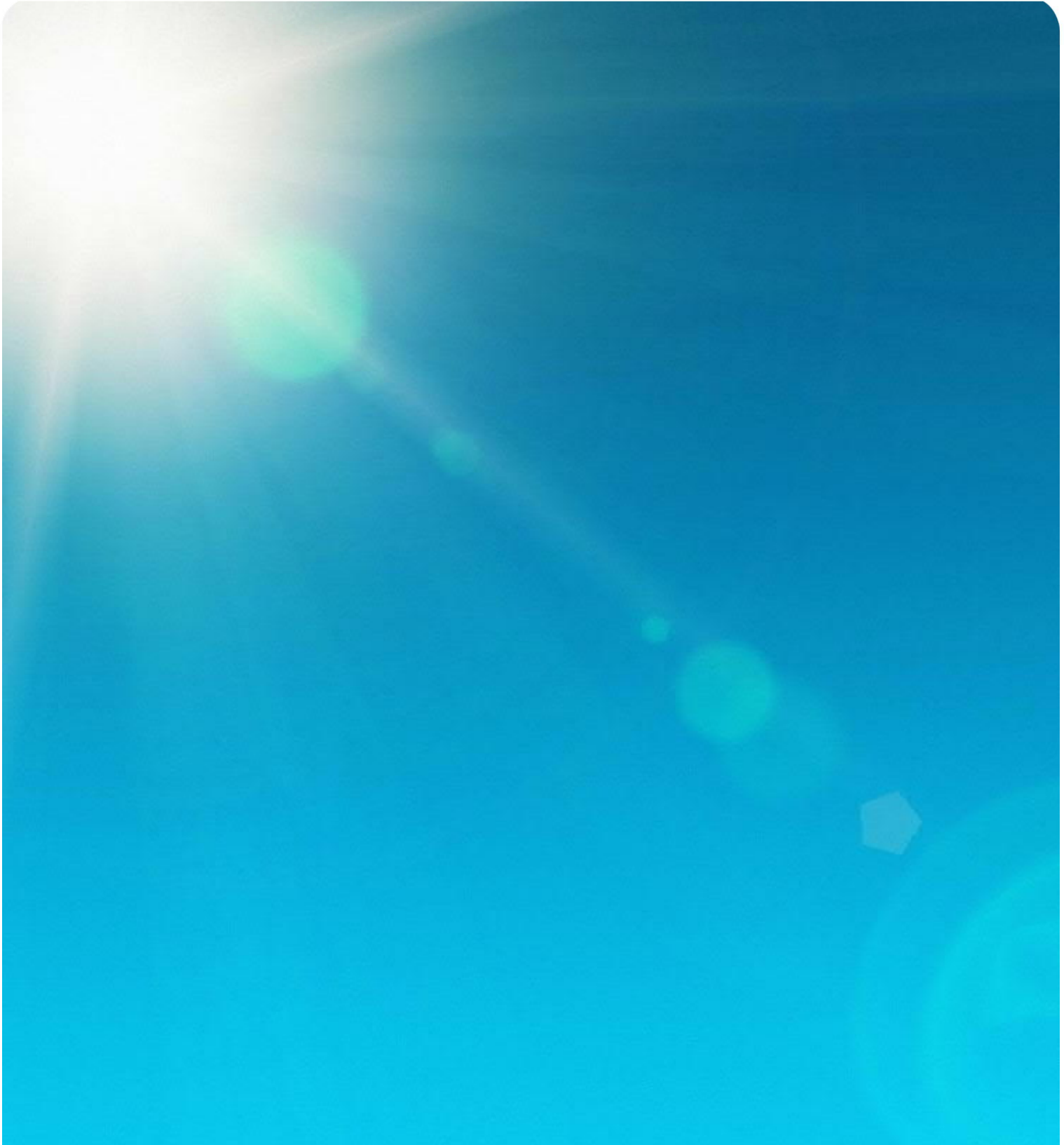


March 2022

# Appendix R – Marine Modelling Report

Australia-Asia PowerLink Environmental Impact Statement



# Hydrodynamic, Wind Wave and Sediment Transport Modelling



# Hydrodynamic, Wind Wave and Sediment Transport Modelling

Sun Cable Australia-Asia PowerLink Environmental Impact Statement

Prepared by MetOcean Dynamic Solutions Pty Ltd

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## Abbreviations

Abbreviation / Unit	Description
AAPowerLink	Australia-Asia PowerLink
EEZ	Australia's Exclusive Economic Zone
AIMS	Australian Institute of Marine Science
BoM	Bureau of Meteorology
BRAN	Bluelink ReANalysis
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEPWS	Department of Environment, Parks and Water Security
DTVs	Default Trigger Values
EcOz	EcOz Environmental Consultants
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
EP Act	Environmental Protection Act 2019
EPBC Act	Environment Protection and Biodiversity Conservation Act
ERS	European Remote Sensing
GFO	Geosat Follow-on
GW	Gigawatt
ha	Hectare
HDD	Horizontal Directional Drilling
HVDC	High-voltage Direct Current
kg/m <sup>3</sup>	Kilogram per cubic metre
km	Kilometre
kV	Kilovolt
LSJ	Land Sea Joint (station)
m	Metre
MetOcean	MetOcean Dynamic Solutions Pty Ltd
mg/L	Milligrams per Litre
mm	Millimetre
MSL	Mean Sea Level
µm	Micrometre or micron, 1 x 10 <sup>-6</sup> m
NAXA	The North Australia Exercise Area (military)
NT	Northern Territory
OHTL	Overhead Transmission Line
PSD	Particle Size Distribution
SSC	Suspended Sediment Concentrations
Sun Cable	Sun Cable Pty Ltd
TMD	Tidal Model Driver

Abbreviation / Unit	Description
TOR	Terms of reference
VSCs	Voltage Source Converters
WQO	Water Quality Objective

## Executive Summary

Sun Cable Pty Ltd is developing the Australia-Asia PowerLink, which will establish a high-voltage direct current (HVDC) transmission network, connecting Northern Territory and Singapore energy markets to a new solar precinct in Northern Australia. A subsea fibre optic cable network will extend approximately 4,200 km from Murrumujuk in the Northern Territory to Singapore, via Indonesia. The environmental authorities decided that the proposed action in Australian waters requires formal assessment at the level of an Environmental Impact Statement (EIS).

In order to support the EIS, MetOcean Dynamic Solutions Pty Ltd was engaged to conduct a modelling study to determine transport, extents and dispersion of suspended sediment plumes that could occur as a result of the proposed submarine cable laying operations. The final approach for the submarine cable laying operations has yet to be decided, nevertheless conventional trenching for land/sea crossing and high-pressure jetting techniques were modelled as the most probable approach.

A numerical model representation of ocean circulation and waves within the area of interest was required to assess the transport phenomena resulting from tidal, wind wave and meteorological forcing. The Delft3D modelling package, which includes the hydrodynamic (FLOW), wave (WAVE) and water quality (DELWAQ) modules, was selected as a modelling platform for the project. The DELWAQ model was used to predict far-field suspended sediment temporal and spatial patterns.

Two detailed model configurations were developed for the project development areas: (1) a nearshore model covering Beagle Gulf and Darwin Harbour, and (2) an offshore model covering the project area in the Timor Sea.

Time-varying, spatially homogenous wind and space-varying tidal components were used to drive the nearshore hydrodynamic and wave models in a coupling mode. Conservative wave boundary conditions were selected to represent waves that may have a significant impact on resuspension of sediments.

The offshore, 3D hydrodynamic model was driven by space-varying tidal components and regional scale three-dimensional currents. The effect of waves in the offshore part of the project was assumed to be negligible and therefore the offshore waves were not modelled.

Both of the hydrodynamic models were successfully validated using local observations. The results of the nearshore coupled hydrodynamic and wave simulations and the offshore hydrodynamic simulations were used as inputs to the corresponding water quality (sediment transport) models.

Based on geotechnical field investigations the material was assumed to be a mixture of clay, silt and fine sand. Conservative volumes and rates of sediment discharges were adopted, assuming a 30% loss of the trench contents to the overlying water layer. Both the nearshore and offshore sediment transport models were run to simulate the effects of trenching operations to simultaneously bury three parallel underwater cables separated by 50-100 m in three successive 50 km paths. In fact, the cables will be laid individually (unless they are bundled) and separated by a distance of 50-200 m. Much smaller environmental effects are expected with cables laid individually at a larger separation distance. It should be noted that Sun Cable proposes to install up to six cables (2 circuits comprised of three cables); however, as only three cables would be installed in a single installation campaign, this number was used in the model assumptions.

Analyses of project operations suggested that localised changes to the coastline and bathymetry due to subsea cable laying and construction activities are likely to be temporary with no significant change to the local topography or sediment characteristics, therefore they were not modelled. In both the nearshore and offshore project areas, the seabed disturbance (direct project impacts) is expected to be limited to an area of up to 10 m wide for each cable and less than 0.01 km<sup>2</sup> for the land sea station/shore crossing.

Water quality objectives were selected as performance criteria to assess the predicted project impacts on water quality. Spatial distributions of median values (50<sup>th</sup> percentile) of predicted suspended sediment concentrations were compared with the performance criteria to determine "typical" water quality impacts and their zone of influence. Maps of the 95<sup>th</sup> percentile concentrations were used to determine the upper level ("worst-case") of possible impacts and their zone of influence.

Based on modelling results for both areas of the project, the predicted median concentrations ("typical" impacts) are below their corresponding water quality objectives, except a small patch (~800 m x 200 m) in proximity to the sources in the nearshore project area.

Modelled nearshore jetting operations indicate that trenching closer to the coast in Shoal Bay would result in higher impacts than further off the coast. Coastal area (20 km x 11 km) would be affected by the 95<sup>th</sup> percentile concentrations ("worst-case") above the water quality objective.

In the offshore project area, the 95<sup>th</sup> percentile concentrations (“worst-case”) are highest (above water quality objective) within approximately 1 km from the route, while concentrations do not exceed 4 mg/L anywhere in the model domain.

With each pass of the trenchers, the plume of suspended sediments would persist for up to five days at the nearby sites before dispersing down to ambient conditions in both project areas. The results suggest that trenching operations would have a relatively short-term effect on the ambient conditions, with far-field concentrations likely to be within the range of natural variability expected for both the nearshore and offshore areas.

Although best efforts were undertaken to reduce model uncertainties in this study, it is important to interpret the results in the context of model limitations.

## 1.0 Introduction

Sun Cable Pty Ltd (Sun Cable) is developing the Australia-Asia PowerLink (AAPowerLink), a renewable energy transmission system that connects Northern Territory (NT) and Singapore to a new, large-scale solar precinct and battery systems located in the Barkly Region of the NT. The project proposal comprises six key components:

- Solar Precinct where electricity will be generated, stored, and transmitted, near Elliott in the Barkly Region, NT
- Overhead Transmission Line (OHTL) to transmit electricity from the Solar Precinct to Darwin
- Darwin Converter Site including Voltage Source Converters (VSC), energy storage and network connection to supply electricity to the Darwin region
- Cable Transition Facilities to enable transition of power cables between land and sea
- Subsea Cable System extending between the Cable Transition Facilities and Singapore
- Singapore Converter Station to receive electricity and supply the Singapore electrical network.

The NT Environment Protection Authority (EPA) decided that the proposed action requires formal assessment under the *NT Environmental Protection Act 2019 (EP Act)* at the level of an Environmental Impact Statement (EIS). The proposal is also being assessed under the *Environment Protection and Biodiversity Conservation Act 1999*. The terms of reference (TOR) for the EIS set out the matters relating to the environment that are to be addressed. The TOR identified a number of key environmental factors that could be significantly impacted by the Proposal, these include the marine environmental quality factor with the following objective:

*Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.*

The TOR requires that a proposal footprint (direct disturbance) and zone of influence (indirect disturbance) are to be established to identify the components of the environment (under the marine environmental quality factor) that could be impacted by implementation of the proposal.

MetOcean Dynamic Solutions Pty Ltd (MetOcean) was engaged by EcOz Environmental Consultants (EcOz) to provide technical background for the environmental impact assessment of the proposed submarine cabling operations to support the environmental approvals process under both *the NT EP Act* and *EPBC Act*.

This report provides the results of desktop studies and modelling undertaken to inform the assessment of environmental impacts associated with installation of the Subsea Cable System component of the proposal. The system consists of up to six parallel High Voltage Direct Current (HVDC) cables that will extend approximately 4,200 km from the Cable Transition Facilities at Murrumujuk in the NT to Singapore. The portion of the submarine cable route within the NT coastal waters (three nautical miles from the Territorial Sea Baseline) is approximately 100 km long, and the portion in the Commonwealth waters to the edge of Australia's Exclusive Economic Zone (AEEZ) is approximately 640 km (Figure 1). The remaining section outside the AEEZ falls within the jurisdictions of Indonesia and Singapore respectively and is therefore not assessed in this report.

Environmental impacts of submarine cables may occur during their laying, operation and removal stages and usually associated with suspended sediments and increases in turbidity (Taormina et al., 2018). This report presents hydrodynamic, wind wave and water quality (in terms of suspended sediment concentrations) modelling performed to assess the potential impacts on the marine environment that might be caused by Sun Cable submarine cabling operations (Project).

A description of the baseline marine environmental quality is presented in the AAPowerLink EIS Marine Environmental Quality report. Marine ecology assessment is presented in the AAPowerLink EIS Terrestrial Ecology and Marine Ecosystems report.

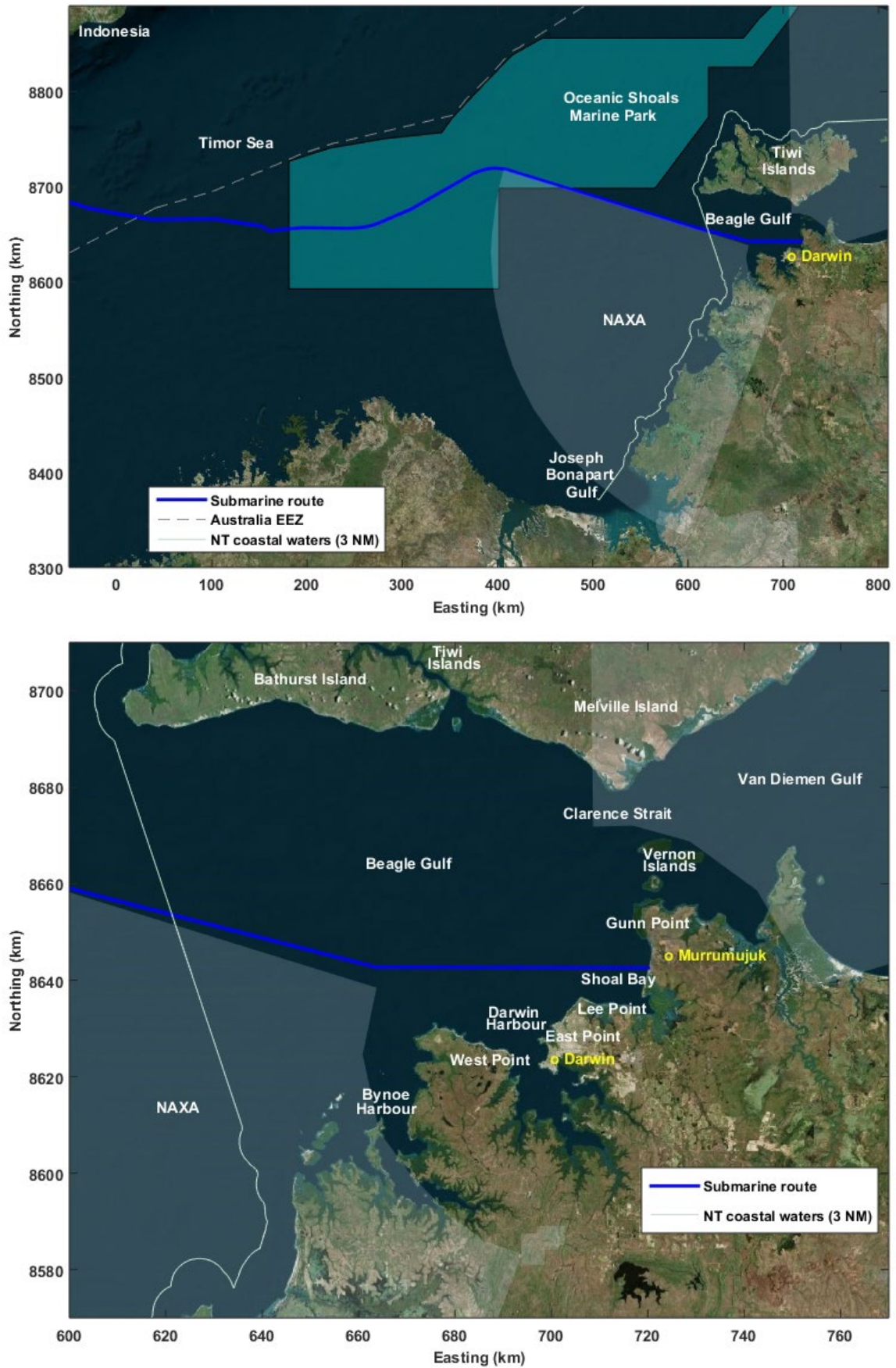


Figure 1 Project area in Australian waters (upper panel), zoom in into NT coastal waters (lower panel). NAXA is North Australia Exercise Area for military forces (Geoscience Australia, 2021)

## 2.0 Relevant legislation

### 2.1 Northern Territory Government

Northern Territory's water resources are managed through a regulatory framework prescribed by the Water Act 1992 and Water Regulations. The key principle on which this legislation is based is that the management of water is guided by its value which is in turn determined by its use or its purpose.

The Water Quality Protection Plan for Darwin Harbour (DLRM, 2014) ensures that water quality objectives (WQOs) are maintained and that the community's values for waterways (beneficial uses) are protected.

### 2.2 Commonwealth Government

Australia's National Water Quality Management Strategy is designed to facilitate water quality management for the productive and sustainable use of Australia's water resources and to protect aquatic ecosystems. The National Water Quality Management Strategy framework, including the Water Quality Guidelines, is voluntary, and different jurisdictions in Australia have different responsibilities. However, the Australian Government is responsible for managing water quality in the marine waters of the AEEZ, outside of state boundaries.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000), revised in 2018, guide the management of water quality for natural and semi-natural water resources. The guidance and guideline values are also voluntary. The main focus of the guidelines is on water and sediment quality within the context of broader ecosystem health management.

## 3.0 Assessment criteria

The Darwin Harbour WQOs provide locally derived guideline values for water quality indicators in Darwin Harbour, including Shoal Bay, to protect and sustain the identified environmental values and beneficial uses (Fortune, 2010). These include:

- To maintain and protect the ecological condition of marine, estuarine and freshwater ecosystems of the Darwin Harbour Region
- To maintain marine, estuarine and fresh water quality so that it is suitable for activities such as swimming and other direct water contact sports
- To maintain water quality for the production and consumption of aquatic foods derived from aquaculture, recreational, commercial or indigenous food gathering.

The Harbour's water quality has been graded annually against the Darwin Harbour WQOs and presented in the form of a Report Card since 2009 by the Department of Environment, Parks and Water Security (DEPWS) of the NT Government (e. g. Fortune, 2019).

ANZECC and ARMCANZ (2000) provide generic ranges of default trigger values (DTVs) for water quality indicators to help users assess whether water quality of a water resource is good enough to allow it to be used for humans, food production or aquatic ecosystems.

Key water quality indicator relevant to this study is turbidity or suspended solids (suspended sediment concentrations). Suspended solids and suspended sediment concentrations both represent the solid-phase material within the water column, with difference in the analysis method (Caltest, 2021). Turbidity is a measure of the light scattering property of water due to material suspended in the water, and is correlated with suspended solids. ANZECC and ARMCANZ (2000) indicate that ranges for turbidity and suspended solids are similar.

Table 1 shows WQOs established by ANZECC and ARMCANZ (2000) for tropical Australia and reported by DEPWS and DTVs for Darwin Harbour. Low DTVs are normally indicative of offshore waters. Higher DTVs are representative of estuaries or inshore coastal waters due to the wave/current-induced resuspension or input of turbid water from the catchment (ANZECC and ARMCANZ, 2000).

**Table 1** Reported water quality objectives and trigger values

Parameter	DTVs (ANZECC and ARMCANZ)	WQOs (DEPWS)
Turbidity (NTU)	1-20	<4
Suspended solids (mg/L)	1-20	<10*

\*As reported in Fortune (2015)

The adopted assessment criteria (WQOs) for the nearshore and offshore Project parts (Section 4.1.1) are presented in Table 2. Following the approach used for estimating water quality grades in Darwin Harbour by DEPWS (Fortune, 2019), median values (the 50<sup>th</sup> percentile) of predicted suspended sediment concentrations (SSC) were compared with the performance criteria to establish “typical” water quality and “typical” zone of Project influence (indirect disturbance) on the marine environment. The 95<sup>th</sup> percentile SSC were used to assess the upper level (“worst-case”) of possible Project impacts and establish “worst-case” zone of influence.

