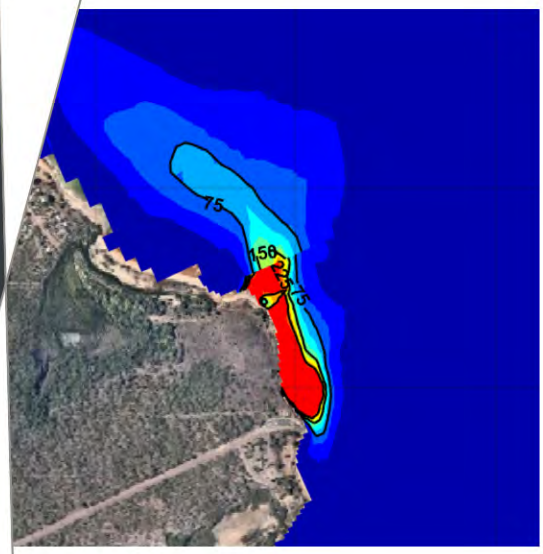
Sediment Transport Report

New Marine Facilities to Service Mandorah and Cox Peninsula

ZMD01890



Prepared for

Department of Infrastructure, Planning and Logistics

20 February 2022

Cardno

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1 Introduction

1.1 Project Background

The existing Mandorah Jetty and Boat Ramp are key infrastructure facilities servicing the Mandorah, Wagait and Belyuen communities, as well as visitors to the area from Darwin and surrounds. Mandorah Jetty supports the only ferry service from Darwin to the Cox Peninsula. The Mandorah boat ramp is located just south of the Jetty, with both facilities sharing a common onshore carpark facility.

Previous studies (e.g. Jacobs, 2016 and 2019) identified shortcomings in the design of the existing facilities, such as Disability Discrimination Act (DDA) non-compliance of the existing Jetty, and investigated various options to improve the ferry berthing facility and boat ramp. The Department of Infrastructure, Planning and Logistics (DIPL) commissioned Cardno to develop and assess options for new marine facilities at Mandorah. The key project objectives included selection and design of a facility that:

- Addresses issues faced by the existing Mandorah Jetty and boat ramp. These issues include the highly exposed nature of the site, DDA non-compliance, passenger safety issues and safety and sedimentation issues of the existing boat ramp;
- Minimises construction and whole-of-life costs;
- Allows for uninterrupted ferry service operation during construction; and
- Provides a safe and enjoyable passenger experience.

DIPL and Cardno have now developed, assessed and designed a preferred option for new marine facilities at Mandorah. The facilities comprise a dredged basin, two large breakwaters, boat ramp, gangway and pontoon, and onshore ferry terminal and parking facilities (**Figure 1-1**).

1.1.1 Site Location

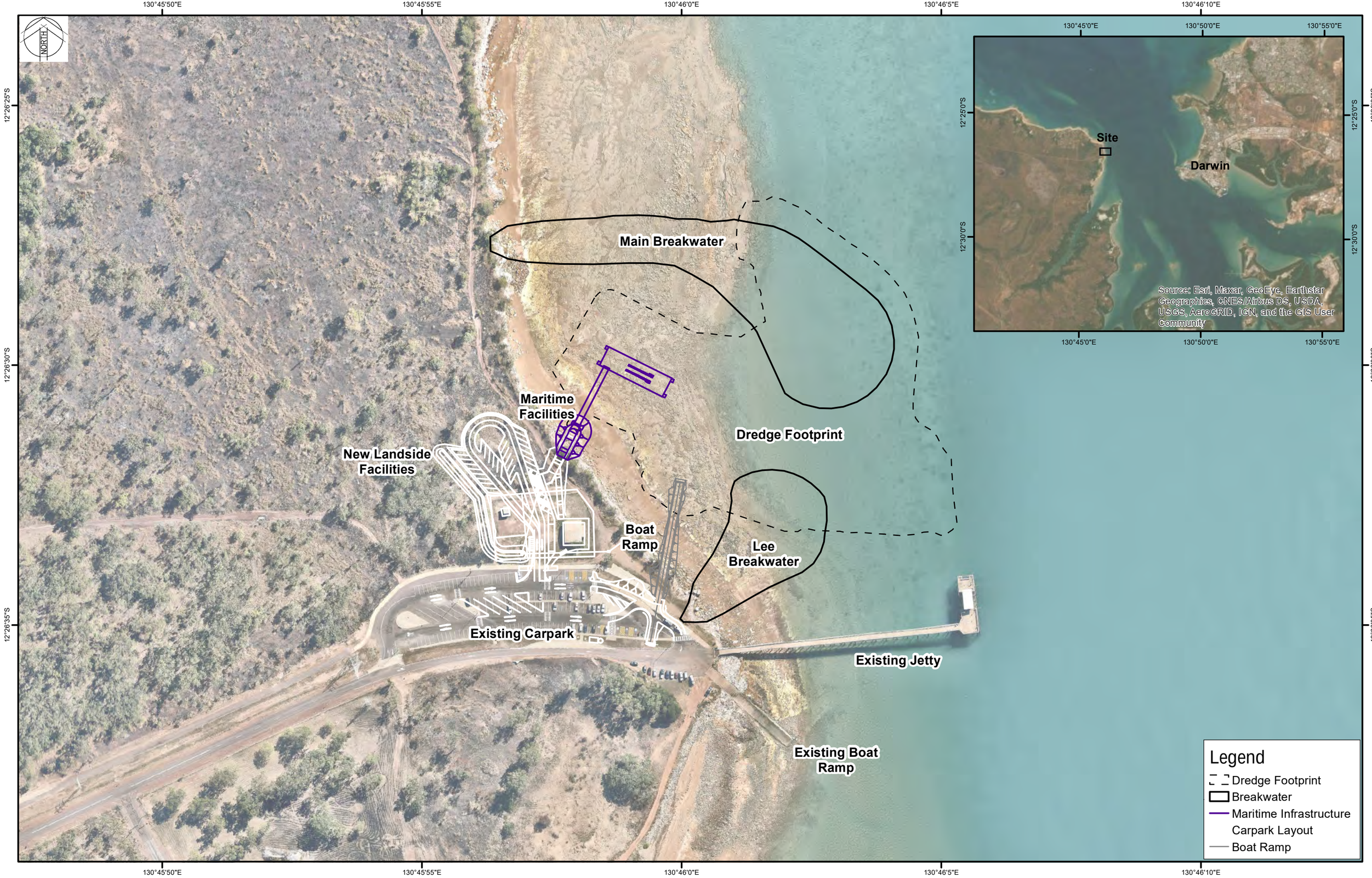
Mandorah is located near the eastern tip of the Cox Peninsula in the Northern Territory, approximately six kilometres to the west of Darwin. Access to Mandorah from Darwin is via the regular ferry service, or by driving approximately 120 km along the road network.

1.2 Purpose and Structure of this Document

The purpose of this *Sediment Transport Report* is to describe the investigation, modelling and implications of sediment transport processes that are relevant to the projects site and proposed project. The report summarises and assesses existing information relating to sediment transport through desktop review. The key sediment transport processes relevant to the project are harbour siltation, sedimentation and dredge plume dispersion. These processes have implications for design and construction, operations and environmental impact assessment.

The document has been structured as follows:

- This Section (**1**) introduces the project and context and purpose of this report;
- **Section 2** details existing data and information relevant to sediment transport in the vicinity of the project site and relevant to the project;
- **Section 3** describes further field investigations undertaken as part of the project to fill relevant data gaps;
- **Section 4** details the assessment of siltation relevant to the proposed project;
- **Section 5** details the assessment of sedimentation relevant to the proposed project;
- **Section 6** details the assessment of dredging and disposal sediment plume dispersion relevant to the proposed project; and
- **Section 7** outlines the conclusions of the investigations and their implications in terms of the overall project.



Cardno

Darwin, Northern Territory

Date
11/01/2022

Size
A3

Scale
0 100 Meters

SITE LOCALITY

MANDORAH MARINE FACILITIES
SEDIMENT TRANSPORT REPORT
FIGURE 1-1

1.3 Reference Documents

Various investigations and studies have been carried out as part of the overall development and design project to date. This report documents a component of these investigations. The following documents are referenced in, or should be given due consideration when reading, this report:

> Directly relevant:

- *Environmental Referral Report* (Cardno, 2022a): This document provides the necessary details to refer the project to the NT EPA. This *Sediment Transport Report* is an appendix to the referral document, providing the necessary context for assessing risk to the marine environment associated with sediment transport from the project;
- *Metocean Report* (Cardno, 2022b): Details the metocean information and investigations for the project site that inform design of the new proposed infrastructure. The report details the underlying physical metocean processes that drive sediment transport processes that have been described in this report;
- *Marine Environment Report* (Cardno, 2022c): Details the marine environment (including physical properties related to sediment) and ecology relevant to the project site. The results of sediment transport investigations are important for understanding potential impacts to the marine environment detailed in the report;
- *SAP Implementation Report* (Cardno, 2022i): Details marine sediment quality investigations undertaken to understand any contamination within the dredging and disturbance area and guide proper handling and disposal of dredge material; and
- *Draft Dredging and Spoil Disposal Management Plan (DSDMP)* (Cardno, 2022d): Defines the dredging actions and necessary controls to avoid or minimise risk for, and impact to, the marine environment.

> Relevant to the overall project:

- *Design Report* (Cardno, 2022e): Details the design requirements, basis, inputs, calculations and outcomes for the new proposed infrastructure;
- *Geotechnical Report* (Cardno, 2022f): Details the geotechnical information and investigations for the project site that inform design of the new proposed infrastructure;
- *Terrestrial Environment Report* (Cardno, 2022g): Details the terrestrial environment and ecology relevant to the project site, similar to the function of the report for the marine environment; and
- *Draft Construction Environmental Management Plan (CEMP)* (Cardno, 2022h): Defines likely construction activities and controls required to avoid or minimise environmental impact.

2 Existing Information and Inputs

2.1 Metocean Conditions

To properly understand sediment transport processes at the site, a detailed and comprehensive understanding of the site's metocean conditions must first be obtained. This is achieved by developing numerical models (e.g. hydrodynamic and wave) and validating and calibrating these with data collected data (e.g. wave, currents and water level). The project's *Metocean Report* (Cardno, 2022b) provides comprehensive details of the metcoean modelling and input data, and should be reviewed to understand the conditions underpinning sediment transport assessment in this report.

2.2 Water Quality

Baseline water quality, in terms of turbidity or suspended sediment concentration, is well understood at the project site, with monitoring being conducted continuously for over 2 years during the INPEX Nearshore Environmental Monitoring Program. Continuous near-bed turbidity (NTU) records collected (15 min interval) at site directly offshore Mandorah (MAN_01), as well as two sites within Woods Inlet (WOD_01 and WOD_02). Other sites of relevance include:

- Charles Point (CHP_02), alongshore to the west north west of the site; and
- Fanny Bay (FAN_01 and FAN_02), where turbidity data can be compared to observed siltation rates for the Cullen Bay Ferry Facility.

Site locations are depicted in **Figure 2-1** and the turbidity datasets for the monitoring period are shown in **Figure 2-2**.

Figure 2-1 Inpex Ichthys water quality monitoring locations (Inpex, 2014)

Total suspended solids (TSS) and particle size distribution (PSD) samples for correlation with NTU values were also collected throughout Darwin Harbour by Cardno for the Ichthys Project. These were combined to develop a relationship between TSS and NTU, which can be used to approximate ambient TSS concentrations at the site. This relationship is plotted in **Figure 2-3**.

