriate measures will be taken to reduce emissions in a timely manner, and recorded.

Appendix E

Marine monitoring strategy

E-1 Marine monitoring strategy

GEMCO are committed to developing and implementing a CEMP and OEMP for the Proposal. Embedded within these documents will be monitoring programs to support adaptive management of the Proposal. The following sections outline the approach to monitoring in the marine environment.

E-1-1 Marine water quality

Marine water quality will be monitored under three program elements:

– Continuation of the established GEMCO Marine Environment Monitoring Program (MEMP)
– Receiving environment monitoring to validate the findings of the marine discharge mixing zone modelling
– Receiving environment monitoring to inform adaptive management during construction and operation.

Continuation of GEMCO MEMP

The GEMCO MEMP was established in 2013. This program will continue for the duration of the Proposal. The MEMP includes:

– Monitoring at sites in the vicinity of the port and at control locations to the north and south of the port
– Annual sampling (generally during neap tides of October-December) for analysis of metals, hydrocarbons and nutrients collected from:
  - Surface waters
  - Sediments
  - Biota (fish and oysters – metals and hydrocarbons) (undertaken every two years)
– Monthly water quality monitoring of the receiving environment in relation to the treated effluent discharge at Milner Bay. This comprises analysis of surface waters for metals, nutrients and total suspended solids (TSS), as well as in situ monitoring of turbidity, EC, total dissolved solids (TDS) and dissolved oxygen (DO) in surface waters.

Model validation monitoring

Modelling has been undertaken to inform the impact assessment for the Proposal. This has included the prediction of mixing zones associated with excess water discharge. Following commencement of the Proposal operation, a monitoring event will be undertaken to measure water quality parameters within and beyond the predicted mixing zones. Parameters to be measured will include metals, nutrients, pH and TSS.

Results will be used to inform any possible amendments to the GEMCO MEMP.

Receiving environment monitoring

A receiving environment monitoring program (REMP) will form the basis of an adaptive management program during construction and operation. The REMP will be based on the principles and key research findings that have been published by the Dredging Science Node of the Western Australian Marine Science Institution (WAMSI DSN). The outputs from the WAMSI DSN are considered to be leading practice technical guidance for marine dredging by the NT EPA, as noted in the Draft Marine Dredging Guideline (NT EPA, 2023).

Table E.1 provides details regarding proposed REMP program elements.

Table E.1 Receiving environment monitoring program details

Program element	Details
Monitoring locations	As detailed in the modelling report (Appendix A), no zones of impact apply (ZoHI and ZoMI) for the proposed discharge activities. GEMCO will establish three monitoring locations, comprising: – One test location at the reef area between the marine footprint and the wharf, within the modelled Zone of Influence – One test location to the south of the marine footprint in proximity to the rocky reef/seagrass area, within the modelled Zone of Influence – One far-field reference location beyond the modelled Zone of Influence. Monitoring will be undertaken on the seabed, in waters no greater than 5 m lowest astronomical tide (LAT).
Parameters	At each location turbidity and underwater light (photosynthetic active radiation – PAR) will be monitored.
Monitoring frequency & relevant statistics	Parameters will be measured in near-real time at 15 minute burst intervals, with collated data presented as the following statistics: – Turbidity (NTU): 15-minute burst mean, daily average, 7 day and 14 day running mean – Underwater light (PAR): 15-minute burst median, daily light integral (DLI) (mol/m^2/day), 7 day and 14 day DLI running mean.
Program duration	The REMP will be established prior to the commencement of construction to collect baseline water quality data. This data will be used to confirm the appropriateness of the nominated ecologically relevant trigger values (refer to “Adaptive Management–threshold determination” below). The program will remain in place for the duration of construction and for the first year of operation. In parallel to the REMP, monitoring of discharge water quality is proposed to be undertaken during discharge activities; data will be used to support interpretation of the receiving environment monitoring results. After one year of REMP operational monitoring the data will be reviewed to confirm adequacy of the of the operational controls associated with monitoring of discharge water. This review will inform potential revisions to the REMP and/or need for continued monitoring.
Data & Field QA/QC	Biofouling of deployed equipment will be managed via a monthly maintenance program. Monthly maintenance will also enable management of batteries, data downloads and equipment changes. All deployed equipment will be serviced and maintained in accordance with manufacturer specifications, with appropriate calibrations applied. Collected data will be reviewed against set QA/QC criteria, with unreliable data removed from the data set.
Data accessibility	During baseline monitoring data will be downloaded during monthly maintenance events. During construction and operation telemetered buoys will be deployed, with data transmitted in near real time to an online platform for display and analysis.

Adaptive management – threshold determination

Corals and seagrasses are unable to distinguish between natural and anthropogenic turbidity related events (Jones et al., 2017). As such the determination of threshold values to manage sub-lethal and lethal impacts to these sensitive receptors must consider cumulative pressure, encompassing intensity and duration. The use of running mean intervals over a number of telescoping timeframes enables this such that the influence of short-term acute events as well as longer-term chronic events are captured (Jones et al., 2015). Running mean interval timeframes must be ecologically relevant, covering periods where sub-lethal responses are likely to commence, enabling management intervention in a timely manner. Further, they must also be relevant to the sensitive receptors present on site.