**Table 2** Adopted WQOs for the Project

Parameter	WQO-nearshore	WQO-offshore
Suspended solids (mg/L)	10	2

## 4.0 Methodology

### 4.1 Modelling approach

Prediction of potential effects that might be caused by Project submarine cable laying operations cannot be made with any degree of confidence without a comprehensive understanding of the existing environment in the study area. As part of the EIS, detailed reviews of the metocean conditions, climate, geomorphology, water and sediment quality were undertaken by the study team and presented in the AAPowerLink EIS Marine Environmental Quality report.

The main environmental effects of cable laying operations in the marine environment are usually associated with suspended sediments and increases in turbidity that may affect water quality. These effects are highly dependent on transport phenomena resulting from tidal, large scale current and/or meteorological forcing and waves.

Therefore, a two-fold approach was used for modelling:

- Predicting ocean circulation and wind wave patterns within the area of interest using wind wave and hydrodynamic models
- Predicting temporal and spatial effects of plumes, that may result from Project releases of suspended sediments, using a far-field water quality model.

#### 4.1.1 Study areas

The study area includes the portion of the submarine cable route within the NT coastal waters and another portion within the Commonwealth waters (see Figure 1). Due to the complex nature of the marine environment, which can be affected by different physical processes in the nearshore and offshore parts of the route (for more details see the AAPowerLink EIS Marine Environmental Quality report), the study area was divided into two compartments:

- The nearshore development area that extends along the submarine cable route for approximately 100 km from the land sea joint station near Murrumujuk in Shoal Bay into Beagle Gulf and the Timor Sea (Figure 1, lower panel). The area includes Shoal Bay Coastal Reserve and Tree Point Conservation Reserve protected by the NT government.
- The offshore development area, which includes the submarine cable route (approximately 640 km) in the waters of the Timor Sea to the edge of Australia’s EEZ (Figure 1, upper panel). The route traverses the western part of the Oceanic Shoals Marine Park protected by the Commonwealth.

#### 4.1.2 Key steps

The modelling methodology comprised the following key steps:

- Synthesis of the available, present-day bathymetry and coastline data sets

- Collation and pre-processing of relevant metocean data to provide inputs to the hydrodynamic and wind wave models
- Selection of appropriate modelling periods
- Schematisation of Project operations and development of model scenarios and inputs in consultation with Sun Cable
- Definition of the boundary conditions and inputs to the hydrodynamic and wave models
- Hydrodynamic model development, calibration and validation, where site specific monitoring data are available
- Wind wave model development
- Hydrodynamic and wind wave model runs
- Water quality model development and runs for Project submarine cable laying operations
- Post-processing, visualisation/mapping and interpretation of the modelling results.

Two separate sets of numerical models were developed for the Project to assess the impacts for the nearshore and offshore development areas.

The results were used to establish “typical” and “worst-case” water quality impacts and Project zone of influence that was determined by predicted levels of SSC above adopted WQOs. Project footprint (direct disturbance) was determined based on assessment of potential seabed disturbance due to the submarine cabling operations.

## 4.2 Data sources

### 4.2.1 Bathymetry and coastline

Detailed bathymetric data, which include information about the depths and underwater terrain, are required as an input to the hydrodynamic and wind wave models. The effect of incorrect bathymetry on computational fluid dynamics and wind wave models can be significant and, as such, the accuracy of bathymetry can be crucial to the success of the numerical models.

A number of data sources were investigated and several datasets were selected to represent the bathymetry of the Project area, such as:

- High resolution data (~1 m) collected in 2010-2011 in Darwin Harbour and collocated by Geoscience Australia (Siwabessy, 2015)
- High resolution data (~1 m) for Darwin Harbour collected and processed by Australian Institute of Marine Science (AIMS) in 2014 (AIMS, 2014)
- High resolution (~1 m) Outer Darwin marine survey data 2015 acquired by Geoscience Australia in collaboration with AIMS and the Department of Land Resource Management of the NT Government (Siwabessy et al., 2016)
- Australian bathymetry and topography grid (~250 m) Geoscience Australia (Whiteway, 2009)
- Survey data along the submarine route provided by Sun Cable.

The above data sets were combined (see Table 3) to produce bathymetry required for the hydrodynamic and wave models for the nearshore and offshore components of the Project. The resulting model bathymetry is presented in Figure 4 and Figure 6.

Vertical Datum for these data sets is Mean Sea Level (MSL). Coastline data were obtained from Geoscience Australia (Bishop-Taylor et al., 2021).

### 4.2.2 Wind and sea level

Wind and sea level are important parameters in modelling of both currents and waves, which in turn affect sediment transport and dispersion. Therefore, realistic representations of wind and sea level conditions are important in the numerical modelling of currents, waves and ultimately sediment transport.

As part of the Australian Baseline Sea Level Monitoring Project, the Bureau of Meteorology (BoM) maintains an array of SEAFRAME stations (BOM, 2021), which measure sea level and record meteorological parameters.

For the purposes of this study, wind and sea level observations collected by the closest to the Project area BoM station (071014, located 12.47°S, 130.85°E) were obtained for a 30-year period (1991-2020). Analyses of these data are presented in the AAPowerLink EIS Marine Environmental Quality report.

The measured wind speeds and directions for June-July 2016 were used in this study as input parameters to the nearshore hydrodynamic and wave models. For the offshore component of the study, gridded hindcast modelling outputs sourced from WaveWatch III (CSIRO, 2021; Durrant et al., 2014) were used for analyses of wind (see the AAPowerLink EIS Marine Environmental Quality report). The effect of wind was incorporated into the offshore model indirectly through timeseries of large-scale currents.

The monitored sea level data for the same period were used for model validations.

#### **4.2.3 Tides**

Space varying tidal component data were extracted from the Tidal Model Driver (TMD), which assimilates various satellite altimetric datasets, such as Topex Poseidon, Topex Tandem, ERS (European Remote Sensing), and GFO (Geosat Follow-on), as well as in-situ observations (Egbert and Erofeeva, 2002). These data were used as inputs for both the nearshore and offshore models.

#### **4.2.4 Currents**

Current regime of the offshore Project area is affected by the large-scale currents which are dominated by the Indonesian Throughflow (for more detail see the AAPowerLink EIS Marine Environmental Quality report). Therefore, it is important to incorporate the effects of large-scale circulation into the offshore model. There were no relevant monitoring data available for the offshore part of the Project, therefore, reanalyses by BRAN (BlueLink ReANalysis; Oke, et al., 2013; BRAN, 2021) were used to extract currents. BRAN is based on a global ocean model called OFAM (Ocean Forecasting Australia Model) developed as part of the BLUElink partnership program between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), BoM, and the Royal Australian Navy.

#### **4.2.5 Waves**

Waves are an important metocean parameter for sediment transport studies, because waves may define the processes of sediment resuspension and settlement (see e. g. Langtry et al., 2009; Makarynska and Makarynsky, 2017). To model waves nearshore, wave open boundary conditions must be prescribed for a selected model domain.

As part of the Integrated Marine Observing System (IMOS) initiative of the Australian Government, since July 2010, AIMS has been maintaining a wave monitoring buoy moored in Beagle Gulf at 12.34°S, 130.70°E. Data from the AIMS buoy (AIMS, 2021) were used in this study to derive boundary conditions for the wave model. Analyses of these data are presented in the AAPowerLink EIS Marine Environmental Quality report.

For the offshore part of the Project, outputs of gridded hindcast modelling by WaveWatch III (CSIRO, 2021; Durrant et al., 2014) were used for analyses of waves (see the AAPowerLink EIS Marine Environmental Quality report). However, due to the relatively deep waters (~60-140 m) in the offshore Project area, waves are not expected to significantly contribute to the bed load transport and/or bed sediment suspension and re-suspension, or erosion/accretion. Therefore, waves were not modelled for the offshore Project area.

#### **4.2.6 Sediment data**

Modelling of the proposed submarine cable laying operations requires the information on geotechnical conditions in the study area. Geotechnical conditions, including sediment type distribution, strength and grain size classification, were investigated along the offshore part of the submarine cable route and within Darwin Harbour by Sun Cable (Guardian Geomatics, 2021). Analyses of these data are presented in the AAPowerLink EIS Marine Environmental Quality report. However, no survey data were collected by Sun Cable in Shoal Bay. Therefore a literature review was undertaken to characterise sediments in the Project area, which indicated that moderate to large proportions of mud (silt and clay) were identified in shallow waters of Shoal Bay and at various locations in deeper parts of the nearshore study area (for more detail see the AAPowerLink EIS Marine Environmental Quality report).

Based on the testing of collected sediment samples and literature review the material along the submarine route would predominately be a mixture of clay (<2 µm), silt (2-60 µm), fine sand (0.06-2.00 mm) and gravel (>2 mm) in variable proportions along the route. The grain density of the sediments would range from 2,460 kg/m<sup>3</sup> to 2,760 kg/m<sup>3</sup> along the route depending on the composition of sediments. Another important parameter is the bulk density of undisturbed materials. In this study, a single conservative value of 1,750 kg/m<sup>3</sup> (e.g. Tenzer and Gladkikh, 2014; Richardson and Jackson, 2017) was assumed for all sediments along the route.

In general, only fine materials, such as clay, silt and fine sand, are expected to stay suspended in the water column long enough to create plumes. Therefore, gravel was excluded from the modelling as it tends to fall to the seabed relatively quickly.

#### 4.2.7 Summary of data sources

Summary of data used in this study is presented in Table 3.

**Table 3** Data sources summary

Parameter	Source name	Nearshore model	Offshore model
Bathymetry*	Darwin Harbour 2010-2011 data (Siwabessy, 2015)	Model input	
	Darwin Harbour 2014 data (AIMS, 2014)	Model input	
	Outer Darwin Harbour 2015 data (Siwabessy et al., 2016)	Model input	
	Australian bathymetry (Whiteway, 2009)		Model input
	Survey data from Sun Cable	Model input	Model input
Wind speed and direction	Australian Baseline Sea Level Monitoring Project (BOM, 2021)	Model input	
Sea level	Australian Baseline Sea Level Monitoring Project (BOM, 2021)	Model calibration and validation	Model calibration and validation
Tides (tidal constituents)	TMD (Egbert and Erofeeva, 2002)	Boundary conditions	Boundary conditions
Currents	Bluelink reanalysis (BRAN, 2021)		Boundary conditions
Waves	IMOS buoy (AIMS, 2021)	Used to derive boundary conditions	
Sediment parameters	Sun Cable (Guardian Geomatics, 2021), Tenzer and Gladkikh (2014)	Used to estimate discharges	Used to estimate discharges

\*Datasets were combined to provide model bathymetry

### 4.3 Modelling software

#### 4.3.1 Delft3D

The Delft3D modelling package (Deltares, 2014a) was selected as a modelling platform for the Project. Delft3D is an integrated flow, wave and transport modelling system from Deltares, an independent institute for applied research based in Delft and Utrecht, the Netherlands. Models comprising this package have been widely used and have proven their capabilities in the waters of Australia and other locations around the globe. The software package is being continuously improved using innovative modelling algorithms and techniques.

The FLOW module is the heart of Delft3D, which is a multi-dimensional (2D or 3D) hydrodynamic simulation program that calculates non-steady flow and transport phenomena resulting from tidal and meteorological forcing on curvilinear, boundary fitted or spherical grids.

For the interactions between waves and currents the Delft3D-FLOW model can be coupled with the Delft3D-WAVE model (Deltares, 2014b). The core of Delft3D-WAVE is the third-generation SWAN (Simulating WAVes Nearshore) model, which has been developed to simulate the evolution of random, short-crested wind-generated waves in estuarine and coastal as well as open-ocean conditions (e. g. Holthuijsen et al, 1993; Booij et al, 1999; Ris et al, 1999; Makarynsky et al, 2000).

DELWAQ of the Delft3D suite is specifically designed for far-field water quality modelling. Far-field models are efficient tools in predicting behaviour of a plume in a region where the mixing and transport processes are dominated by ambient flow conditions. This region lies beyond a relatively small near-field zone (close to the discharge location) where the initial mixing takes place.

DELWAQ uses the hydrodynamic and wave generated conditions (velocities, water elevations, vertical eddy velocity and vertical eddy diffusivity, bed shear stress) calculated by the Delft3D-FLOW and Delft3D-WAVE modules. DELWAQ has one or more "state variables", "pollutants" or "substances", which enter the modelled area. The model solves the advection-diffusion-reaction equation on a predefined computational grid and is based on a rich library of substances and processes, which can be selected to put water and sediment quality models together. The model allows for the simulation of the substance concentrations in the water column and in the sediment. The sedimentation process in the model is accounted for by means of a settling velocity, while erosion of bed sediment, causing resuspension of sediment, is governed by a function of the bed shear stress.

#### 4.3.2 Modelling limitations

Modelling of hydrodynamics and wind waves should be regarded as a tool for the identification and characterisation of plausible current and wave field patterns and parameters within the study area. When reviewing modelling outputs, it is important to interpret the results in the context of the model limitations and uncertainties.

The major limitations and uncertainties of the used current and wind wave models (and any numerical model in general) arise from the use of theoretical, analytical and/or parametrical numerical expressions employed to describing the real-world hydro-meteorological processes. These numerical expressions reflect the current understanding of the forces driving and affecting the modelled processes; the understanding should be regarded as limited. In general, the more complicated the system modelled, the more parameterisations (or approximations) are required in order to represent the modelled processes. Thus, there are inherently a number of "tunable" parameters that are required as input into the models.

The model uncertainties are also related to the idealised, spatially discretised representations of ambient geometry/bathymetry and coastlines, as well as to the temporally discretised representations of the surface and open boundary conditions, such as winds and tides. Both the spatial and temporal discretisation of the geometry, surface and boundary conditions are arbitrary; the selected and implemented discretisation is always dependent on the spatial and/or temporal resolution of the available project data, as well as model requirements and limitations, and the researcher/consultant's professional skills and experience. These may lead to some isolated bathymetric features (for instance, bars and depressions) and short-term wind and sea level variability (for instance, such as wind gusts and wave setup) being excluded from model consideration.

The DELWAQ modelling results of spatial spreading, transport and dispersion of released sediments are mostly due to physical forcing, such as wind wave and water current action. Errors and uncertainties associated with hydrodynamic modelling outcomes can be translated into the DELWAQ results. Limited knowledge of the rates of suspension and characteristics of suspended material can also lead to large uncertainties in model estimates of sediment transport and fate.

All the above may affect the modelling outcomes.

## 5.0 Modelling

### 5.1 Schematisation of Project operations

A land sea joint station will facilitate the transition of the HVDC cables from onshore to offshore. Cables will transition from land to water either via conventional trenching or via conduits installed using horizontal directional drilling (HDD), depending on the local site conditions and environmental and heritage values.

At the time of preparation of this report, conventional trenching for land/sea crossing and high-pressure water injection or jetting/jet trenching technique were assumed to be the most likely options for the cable laying operations. Jet trenching technique has advantages for sands and soft clays. For instance, remotely operated vehicle equipped with jets can operate in deep water, and soft sediments, which are unfavourable for other methods (Njock et al., 2020).

A jetting system works by fluidising the seabed sediments by powerful high pressure water injection. The cable then sinks under its own weight through the fluidised sediments and is buried as the sediment returns to its pre-jetted condition (ASA, 2006; Njock et al., 2020). However, at high velocity/pressure seabed sediments can be eroded or scoured, transporting sediment particles away. Therefore, several passes may be required to complete the burial (NIRAS, 2015).

In this study, three parallel cables spaced 50-100 m apart were assumed to be laid and buried simultaneously by the jetting technique with no bed preparation. This is a conservative assumption. In fact, due to the lack of operational equipment and workforce the cables will be laid individually (unless they are bundled) and separated

by a distance of 50-200 m. Much smaller environmental effects are expected with cables laid individually at a larger separation distance.

The cables were assumed to be buried to a minimum depth of 1.2 m below present seabed level in three separate working steps (paths of 50 km each). However, the burial risk assessment conducted by Sun Cable recommended a burial depth of 0.6 m below seabed. The resulting release of sediments to the water column from the recommended depth (0.6 m) would be twice lower compared to the modelled in this study. Moreover, the impacts will be further reduced if only two paths will be required to achieve the recommended burial depth.

A simplified rectangular shape with 0.75 m width was assumed for the fluidised trench. The jetting equipment moves at approximately 300 m/h along the cable path.

The source strength was estimated as the time rate of sediment (discharge) that is injected into the water column from the jetting process. It is defined as the fraction of the cross-sectional area of the trench times the forward speed of the jet as it moves along the trench.

Based on past studies of jetting (e. g. ASA, 2006; RPS, 2015; VikingLink, 2017) and as a conservative approach it was assumed that 30% of the total sediment volume fluidised within the trench will be distributed vertically through the overlying water layer by the jetting device. The remaining 70% of the sediment was assumed to remain within the limits of the trench during the burial process. The same assumptions were applied to the trenching of land/sea cable crossing.

The cable laying operations will be performed on a 24-hour basis to ensure minimal navigational impact on other users and to maximise efficient use of favourable weather conditions and vessel and equipment time.

Summary of schematisation of cabling operations is presented in Table 4.

**Table 4** Summary of schematisation of jetting operations

Parameter	Units	Value
Number of parallel cables simultaneously laid		3
Distance between cables	m	50-100
Number of passes required for cable burial by jetting for each cable		3
Length of one path	km	50
Number of days between consequent passes	day	7
Trenching speed	m/h	300
Trench width	m	0.75
Trench depth	m	1.2
Amount of sediment within the trench that is disturbed into water column	%	30
Volume of sediment within the trench that is disturbed into water column per 1 m length of trench for a single cable	m <sup>3</sup>	0.27
Type of sediment discharge along the path		Continuous (24 hours a day) in time and moving along the cable route

## 5.2 Modelling scenarios

Two modelling scenarios were developed based on schematisation of Project cabling operations for the Project development areas: the nearshore and the offshore. These scenarios are summarised in Table 5.

Cable laying operations were represented in the models as continuous moving sources over a 7-day period along a separate 50 km path for each of the three cables (Figure 2). After that period, the jetting equipment was assumed to return to the starting points and repeat the operation twice, which would represent three paths in total for all three cables.

For the nearshore scenario, sediments were assumed to have high clay content, with fractions of clay (36%), silt (17.5%) and sand (25%) based on limited survey data provided by Sun Cable at the closest location to the proposed subsea route. This sediment composition was assumed as spatially constant along the subsea route. Using high clay content (36%) represents a conservative approach. As indicated in the AAPowerLink EIS Marine Environmental Quality report, sediment composition is likely to vary along the route with possibly lower concentrations of fine-grained material. It is the fine particles that are usually seen as turbid cloud or plume due to their lower settling velocities. Depending on the hydrodynamic conditions and the type and size of the fine particles, these may be transported far away from the discharge locations.

For the offshore scenario, sediment concentrations for the three moving sources were calculated using the particle size distribution (PSD) data closest to the discharge locations. The PSD data were averaged for each site based on samples at different depths. To provide better spatial coverage the PSD data were linearly interpolated between the sampling locations. As a conservative approach, a 50 km section of the submarine cable route was selected (Figure 4). This was to represent a single laying operations path with the highest potential effect on the Oceanic Shoals Marine Park.

In both scenarios, released materials were represented in the models by reading in time-series of material concentrations (clay, silt and fine sand) for each of the sources.