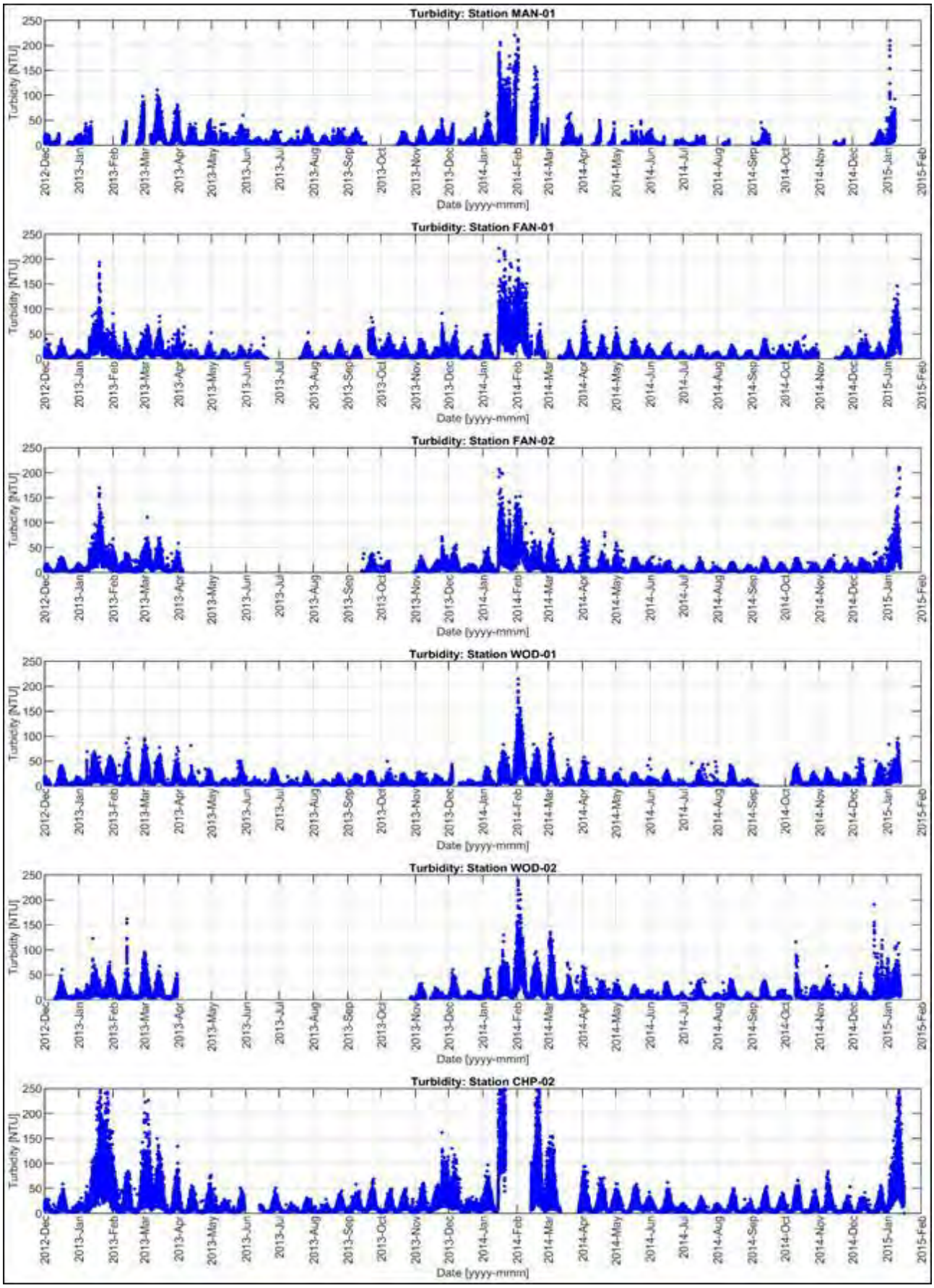


Figure 2-2 Turbidity measurements at monitoring sites relevant to Mandorah – Inpex Ichthys Project (Cardno, 2015)

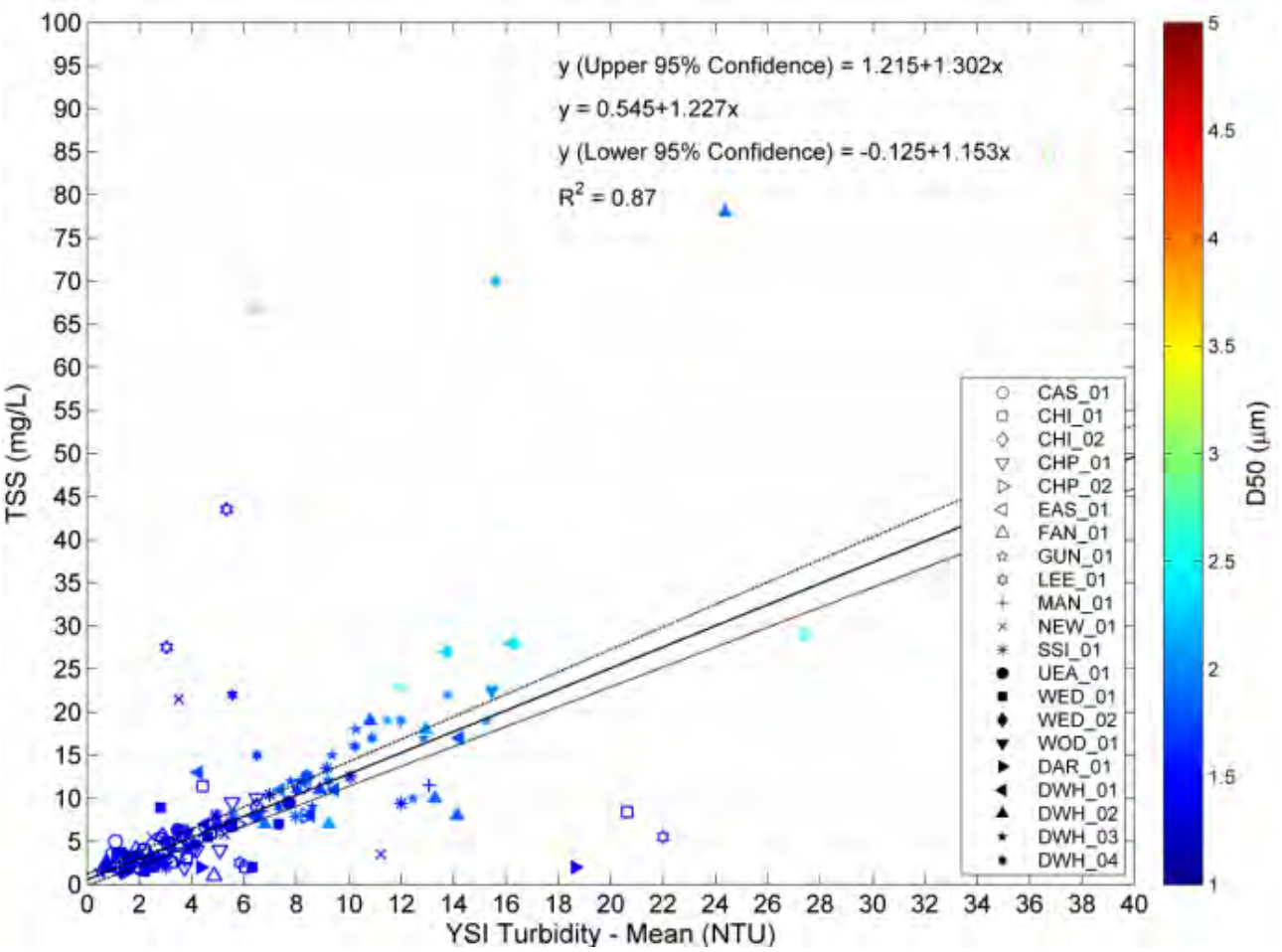


Figure 2-3 Darwin Harbour NTU vs TSS relationship – Inpex Ichthys Project (Cardno, 2014)

2.3 Sediment Properties

2.3.1 Historical

Existing historical data relating to the properties of surficial sediments within the proposed dredge area is limited. Four samples were collected by Douglas Partners (2016). These results indicate that sands and marine sediments (silts and gravelly sand) overlay very low to low strength (with some Medium strength bands) rocks of the Darwin Member and extremely low strength meta-siltstone (which underlies that Darwin Member at the landward end of the development).

2.3.2 Geotechnical Investigations (Cardno, 2022)

Cardno undertook a detailed geotechnical investigation, as well as sediment sampling and analysis, within the project footprint in 2019. Detailed assessment of the physical and chemical properties of sediments sampled in the area are found in the *SAP Implementation Report* (Cardno, 2022i) and geological properties are detailed in the *Geotechnical Report* (Cardno, 2022f). Field logs are also provided in **Appendix A**.

2.3.2.1 Profile Description

- There is limited marine bed sediment in the area, the deepest refusal depth for push coring was 0.8 metres and for most sample locations the refusal depth was less than 0.5 metres; and
- Field observations noted unconsolidated sediment largely as marine SAND, dark grey.

2.4 Data Gaps

The key data gap identified with respect to sediment transport processes, following review of historical information and execution of geotechnical and sediment quality sampling in the project footprint, was an understanding of sediment properties in the nearshore areas adjacent the proposed project. The nature of this sediment is a required input to understand longshore sediment transport processes at the site. Further field investigations (**Section 3**) were undertaken to fill this data gap.

3 Field Investigations

3.1 Aims and Objectives

The purpose of this additional sediment sampling was to characterise the PSD of available sediment adjacent to, but outside, the project area to inform longshore sediment transport assessment.

3.2 Survey Area

Sediment sampling sites were selected to represent the nature of available sediment in the littoral zone, to the north and south of the project site. Sediment sampling locations are depicted in **Figure 3-1**.

3.3 Sampling Methods

The scope of work undertaken as part of the longshore drift assessment was carried out in accordance with the following guidelines, to the extent relevant to an assessment of this nature:

- Australian Standard 2003. Method of testing soils for engineering purposes. Method 3.6.3: Soil classification tests—Determination of the particle size distribution of a soil—Standard method of fine analysis using a hydrometer. AS 1289.3.6.3-2003.
- NAGD 2009. National Assessment Guidelines for Dredging. Commonwealth of Australia, Canberra, 2009.

Sediment sampling was carried out between 3 March 2020 and 11 March 2020 by trained and experienced staff to ensure that the correct sampling procedures were followed. Surface samples were collected at 11 sampling sites (4 beach samples and 7 seabed samples) employing a grab sampling method.

3.4 Quality Assurance and Control Measures

Quality control procedures were followed in accordance with guidelines for sampling presented in the methodology *Soil classification tests—Determination of the particle size distribution of a soil—Standard method of fine analysis using a hydrometer. Australian Standard* (*AS 1289.3.6.3-2003*).

Samples were collected directly into appropriately labelled zip-lock bags and delivered to the laboratory under Chain of Custody documentation (**Appendix B**).

3.5 Analytical Methods

All soil analysis was undertaken by ALS Global Laboratories (Sydney) [National Association of Testing Authorities (NATA) accreditation number 825].

The analytical schedule for particle size distribution are presented in **Figure 3-1.**

Table 3-1 Analytical schedule - PSD

Material	Volume	Total Samples	Sample ID	Laboratory Schedule
Sediment	1 x 500mL bag per sample.	11	MS1-4, MBS1-7	11 samples for PSD by hydrometer

3.6 Results

The median particle diameter (D_{50}) from each PSD sample is presented below in **Table 3-2.** Laboratory results and analysis are presented in **Appendix C**.

Cardno

West Perth, Western Australia

Date
17/11/2021

Size
A3

Scale
1:5,000

0 100 200Meters

PSD SAMPLING LOCATIONS

MANDORAH MARINE FACILITIES

SEDIMENT TRANSPORT REPORT

FIGURE 3-1

Table 3-2 Median Particle Diameter (D_{50})

Sediment Sample	D_{50} (mm)
Onshore Samples	
MBS1	0.694
MBS2	1.041
MBS3	1.104
MBS4	1.827
MBS5	1.437
MBS6	1.222
MBS7	0.695
Offshore Samples	
MS1	0.150
MS2	0.146
MS3	0.288
MS4	0.184

4 Siltation Assessment

4.1 Methodology

An estimation of the annual siltation inside the harbour basin, for the harbour design, has been derived based on the theory of Van Rijn (2012a). This involved using measured water levels, currents and turbidity data, together with the proposed harbour characteristics (total surface area, entrance width and entrance configuration) to calculate the exchanged volume of water and suspended sediment. This assessment includes variable concentrations throughout the year to estimate sedimentation rates within the proposed harbour basin.

The sedimentation estimates are based on the conversion of turbidity measurements to concentration of suspended sediment at Mandorah, collected during the Inpex Ichthys Project (Cardno, 2015) (**Figure 4-1**).

Water levels and current velocities corresponding to the period of suspended sediment measurements outside the harbour were estimated using the hydrodynamic modelling results, detailed in the *Metocean Report* (Cardno, 2022b). Siltation estimates were then calculated for the harbour by applying Van Rijn's method for the period between January 2013 to January 2015. A sedimentation estimate has been calculated every 5 minutes.

4.2 Results

Using an effective average settling velocity of 0.202 mm/s (which is based on the measured suspended sediment particle size distribution during recorded by Cardno), the yielding sedimentation rate is approximated as 210 mm/yr. This corresponds to a trapping efficiency of 0.24.

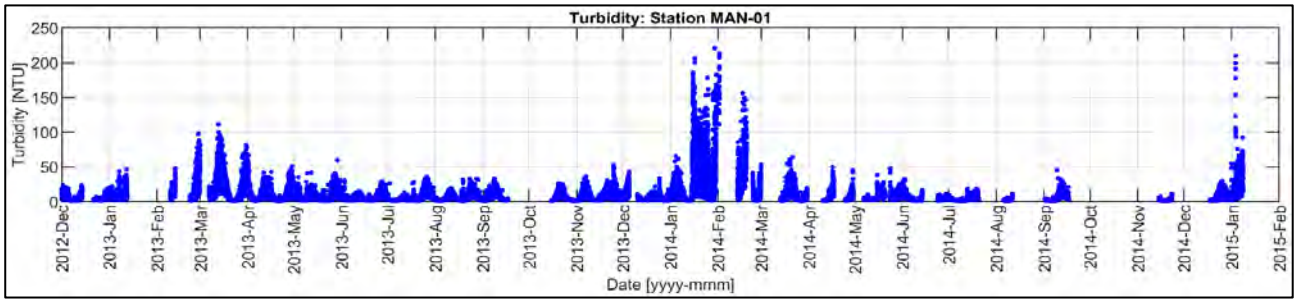


Figure 4-1 Turbidity time series at Mandorah Station

Note that this estimate is likely to be a conservative assessment of harbour siltation, as:

- The sedimentation volume is based on a dry bulk density of 350 kg/m3. This represents freshly deposited mud, and will consolidate over time as more sediment is deposited above it, which will double (or more) over time, halving the volume;
- The turbidity measurements were collected during a large-scale dredging campaign in Darwin Harbour, which may include elevated turbidity levels due to the dredging works; and
- The passage into and out of the harbour by the ferry, and to a lesser extent, recreational vessels, will stir up freshly deposited sediment, thereby reducing the amount of sediment retained in the harbour.