Fisher et al. (2019) note that when using the running mean approach total pressure on the system must be accounted for. Therefore, in the application of running mean intervals the following will be undertaken (per Fisher et al., 2019, p36):

- Pressure experienced at each site will be calculated using the parameter of light; it will be calculated in absolute terms (i.e. a running mean of ***x*** DLI (mol/m^2/day) over a period of ***y*** days)
- Pressure experienced at each site will not be calculated as a change in light conditions at sensitive receptor sites relative to reference sites
- Specified running mean time intervals will be used to track changes in light conditions at each site rather than coarser time averaging approaches.

For the management of sub-lethal and lethal responses of corals to turbidity and light stress Fisher et al. (2019) notes that there are multiple lines of evidence that indicate that a 14-day running mean period is an appropriate time scale. Collier et al. (2016) have identified minimum light requirements for maintaining seagrass abundance (biomass, density, percent cover) for species that occur in the Great Barrier Reef World Heritage Area; these species also occur in the Gulf, including at Groote Eylandt. Running mean intervals range from 1-14 days depending on the sensitivity and resilience of each species.

Preliminary threshold values have been nominated in Table E.2. These values are based on scientific literature and are relevant to the benthic communities present in the region. Baseline data will be used to test the appropriateness of these preliminary thresholds prior to the commencement of construction.

Table E.2 Preliminary threshold values for corals and seagrasses based on daily light integral (DLI)

Sensitive receptor type	Running mean interval	DLI threshold value	Days to impact
Coral*	14 days	2.3 mol/m^2/day	49 days*#
Seagrass^	7 days	2.0 mol/m^2/day	14 days^

* From Jones et al. (2020)

\# Most corals except *Pollicipora damicornis* capable of adjusting to 2.3 mol/m^2/day over 7 week period (Jones et al., 2020)

^ From Collier et al. (2016) – Appendix 1, Table 1

An adaptive management program will be established based on confirmed threshold values. This program will implement a tiered early warning system whereby management interventions will be implemented prior to impact being realised (as defined by days to impact in Table E.2). Management interventions will be tailored to the program stage and could include the following:

- During construction:
  - Review of efficacy of installed silt curtains
  - Modification of trenching works (location, duration, etc)
  - Temporary cessation of trenching works
- During operation:
  - Review of monitoring data at NH2 quarry. In-line real time turbidity monitoring will support assessment of the quality of water being discharged.
  - Review of management of water storage (NH2 quarry)
  - Modification or temporary cessation of excess water discharge.

E-1-2 Benthic communities

Primary producer communities: Coral, seagrass and macroalgae

A primary producer monitoring program will be established to monitor the extent and composition of coral, seagrass and macroalgae communities within the Project area as well as at a reference location beyond the modelled Zone of Influence. Table E.3 provides details regarding this program.

Table E.3 Coral and seagrass monitoring program details

Program element	Details
Monitoring locations	Monitoring will be undertaken at three locations, corresponding with the habitats to be monitored under the REMP: – One test location at the reef area between the marine footprint and the wharf, within the modelled Zone of Influence – One test location to the south of the marine footprint in proximity to the rocky reef/seagrass area, within the modelled Zone of Influence – One far-field reference location beyond the modelled Zone of Influence (note this may require two different locations to provide reference for both coral and seagrass/macroalgae).
Methodology	At each location a benthic assessment will be undertaken to determine: – Presence and composition of seagrasses, including species and percentage cover – Presence and composition of macroalgae, including species (or growth morphology) and percentage cover – Presence and composition of coral communities, including species (or growth morphology), percentage cover, and health indicators including evidence of bleaching/smothering/disease/predation.
Monitoring frequency	Monitoring will commence prior to construction and will be undertaken twice a year for a minimum of two years. This will span the pre-construction, during construction and operational periods. The need for ongoing monitoring will be determined in consultation with the ALC and other relevant stakeholders.
Analysis and reporting	Collected data is to be analysed and presented to the ALC and any other interested parties on an annual basis.

Infauna

An infauna monitoring program has been established to monitor infauna communities within the Project area, as well as at a reference location beyond the modelled Zone of Influence. This program has been committed to by GEMCO in response to queries raised by the ALC regarding infauna composition. This program is not intended to become a means of measuring compliance of the Proposal, but rather a mechanism to gather and share knowledge with Traditional Owners. Table E.4 provides details regarding this program.

Table E.4 Infauna monitoring program details

Program element	Details
Monitoring locations	Monitoring locations will be nominated within the marine footprint, Zone of Influence and at a far field reference location
Methodology	At each site three replicate samples are collected for analysis (n=3). Samples will be collected using a 1L van veen grab sampler deployed from a vessel to the seabed. Upon retrieval each sample will be individually processed through a 1 mm mesh sieve using marine water. Retained infauna will be collected and preserved for later analysis. Retrieved samples will also be photographed, with sediment composition and any other relevant attributes recorded.
Monitoring frequency	Monitoring is proposed to be undertaken twice a year for a minimum of two years. This will span the pre-construction, during construction and operational periods. The need for ongoing monitoring will be determined in consultation with the ALC.
Taxonomic resolution	Collected samples are subject to identification and enumeration. Family-level taxonomic identification will be applied.
Analysis and reporting	Collected data is to be analysed and presented to the ALC on an annual basis.

E-1-3 References

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