**Table 5** Modelling scenarios

Scenario	Flow rate (m <sup>3</sup> /s)	Release rate of clay	Release rate of silt	Release rate of sand
Nearshore	0.02	Spatially constant	Spatially constant	Spatially constant
Offshore	0.02	Spatially variable	Spatially variable	Spatially variable

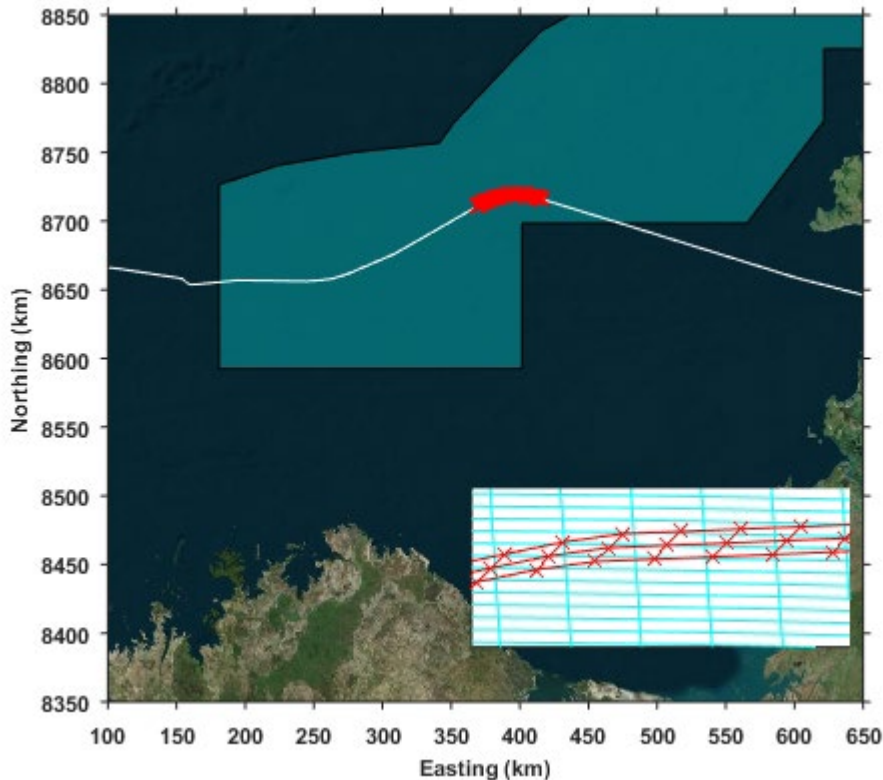


Figure 2 Model schematisation of offshore Project discharges with zooming in into model grid. Red crosses show locations of discharges, red lines indicate three parallel cables and the cyan grid is the model grid; white line shows submarine cable route and grey polygon shows Oceanic Shoals Marine Park

### 5.3 Simulation period

Installation of the marine cables is scheduled to begin in 2025 and be finalised by 2029. The availability of factory capacity for cable manufacture will ultimately determine the overall schedule of the Project.

Although cable installation may take place during both dry and wet seasons, dry season metocean conditions were adopted for the study because of the possible ecological impact of unseasonal increases in suspended sediment concentrations. To capture the effect of wet season conditions on sediment transport resulting from Project operations additional modelling exercises may be necessary.

July 2016 was adopted to represent dry season conditions in the study area. This modelling period was assumed to capture physical aspects of the modelled system in terms of winds, tidal elevations, currents and waves.

To ensure the quality of the model outcomes, several days in June 2016 were allowed for the model to stabilise before simulating Project discharges. The model simulations also included several additional days after cessation of the discharges to assess how quickly plume concentrations would decrease with time.

It should be noted that the timing of Project discharges coincides with particular tidal phases as the sources move in time and space, and thus the results may not be as accurate for the situations with different timing of Project discharges.

### 5.4 Model setup

#### 5.4.1 Delft3D-FLOW and Delft3D-WAVE

Two detailed model configurations were developed for the Project development areas: (1) a nearshore model covering Beagle Gulf and Darwin Harbour (Figure 3), and (2) an offshore model covering the Project area in Beagle Gulf and the Timor Sea (Figure 5).

##### 5.4.1.1.1 Nearshore model

An orthogonal curvilinear grid with 42,900 computational nodes (Figure 3) was developed to provide higher resolution (less than 40 m) in Shoal Bay, and relatively low resolution (more than 250 m) elsewhere, thus saving

computational effort and ensuring more accurate results in the area of interest. The model bathymetry is shown in Figure 4.

Considering the dominance of tidal forcing in the area, a depth averaged approach (2D) was adopted and the model grid was assumed to have one vertical computational layer. This approach is appropriate if the fluid exhibits vertically well mixed flow regimes. In the dry season, Darwin Harbour, including its outer parts such as Shoal Bay, is vertically well mixed (e. g. Padovan, 2003; Williams et al., 2006; Makarynska and Makarynsky, 2017). The open-ocean boundary conditions of Delft3D-FLOW were forced by space-varying tidal components and time-varying, spatially homogenous winds.

The diurnal and semi-diurnal space varying tidal components extracted from TMD were applied to the open boundary. The diurnal components included K1, O1, P1 and Q1 and semi-diurnal components included M2, S2, N2 and K2. Additionally, the shallow water components M4, MS4, MN4 and long-period components Mf, Mm were used.

For the interaction between waves and currents the Delft3D-FLOW model was coupled with the short-waves Delft3D-WAVE model. The same model domain and the same modelling periods as for the Delft3D-FLOW model were adopted for the wave model. Wave boundary conditions were selected to represent a conservative approach, with waves that may have a significant impact on sediment transport in the area (e. g. Makarynsky and Makarynska, 2011). Waves with significant wave height of 2 m, peak period of 8 s and 300° direction (longest fetch) were assigned at the boundary based on the analysis of data presented in the AAPowerLink EIS Marine Environmental Quality report.

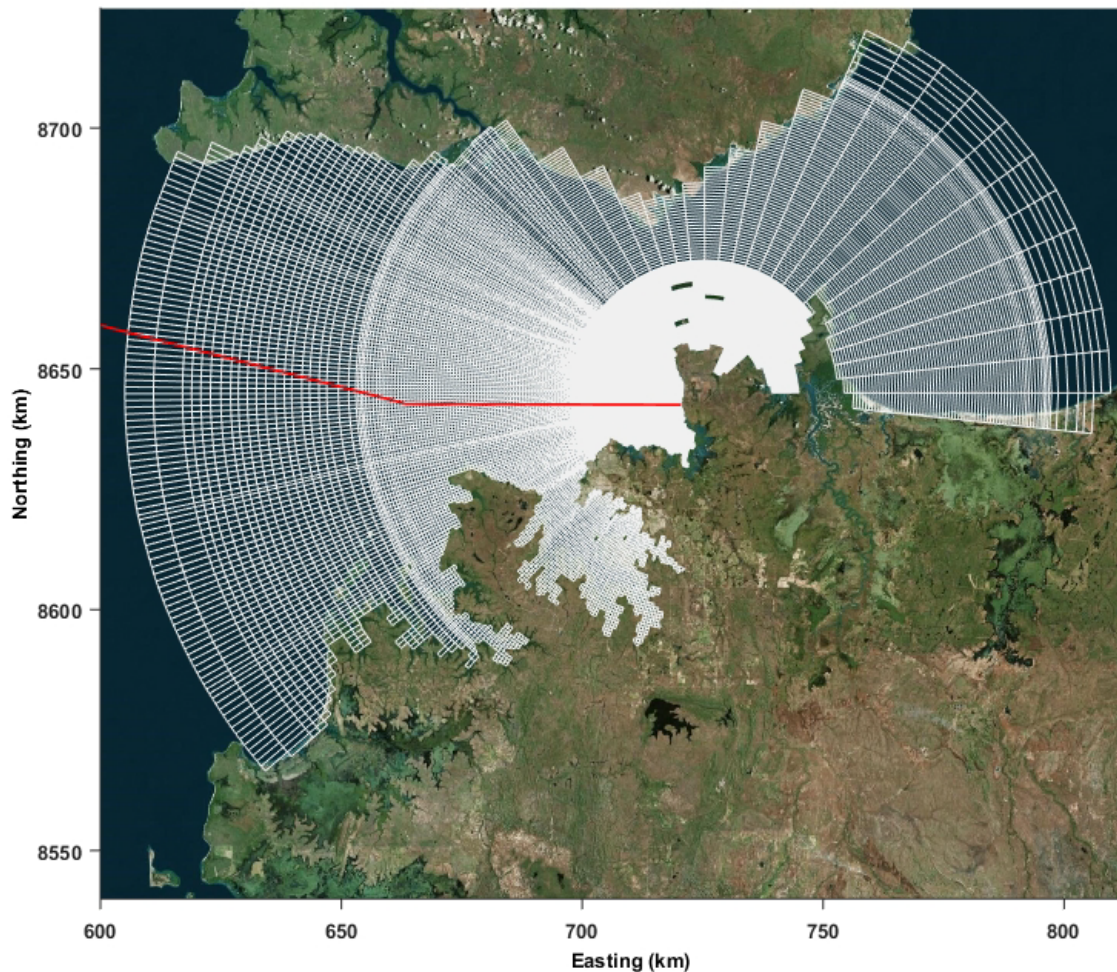


Figure 3 Nearshore model computational grid, intense white colour indicates sections with higher grid resolution. Red line shows part of submarine route

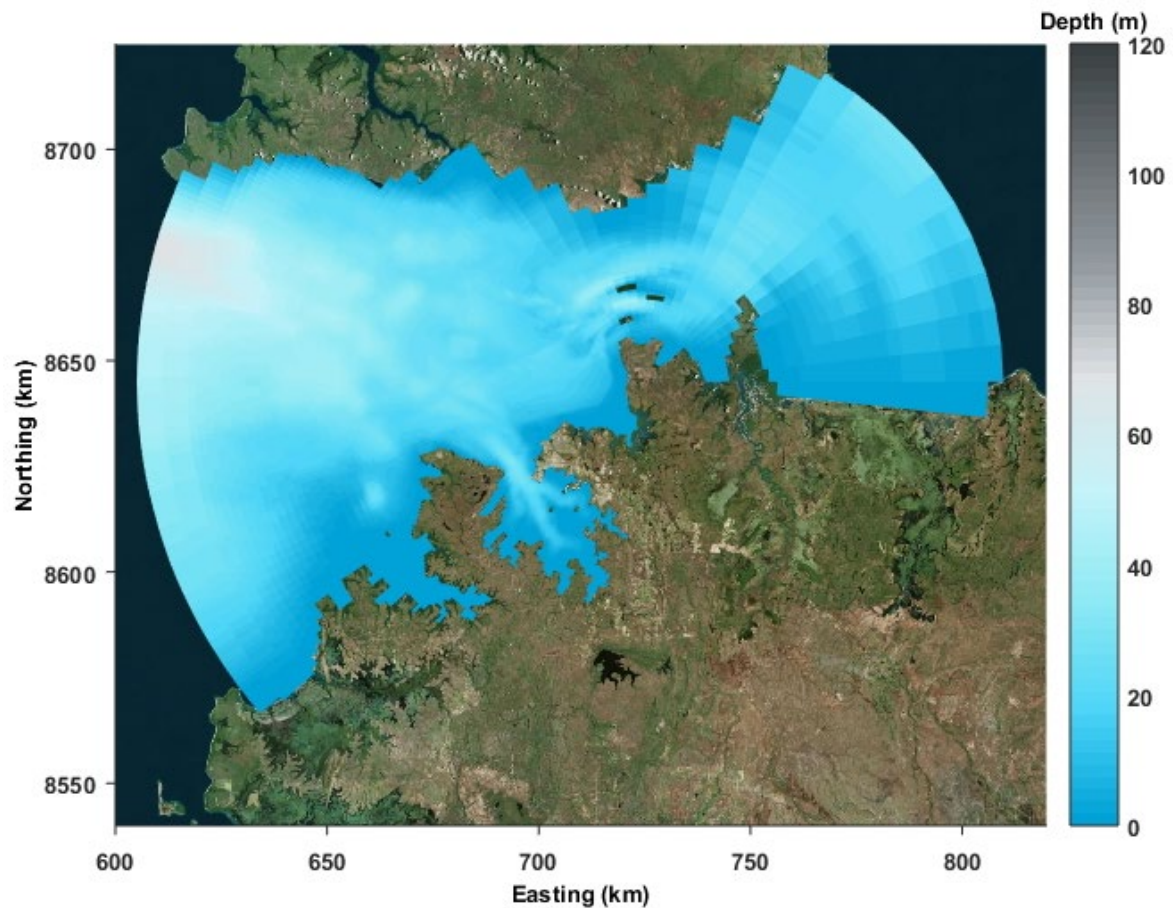


Figure 4 Nearshore model bathymetry (MSL)

#### 5.4.1.1.1 Offshore model

The model domain was developed to incorporate predominant tidal flows, large scale currents and effects of complex coastline and bathymetric features in the offshore Project area (Figure 5). The domain consists of two grids: a coarse grid with 104,335 computational nodes and a detailed “nested” grid with 337,960 nodes and three vertical sigma layers (e. g. Makarynskyy and Makarynska, 2019) to resolve the cable laying operations along the submarine route. The “nested” grid resolution varies from less than 40 m near the cable to more than 250 m elsewhere. The model bathymetry is shown in Figure 6.

To provide the open-ocean boundary conditions to the three-dimensional hydrodynamic model, two sources of information were used:

- Space-varying tidal component data were extracted from the TMD
- Regional scale, three-dimensional ocean currents were obtained from BRAN (for more details see Section 4.2.4).

All the extracted data were converted into suitable Delft3D-FLOW model formats.

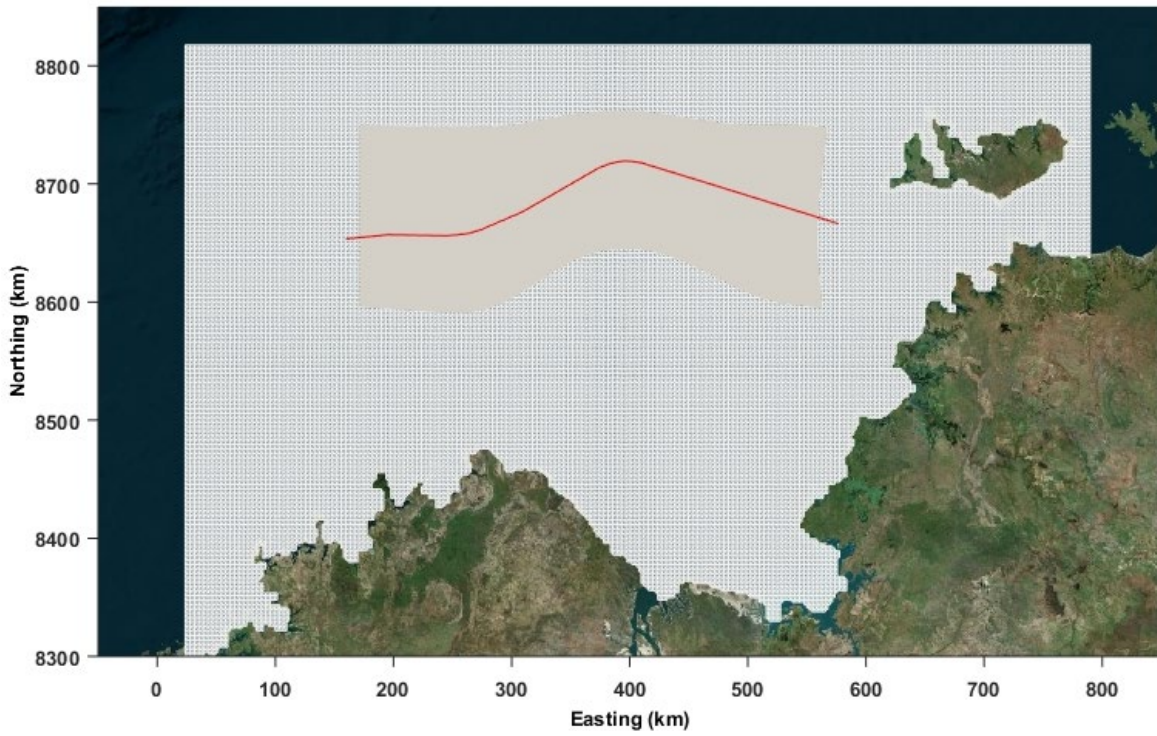


Figure 5 Offshore model computational grid, intense grey colour indicates sections with higher grid resolution. Red line shows part of offshore submarine route

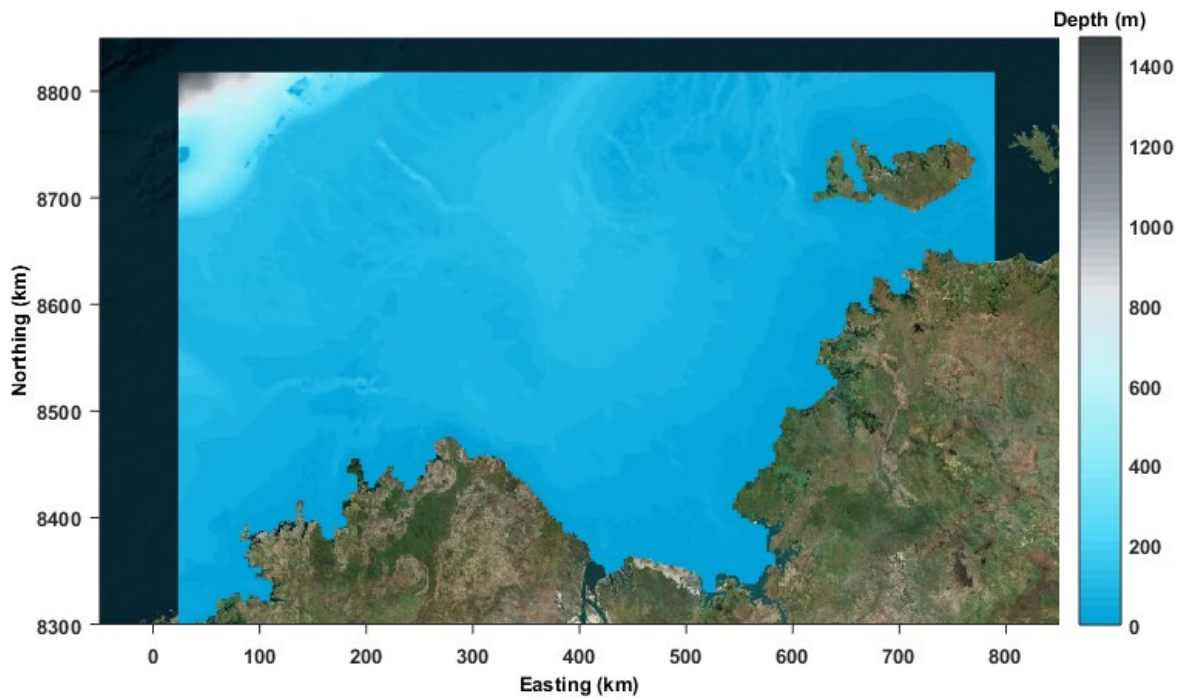


Figure 6 Offshore model bathymetry (MSL)

## 5.4.2 DELWAQ

Following the same approach as for the hydrodynamic modelling, two separate DELWAQ models were developed for the nearshore and offshore Project areas (see Section 4.1.1 for more details). The same model domains (nearshore (Figure 3) and offshore “nested” (Figure 5)) and the same modelling period as for the Delft3D-FLOW model were adopted for the DELWAQ models. DELWAQ used spatial and temporal representations of hydrodynamic fields for both models, with addition of wave fields for the nearshore model, to define transport forcing and deposition rates for the released materials.

Initial and boundary conditions in DELWAQ were selected as having no influence on the transport processes in the study areas; essentially, the initial and boundary parameter values were set to zero. This is a typical approach for modelling of sediment releases, because it ensures that all the impacts on water quality can be identified and then considered relative to the natural background concentrations (if required). All modelled material releases were based on the proposed cable installation operations for the selected scenarios (Section 5.2), which deemed to have higher environmental effects compared to the operation and maintenance Project activities.

### 5.4.2.1 Settling velocity

The vertical sediment transport in the model is based on the sedimentation and resuspension flux, which are dependent on the settling velocity and critical stress for resuspension, respectively. Settling velocity of fine particles (within the range of diameters from 0.002 mm to 0.05 mm) was calculated based on Stokes' Law, assuming that particles are spherical and no flocculation occurs. In this approach, the diameter of the particle is a very sensitive parameter as grains of slightly different sizes may settle at very different rates, because their settling velocities are proportional to the square of the diameter. As a conservative approach, the settling velocities for the lower limit within the particle size groups were assumed as follows:

- 0.2 m/day for clay (particles <0.002 mm)
- 5.0 m/day for silt (0.002-0.06 mm particles)
- 515.0 m/day for fine sand (0.06-2.00 mm particles).

### 5.4.2.2 Critical stresses

In the model, the critical shear stress plays an essential role in defining whether or not deposition/sedimentation of suspended particles or resuspension/erosion of bed material will occur. Sedimentation takes place when the shear stress drops below a critical value. On the other hand, erosion occurs when the shear stress exceeds the critical value for resuspension. Critical shear stress for resuspension/erosion of material in the bottom layer was set to 0.2 N/m<sup>2</sup>. The threshold for deposition/sedimentation was set to 0.1 N/m<sup>2</sup>. These values were selected according to measurements, which have been observed to range between 0.02 N/m<sup>2</sup> and 5.0 N/m<sup>2</sup> for resuspension/erosion and 0.06 N/m<sup>2</sup> and 0.1 N/m<sup>2</sup> for deposition/sedimentation (Whitehouse et. al, 2000).