5 Sedimentation Assessment

5.1 Introduction

The purpose of this investigation is to examine the likely effects of the proposed harbour works on the regional shoreline and to estimate any ongoing maintenance requirements. This requires the estimation of long-term longshore sediment transport rates in the region near the harbour.

The Longshore Sediment Transport (LST) calculations were undertaken using the LITDRIFT module of the DHI LITPACK Littoral Processes FM modelling system. This module simulates the sediment transport (net and gross) under time-varying wave, water level, and currents conditions across realistic shore normal seabed profiles that are based on survey and spatially variable sediment characteristics – where the data is available.

For this analysis, the sediment transport modelling has been undertaken along one (1) representative profile in pre-development scenario to estimate the potential LST rates at the Mandorah harbour site.

This initial analysis is undertaken using an individual scenario events approach using 34 years (1985-2019) of wave climate data developed from SWAN wave modelling for the selected shore normal location, and its corresponding hindcast water level from the developed Delft3D hydrodynamic model constituents.

This document presents the preliminary outcomes of this sediment transport/coastal processes study.

5.2 Sediment Data

Sediment samples were collected just 200m south of the existing jetty. Yellow dots shown in **Figure 5-1** indicate each sediment sampling point, and the orange line indicates the location of the cross-shore profile. Average d50 of the sediment samples is taken at 1.221mm. This value was used as input for the LITPACK sediment transport modelling.

Figure 5-1 Sediment samples location collected for particle size distribution

5.3 Longshore Sediment Transport Modelling

Cardno has undertaken longshore sediment transport modelling using the LITDRIFT module of the LITPACK coastal processes modelling system developed by the Danish Hydraulics Institute. It is used internationally for assessment of coastal processes. LITDRIFT computes longshore sediment transport from a time-series of wave and water level parameters. Natural beach profiles, graded sediments, currents, wind and local roughness can be included. Generally, the highest transport rate occurs in the breaking wave zone.

5.3.1 Model Setup

5.3.1.1 Profiles

For this study, longshore sediment transport has been modelled for one (1) shore normal profile as indicated in **Figure 5-2**. The bathymetric details of these profiles have been derived from the consolidated bathymetric and topographic data, and are presented in **Figure 5-3**.

Figure 5-2 The Location of considered profile at the Proposed Mandorah Harbour Site

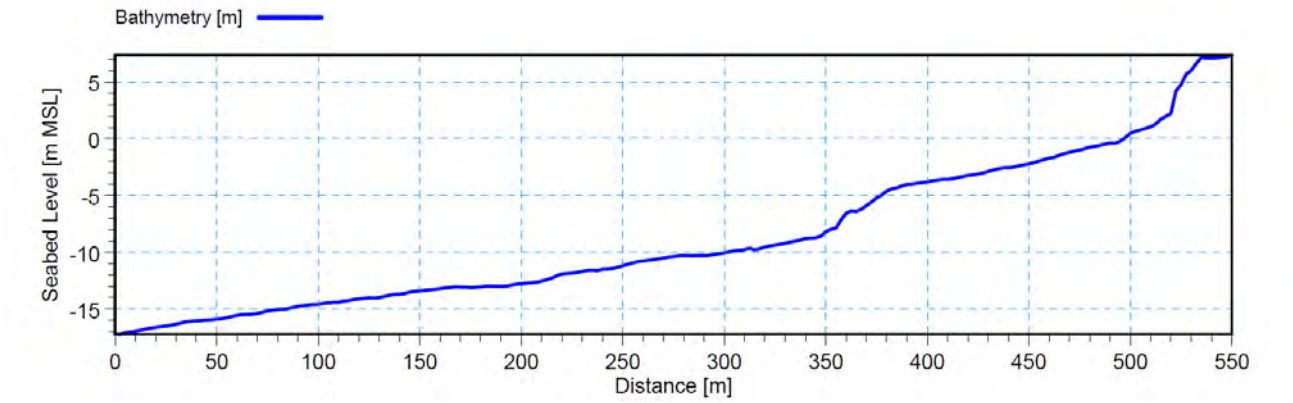


Figure 5-3 The Bathymetry of Profile used for Litdrift Modelling

5.3.1.2 Shore Normal Direction

A key input to the sediment transport assessment is the direction of the normal to the shoreline. For this analysis, shore normal direction is taken at 90ºN based on the nearshore contours.

5.3.2 Modelling Results

5.3.2.1 Q-Alpha Curves

The longshore transport is highly sensitive to the orientation of the shoreline normal. A change in the shoreline normal will affect the angle between the approaching waves and the shoreline normal, which is one of the key parameters for longshore sediment transport. This is illustrated in **Figure 5-4**, in which a coastline is shown for two different shoreline orientations. Waves are in both cases approaching the shoreline from the east. The beach in the left panel has a shoreline normal towards south-east which causes longshore transport towards south (indicated by the blue arrow). The shoreline normal in the right panel is oriented towards north-east, which causes transport towards north (indicated by the blue arrow).

Changes to shoreline orientation occur naturally in response to seasonal variations in the wave climate and in response to long term trends in erosion/deposition. The shoreline orientation will in particular change if changes to the upstream sediment supply occur. e.g., if sediment is blocked at a point along the shoreline, then the downstream shoreline will turn up against the predominant waves such that the longshore transport on the downstream beach is also zero. The calculated longshore transport is then shown as a function of the shoreline orientation thus forming a so-called Q-α curve.

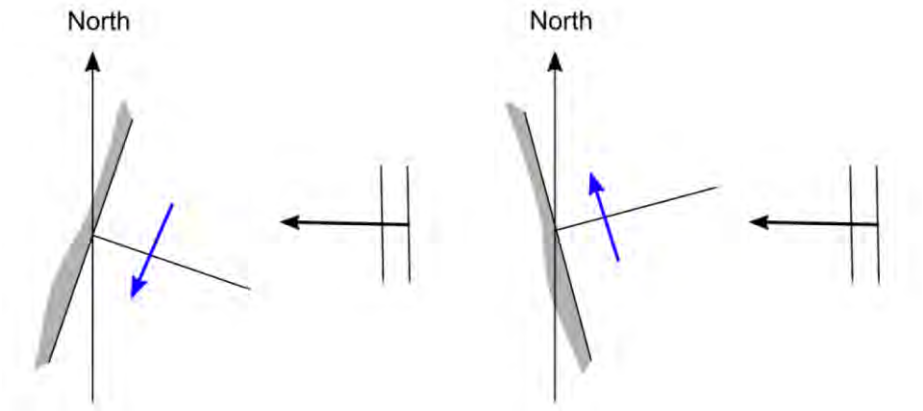


Figure 5-4 Schematic showing the effect of changes in shoreline orientation on longshore transport (DHI, 2020).

Figure 5-5 shows the Q-α curve for the analysed profile. The figure shows both the variation of the potential gross-transport (red curve) and the potential net transport (blue curve). Note that the gross-transport and net transport are to be defined positive for transport towards the south and negative towards the north.

The figures show that the net transport is generally towards the south.

The slope of the net transport i.e. the change in net transport per degree change in shoreline orientation, gives a measure of the sensitivity of the net transport to changes in shoreline orientation. The sensitivity of the net transport to changes in shoreline orientation is around 330 m3/deg near the present orientation, and ranges from 51 to 354 m3/deg.

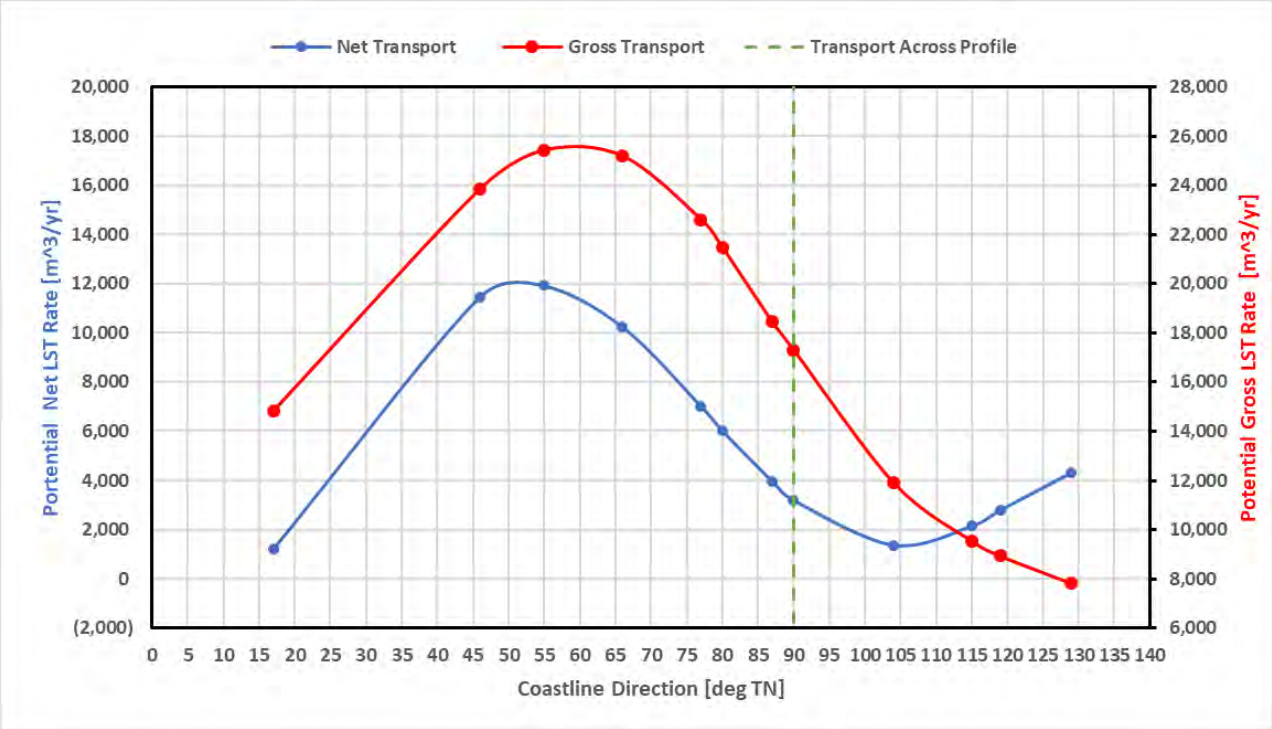


Figure 5-5 Q-α Curve for Selected Profile

5.3.3 Potential Longshore Sediment Transport Rates

As the shoreline orientation at the site is variable, the peak sediment transport rates have been assumed from the Q- α curve to define the potential longshore transport at the site. This equates to an approximate net southerly transport of 12,000 m^3/year, as described in **Table 5-1**. Noting that the shore normal direction varies from about 55º to 130º at the site, the net-transport rate is likely to be lower than this, between 2,000 and 12,000 m^3/year.

Table 5-1 Potential Longshore Sediment Transport Rates at the Selected Profile

Potential Rate	Rate [m^3/yr]
Net Transport	12,000
Gross Transport	25,000

5.3.4 Shoreline Evolution Investigation

The construction of coastal structures such as shore connected breakwaters as proposed for the Mandorah Ferry Terminal will alter the coastal sediment transport regime. Based on a review of historic imagery this shoreline appears to have been relatively stable over the last 10 years, and would be considered to be in equilibrium with the wave climate.

The breakwaters will essentially block longshore sediment transport, which as a result of this, the shoreline will accrete on the updrift side, with commensurate erosion on the downdrift side. The extent and rate of shoreline changes updrift of the harbour have been estimated utilising the analytical solution of equation of motion and continuity in the alongshore direction, along with the potential net transport rates estimated using LITPACK (see **Section 5.3**).

Figure 5-6 depicts the shoreline evolution updrift of Mandorah main breakwater over a 15-year period. The calculations have been undertaken based on the following assumptions:

> A potential net longshore sediment transport rate of 12,000 m^3/year

- An active beach profile depth of 4.5m, based on the Hallemeier closure depth formula
- An angle of 15° between the shore-normal direction and the morphological wave direction (the direction in which the longshore sediment transport is minimal (see the Q-α curve in **Figure 5-5**).
- An effective breakwater length of 100m (measured from MSL to the start of the bend)

Based on these assumptions, it is estimated that after about 11 years the shoreline will reach the tip of the breakwater and sediment could start to be transported around the breakwater.

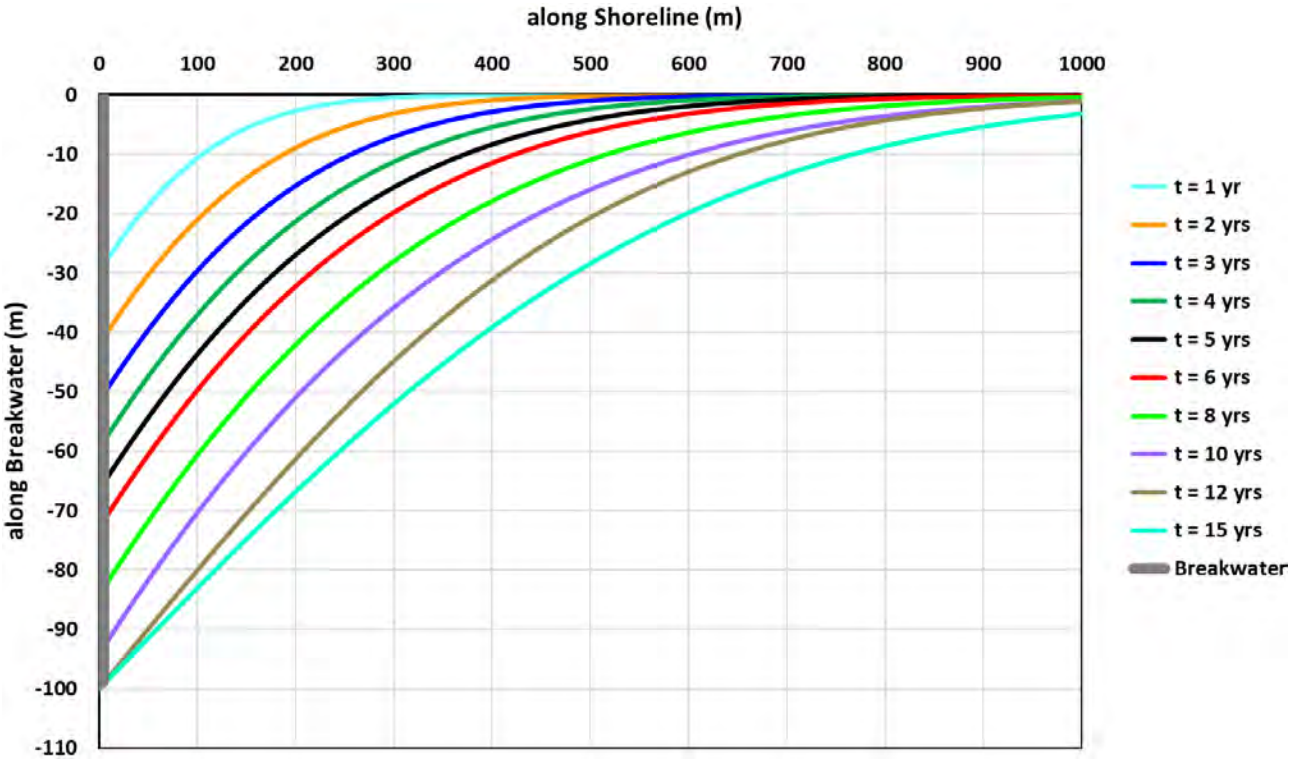


Figure 5-6 Shoreline Morphological Changes Updrift of the Main Breakwater

Whilst the investigation gives an estimate for when the shore will start to bypass the breakwater, the following uncertainties exist with regards to change to shoreline evolution:

- There is only 300 m of shoreline north of the main breakwater before making a 120° turn to the north west. Accretion rates may not follow the shape shown in **Figure 5-6** around a bend of such angle, instead sediment transport may continue southward, increasing the rate sand is trapped against the main breakwater. If this was to occur, sand would start to bypass the breakwaters at an earlier point in time; and
- This investigation has used potential sediment transport, which assumes there is sufficient available sand for these rates to occur. However, based on the available bathymetric data as well as the geological features of the study area, it appears that there is a lot of shallow rock in the area. This means that the sediment transport rates presented in this report and used for this assessment are likely larger than what is occurring in reality.

It is therefore recommended that the design and implementation of any sand bypassing system to be based upon routine monitoring of the shoreline position over the first years after breakwaters construction – land or aerial surveys on an annual basis until the real outcome has been determined.

6 Plume Dispersion Assessment

The potential impacts on the ecology of the marine environment surrounding the proposed project during construction must be assessed. A likely key impact on the environment could be caused by sediments brought into suspension during breakwater construction and dredging activities. Cardno have undertaken sediment plume modelling to predict the suspended sediment load and likely sedimentation within the surrounding marine environment due to construction activities. This model is based on Cardno's calibrated 3D hydrodynamic model (see Cardno, 2020b). This section provides an overview of the modelling carried out to define the flow fields and current speeds within the study area as well as the fine sediment transport and dispersion model to simulate the advection-dispersion of the suspended sediments released as part of the dredging activities. Brief details on the numerical model, model setups, basic assumptions and methodology are described below.

6.1.1 Delft3D Modelling System

The Delft3D hydrodynamic modelling system has been utilised in this study. It is a world leading hydrodynamic, sediment transport and water quality modelling system developed by Deltares in The Netherlands. It has been extensively utilised by Cardno at sites around Australia and internationally. The Delft3D modelling system can be used to simulate tides, wind, pressure and wave forcing, stratification, sediment transport, dredge material dispersion and water quality. Delft3D is comprised of several modules that provide the facility to undertake a range of studies. All studies generally begin with the Delft3D-FLOW module. From Delft3D-FLOW, details such as velocities and water levels along with density, salinity and temperature (where required), can be provided as inputs to the other modules.

Many nearshore areas include shallow inter-tidal regions; consequently, Delft3D includes a robust and efficient wetting and drying algorithm to handle this process. Delft3D includes a Domain Decomposition (DD) capability to facilitate computation by having fine grids at nearshore locations or areas of interest where bathymetric and structure details vary significantly and coarser offshore grids where a larger model extent is required, but seabed bathymetric changes are generally smaller. This procedure allows efficient modelling to be undertaken without sacrificing resolution where it is needed.

6.1.2 Hydrodynamic Modelling

The hydrodynamic modelling undertaken in this study was used to define the water level variations and currents around the study area. Details on the development of the hydrodynamic model can be found in the *Metocean Report* for the project (Cardno, 2021*)*.

6.2 Model Setup

6.2.1 Inputs and assumptions

6.2.1.1 General assumptions

The plume modelling has been based on the following assumptions:

- Rock has been assumed to be dredged by backhoe dredge and unconsolidated sediments by a Cutter Suction Dredge (CSD);
- Results from neap simulations have been interpreted as a worst-case scenario to predict Total Suspended Solids (TSS) for longer dredge campaigns;
- Results from spring/neap simulations can be combined to predict the sediment deposition thickness for longer dredge campaigns;
- It is predicted that if there are some stoppages during the dredging works (due to weather condition, equipment maintenance, etc.), the suspended sediment concentration and deposition thickness will be lessened. So, the scenario adopted in this study (assuming no work stoppages) is conservative; and

> Backhoe and CSD operations have been assumed will cease simultaneously. In reality the backhoe will be in operation longer than the CSD, modelling results provide a conservative (higher) estimate of the dredge plume.

6.2.1.2 Schedule

The modelling was based on the following schedule:

> Total runtime of 15 days, this includes ~2-day model warm up time, 10 days dredging and ~2-days to allow any remaining fines in the water column time to settle;

> Run during daylight hours only, 4 hours during ebb and 4 hours during flood with a 1-hour break at slack tide;

> Production rates have been fixed at 200 m^3/hr (DIPL, 2017) for a CSD dredging soft sediment and 121.5 m^3/hr (Bray, Bates & Land, 1996) for a backhoe dredging rock;

> Total volume of unconsolidated sediment dredged = 16,000 m^3 (conservative volume) and rock (dredged concurrently) = 9,700 m^3; and

> Backhoe and CSD have been modelled operating simultaneously.

6.2.1.3 Materials

> Rock:
  - Fines content in rock: 1% by mass;
  - Spillage of fines from rock at source: 100%; and
  - Rock assumed to be disposed onshore.

> Unconsolidated sediments:
  - Fines content in mud: 50% by mass;
  - Spillage of fines from rock at source: 1% (DIPL, 2017); and
  - All mud assumed to be disposed of offshore.

6.2.1.4 Sediment Transport Parameters

A summary of the sediment transport parameters used for the dredge plume dispersion modelling are as follows. Sediments have been modelled as cohesive with transport parameters established based on typical values presented in literature and Cardno's extensive experience.

> Critical Bed Shear Stress for Deposition (Sedimentation): 0.08 N/m^2 (Whitehouse et. al., 2000)

> Critical Bed Shear Stress for Erosion: 0.10 N/m^2 (Whitehouse et. al., 2000)

> Erosion Parameter: 0.0001 $kg/m^2/s$

> Fresh Settling Velocity: 0.5 mm/s (INPEX Browse, Ltd., 2011)

> Specific Density of Sediment Grains: 2650 kg/m^3

> Mean sediment diameter (D_{50}): 0.02 mm

> Dry Bed Density of Deposited, Weakly to Medium Consolidated Sediment: 250 kg/m^3 (Van Rijn, 2012b)

> Reference Density for Hindered Settling: 250 kg/m^3

6.2.2 Scenarios

Table 6-1 contains the variables altered in each of the four scenarios modelled.

Table 6-1 Scenario inputs

Scenario	Tidal cycle	Resuspension of fines at disposal site
1	Spring	10%
2	Neap	10%
3	Spring	15%
4	Neap	15%

6.3 Disposal site

The modelled disposal site is located approximately 1.2 km north east of the dredge site with a depth of 13.5 m. Current speeds at the site are relatively high, reaching 1.5 m/s in a spring tide ebb flow and ~0.5 m/s in a spring tide flood flow - favourable conditions for the dispersal of sediment through the water column. Benthic habitat mapping shows the disposal site to be above sponge habitat with seagrass to the north and bare sediment to the south. **Figure 6-1** shows the location of the proposed disposal site.

130°46'0"E

12°26'0"S

12°26'30"S

NORTH

DISPOSAL SITE
(692313, 8625139)

Legend
- Proposed Disposal Site
- Breakwater
- Project Footprint

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cardno

Darwin, Northern Territory

Date
1/12/2021

Size
A3

Scale
1:7,942

0 100 200 300 400 Meters

PROPOSED DISPOSAL SITE

MANDORAH MARINE FACILITIES
SEDIMENT TRANSPORT REPORT
FIGURE 6-1

6.4 Results

The results of the dredge plume modelling are presented in the form of Total Suspended Solids (TSS). Increases in sediment concentrations and turbidity levels arising from the spillage of the dredged sediments from the backhoe dredge or CSD may under certain conditions have adverse effects on marine flora and fauna by reducing light penetration into the water column and by physical disturbance. Typically, these are short-term (temporary) effects limited to the near-field. The risk of adverse impacts was assessed by evaluating concentrations of suspended fine sediments due to the dredging and disposal activities and comparing these to environmental guidelines. Note that the concentrations presented in this report should be interpreted as above background.

Discussions have been made based on 'worst-case' conditions, with selected model outputs presented for analysis. Two rates of resuspension of fines at the disposal site were modelled as a sensitivity test. The sediment plume did not show considerable changes between the two rates and therefore, the higher resuspension rate (15%), has been adopted for any further analysis. Detailed model outputs for all four modelled cases are documented in **Appendix D.**

The severity of impact to ecological habitats resulting from increased suspended sediment concentrations and turbidity is highly dependent on the frequency and duration of exposure. By carrying out a probability of exceedance assessment, the spatial extent and concentration of suspended sediments (above background) have been presented in terms of percentiles ranging between the 50th and 95th percentile and the maximum. Analysis of the results has been made at the near-bed, mid-depth and surface of the water column at all model grid points.

For the purpose of assessing worst case suspended sediment concentrations, 95th percentile plots have been presented in the following section (see **Figure 6-2** and **Figure 6-3**). It should be noted that while the maximum values (See **Appendix D**) indicate the peak values over the duration of the simulation, these peaks occur for short durations (hours).

Overall, magnitudes of suspended sediment concentrations are greater at the dredge site when compared to the disposal site. For all scenarios, 95th percentile suspended sediment concentrations of greater than 50 mg/L are localised within the dredge footprint. This outcome is mainly attributed to the fact that current speeds in those areas are relatively low so the suspended fine sediment does not disperse, and remains within the project area until the dredging works stop for the day.

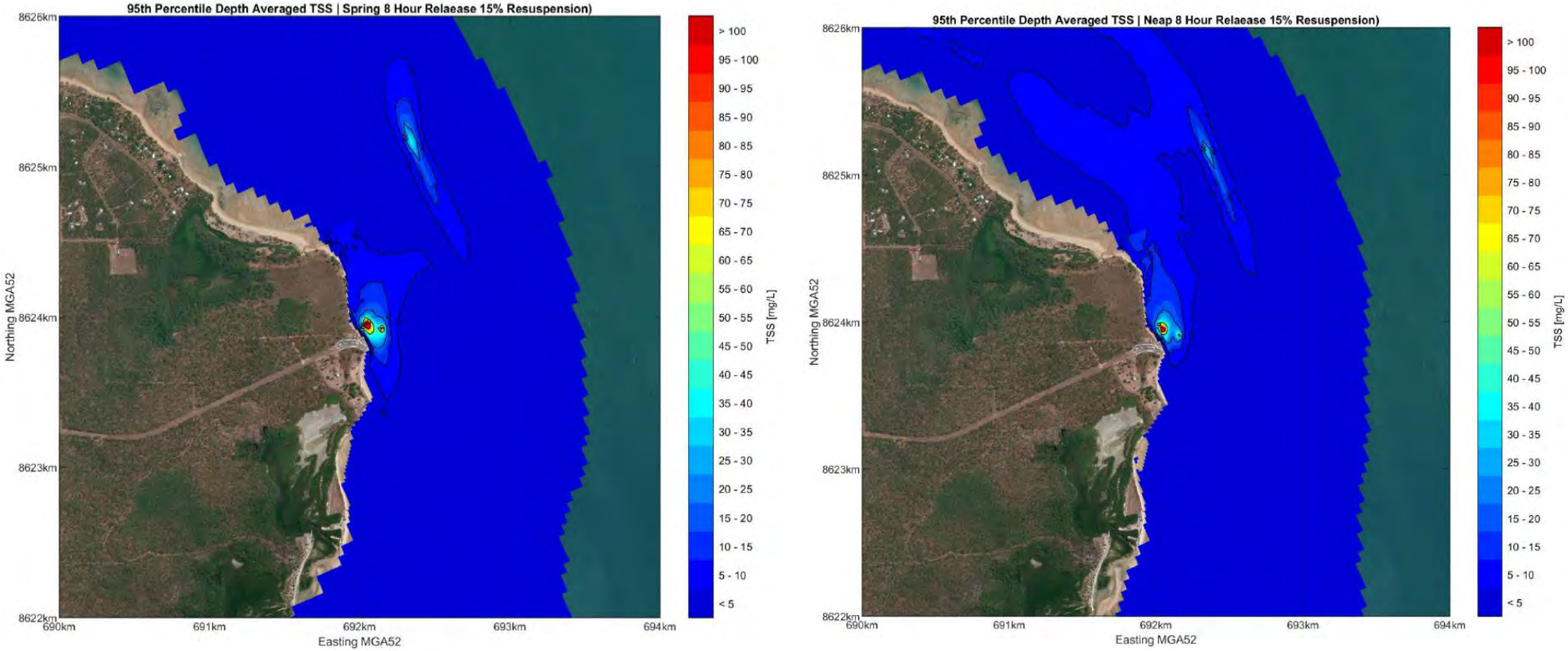


Figure 6-2 95th Percentile TSS depth averaged concentrations for Scenarios 3 (spring) and 4 (neap).