## 5.5 Summary of model assumptions

The hydrodynamic and wave modelling were undertaken under the following assumptions:

- Selected modelling periods capture physical aspects of the modelled system in terms of tidal elevations, currents and wave-current interaction
- No extreme weather conditions were simulated.

A number of separate assumptions were made for the hydrodynamic and wind wave models.

Delft3D-FLOW assumptions:

- Depth averaged modelling approach (2D) for the nearshore model
- Forcing at the open boundaries by astronomical tides from the TMD tidal model for the nearshore model
- Spatially constant time-variable wind for the nearshore model
- Three-dimensional approach for the offshore model
- Forcing at the open boundaries by astronomical tides from the TMD tidal model and BRAN currents for the offshore model
- Spatially variable depth-dependent bottom roughness.

Delft3D-WAVE assumptions:

- Spatially constant time-variable wind
- Worst-case swell from north-west at the open boundaries.

DELWAQ assumptions:

- Three parallel cables will be laid simultaneously and buried independently by the jetting technique with no bed preparation
- Estimated discharges and their durations are representative of Project operations
- Project timing represents realistic case environmental conditions in the area
- Discharge locations are representative of Project operations
- Modelled sediment composition is based on typical properties of the samples collected during the field investigation and laboratory analysis
- No sediment contamination being modelled
- Project impacts were assessed in isolation - no background concentrations were taken into account
- No mitigation measures were assumed for modelling of cabling operations.

The above assumptions were considered appropriate for the area and modelling objectives.

## 5.6 Model calibration and validation

Both the hydrodynamic nearshore and offshore models were successfully calibrated and validated using local sea level observations (for more detail see Appendix A). There were no data provided to calibrate and validate the wave model. However, visual inspections of wave fields were undertaken to ensure quality of the results. “Snap shots” of modelled wave fields are presented in Appendix A. The presented results suggest that the model was accounting for wave energy attenuation and refraction processes well.

Specific calibration of the far-field sediment transport modelling, both nearshore and offshore, was not undertaken as no suitable site-specific data were available. However, the DELWAQ model has been extensively applied, calibrated and validated in dredge plume investigations around the world, including Australia (e. g. Provis and Aijaz, 2009; Makarynska and Makarynsky, 2017).

## 5.7 Model results

To quantify the impacts from Project cable laying operations, two sediment transport scenarios, representing the nearshore and offshore Project areas, were modelled (Table 5).

Clay, silt and fine sand were modelled separately as inorganic matter to predict their individual concentrations, which were then processed into total concentrations of suspended sediments in the water column for the nearshore scenario and in the top and bottom layers of water for the offshore scenario.

The results were presented as colour contour maps for the 5<sup>th</sup>, 20<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentiles of SSC at each model grid point. Percentiles generally provide a sufficient set of results to represent spatial patterns of SSC. These statistics indicate SSC below which a given percentage of the predicted SSC fall within the model domain over the modelled period. For example, if the 95<sup>th</sup> percentile SSC is 10 mg/L, then SSC will be less than this value (10 mg/L) for 95% of the time, or conversely SSC will exceed 10 mg/L for 5% of the time. The 50<sup>th</sup> percentile SSC is a measure of the median conditions.

In addition to the visualisation of spatial distribution, timeseries of predicted SSC were extracted for the selected numerical monitoring stations.

### 5.7.1 Nearshore scenario

#### 5.7.1.1 Spatial extent

Figure 7 shows the spatial distribution of the 50<sup>th</sup> percentile (median) SSC for the nearshore scenario. The modelling results suggest that the median SSC greater than 10 mg/L (above WQO) occur in a small (~800 m x 200 m) shallow area nearshore. The area along the route that extends for about 15 km from the shore would receive SSC of 3-10 mg/L.

The results presented in Figure 8 indicate that the 95<sup>th</sup> percentile SSC are highest (above 50 mg/L) in the coastal area (~4 km x 3.5 km) within Shoal Bay, reaching values in excess of 200 mg/L nearshore. This indicates that the combined wave/tide action plays an important role in resuspension of fine sediments. The concentrations appear to be higher along the cable route, where the sediment source originate from, steadily decreasing with distance from the source.

Model results show SSC greater than 10 mg/L (above WQO) extend from the shore to the west along the route as well as laterally, filling the lower part of the bay. The area occupied by these concentrations is approximately

20 km x 11 km. Due to the effect of tides, SSC in the range of 3-10 mg/L would penetrate Darwin Harbour in the south and reach the Vernon Islands in the north.

The predicted variation in SSC appear to be within the natural range for Darwin Harbour. For instance, the reported natural range by URS (2011) for SSC is 6 mg/L to 140 mg/L and for turbidity 0 NTU to 145 NTU. Nicholas et al. (2019) indicated that turbidity in Darwin Harbour can vary from 5 NTU to 400 NTU (for more detail see the AAPowerLink EIS Marine Environmental Quality report). The relationship between turbidity and SSC can vary, however ranges for turbidity and SSC can approximately be considered similar (ANZECC and ARMCANZ, 2000).

It should be noted that the predicted concentrations would be in 95% of cases lower than the 95<sup>th</sup> percentile values reported above.

Spatial distributions of the 5<sup>th</sup> and 20<sup>th</sup> percentile concentrations are presented in Appendix B.

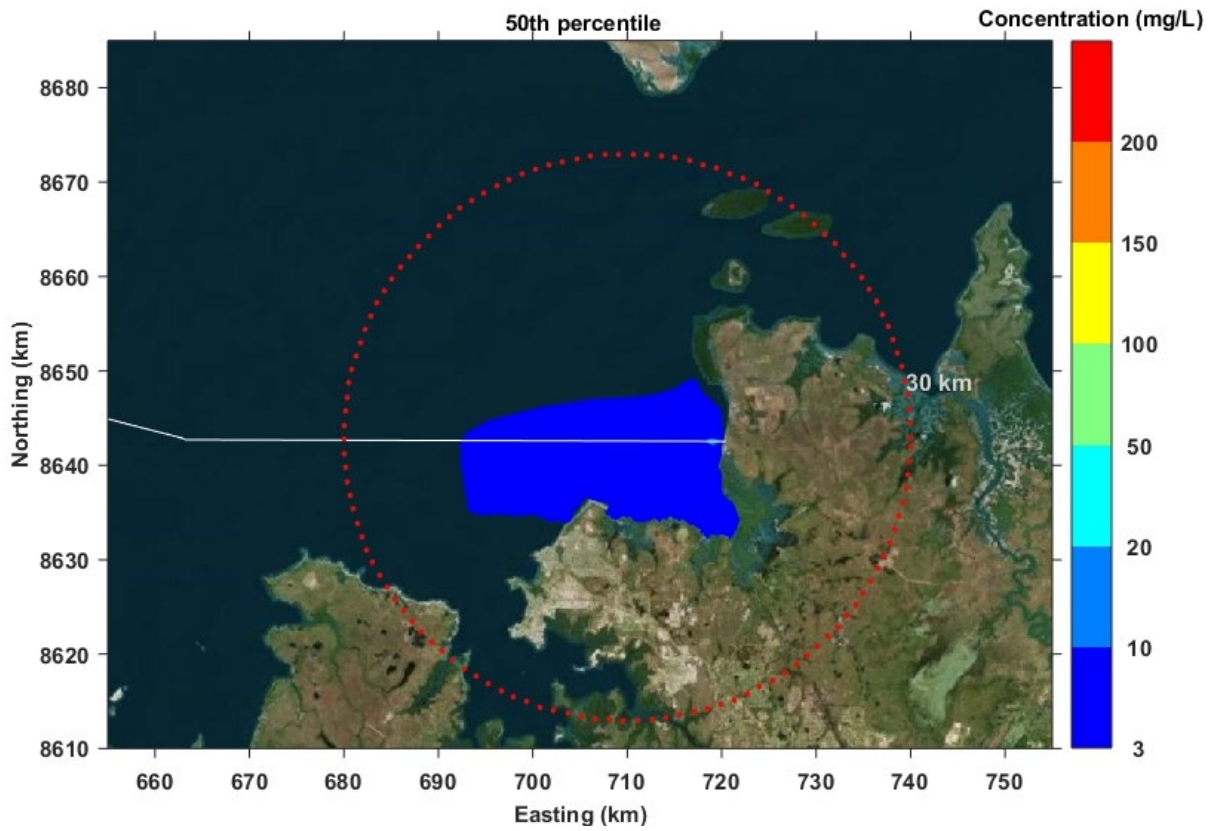


Figure 7 The 50th percentile of SSC predicted for nearshore scenario. White line indicates submarine cable route, red dots show 30 km radius scale

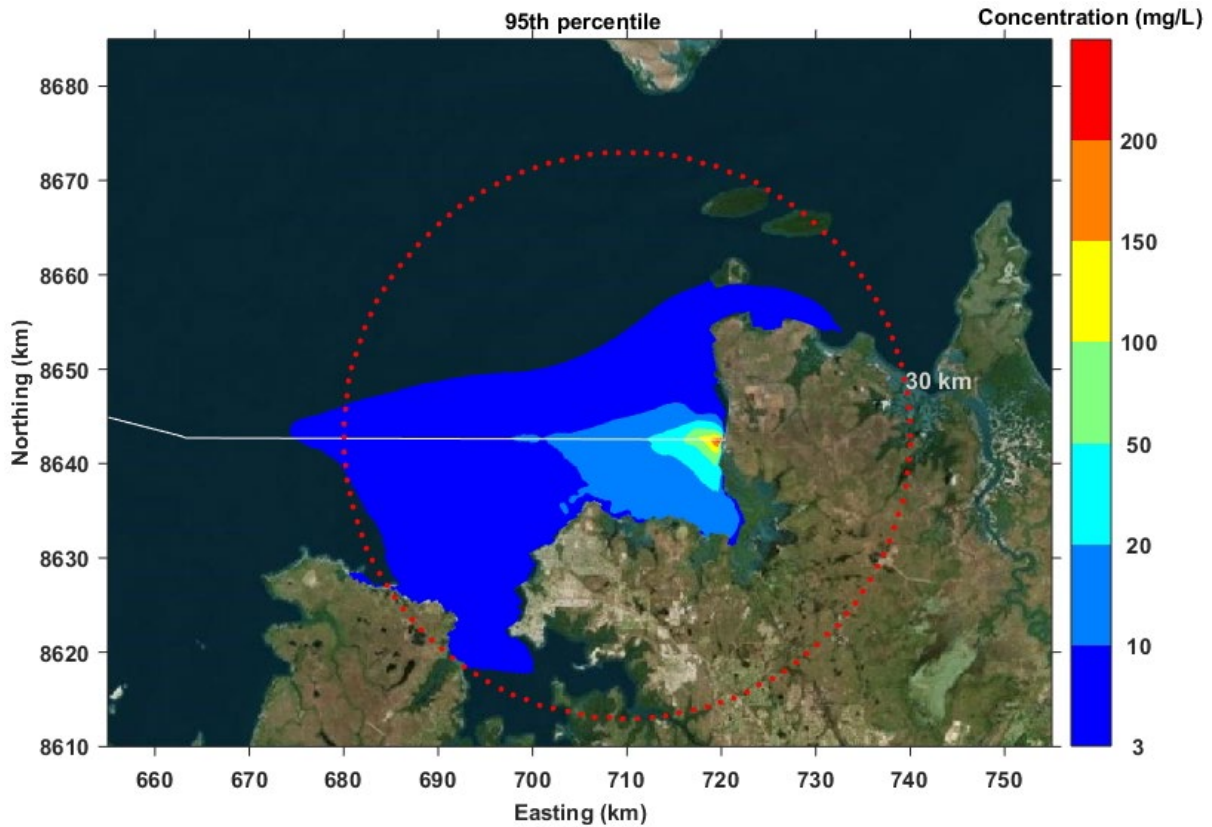


Figure 8 The 95th percentile of SSC predicted for nearshore. White line indicates submarine cable route, red dots show 30 km radius scale

### 5.7.1.1 Temporal variation

Timeseries of modelled SSC were extracted for 21 numerical monitoring stations shown in Figure 9. The extracted timeseries for four selected stations (P1 – P4), covering both sides of the proposed submarine cable route, are presented in Figure 10 along with computational segment depth indicating tidal variation. Timeseries for other 17 numerical stations at ecologically sensitive locations are presented in Appendix B.

Figure 10 demonstrates that SSC rise when jetting trenchers pass the fixed numerical stations (P1 – P4), and drop significantly after the discharge stops. Three distinctive peaks in SSC result from three consecutive paths (seven days apart) of the three trenchers doing simultaneous work. After the third peak, it takes approximately four days for SSC to drop back to low levels (below 2 mg/L).

Concentrations generally decrease slower during the neap tide due to the lower current velocities. The lowest mixing occurs during slack tides when the weakest currents occur between the flood and ebb tides.

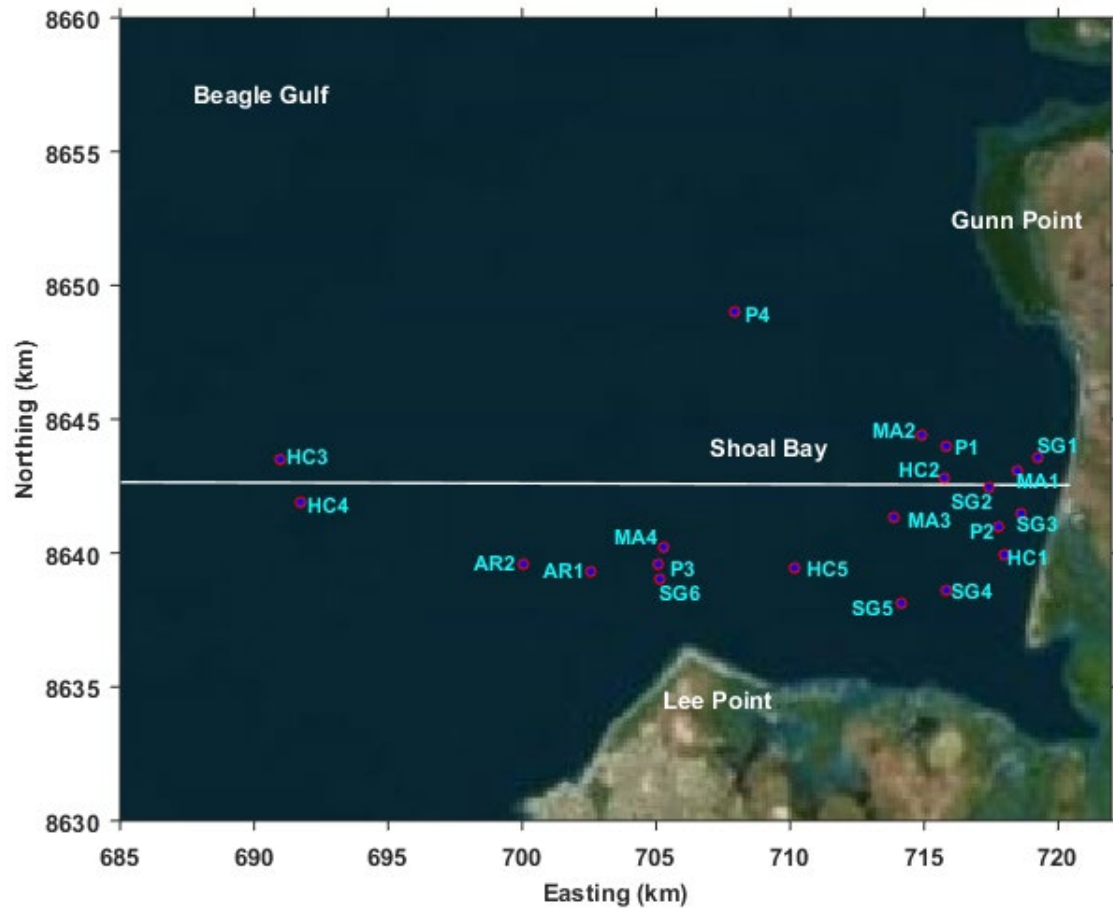


Figure 9 Nearshore numerical monitoring timeseries locations. White line indicates submarine cable route

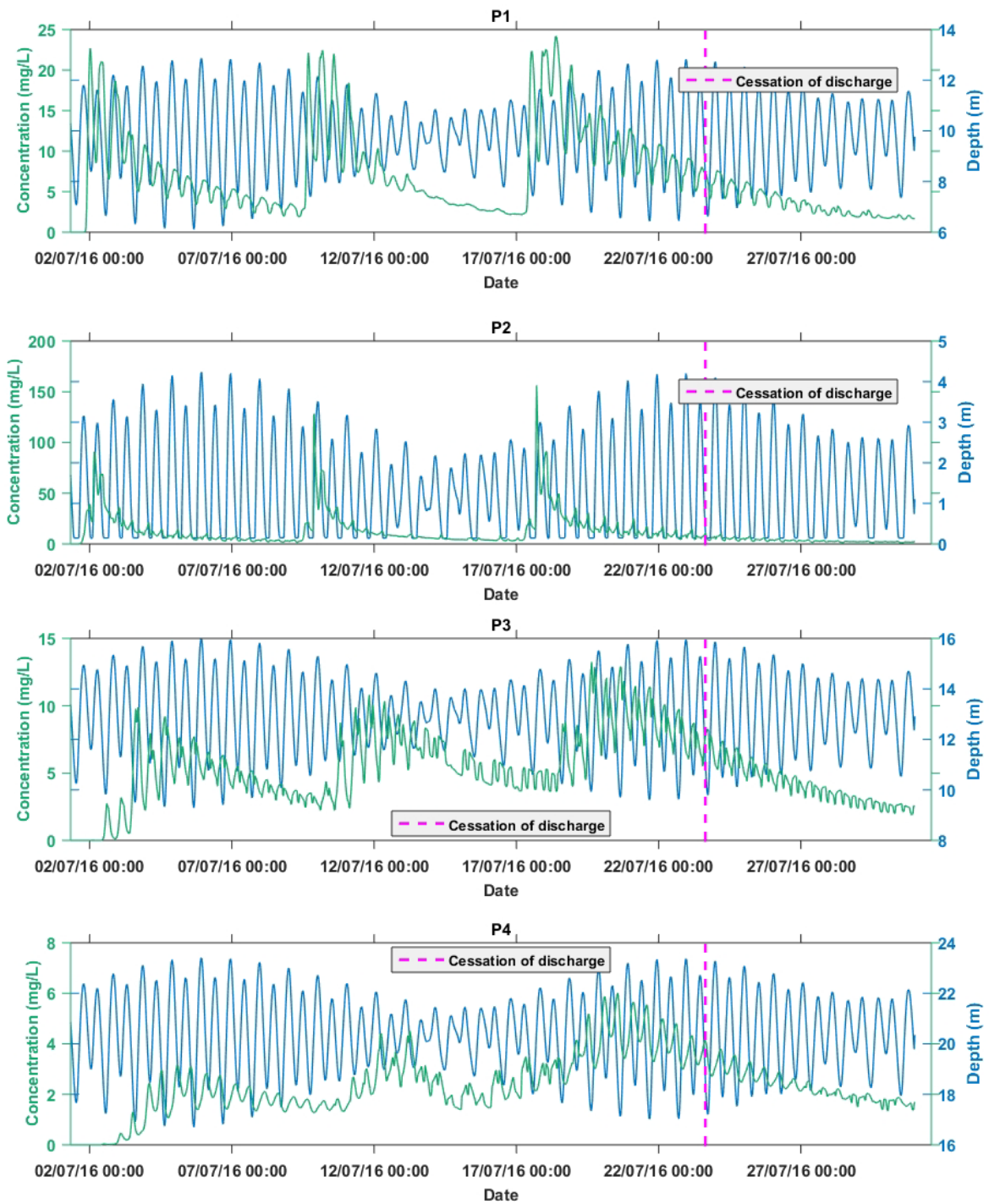


Figure 10 Timeseries of modelled SSC (green line) and variation of depth (blue line) for selected numerical monitoring stations (nearshore scenario)

## 5.7.2 Offshore scenario

### 5.7.2.1 Spatial extent

#### 5.7.2.1.1 Top layer

The modelling results indicate that SSC above 1 mg/L did not reach the top layer of the water column. Therefore, spatial distributions of the predicted 5<sup>th</sup>, 20<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentile SSC for the top layer are not presented in this report.

**5.7.2.1.1 Bottom layer**

The predicted 5<sup>th</sup>, 20<sup>th</sup> and 50<sup>th</sup> percentile SSC in the bottom layer were less than 1 mg/L for the entire study area and therefore were not presented here.

The 95<sup>th</sup> percentile SSC (Figure 11) show that the suspended sediments with the highest concentrations (above WQO of 2 mg/L) oscillate north-south within approximately 1 km from the route. The actual location of these oscillations would be determined by the relationship between the time of the tide, the jetting time and location. The highest SSC do not exceed 4 mg/L.