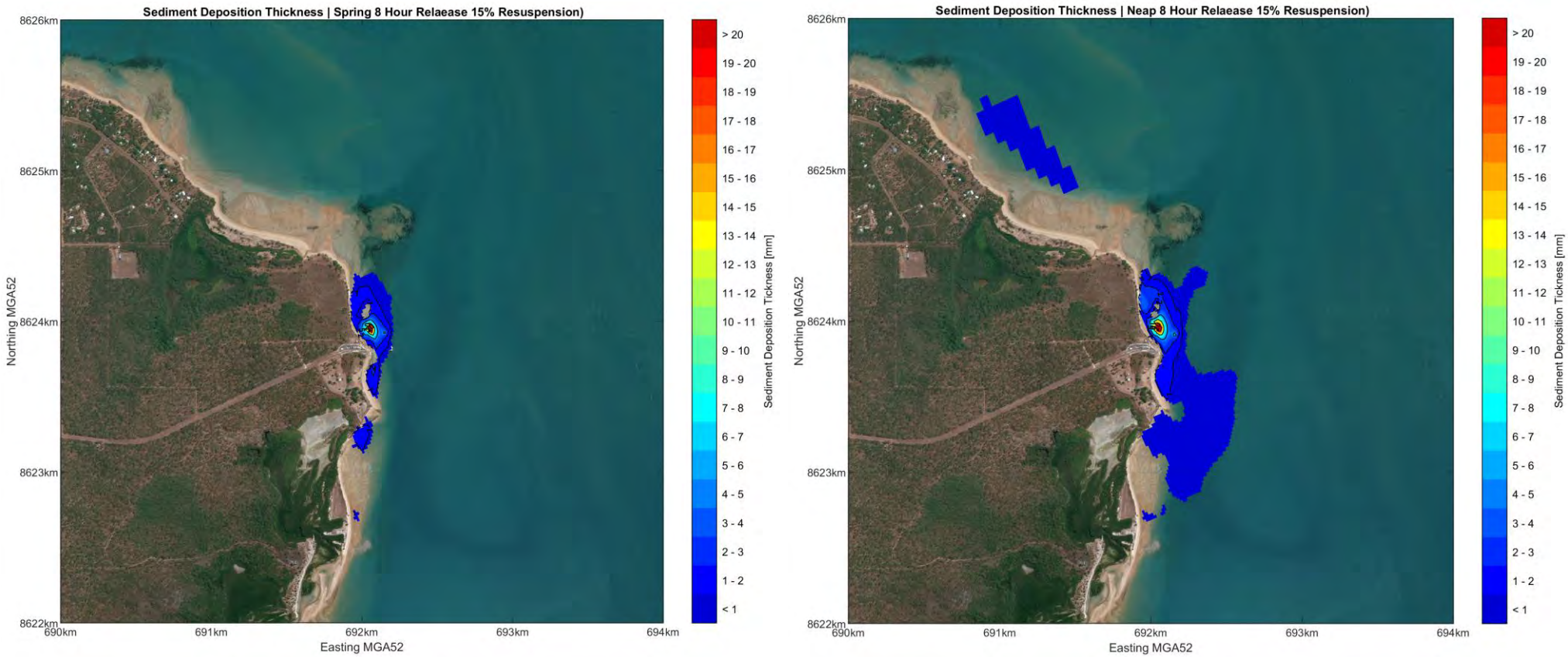


Figure 6-3 Sedimentation deposition thickness mapping Scenarios 3 (spring) and 4 (neap).

7 Conclusions and Project Implications

7.1 Siltation

7.1.1 Operational

The breakwaters are designed to reduce wave and current conditions for the safe navigation of vessels, leading to an unavoidable decrease in velocities and increase in siltation. To maintain desired bed levels within the proposed tolerances, maintenance dredging will be required at regular temporal intervals. The sedimentation rate calculated in **Section 4** provides an estimate of the length of maintenance dredging intervals required to keep bed levels within the siltation allowance of 0.3 m. Modelled sedimentation rates result in a maintenance dredging interval of 1.4 years.

$$Maintenance\ Interval = \frac{0.3\ m}{0.210\ m\ /yr} = 1.4\ years$$

As stated in **Section 4**, this sedimentation rate is likely to be a conservative estimate due to the following:

- The sedimentation volume is based on a dry bulk density of 350 kg/m3. This represents freshly deposited mud, and will consolidate over time as more sediment is deposited above it, which will double (or more) in density over time, halving the volume; and
- The passage into and out of the harbour by the ferry, and to a lesser extent, recreational vessels, will stir up freshly deposited sediment, thereby reducing the amount of sediment retained in the harbour.

Hydrographic survey should be regularly undertaken upon the completion of construction of the marine facilities to quantify sedimentation rates within the basin. As the predicted sedimentation rate is likely conservative, measured sedimentation rates are expected to lesser, extending the interval required between maintenance dredging campaigns.

It is more likely, due to the above, that maintenance dredging would be required approximately every 5 to 7 years. This is in line with similar facilities within Darwin Harbour, for example Cullen Bay Ferry Terminal.

7.1.2 Environmental

There are not expected to be any adverse environmental impacts due to siltation within the marine facilities as any benthic habitat and/or benthic communities will be removed during the capital dredging campaign.

7.2 Sedimentation

7.2.1 Operational

As the shoreline orientation at the site is variable, the peak sediment transport rates have been assumed from the Q-α curve to define the potential longshore transport at the site. This equates to an approximate net southerly transport of 12,000 m^3/year, as described in **Table 7-1** below. Noting that the shore normal direction varies from about 55º to 130º at the site, the net-transport rate is likely to be lower than this, between 2,000 and 12,000 m^3/year.

Table 7-1 Potential Longshore Sediment Transport Rates at the Selected Profile

Potential Rate	Rate [m3/yr]
Net Transport	12,000
Gross Transport	25,000

Bypassing is a method of longshore redistribution of sediment along a coastline. Bypassing refers to the action of moving sediment from the ‘updrift’ side of a coastal feature or structure to the ‘downdrift’ side – enabling the longshore transport that was interrupted. Sediment can be transferred by truck, barge or via pumping as a

slurry mixture. A routine bypassing program equal to the natural rate of longshore drift will prevent both the widening of the beach north of the breakwater and erosion on the lee side of the structure.

As detailed in **Section 5**, there may not be sufficient sand to support the predicted sediment transport volumes due to underlying rock layers. It is therefore recommended that the design and implementation of any sand bypassing system to be based upon routine monitoring of the shoreline position over the first years after breakwaters construction – land or aerial surveys on an annual basis until the real outcome has been determined.

7.2.2 Environmental

Interruption to the net southerly transport of sediment down the coastline by the main breakwater is likely to result in changes to the shoreline north of the breakwater. The build-up of sediment unable to travel south due to the breakwater will cause the beach width to widen, smothering the existing seabed. **Figure 7-1** shows the potential shoreline change. The area which is expected to be smothered is intertidal, whilst not covered by benthic habit mapping, it is not expected that any sensitive communities are present in the area. If a sand bypassing was successfully implemented smothering of the existing seabed would be minimised.

130°45'40"E

130°46'0"E

12°26'20"S

12°26'40"S

NORTH

Legend

- Breakwaters
- Potential long-term accretion (10 years)
- Potential long-term erosion (10 years)

Benthic Habitats

- Sponges
- Bare Ground
- Mixed Filter Feeders/Octocorals
- Corals
- Macro Algae
- Seagrasses (Halodule & Halophila)

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cardno

Darwin, Northern Territory

Date
2/03/2022

Size
A3

Scale
1:4,250

0 100 200Meters

LONG TERM COASTAL LANDFORM CHANGE

MANDORAH MARINE FACILITIES

SEDIMENT TRANSPORT REPORT

FIGURE 7-1

7.3 Dredge Plume Dispersion

7.3.1 Zones of Influence

Dredge plume modelling was interpreted with respect to the NT EPA's (2013) requirement of assessing potential impacts of dredging on the marine environment. The assessment requires a spatially-based zonation scheme described by the Western Australian (WA) EPA (2016), which acts as a common basis when describing predicted extent, severity and duration of impacts due to dredging. The three zones each represent a level of impact as outlined by WA EPA (2016) and are described below:

- Zone of High Impact (ZoHI) "is the area where impacts on benthic communities or habitats are predicted to be irreversible";
- Zone of Moderate Impact (ZoMI) "is the area within which predicted impacts on benthic organisms are recoverable within a period of five years following the completion of the dredging activities"; and
- Zone of Influence (ZoI) "is the area within which changes in environmental quality associated with dredge plumes are predicted and anticipated during the dredging operations, but where these changes would not result in a detectible impact on benthic biota".

7.3.2 Thresholds

In order to determine the three zones of influence, thresholds for sedimentation and turbidity due to dredging activities are required. Adopted thresholds have been kept consistent with those used in the Darwin Port Long Term Dredge Management Plan (AECOM, 2018). The thresholds were developed using a full year dataset of water quality in East Arm (the site of a previous dredging program in Darwin Harbour, south east of Mandorah) recorded by URS (2011) for the INPEX project.

In order to determine the three zones of influence specific to the project site, thresholds have been developed based on ambient turbidity conditions monitored at Mandorah across a 2.5-year period, as part of the INPEX Ichthys Nearshore Environmental Monitoring Program (INPEX Browse, 2014). The dataset acts as a baseline at Mandorah, spanning both the wet and dry seasons. Tolerance limits have been calculated from this baseline dataset presuming that biological communities at Mandorah will be stressed if they are exposed to conditions that regularly exceed the 95th percentile of baseline concentrations. As the timing of the dredging works has not yet been confirmed, thresholds for both wet and dry season are provided, due to variation in background concentrations between seasons.

The long-term dataset has been analysed to calculate (for distinct wet and dry season):

- 99th percentile concentrations (high intensity, individual exceedances);
- 95th percentile concentrations (frequency and duration exceedances);
- 90th percentile concentrations (frequency and duration exceedances); and
- Median (50th percentile) concentrations (background levels to subtract from exceedance levels).

These statistics, along with the average duration of exceedance, are presented in **Table 7-2**.

Table 7-2 Calculated TSS values for various percentiles at Mandorah – average exceedance duration in brackets (24-hour rolling mean)

Season	Median (50th percentile)	90th percentile	95th percentile	99th percentile
Wet season	7 mg/L	39 mg/L (127 hours)	56 mg/L (62 hours)	142 mg/L (89 hours)
Dry season	3 mg/L	11 mg/L (55 hours)	14 mg/L (31 hours)	18 mg/L (22 hours)

These levels and durations have been applied to develop TSS trigger levels (above background), for both wet season and dry season. These are presented in **Table 7-3**. It must be noted that turbidity measurements collected at Mandorah were near bed (1m above the bed), where levels are generally higher than the depth averaged turbidity (or TSS). As such, it is necessary to translate near bed measurements to depth-averaged

measurements (which are output by dispersion modelling). A relationship for this was also developed during the INPEX Ichthys Project (Cardno, 2013). Note MESSC is equivalent to TSS.

$$MESSC = 1.0 \times Bottom\ NTU$$

The data collected previously at Mandorah is considered to be a reliable baseline dataset, due to its long duration and high measurement frequency. However, the relationships developed between TSS and NTU, and between near bed NTU and depth averaged TSS, are based on data collected throughout Darwin Harbour. These relationships should generally be developed on a site-specific basis. It has therefore been recommended that initial monitoring activities collect data to refine these relationships and, therefore, the trigger values above as part of monitoring actions in the Draft DSDMP (Cardno, 2022d).

7.3.3 Mapped Zones of Impact

The zones have been calculated for the project and are presented, considering seasonality, tides and the distribution of BCH, in **Figure 7-2** to **7-5**. Various plots are necessary to define zones during both Wet and Dry Season (due to very different background concentrations), as well as during neap and spring tide (due to different hydrodynamic dispersion).

7.3.3.1 Zone of High Impact

The ZoHI has been characterised using 85th percentile TSS plots output by the dredge plume modelling. Areas with TSS concentrations higher than 11 mg/L during the dry season and 49 mg/L in the wet season have been classed as causing recoverable impacts on benthic organisms.

7.3.3.2 Zone of Medium Impact

The ZoMI has been characterised using 90th percentile TSS plots output by the dredge plume modelling. Areas with TSS concentrations higher than 11 mg/L during the dry season and 49 mg/L in the wet season have been classed as causing recoverable impacts on benthic organisms.

7.3.3.3 Zone of Influence

The ZoI has been characterised using 95th percentile TSS plots output by the dredge plume modelling. Areas with TSS concentrations higher than 11 mg/L during the dry season and 49 mg/L in the wet season have been classed as causing recoverable impacts on benthic organisms.

Sediment deposition has also been modelled, with results indicating negligible deposition (< 2mm) outside of the direct project footprint. As such, the key risks to BCH due to dredge plume dispersion are those associated with TSS/turbidity.

130°45'45"E
130°46'0"E
130°46'15"E
12°25'45"S
12°26'0"S
12°26'15"S
12°26'30"S
NORTH

Legend

- Breakwater
- Project Footprint
- Offshore Disposal Area (sediments)
- >2.5mm Sediment Deposition Zone
- ZoHI (Project Footprint & Buffer)
- ZoHI
- ZoMI
- ZoI

Benthic Habitats

- Sponges
- Bare Ground
- Mixed Filter Feeders/Octocorals
- Corals
- Macro Algae
- Seagrasses (Halodule & Halophila)

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cardno

Darwin, Northern Territory

Date
16/12/2021

Size
A3

Scale
1:5,000

0 50 100 150 200 Meters

IMPACT MAP - NEAPTIDE & DRY SEASON

MANDORAH MARINE FACILITIES
SEDIMENT TRANSPORT REPORT
FIGURE 7-2

130°45'45"E
130°46'0"E
130°46'15"E
12°25'45"S
12°26'0"S
12°26'15"S
12°26'30"S

NORTH

Legend

- Breakwater
- Project Footprint
- Offshore Disposal Area (sediments)
- >2.5mm Sediment Deposition Zone
- ZoHI (Project Footprint & Buffer)
- ZoHI
- ZoMI
- ZoI

Benthic Habitats

- Sponges
- Bare Ground
- Mixed Filter Feeders/Octocorals
- Corals
- Macro Algae
- Seagrasses (Halodule & Halophila)

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cardno

Darwin, Northern Territory

Date
16/12/2021

Size
A3

Scale
1:5,000

0 50 100 150 200 Meters

IMPACT MAP - SPRING TIDE & DRY SEASON

MANDORAH MARINE FACILITIES
SEDIMENT TRANSPORT REPORT
FIGURE 7-3

130°45'45"E
130°46'0"E
130°46'15"E
12°25'45"S
12°26'0"S
12°26'15"S
12°26'30"S

NORTH

Legend

- Breakwater
- Project Footprint
- Offshore Disposal Area (sediments)
- >2.5mm Sediment Deposition Zone
- ZoHI (Project Footprint & Buffer)
- ZoHI
- ZoMI
- ZoI

Benthic Habitats

- Sponges
- Bare Ground
- Mixed Filter Feeders/Octocorals
- Corals
- Macro Algae
- Seagrasses (Halodule & Halophila)

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cardno

Darwin, Northern Territory

Date
16/12/2021

Size
A3

Scale
1:5,000

0 50 100 150 200 Meters

IMPACT MAP - NEAPTIDE & WET SEASON

MANDORAH MARINE FACILITIES
SEDIMENT TRANSPORT REPORT
FIGURE 7-4

130°45'45"E
130°46'0"E
130°46'15"E
12°25'45"S
12°26'0"S
12°26'15"S
12°26'30"S
NORTH

Legend

- Breakwater
- Project Footprint
- Offshore Disposal Area (sediments)
- >2.5mm Sediment Deposition Zone
- ZoHI (Project Footprint & Buffer)
- ZoHI
- ZoMI
- ZoI

Benthic Habitats

- Sponges
- Bare Ground
- Mixed Filter Feeders/Octocorals
- Corals
- Macro Algae
- Seagrasses (Halodule & Halophila)

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cardno

Darwin, Northern Territory

Date
16/12/2021

Size
A3

Scale
1:5,000

0 50 100 150 200 Meters

IMPACT MAP - SPRING TIDE & WET SEASON

MANDORAH MARINE FACILITIES
SEDIMENT TRANSPORT REPORT
FIGURE 7-5

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APPENDIX A

FIELD LOGS

Location	Date	Time	Sampler	Conditions	Sampling Method	Handling/storage	Description
BH2014	26/9	08:30	DS/PT	FINE, CALM 3.4m DEPTH	PUSH CORE THEN SPT	JAR/BAG on ICE	MARINE SAND, DARK GREY, SOME ORGANICS UNIFOR material from 5 separate cores to get enough sediment for testing.
BH2010	26/9	09.30	DS/PT	FINE, CALM	PUSH CORE THEN SPT		
BH2012	26/9	10:30	DS/PT	"	"		MARINE SAND, DARK GREY, SOME ROCK AND GRAVEL 2 SEPARATE CORES
BH2008	26/9	11:00	DS/PT	FINE, CALM 4.6m DEPTH	"		CORAL/SHELLS AT SURFACE, MARINE SEDIMENT GREY
" TRIP1		11:30-13:00			"		MULTIPLE CORES REQ. (3) DARK MARINE SED
" TRIP2		13:00-13:30			"		" (2) ↗ TO REFUSAL RED/BROWN SHELL GRIT
[redacted]							
BH2019	27/9	07:30	PT	FINE, CALM	"		SAND, GREEN CLAY 2 SEPARATE CORES
BH2016	27/9	08:00	PT	"	"		REFUSAL 0.8m SOME GRAVELS MARINE SAND, RED CLAY
" SPLIT 1		08:15	PT		"		MARINE SAND, SHELL FRAGMENT SOME RED CLAY
SPLIT 2		08:30	PT	"	"		" "
BH2018	27/9	09:00	PT	"	"		3 SEPARATED CORES MARINE SAND RED CLAY
BH2011	27/9	09:45	PT				3 SEPARATED CORE MARINE SAND, SOME SHELL FRAGMENTS
BH2009	27/9	10:20	"				4 CORES NEEDED. GREY SAND
BH2007	27/9	11:05					4 CORES NEEDED. GREY SAND SOME RED CLAY
BH2017	27/9	12:00	"	"	"	"	MARINE SAND, GRAY 4 CORES REFUSAL 0.3m
BH2013	27/9	13:00	"	WINDY			GREY MARINE SAND REFUSAL 0.3m
BH2002	28/9	07:45	"	FINE. CALM			GREY MARINE SAND RED CLAY REFUSA 3 CORES NEEDED
BH2003	28/9	08:00	"	"	"	"	GREY MARINE SAND 1 CORE NEEDED

Location	Date	Time	Sampler	Conditions	Sampling Method	Handling/storage	Description
BH2001	28/9	08:25	PT	FINE & CALM	PUSH CORE THEN SPT	JAR/BAG ON ICE	GREY MARINE SAND SOME GRAVEL 3 CORE NEEDED
BH2006	〃	08:45	PT	〃	〃	〃	GREY MARINE SAND 2 CORE NEEDED
BH2004	28/9	09:10	PT	〃	〃	〃	GREY MARINE SAND, GRAY CLAY 2 CORES NEEDED
BH2005	28/9	09:30	PT	〃	〃	〃	GREY MARINE SAND, SOME CLAY AND GRAVEL 2 CORES NEEDED
BH2015	28/9	10:00	PT	〃	〃	〃	GREY MARINE SAND, 2 CORES NEEDED

APPENDIX

B

SEDIMENT SAMPLING COC

13.04.20

CHAIN OF COUSTODY

ALS Laboratory: please tick →

ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com
NEWCASTLE 5 Rose Gum Road Warabrook NSW 2304 Ph: 02 4968 9433 E: samples.newcastle@alsglobal.com
NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 02 4423 2063 E: nowra@alsglobal.com
PERTH 26 Rigali Way Wangara WA 6065 Ph: 08 9406 1301 E: samples.perth@alsglobal.com
SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com
WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: wollongong@alsglobal.com

CLIENT: Cardno (NT) Pty Ltd	TURNAROUND REQUIREMENTS: (Standard TAT may be longer for some tests e.g., Ultra Trace Organics)	☐ Standard TAT (List due date): ✓	FOR LABORATORY USE ONLY (Circle)
OFFICE: 93 Mitchell Street, Level 6, Darwin 0800			Custody Seal Intact? Yes No (N/A)
PROJECT: Mandorah Marine Facilities	ALS QUOTE NO.: EN/024/18	COC SEQUENCE NUMBER (Circle)	Free ice / frozen ice bricks present upon receipt? Yes No (N/A)
PURCHASE ORDER NUMBER: DZ1910	COUNTRY OF ORIGIN: AUSTRALIA	COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: 3.2 °C
PROJECT MANAGER: Daniel Strickland CONTACT PH: 08 8461 0703		OF: 1 2 3 4 5 6 7	Other comment:

SAMPLER: Julian Brown	SAMPLER MOBILE: 0418830919	RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY: Kim
COC Emailed to ALS? YES	EDD FORMAT (or default): Esdat	Julian Brown	Sep M.		
Email Reports to: daniel.strickland@cardno.com.au		DATE/TIME: 01/04/20	DATE/TIME: 01/04/2020 1545	DATE/TIME:	DATE/TIME: 03.04.20 8Am
Email Invoice to: daniel.strickland@cardno.com.au		Before 16:00 on date of sampling			

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Samples placed on ice after collection. 1 jar and green bags frozen upon delivery at laboratory, 1 jar and pulp bag refridgerated upon delivery at laboratory.

ALS USE ONLY	SAMPLE DETAILS MATRIX: Solid(S) Water(W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL Jars / Bags	PSD - As per test parameters on Quote EN/024/18									Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	MBS7	11/03/2020	S		1	X									PSD by hydrometer as per Daniel. 3.4.2020
2	MBS1	11/03/2020	S		1	X									
3	MBS2	11/03/2020	S		1	X									
4	MBS3	11/03/2020	S		1	X									
5	MBS4	11/03/2020	S		1	X									
6	MBS5	11/03/2020	S		1	X									
7	MBS6	11/03/2020	S		1	X									
8	MS1	3/03/2020	S		1	X									
9	MS2	3/03/2020	S		1	X									
10	MS3	3/03/2020	S		1	X									
11	MS4	3/03/2020	S		1	X									
				TOTAL	11	11	0	0							

Subcon / Forward Lab / Split WO
Lab / Analysis: Newcastle
Organised By / Date: PSD 1-4
Relinquished By / Date:
Connote / Courier:
WO No: ES2011348
Attach By PO / Internal Sheet:

Environmental Division
Sydney
Work Order Reference
ES2011348

Telephone : + 61-2-8784 8555

LAB OF ORIGIN: DARWIN

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic

V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;

Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

APPENDIX

C

SEDIMENT SAMPLING RESULTS

Certificate of Analysis

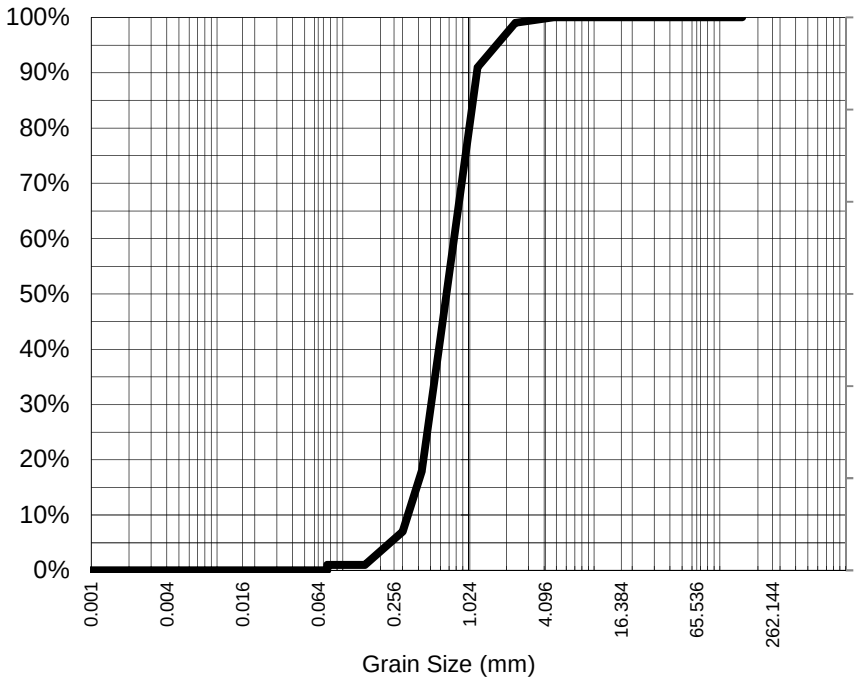
ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-001 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS7

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	91%
0.600	42%
0.425	18%
0.300	7%
0.150	1%
0.075	1%
Particle Size (microns)	

Median Particle Size (mm)*	0.695

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

NATA Accreditation: 825 Site: Newcastle
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NATA
WORLD RECOGNISED ACCREDITATION