Lower SSC of 1-2 mg/L spread mostly in the north-northwestern direction for approximately 15-20 km from the route.

It should be noted, however, that the concentration levels are expected to be relatively short-lived due to the tidal effects that move the plume away from the jetting equipment and disperse it, while sediments settle out from the water column.

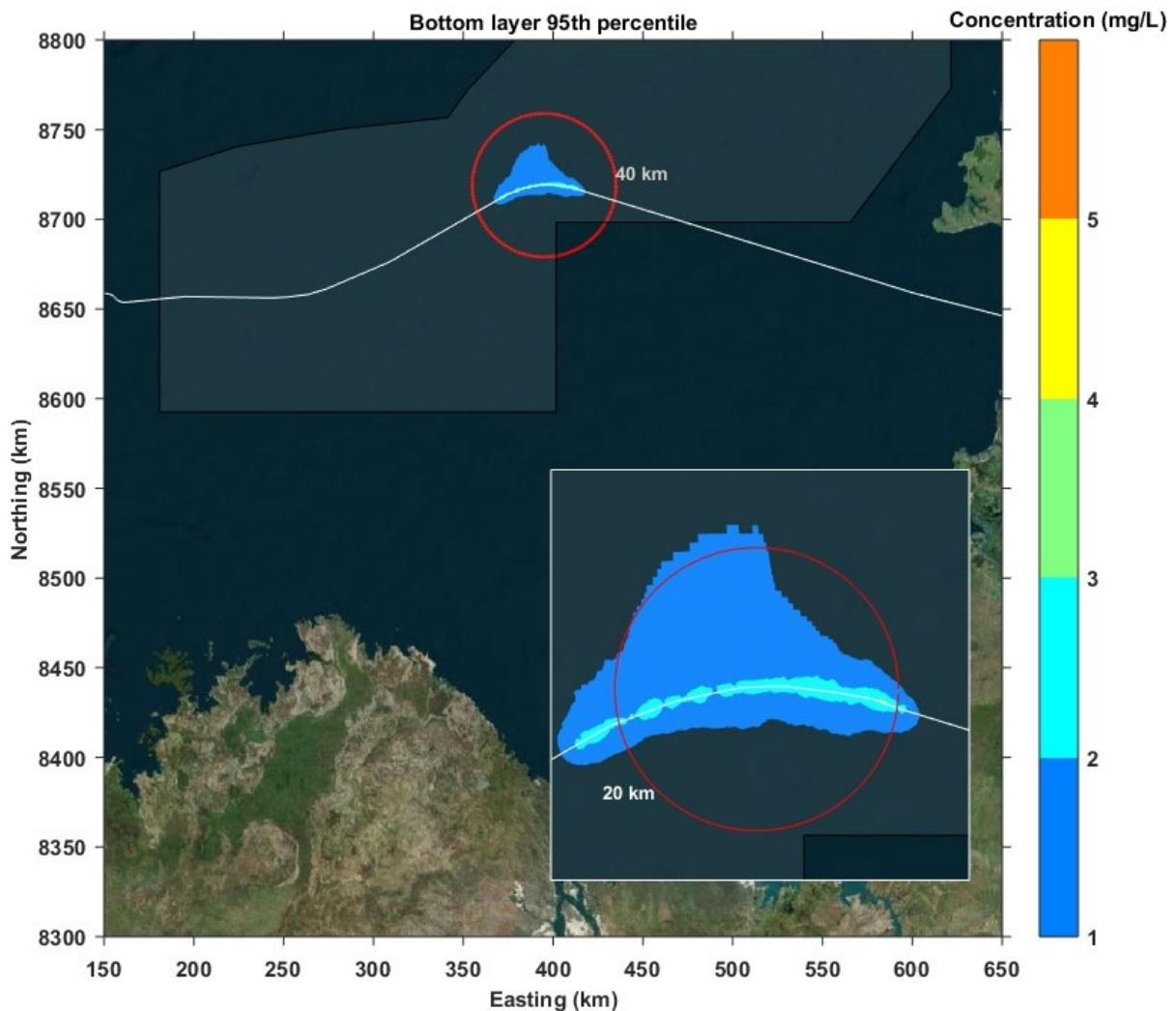


Figure 11 The 95<sup>th</sup> percentile of SSC predicted for offshore scenario (bottom layer) with zooming in into discharge locations. White line indicates submarine cable route, red lines show 20 km and 40 km radius scales and dark grey polygon indicates Oceanic Shoals Marine Park

**5.7.2.1 Temporal extent**

To investigate the effect of jetting operations, timeseries of SSC of clay, silt and fine sand were extracted for the numerical monitoring stations presented in Figure 12. Timeseries for the selected stations are shown in Figure 13 and Figure 14.

It appears that passing jetting equipment (for the three parallel cables) causes three distinctive peaks that correspond to the repeated trenching paths. The oscillations are determined by the relationship between the time

of the tide and the jetting time. Clay and silt, appear to be more susceptible to movement than sand and can more easily reach the top layer and remain in suspension in the water column. However, the concentrations remain low (<1.5 mg/L) throughout the water column. Approximately 3-5 days after jetting operations, the concentrations drop to the very low levels (<0.05 mg/L).

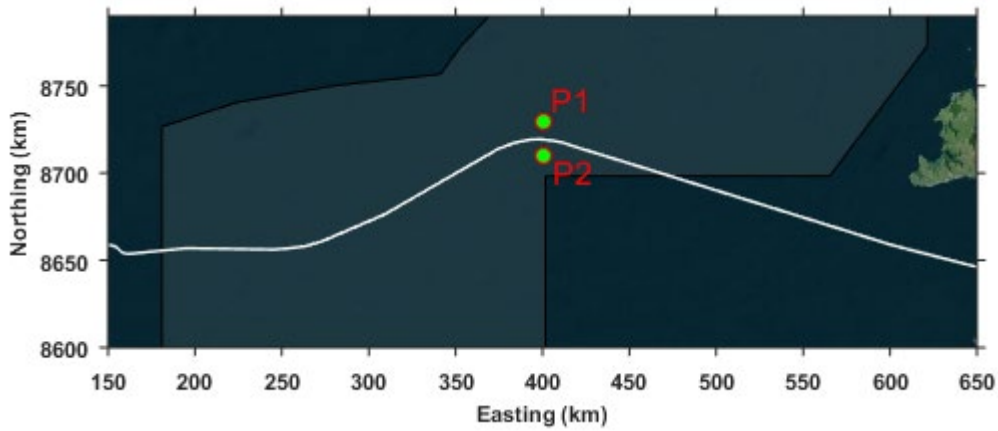


Figure 12 Offshore numerical monitoring timeseries locations. White line indicates submarine cable route

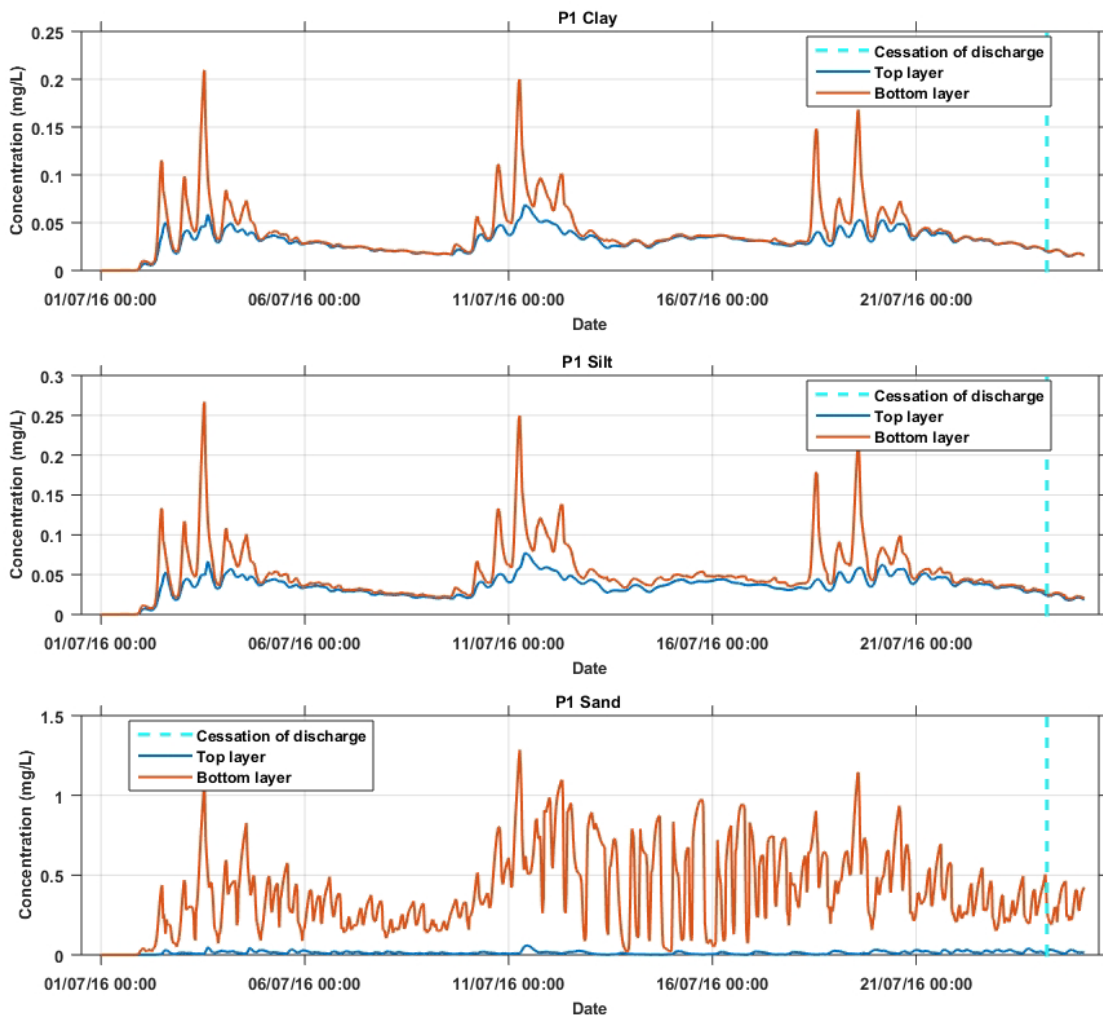


Figure 13 Timeseries of modelled SSC at top (blue line) and bottom (orange line) layers for P1 numerical monitoring station (offshore scenario)

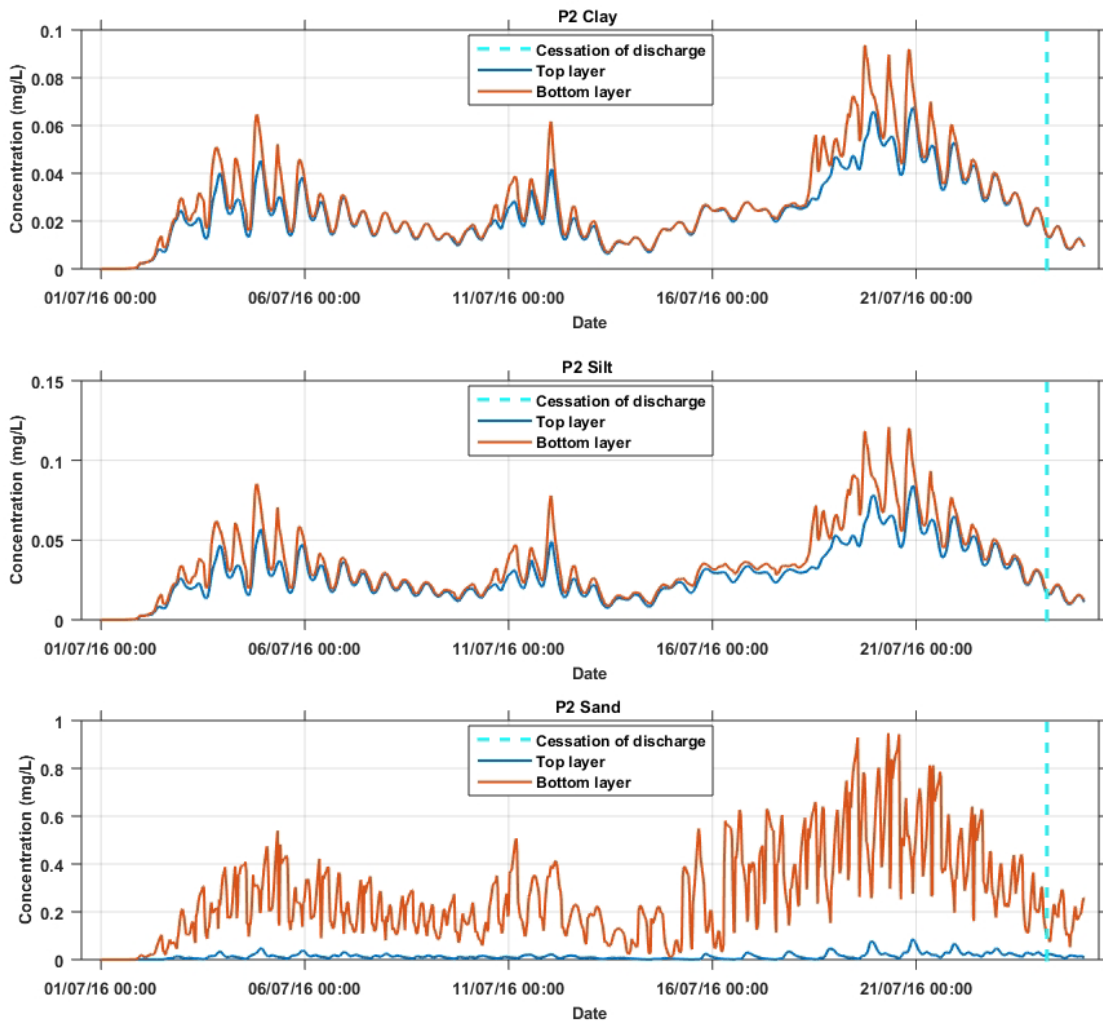


Figure 14 Timeseries of modelled SSC at top (blue line) and bottom (orange line) layers for P2 numerical monitoring station (offshore scenario)

### 5.8 Seabed disturbance

The land sea joint (LSJ) station, which will be located approximately 300 m inland from the beach, will facilitate the transition of the HVDC cables from onshore to offshore. The shore crossing site is where the subsea cables will be winched from a barge located offshore to the LSJ station.

For each cable, a temporary open trench 2 m wide and 0.5-2 m deep will be constructed from the LSJ station across the shoreline out to the low water mark. The construction work will be conducted to avoid impacts to mangroves with minimal possible disturbance to the beach and dune environment (Sun Cable, 2021). The cable will be laid in the trench and then buried using the material excavated from the trench to avoid significant changes to the composition of sediments. It is expected that an area of less than 0.01 km<sup>2</sup> will be affected by the construction. Post-construction, the land surface and seafloor will be reinstated and vegetation will be allowed to regrow.

Localised changes to the coastline and bathymetry could occur as a result of the construction work, with possible small effects on waves and sediment transport within the localised intertidal zone. These effects are likely to be temporary with no significant change to the local topography or sediment characteristics in the Project Area, therefore they were not modelled. According to NIRAS (2015) intertidal biotopes such as sand and mudflats display a low sensitivity to and high recoverability from temporary sediment displacement.

In both the nearshore and offshore Project areas, the seabed disturbance is expected to be restricted to a narrow strip of seabed, limited to an area about 2-3 m either side of each cable (NIRAS, 2015). However, the footprint of seabed disturbance caused during installation is related to the device used and can be up to 10 m wide for each cable (OSPAR, 2009). The Project is at concept stage only and further refinement of the seabed disturbance footprint may be required.

Sea bed disturbance can potentially lead to contamination due to releases of contaminated sediments into the water column from cable burial, recovery of buried cables and repair work. Elevated arsenic concentrations (above default guideline values from ANZECC and ARMCANZ, 2000) were found to be a naturally occurring phenomenon in the Project area (see the AAPowerLink EIS Marine Environmental Quality report). The laying of cables can also lead to increased nutrient releases from sediments. Releases of contaminants (arsenic) and nutrients to the water column are expected to be very low and rapidly diluted beyond the immediate area of the release due to the dynamic nature of the environment. OSPAR (2009) reported that contamination arising from seabed disturbance is only a risk in heavily contaminated locations, which is not characteristic of the Project area (for more detail see the AAPowerLink EIS Marine Environmental Quality report).

## 5.9 Cumulative effects

Cumulative effects, the combined effect of more than one activity, may reinforce the impacts of a single activity due to temporal and/or spatial overlaps. At present, there are no sufficient data available to address any cumulative effects.

## 6.0 Conclusions

A modelling study was undertaken to assess the effects of trenching operations to simultaneously bury three parallel underwater cables separated by 50-100 m in three successive paths of 50 km. The effects were considered separately for the nearshore and offshore scenarios, representing Project operations at two different parts of the submarine cable route.

Median values (the 50<sup>th</sup> percentile) of predicted SSC were used to establish “typical” water quality impacts and zone of influence (indirect disturbance) on the marine environment. The 95<sup>th</sup> percentile SSC were used to assess the upper level (“worst-case”) impacts and zone of influence. Project footprint (direct seabed disturbance) was established based on analyses of Project operations and literature review.

The following key conclusions were driven from the modelling results:

- “Typical” water quality impacts within both the nearshore and offshore Project parts: the predicted median SSC are below their corresponding WQOs (Table 2), except a small patch (~800 m x 200 m) in the area closest to the beach in the nearshore Project part (Figure 7)
- “Worst-case” water quality impacts in the nearshore Project part: trenching in Shoal Bay would affect a small area (~1 km x 1 km) adjacent to the coast with the 95<sup>th</sup> percentile SSC above 200 mg/L (Figure 8). Beyond this area SSC decrease to 10 mg/L (WQO) within 20 km from the coast
- “Worst-case” water quality impacts in the offshore Project part: the highest 95<sup>th</sup> percentile SSC (above WQO of 2 mg/L) oscillate north-south within approximately 1 km from the route, while SSC do not exceed 4 mg/L anywhere in the model domain
- With each pass of the trenchers, the plume of suspended sediments would persist for up to 5 days at the nearby sites before dispersing down to ambient conditions in both Project areas.

Summary of conclusions is presented in Table 6.

Table 6 Summary of conclusions

Impacts	Factor/Source	Nearshore	Offshore
Proposal footprint	Seabed disturbance	<ul style="list-style-type: none"> <li>• Less than 0.01 km<sup>2</sup> for construction of LSJ station/shore crossing</li> <li>• Up to 10 m width for each cable</li> </ul> <p>Localised changes to the coastline and bathymetry could occur as a result of the shore crossing site construction, with possible small effects on waves and sediment transport within the localised intertidal zone. These effects are likely to be temporary with no significant change to the local topography or sediment characteristics</p>	Up to 10 m width for each cable
“Typical” indirect disturbance	The 50 <sup>th</sup> percentile SSC maps	Less than 10 mg/L (WQO) anywhere in the model domain, except a small (~800 m x 200 m) nearshore area	Less than 1 mg/L (below WQO) anywhere in the model domain
“Worst-case” indirect disturbance	The 95 <sup>th</sup> percentile SSC maps	SSC greater than 10 mg/L (above WQO) in ~20 km x 11 km coastal area	SSC greater than 2 mg/L (above WQO) within 1 km from the route in the bottom water layer
Duration of impacts	Timeseries of SSC	Up to 5 days	Up to 5 days

The results suggest that trenching operations would have a relatively short-term effect on the ambient conditions, with the concentrations likely to be within the range of natural variability expected for both the nearshore and offshore areas. Potential releases of contaminants (if any) and nutrients to the water column as a result of seabed disturbance are expected to be very low and rapidly diluted beyond the immediate area of the release due to the dynamic nature of the environment.

All predictions made in this study were based on Project information provided by EcOz, data from other sources, selected numerical modelling techniques, and a number of assumptions discussed throughout this report. A conservative approach was adopted when selecting model input parameters for the Project discharges.

Hydrodynamic, wave and sediment transport modelling by any known technique, including techniques used in this study, is not an exact science. Although best efforts were undertaken to reduce model uncertainties, the results should be interpreted in the context of model limitations. To reduce this uncertainty, it is recommended to use additional site-specific geotechnical information on types and spatial distribution of sediments to be disturbed as well as current speed and wave measurements in the Project area.

## 7.0 References

- AIMS, 2014. High resolution data for Darwin Harbour collected and processed by AIMS. Australian Institute of Marine Science
- AIMS, 2021. Australian Institute of Marine Science, The Beagle Gulf Surface Buoy deployed from May 2015 to July, 2017. Data Centre, AIMS. Accessed 6<sup>th</sup> March 2021
- ASA, 2006. Simulation of Sediment Transport and Deposition from Cable Burial Operations for the Alternative Site of the Cape Wind Energy Project. Report prepared for Cape Wind Associates, LLC, USA. Applied Science Associates, Inc., August 2006.
- Bishop-Taylor, R., Nanson, R., Sagar, S., Lymburner, L. 2021. Digital Earth Australia Coastlines. Geoscience Australia, Canberra. <https://doi.org/10.26186/116268>
- BOM, 2021. The Bureau of Meteorology, Australian Baseline Sea Level Monitoring Project, <http://www.bom.gov.au>, Accessed 6<sup>th</sup> March 2021
- Booij, N., Ris, R., Holthuijsen, L., 1999. A third-generation wave model for coastal regions, Part I, Model description and validation. *Journal of Geophysical Research* 104 (C4): 7649–7666.
- BRAN, 2021. The Bluelink ReANalysis (BRAN) is a multi-year integration of OFAM that assimilates observations using an Ensemble Optimal Interpolation (EnOI) data assimilation system called BODAS (Bluelink Ocean Data Assimilation System). <https://research.csiro.au/bluelink/global/reanalysis/> Accessed March 2021
- Caltest, 2021. Total Suspended Solids Analysis (TSS) and Suspended Sediment Concentration Analysis (SSC). Caltest Analytical Laboratory Environmental Analyses. <http://www.caltestlabs.com>, Accessed 15/08/2021.
- CSIRO, 2021. WaveWatch III hindcast data base. [http://data-cbr.csiro.au/thredds/catalog/catch\\_all/CMAR\\_CAWCR-Wave\\_archive/CAWCR\\_Wave\\_Hindcast\\_aggregate/gridded/catalog.html](http://data-cbr.csiro.au/thredds/catalog/catch_all/CMAR_CAWCR-Wave_archive/CAWCR_Wave_Hindcast_aggregate/gridded/catalog.html) Accessed March 2021
- Deltares, 2014a. Delft3D-FLOW, Simulation of multi-dimensional hydrodynamic flows and transport phenomena, including sediments, User Manual. 710p.
- Deltares, 2014b. Delft3D-WAVE, Simulation of short-crested waves with SWAN, User Manual. 226p.
- DLRM, 2014. Department of Land Resource Management, Northern Territory Government. Darwin Harbour Water Quality Protection Plan. [https://landresources.nt.gov.au/\\_\\_data/assets/pdf\\_file/0011/254855/Water-Quality-Protection-Plan-Feb2014-web.pdf](https://landresources.nt.gov.au/__data/assets/pdf_file/0011/254855/Water-Quality-Protection-Plan-Feb2014-web.pdf)
- Durrant, T., Greenslade, D., Hemer, M. and Trenham, C. 2014. A Global Wave Hindcast focussed on the Central and South Pacific CAWCR Technical Report No. 070.
- Egbert, G.D., Erofeeva, S.Y., 2002: Efficient inverse modeling of barotropic ocean tides, *J. Atmos. Oceanic Technol.*, 19(2), 183-204. ([http://www.esr.org/polar\\_tide\\_models/Model\\_TPXO62\\_load.html](http://www.esr.org/polar_tide_models/Model_TPXO62_load.html))
- Fortune, J., 2010. Water Quality Objectives for the Darwin Harbour Region - Background Document. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport. Palmerston, NT.
- Fortune, J., 2015. Supplement to the 2014 Darwin Harbour Region Report Card. Report No. 01/2015D. Aquatic Health Unit, Department of Land Resource Management. Palmerston, NT.
- Fortune, J., 2019. Darwin Harbour Region 2019 Report Card. Aquatic Health Unit, Department of Environment and Natural Resources. Palmerston, NT
- Geoscience Australia, 2021. NAXA-the North Australia Exercise Area (military). ([http://services.ga.gov.au/gis/services/Defence\\_Restricted\\_Areas/MapServer/WmsServer?](http://services.ga.gov.au/gis/services/Defence_Restricted_Areas/MapServer/WmsServer?)) Accessed November 2021
- Guardian Geomatics, 2021. Australia-ASEAN PowerLink Cable Route Survey. Preliminary Survey Report. Prepared for Sun Cable Pty Ltd, January 2021.
- Holthuijsen, L., Booij, N., Ris, R., 1993. A spectral wave model for the coastal zone. In *Proceedings of 2nd International Symposium on Ocean Wave Measurement and Analysis*, New Orleans, 630–641.

- Langtry, S., Rayson, M., Makarynsky, O., Zapata, M., 2009. Optimal selection of sediment disposal sites in open coast locations, Coasts and Ports in a Dynamic Environment, 16-18 September 2009, Wellington, New Zealand, 7p, CD-ROM.
- NIRAS, 2015. Subsea Cable Interactions with the Marine Environment. Expert review and Recommendations Report, December 2015. Report prepared for Renewables Grid Initiative, United Kingdom.
- Njock, P. G. A., Zheng, Q., Zhang, N. and Xu Ye-S., 2020. Perspective Review on Subsea Jet Trenching Technology and Modeling, Journal of Marine Science and Engineering, 8, 460; doi:10.3390/jmse8060460
- Makarynska, D. and O. Makarynsky, 2017. Hydrodynamic and sediment plume modelling in a macro-tidal estuary. Coasts & Ports 2017 Conference – Cairns, 21-23 June 2017
- Makarynsky, O., Rusu, E., Makarynska, D., 2000. On the question of the SWAN model implementation in a PC platform. Bulletin of the Polytechnic Institute of Jassy, Vol.XLVI(L), 2000, Jassy, Romania, 255-258.
- Makarynsky, O., Makarynska, D., 2011. Calculating bed shear stresses under combined currents and waves in Darwin Harbour, Coasts&Ports2011 Diverse and Developing, 28-30 September 2011, Perth, Australia, 6p, USB.
- Makarynsky, O., Makarynska, D. 2019. Integrated marine monitoring for drilling discharges under mesotidal forcing. Ukrainian Hydrometeorological Journal, 23, 69-83, doi: 10.31481/uhmj.23.2019.07.
- Nicholas, W. A., Smit, N., Siwabessy, P. J. W., Nanson, R., Radke, L., Li, J., Brinkman, R., Atkinson, R., Dando, N., Falster, G., Harries, S., Howard, F. J. F., Huang, Z., Picard, K., Tran, M., Williams D., 2019. Characterising Marine Abiotic Patterns in the Darwin-Bynoe Harbour region: Summary report, Physical Environments, Darwin Harbour Mapping Project. Department of Environment and Natural Resources. Darwin, Northern Territory, Australia. <http://pid.geoscience.gov.au/dataset/ga/127386>
- NIRAS, 2015. Subsea Cable Interactions with the Marine Environment. Expert review and Recommendations Report, December 2015. NIRAS Consulting Ltd
- Oke, P., Sakov, P., Cahill, M., Dunn, J., Fiedler, R., Griffin, D., Mansbridge, J., Ridgway, K., Schiller, A., 2013. Towards a dynamically balanced eddy-resolving ocean reanalysis: BRAN3. Ocean Modelling. 2013; 67:52-70. <https://doi.org/10.1016/j.ocemod.2013.03.008>
- OSPAR, 2009: OSPAR commission. Protecting and conserving the North-East Atlantic and its resources. Assessment of the environmental impacts of cables. – Publication Number: 437/2009.
- Padovan, A. V., 2003. Darwin Harbour water and sediment quality. Proceedings of the Darwin Harbour public presentations, 5-18.
- Provis and Aijaz, 2009. Prediction of plume generation and movement from dredging operations in Port Phillip Bay, Melbourne. Coasts and Ports 2009 Conference, Wellington, New Zealand, 2009
- Richardson, M.D., Jackson, D.R., 2017. Chapter 8 - The Seafloor, in: Applied Underwater Acoustics, Editor(s): Thomas H. Neighbors, David Bradley, Elsevier, Pages 469-552, doi: 10.1016/B978-0-12-811240-3.00008-4.
- Ris, R., Booij, N., Holthuijsen, L., 1999. A third-generation wave model for coastal regions, Part II: Verification. Journal of Geophysical Research 104 (C4): 7649–7666.
- RPS, 2015. Modeling Sediment Dispersion from Cable Burial for Seacoast Reliability Project, Little Bay, New Hampshire. Report prepared for Normandeau Associates, Inc., Bedford, NH
- Siwabessy, P.J.W., Tran, M., Huang, Z., Nichol, S. & Atkinson, I. 2015. Mapping and Classification of Darwin Harbour Seabed. Record 2015/18. Geoscience Australia, Canberra. <http://dx.doi.org/10.11636/Record.2015.018>
- Siwabessy, J., Tran, M., Howard, F.J.F., Smit, N., Williams, D.K., Dando, N., Atkinson, I., Harries, S., 2016. Outer Darwin Harbour Marine Survey 2015: High resolution bathymetry grid. Geoscience Australia, Canberra. <http://pid.geoscience.gov.au/dataset/ga/100093>
- Sun Cable, 2020. Draft Terms of Reference, Australia-ASEAN PowerLink Project Proposal, Main report, October 2020. Prepared by Coffey Services Australia Pty Ltd
- Sun Cable, 2021. Notice of Significant Variation, Australia-ASEAN PowerLink Project Proposal, Main report, August 2021. Prepared by EcOz Environmental Consultants

Taormina, B., Bald, J., Want, A., Thouzeau, G., Lejart, M., Desroy, N. and Carlier A., 2018. A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. *Renewable and Sustainable Energy Reviews*, 96, 380-391.

Tenzer, R., Gladkikh, V., 2014. Assessment of Density Variations of Marine Sediments with Ocean and Sediment Depths. *The Scientific World Journal*, Article ID 823296, 9 pages, doi: 10.1155/2014/823296.

URS, 2011. Summary of the long-term water-quality program for Darwin Harbour. Ichthys gas Field development Project. Report prepared for INPEX

VikingLink, 2017. Modelling of Sediment Disturbance During Trenching of the Proposed Viking Link Interconnector, National Grid Viking Link Ltd and Energinet.dk, Intertek Energy & Water Consultancy Services, UK

Whiteway, T., 2009. Australian Bathymetry and Topography Grid, June 2009. Record 2009/021. Geoscience Australia, Canberra. <http://dx.doi.org/10.4225/25/53D99B6581B9A>

Whitehouse R, Soulsby R, Roberts W, Mitchener H., 2000. Dynamics of estuarine muds. Thomas Telford, London.

Williams, D., Wolanski, E. & Spagnol, S., 2006. Hydrodynamics of Darwin Harbour, in *The Environment in Asia Pacific Harbours*, E. Wolanski (ed.), Springer, Dordrecht, The Netherlands, pp. 461-476.

## 8.0 Report Limitations

MetOcean Dynamic Solutions Pty Ltd (MetOcean) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of EcOz Environmental Consultants Pty Ltd to support preparation of an EIS for the Australia-ASEAN PowerLink Project developed by Sun Cable Pty Ltd.

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## 9.0 Appendix A – Model validation

Tidal measurements collected by Darwin SEAFRAME gauge at an Australian Baseline Sea Level Monitoring Project site (station number 071014, located 12.47°S, 130.85°E) were used in this study for Delft3D-FLOW model validations. No data were available for validations of currents and waves.

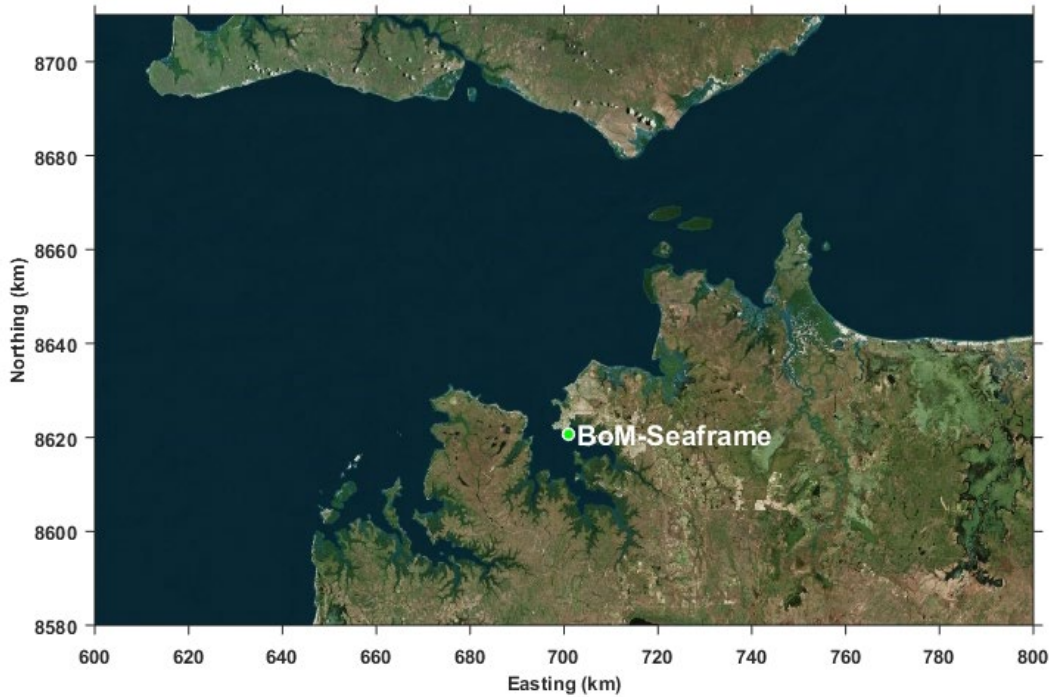


Figure 15 Location of Darwin SEAFRAME tidal gauge (BoM station 071014)

### 9.1 Nearshore model

The good performance of the Delft3D-FLOW model is confirmed by the timeseries and scatter plots presented in Figure 16 and Figure 17, respectively. The data scatter is tight along the best fit line (red line in Figure 17). The mean absolute error calculated using the time series was 0.06 m, and the correlation coefficient was 0.99, which indicate good performance of the model.

The Delft3D-WAVE results were presented as “snap shots” of modelled wave fields in Figure 20. The presented results suggest that the model was accounting for wave energy attenuation and refraction processes well.

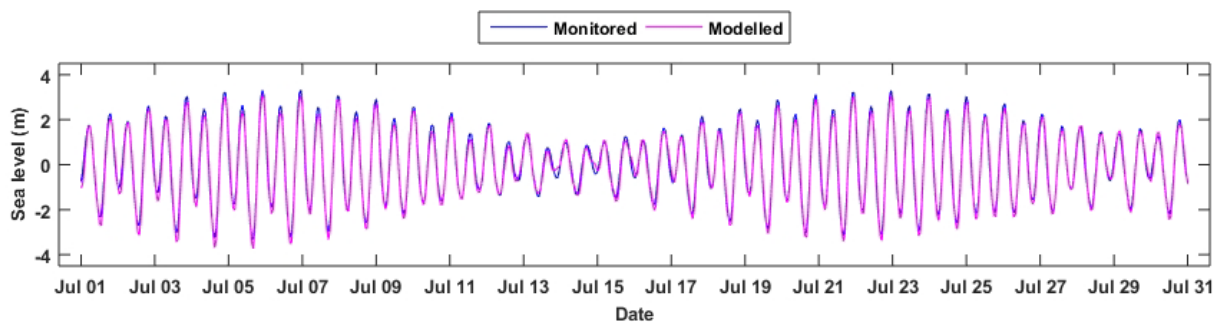


Figure 16 Time series of monitored at Darwin SEAFRAME station (BoM, 071014) and modelled sea level, nearshore scenario

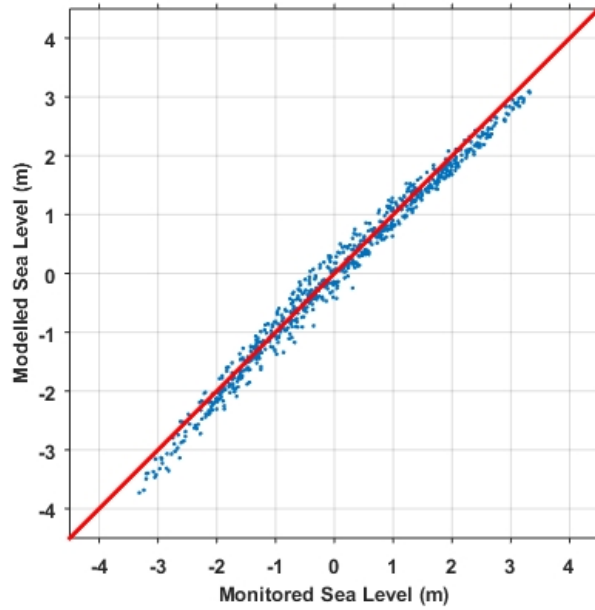


Figure 17 Scatter plot of monitored vs modelled sea level (blue dots) at Darwin SEAFRAME station (BoM, 071014) for July 2016 and best fit line (red line), nearshore scenario

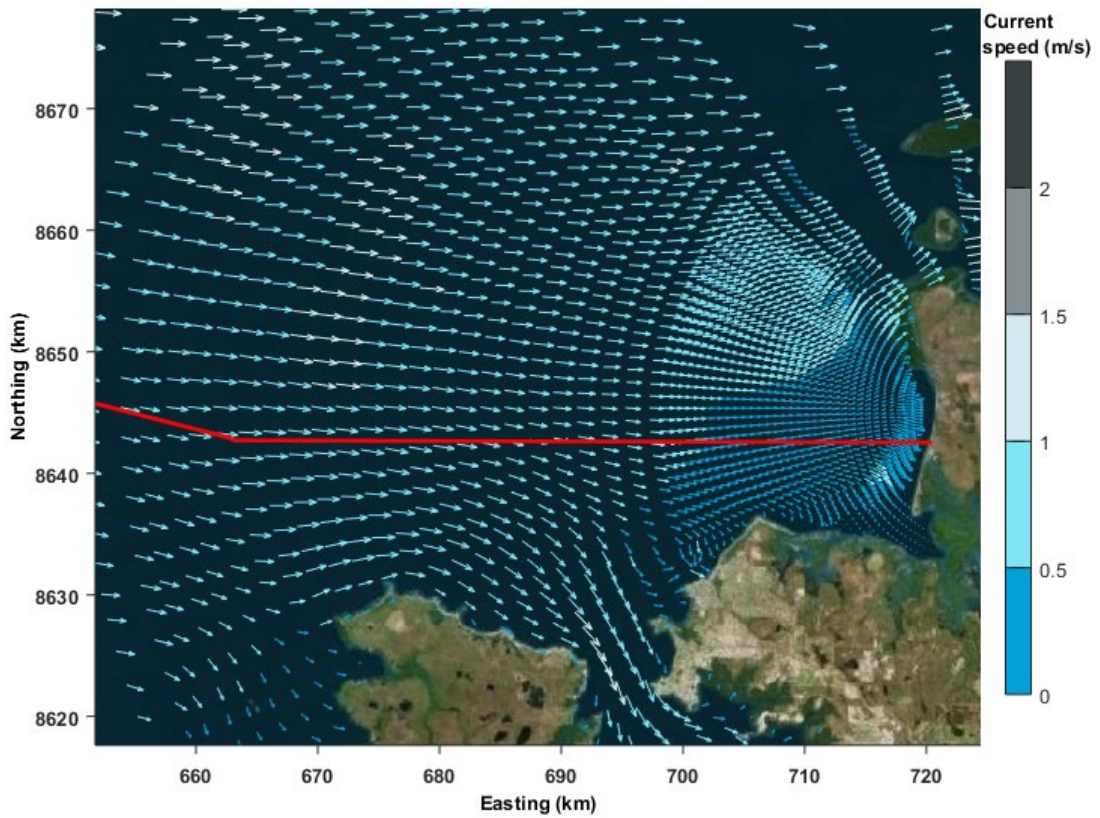


Figure 18 Modelled current velocities for flood (incoming) tide, nearshore scenario. Red line indicates submarine route