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Certificate of Analysis

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Mayfield West, NSW 2304
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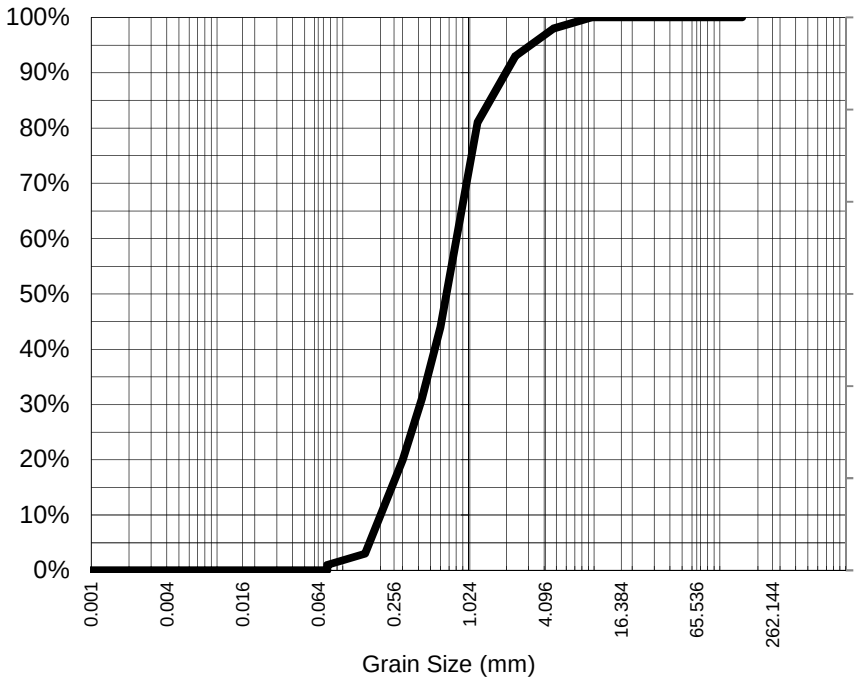
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-002 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS1

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	98%
2.36	93%
1.18	81%
0.600	44%
0.425	31%
0.300	20%
0.150	3%
0.075	1%
Particle Size (microns)	

Median Particle Size (mm)*	0.694

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

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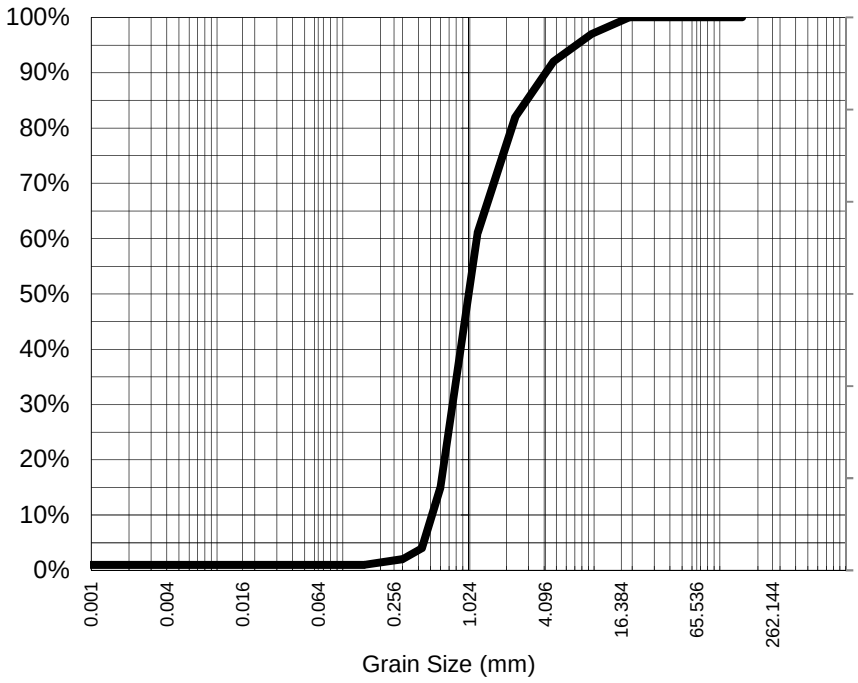
ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-003 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS2

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	97%
4.75	92%
2.36	82%
1.18	61%
0.600	15%
0.425	4%
0.300	2%
0.150	1%
0.075	1%
Particle Size (microns)	
57	1%
40	1%
28	1%
20	1%
15	1%
10	1%
7	1%
5	1%
1	1%

Median Particle Size (mm)*	1.041

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

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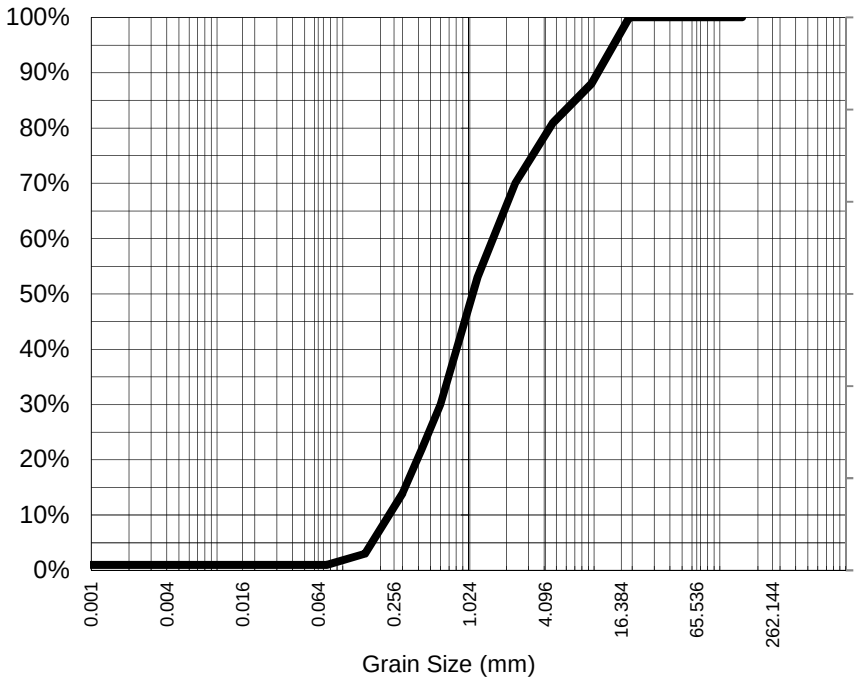
Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-004 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS3

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	88%
4.75	81%
2.36	70%
1.18	53%
0.600	30%
0.425	22%
0.300	14%
0.150	3%
0.075	1%
Particle Size (microns)	
57	1%
40	1%
28	1%
20	1%
15	1%
10	1%
7	1%
5	1%
1	1%

Median Particle Size (mm)*	1.104

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

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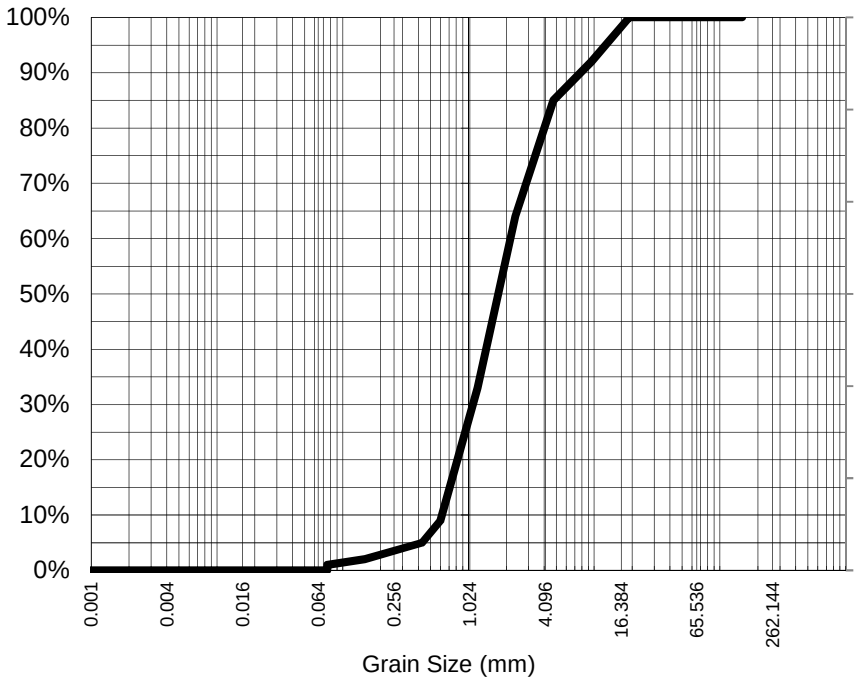
CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-005 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS4

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	92%
4.75	85%
2.36	64%
1.18	33%
0.600	9%
0.425	5%
0.300	4%
0.150	2%
0.075	1%
Particle Size (microns)	

Median Particle Size (mm)*	1.827

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

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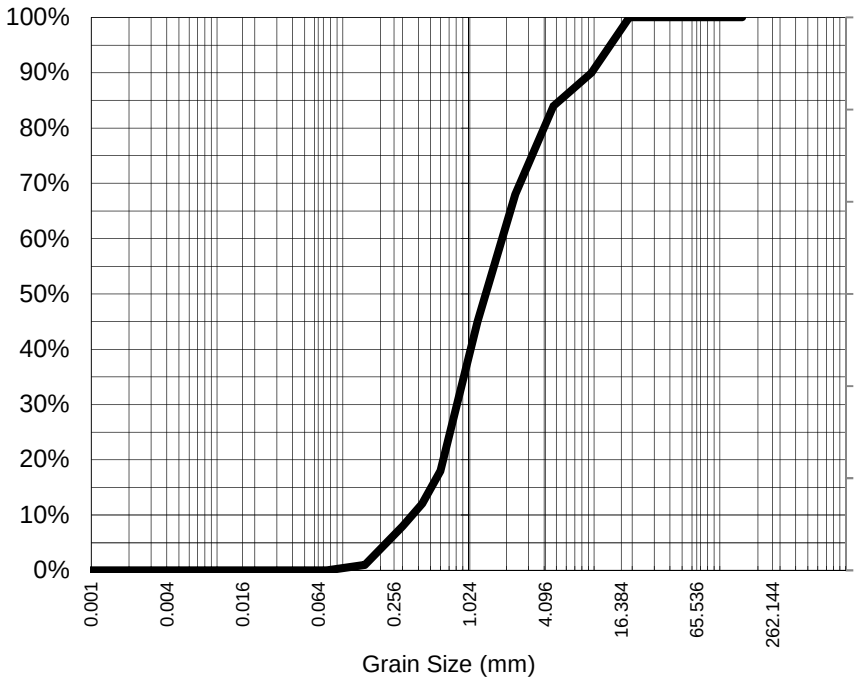
Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-006 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS5

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	90%
4.75	84%
2.36	68%
1.18	45%
0.600	18%
0.425	12%
0.300	8%
0.150	1%
0.075	0%
Particle Size (microns)	

Median Particle Size (mm)*	1.437

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

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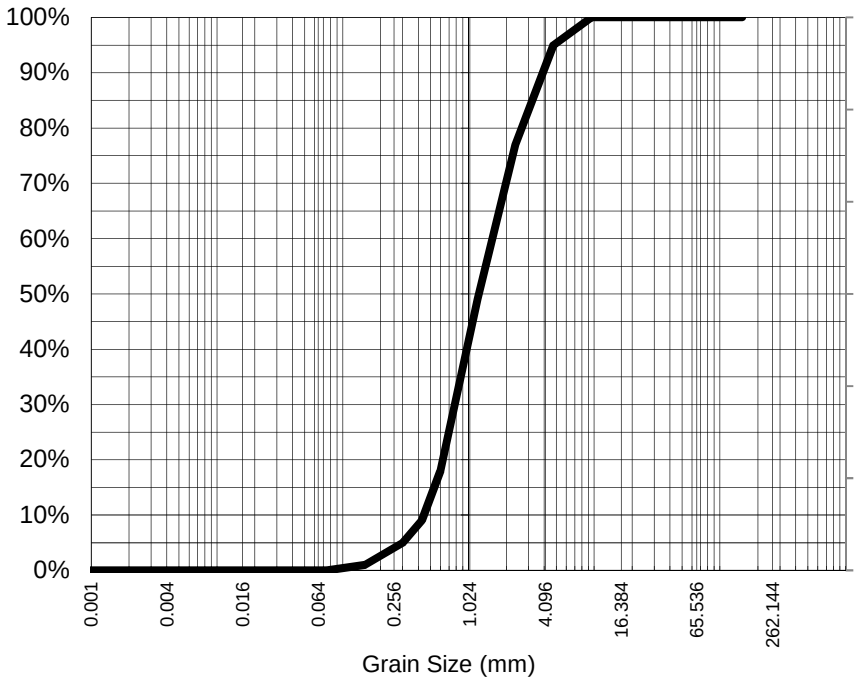
ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-007 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MBS6

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	95%
2.36	77%
1.18	49%
0.600	18%
0.425	9%
0.300	5%
0.150	1%
0.075	0%
Particle Size (microns)	

Median Particle Size (mm)*	1.222

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand,shells	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

NATA Accreditation: 825 Site: Newcastle
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Certificate of Analysis