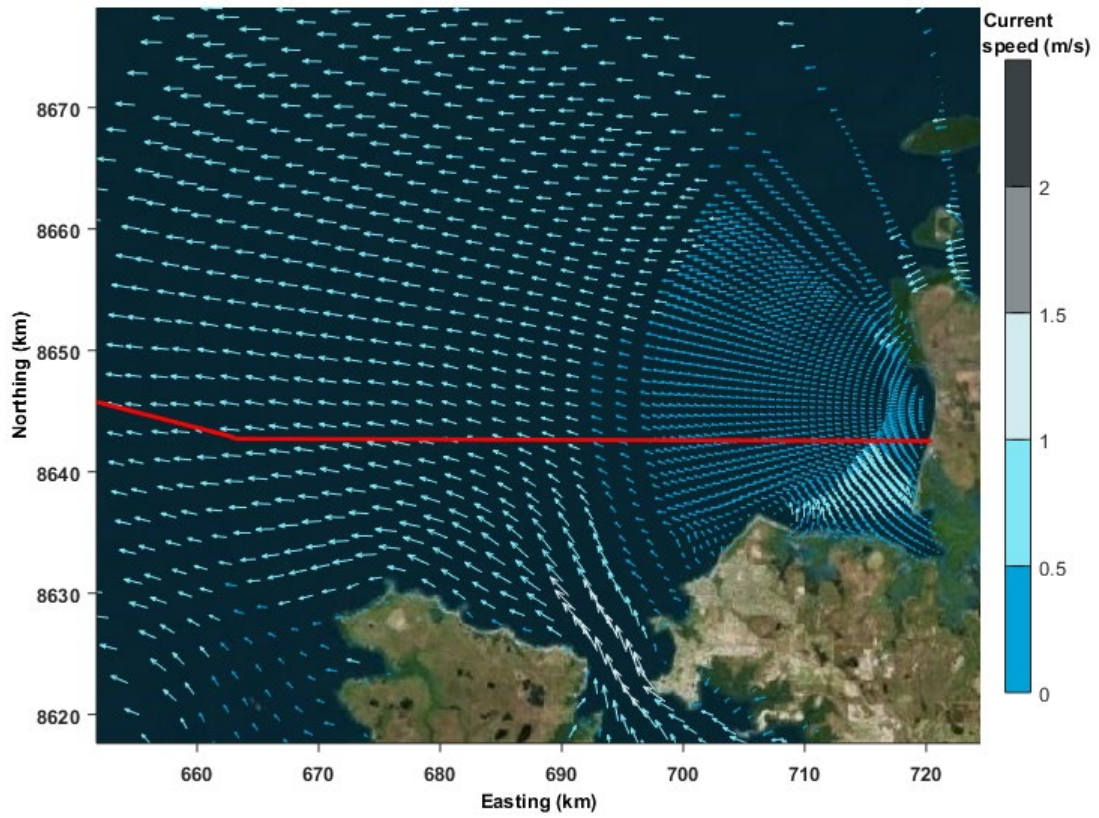


Figure 19 Modelled current velocities for ebb (outgoing) tide, nearshore scenario. Red line indicates submarine route

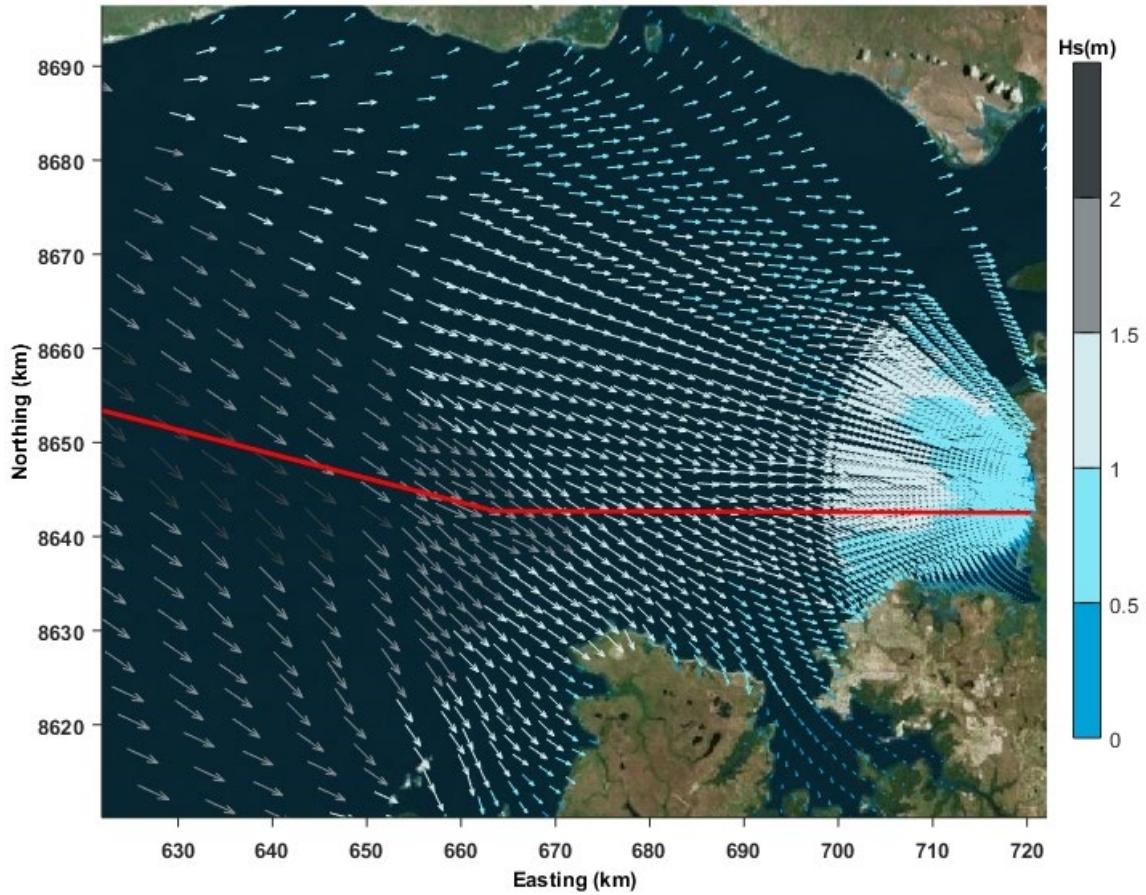


Figure 20 Modelled significant wave height (Hs), nearshore scenario. Vectors show peak wave direction, red line indicates submarine route

## 9.2 Offshore model

Figure 21 presents time series plots of monitored at Darwin SEAFRAME station (BoM, 071014) and modelled at the same location sea level for July 2016. An inter-comparison of the time series suggests that the model performed well and reproduced the range of monitored sea level variability and the timing of peaks.

The good model performance is confirmed by the scatter plot presented in Figure 22; the data scatter is tight along the best fit line (red line in the figure). The mean absolute error calculated using the time series was 0.07 m, and the correlation coefficient was 0.97.

Two example fields of colour-scaled current velocities are presented in Figure 23 and Figure 24. The presented examples suggest that the model was accounting for wetting and drying. The figures also demonstrate that the current velocity fields were properly steered by the local geometry, which was an expected outcome.

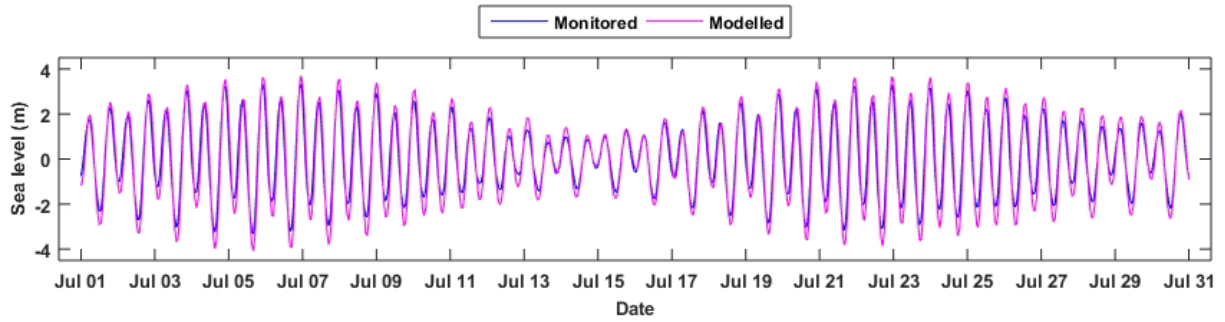


Figure 21 Time series of monitored at Darwin SEAFRAME station (BoM, 071014) and modelled sea level, offshore scenario

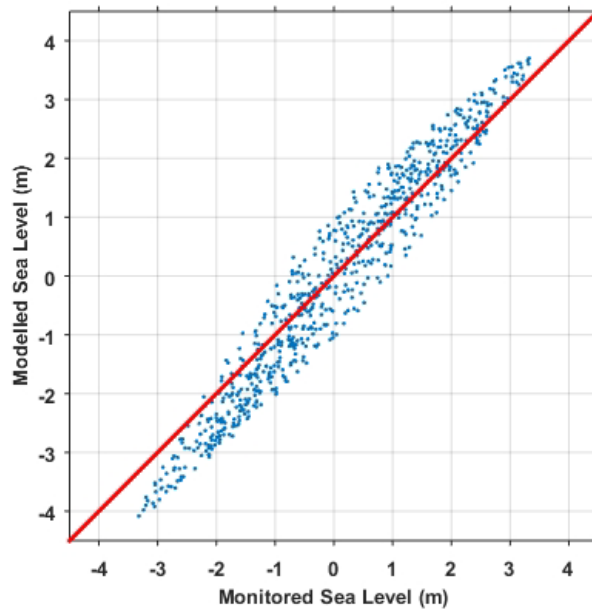


Figure 22 Scatter plot of monitored vs modelled sea level (blue dots) at Darwin SEAFRAME station (BoM, 071014) for July 2016 and best fit line (red line), offshore scenario

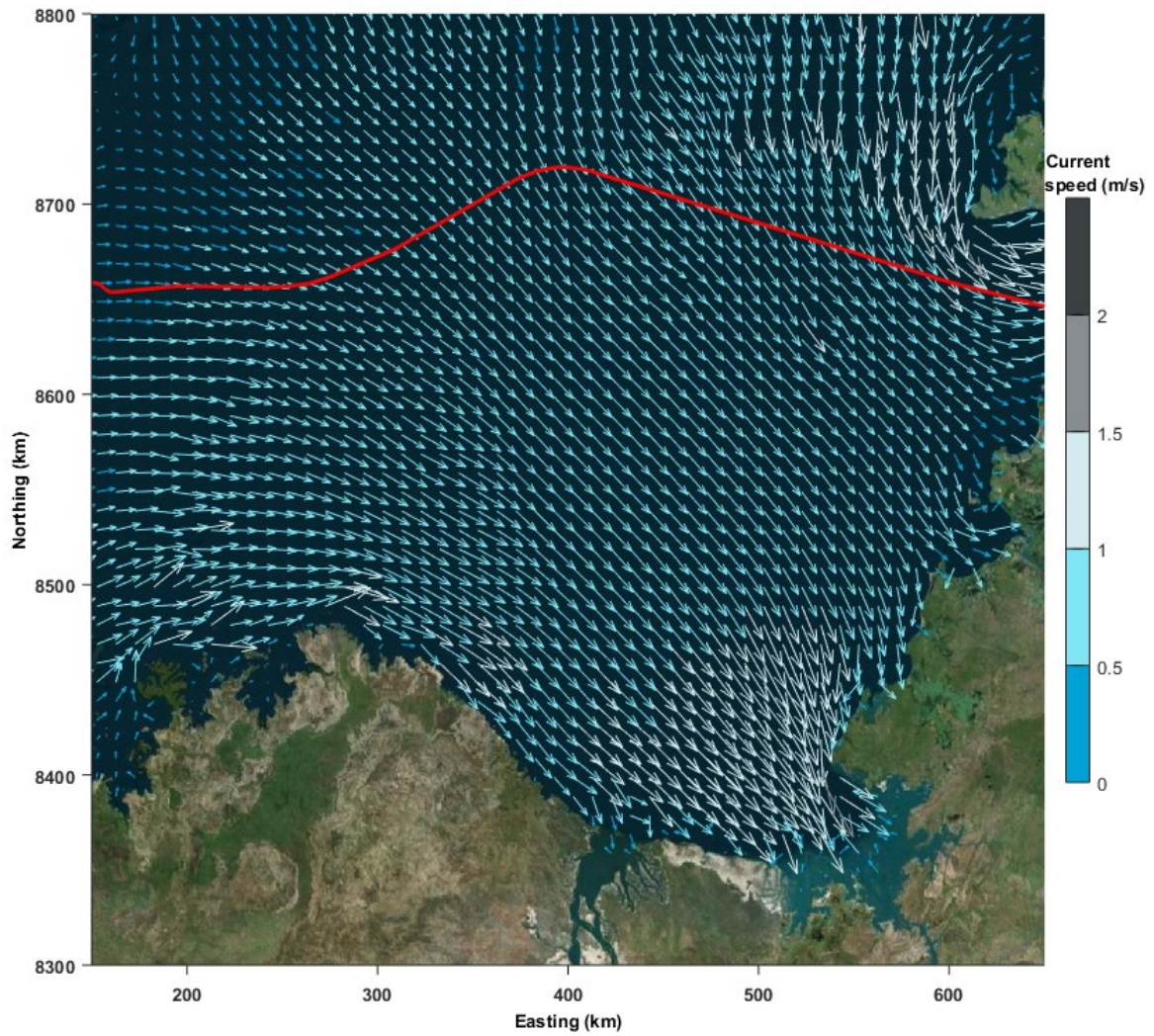


Figure 23 Modelled current velocities for flood (incoming) tide, offshore scenario. Red line indicates submarine route

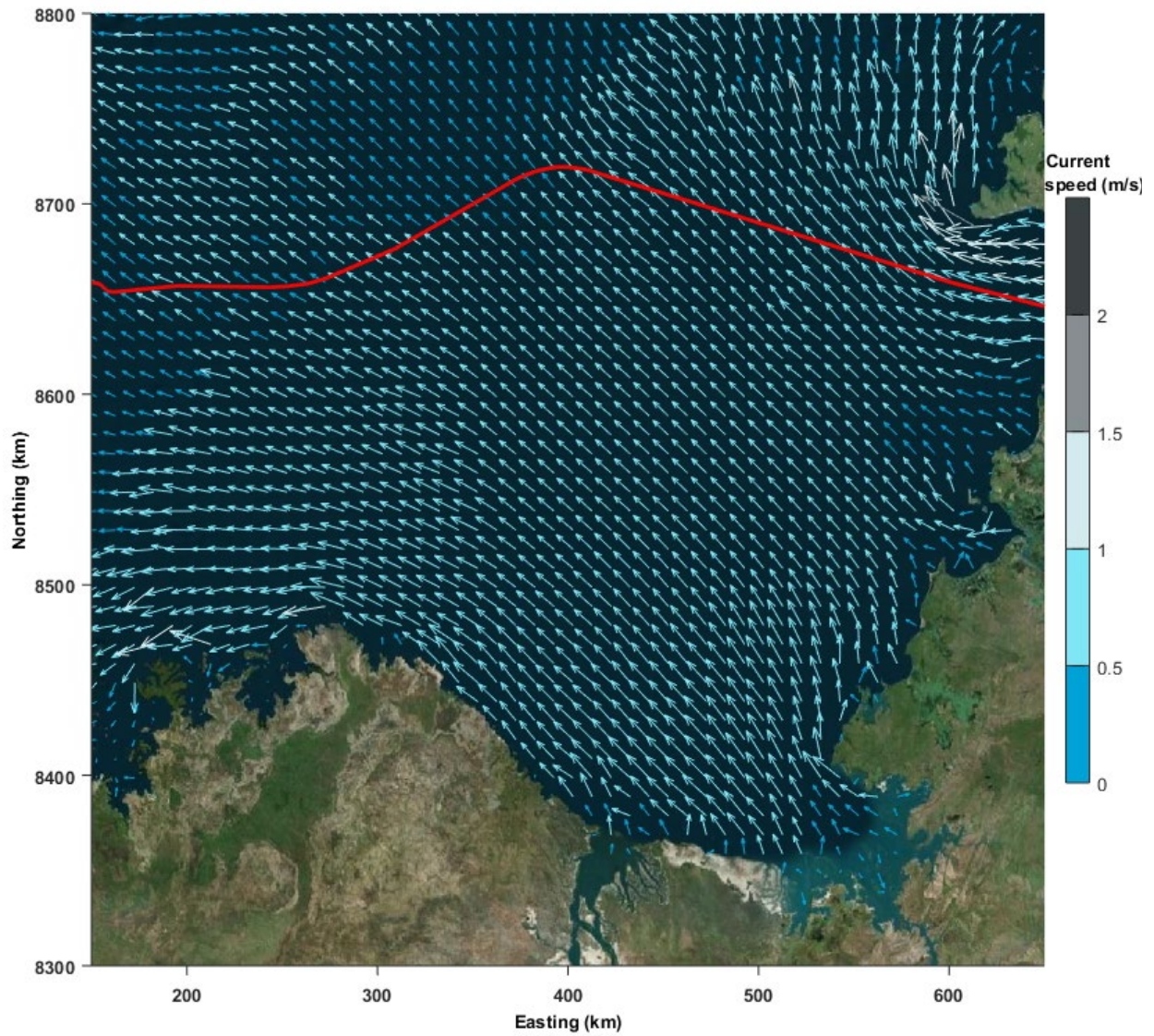


Figure 24 Modelled current velocities for ebb (outgoing) tide, offshore scenario. Red line indicates submarine route

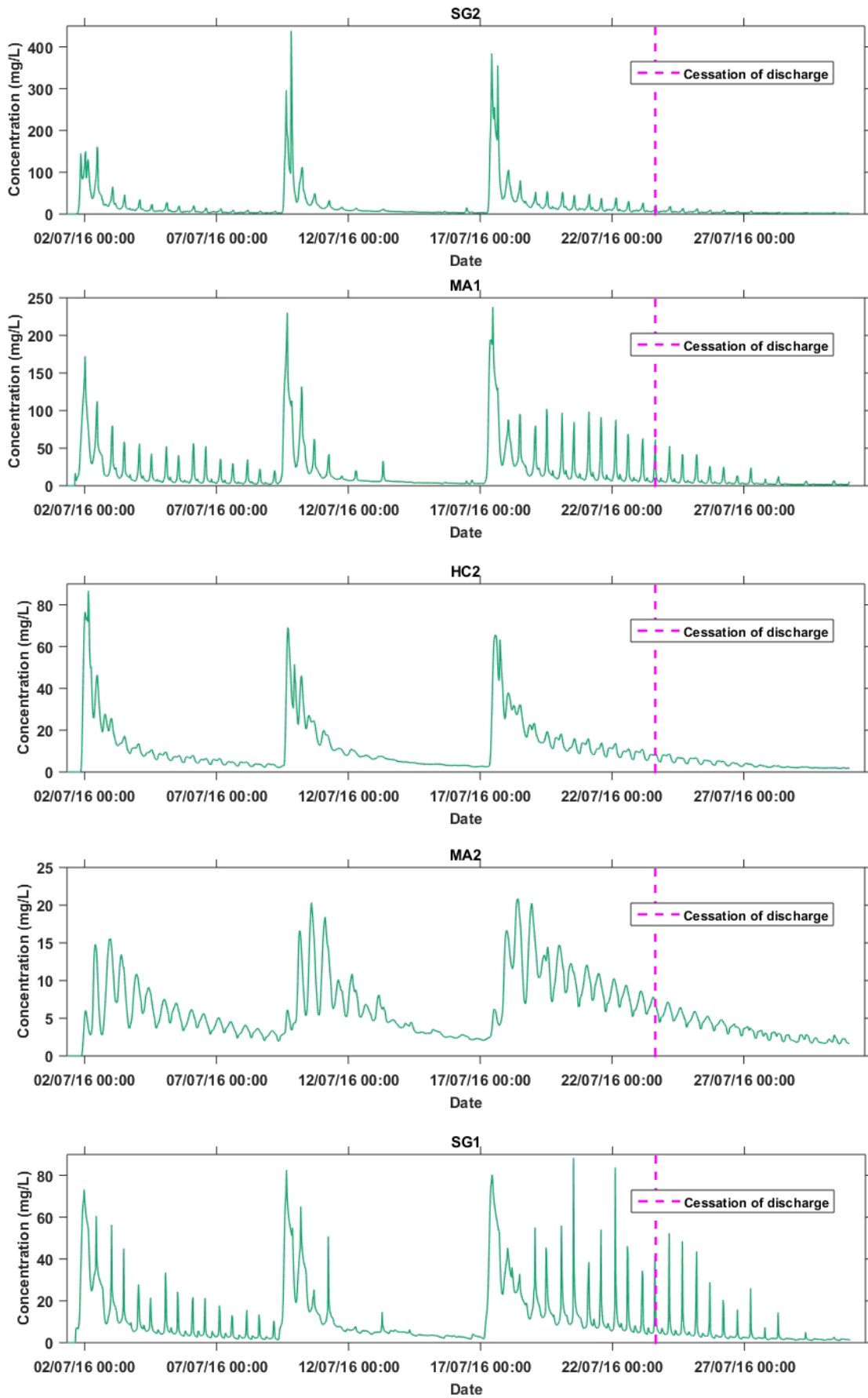
## 10.0 Appendix B – Timeseries and percentile maps of suspended sediment concentrations

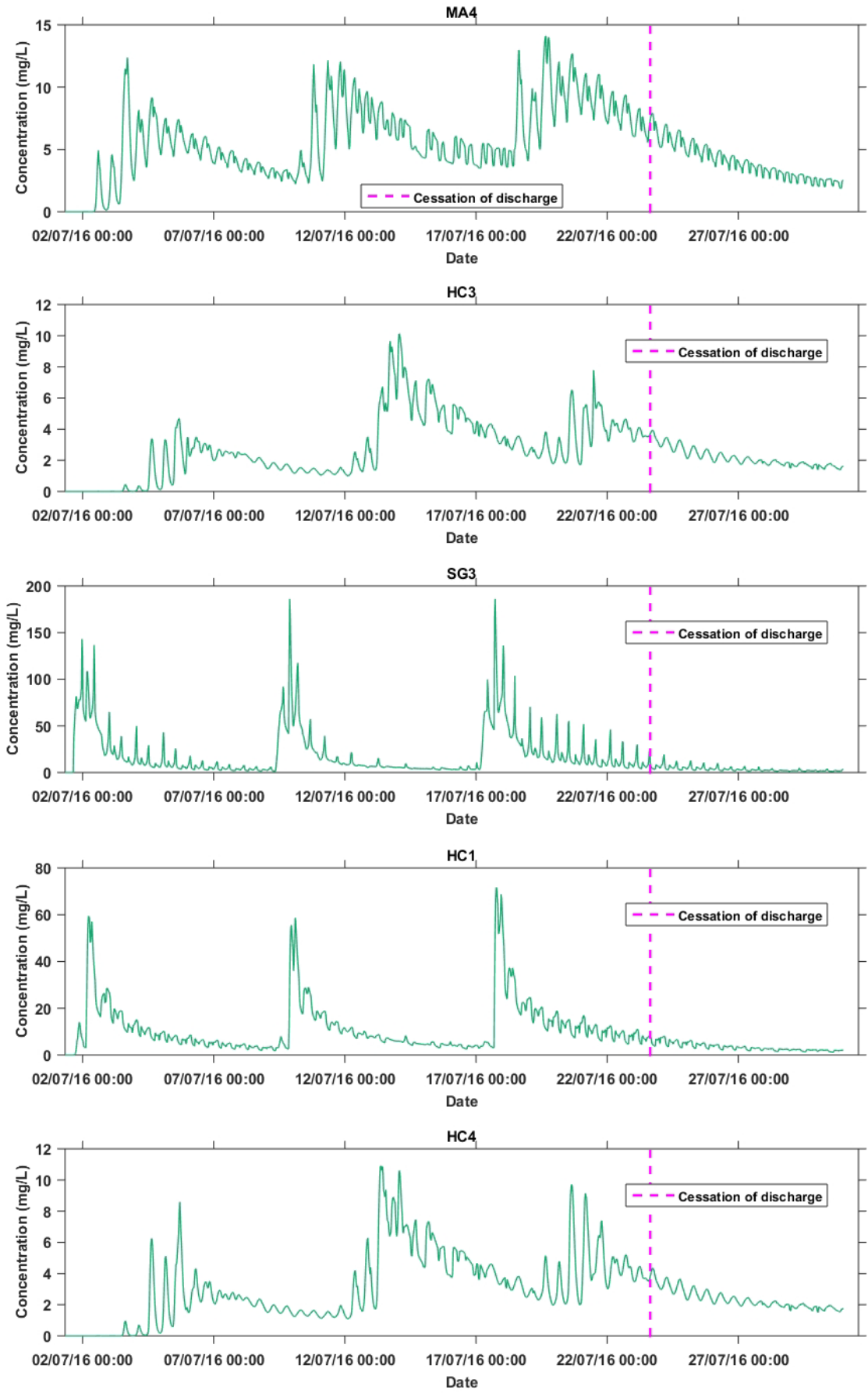
Timeseries of SSC were extracted for a number of ecologically sensitive locations presented in Table 7. Timeseries plots are shown in Figure 25.

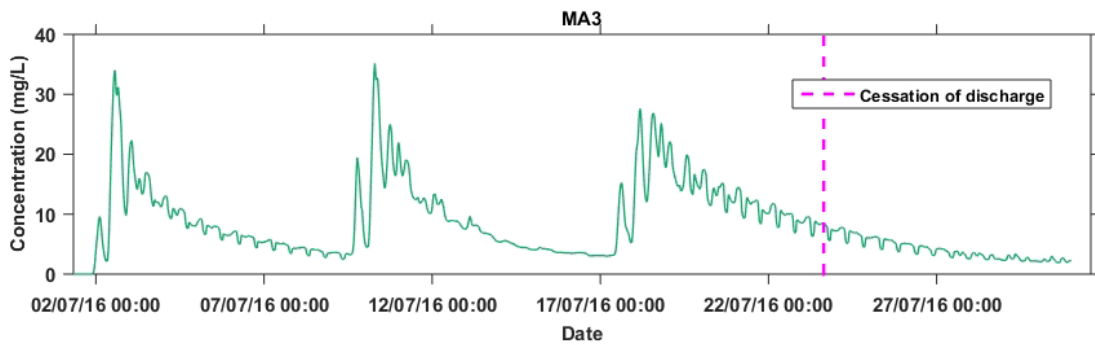
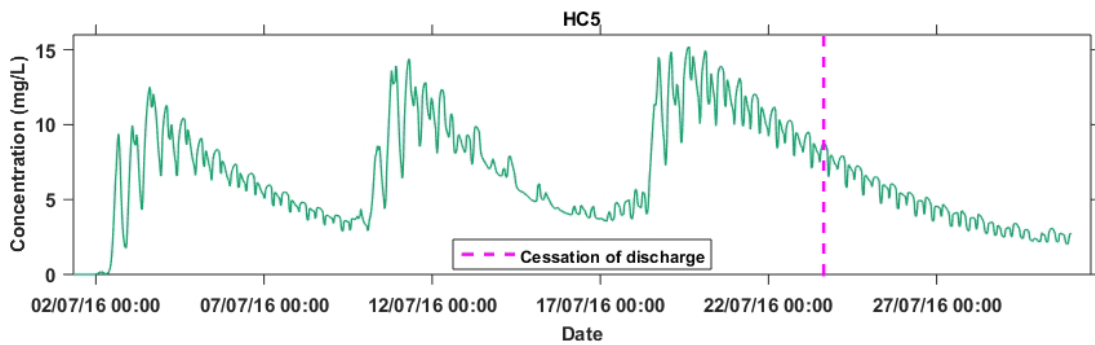
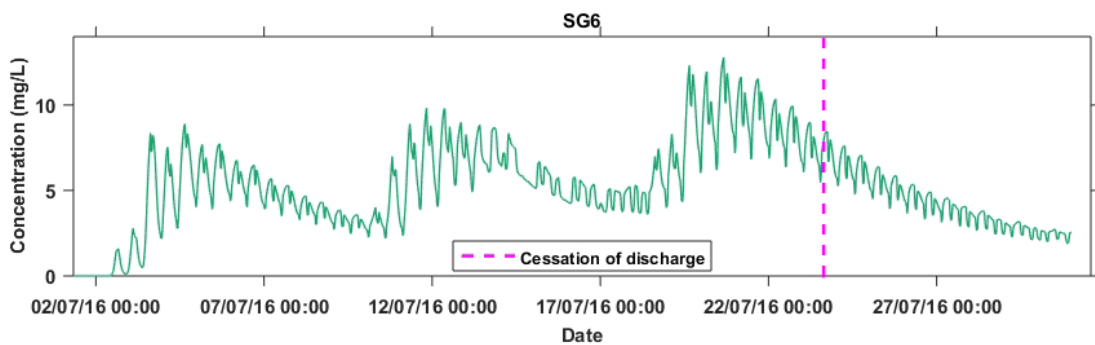
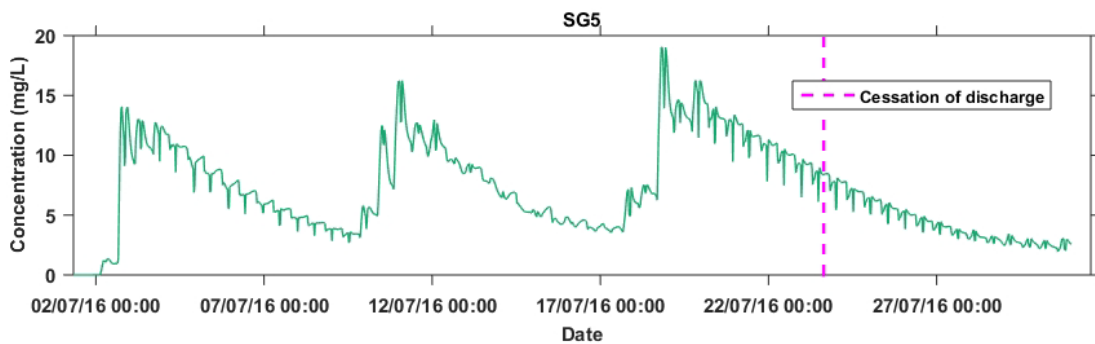
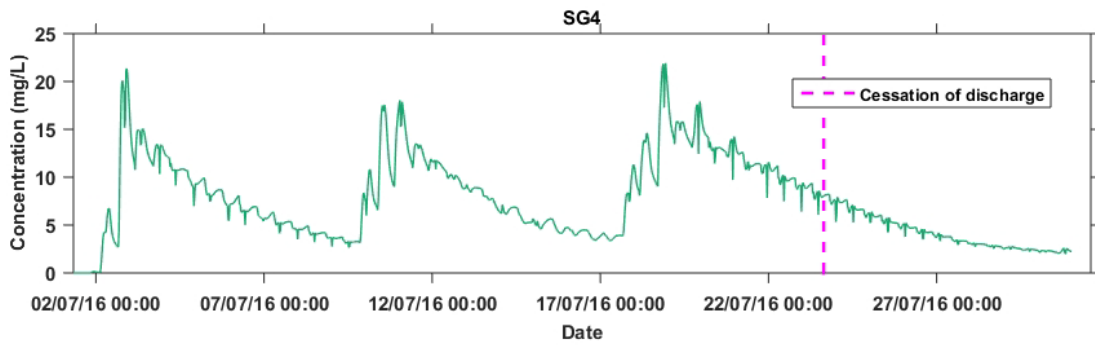
Spatial distributions of the 5<sup>th</sup> and 20<sup>th</sup> percentile SSC for the nearshore scenario are presented in Figure 26 and Figure 27 respectively.

**Table 7 Numerical monitoring stations at ecologically sensitive locations**

Numerical station ID	Ecological indicator	Easting, m	Northing, m
SG2	Seagrass	717,428	8,642,429
MA1	Macroalgae	718,479	8,643,075
HC2	Hard Corals	715,737	8,642,774
MA2	Macroalgae	714,902	8,644,382
SG1	Seagrass	719,212	8,643,585
MA4	Macroalgae	705,274	8,640,239
HC3	Hard Corals	690,968	8,643,524
SG3	Seagrass	718,590	8,641,476
HC1	Hard Corals	717,961	8,639,910
HC4	Hard Corals	691,707	8,641,927
SG4	Seagrass	715,826	8,638,637
SG5	Seagrass	714,140	8,638,096
SG6	Seagrass	705,115	8,639,001
HC5	Hard Corals	710,151	8,639,483
MA3	Macroalgae	713,861	8,641,301
AR1	Artificial Reef	702,588	8,639,278
AR2	Artificial Reef	700,047	8,639,612







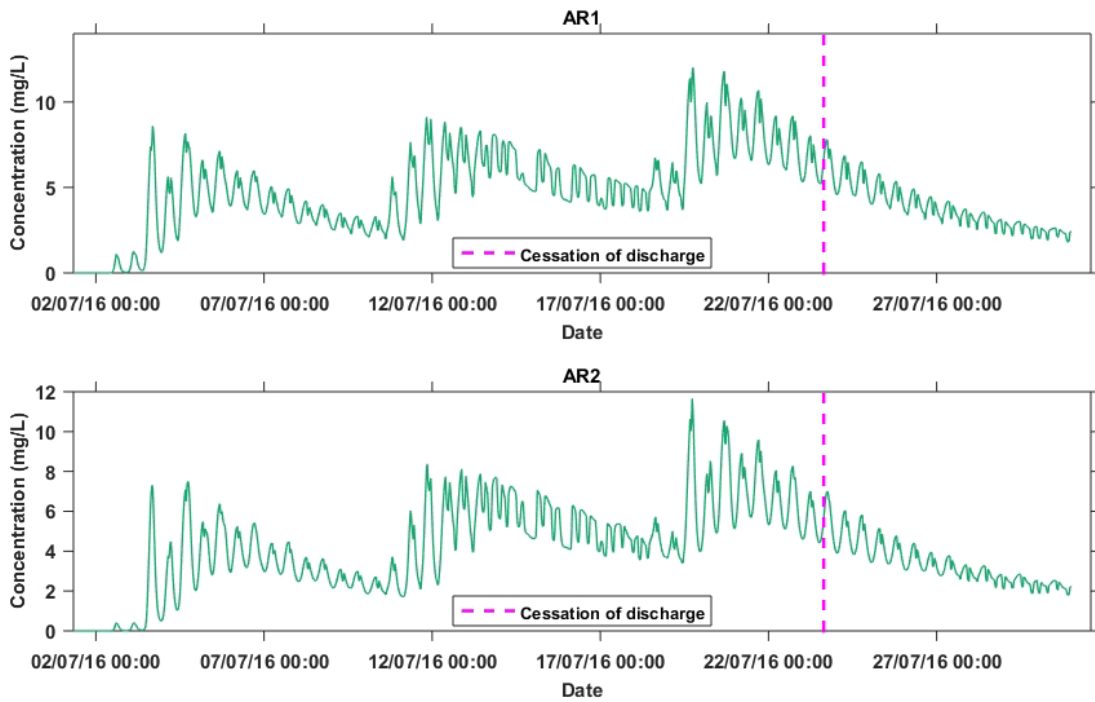


Figure 25 Timeseries of SSC at locations of ecological value

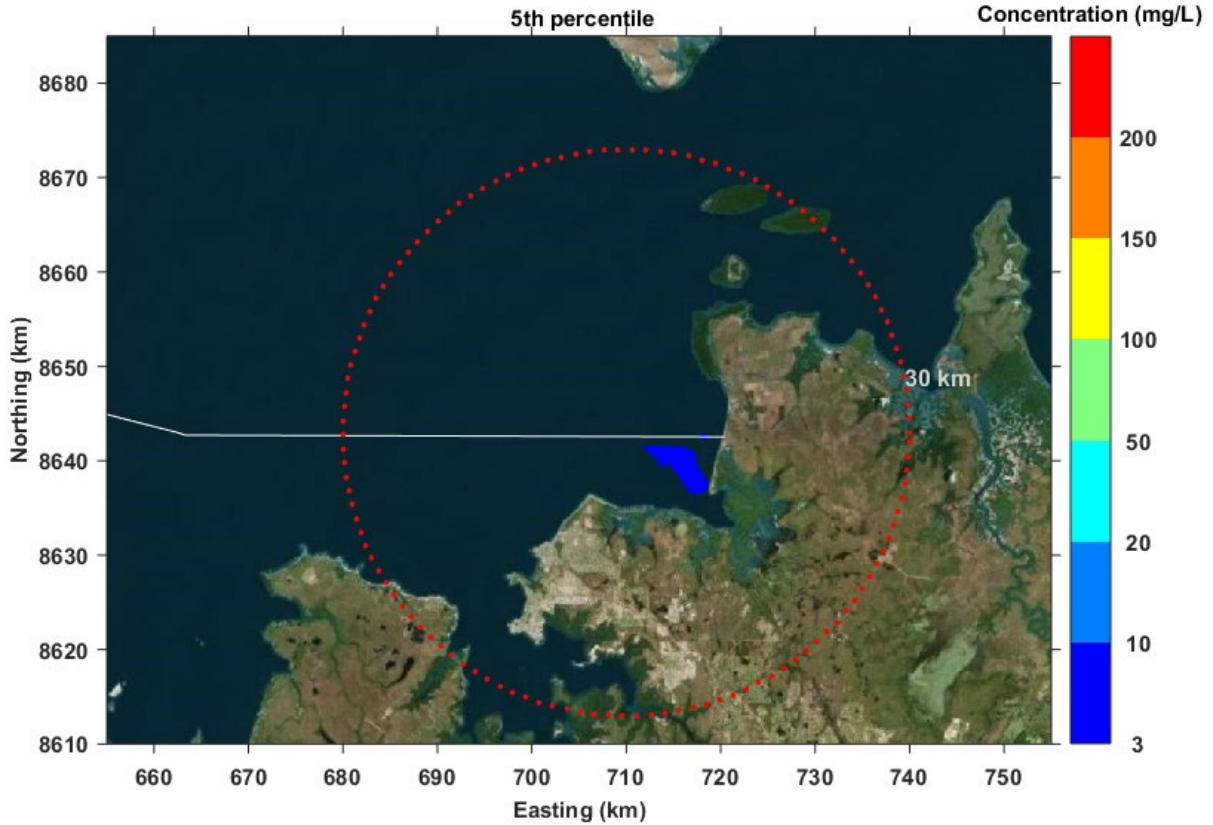


Figure 26 The 5th percentile of SSC predicted for nearshore scenario. White line indicates submarine cable route, red dots show 30 km radius scale

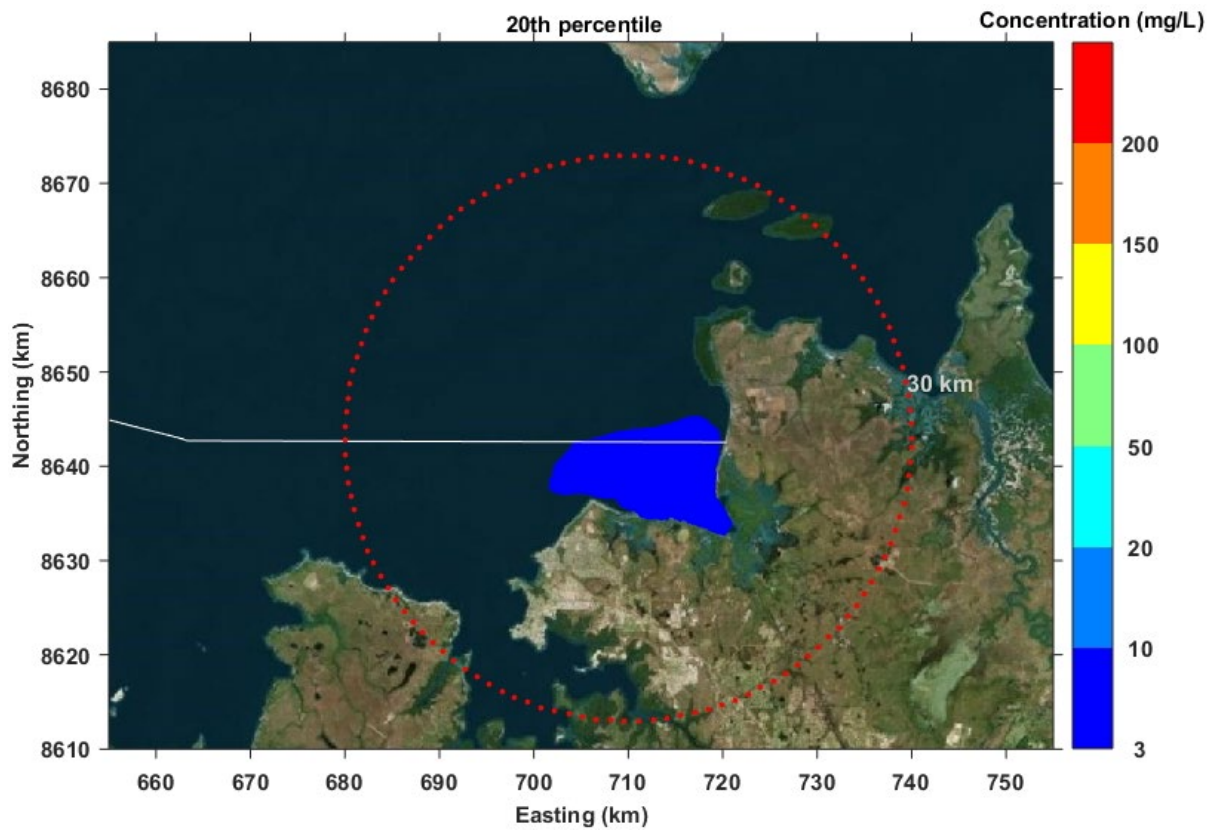


Figure 27 The 20th percentile of SSC predicted for nearshore scenario. White line indicates submarine cable route, red dots show 30 km radius scale