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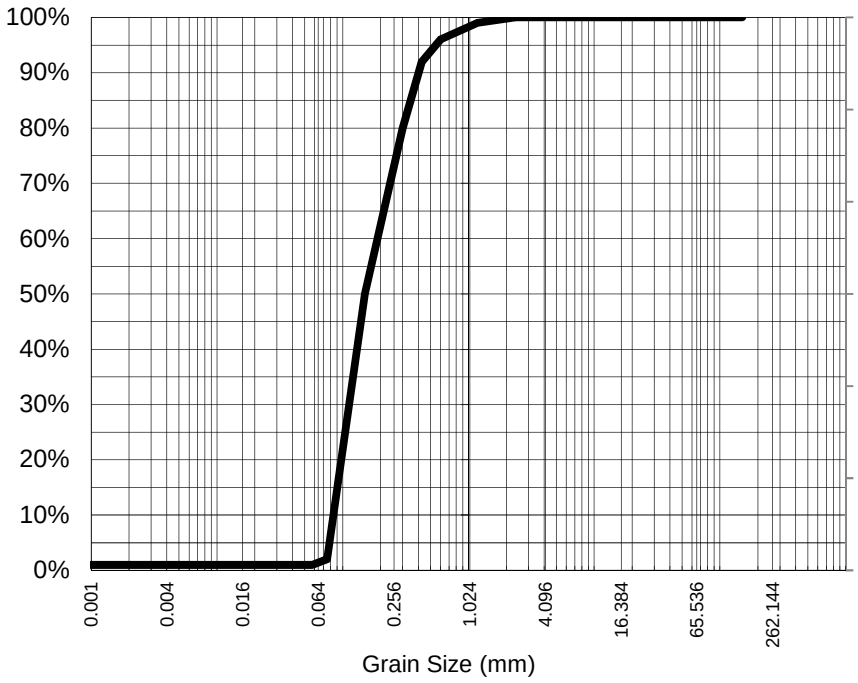
ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-008 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MS1

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	96%
0.425	92%
0.300	80%
0.150	50%
0.075	2%
Particle Size (microns)	
57	1%
40	1%
28	1%
20	1%
15	1%
10	1%
7	1%
5	1%
1	1%

Median Particle Size (mm)*	0.150

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

NATA Accreditation: 825 Site: Newcastle
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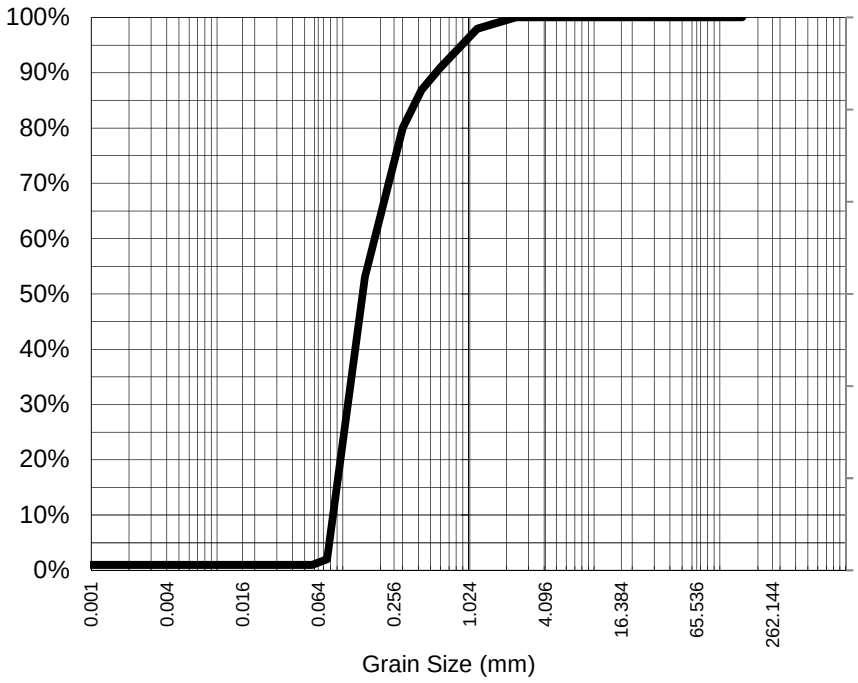
ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-009 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MS2

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	98%
0.600	91%
0.425	87%
0.300	80%
0.150	53%
0.075	2%
Particle Size (microns)	
57	1%
40	1%
28	1%
20	1%
15	1%
10	1%
7	1%
5	1%
1	1%

Median Particle Size (mm)*	0.146

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

NATA
WORLD RECOGNISED ACCREDITATION

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Certificate of Analysis

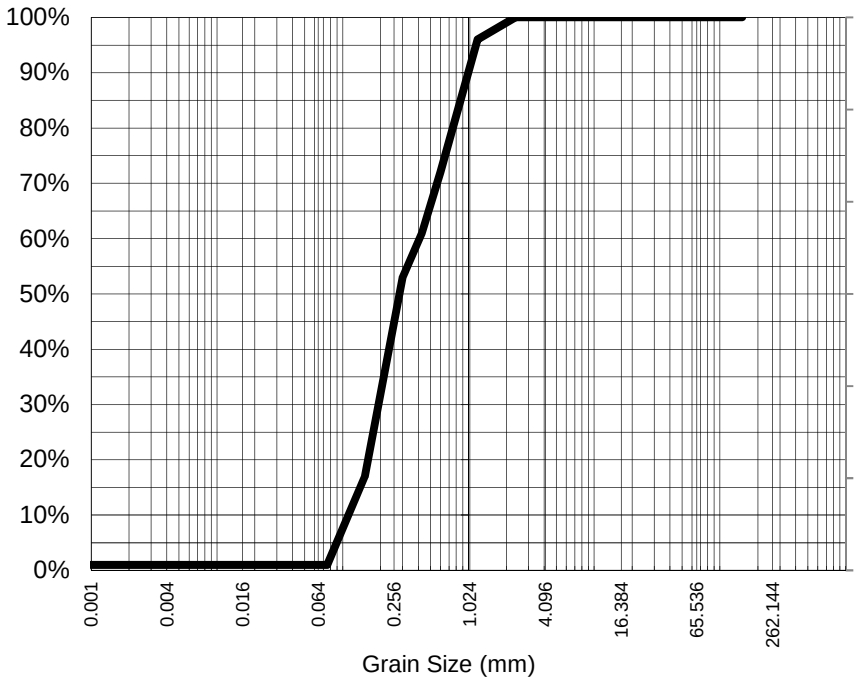
ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-010 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MS3

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	96%
0.600	72%
0.425	61%
0.300	53%
0.150	17%
0.075	1%
Particle Size (microns)	
57	1%
40	1%
28	1%
20	1%
15	1%
10	1%
7	1%
5	1%
1	1%

Median Particle Size (mm)*	0.288

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

NATA Accreditation: 825 Site: Newcastle
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5/585 Maitland Road
Mayfield West, NSW 2304
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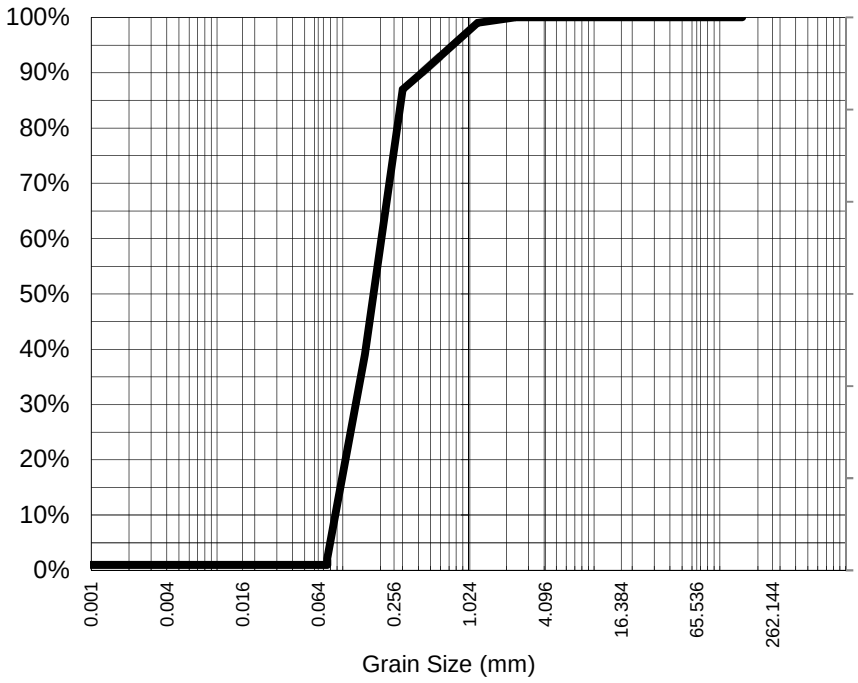
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	DANIEL STRICKLAND	**DATE REPORTED:**	9-Apr-2020
COMPANY:	CARDNO (WA) PTY LTD	**DATE RECEIVED:**	3-Apr-2020
ADDRESS:	222 Planet Street Welshpool WA, Australia	**REPORT NO:**	ES2011348-011 / PSD
PROJECT:	Mandorah Marine Facilities	**SAMPLE ID:**	MS4

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	93%
0.425	90%
0.300	87%
0.150	39%
0.075	2%
Particle Size (microns)	
57	1%
40	1%
28	1%
20	1%
15	1%
10	1%
7	1%
5	1%
1	1%

Median Particle Size (mm)*	0.184

Analysis Notes

Samples analysed as received.

**** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was unable to be performed as insufficient sample was supplied by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer Median Particle Size is not covered under the current scope of ALS's NATA accreditation.***

Sample Comments:	AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly	**Analysed:**	7-Apr-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		

Soil Particle Density (<2.36mm)

NATA Accreditation: 825 Site: Newcastle
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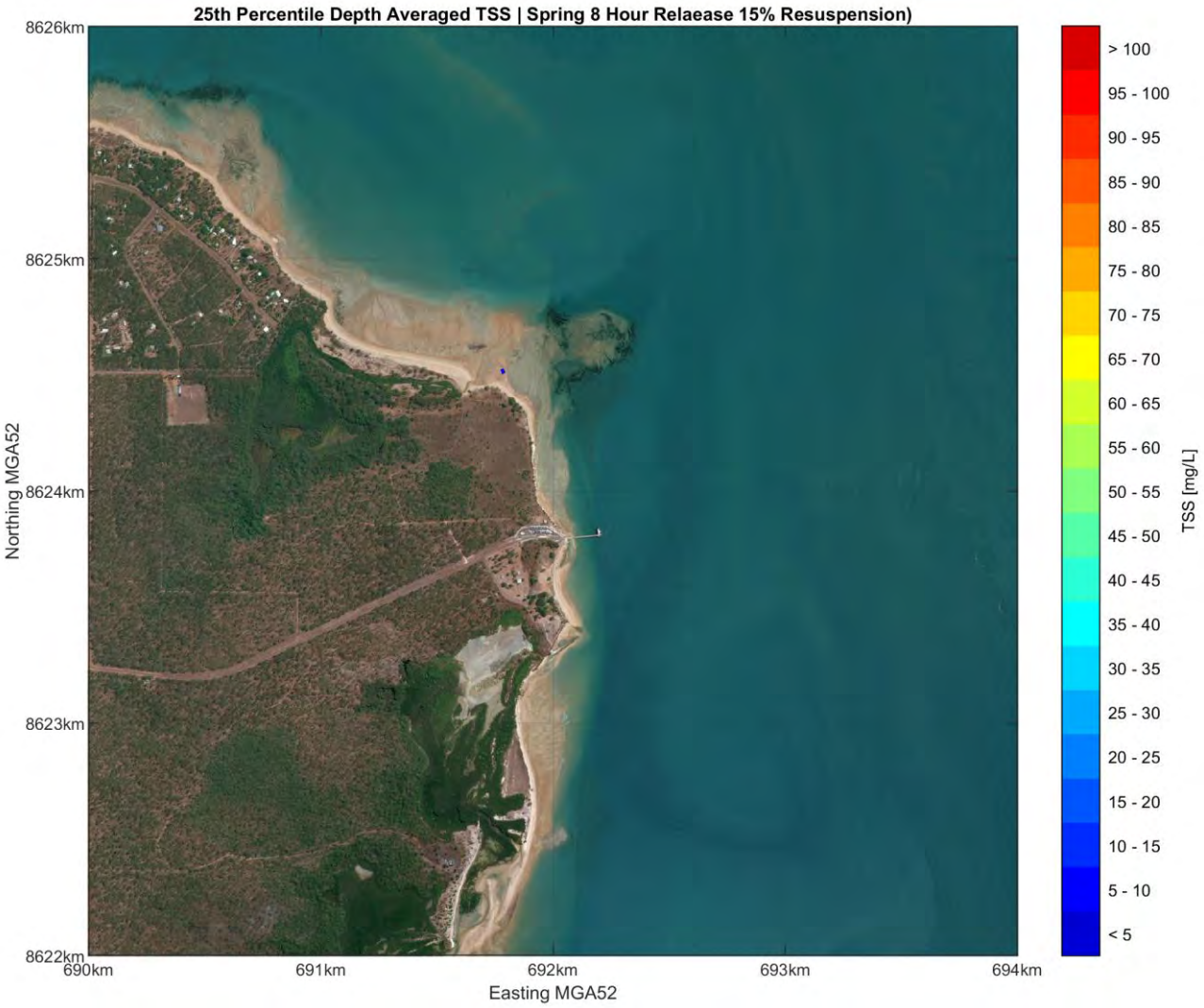
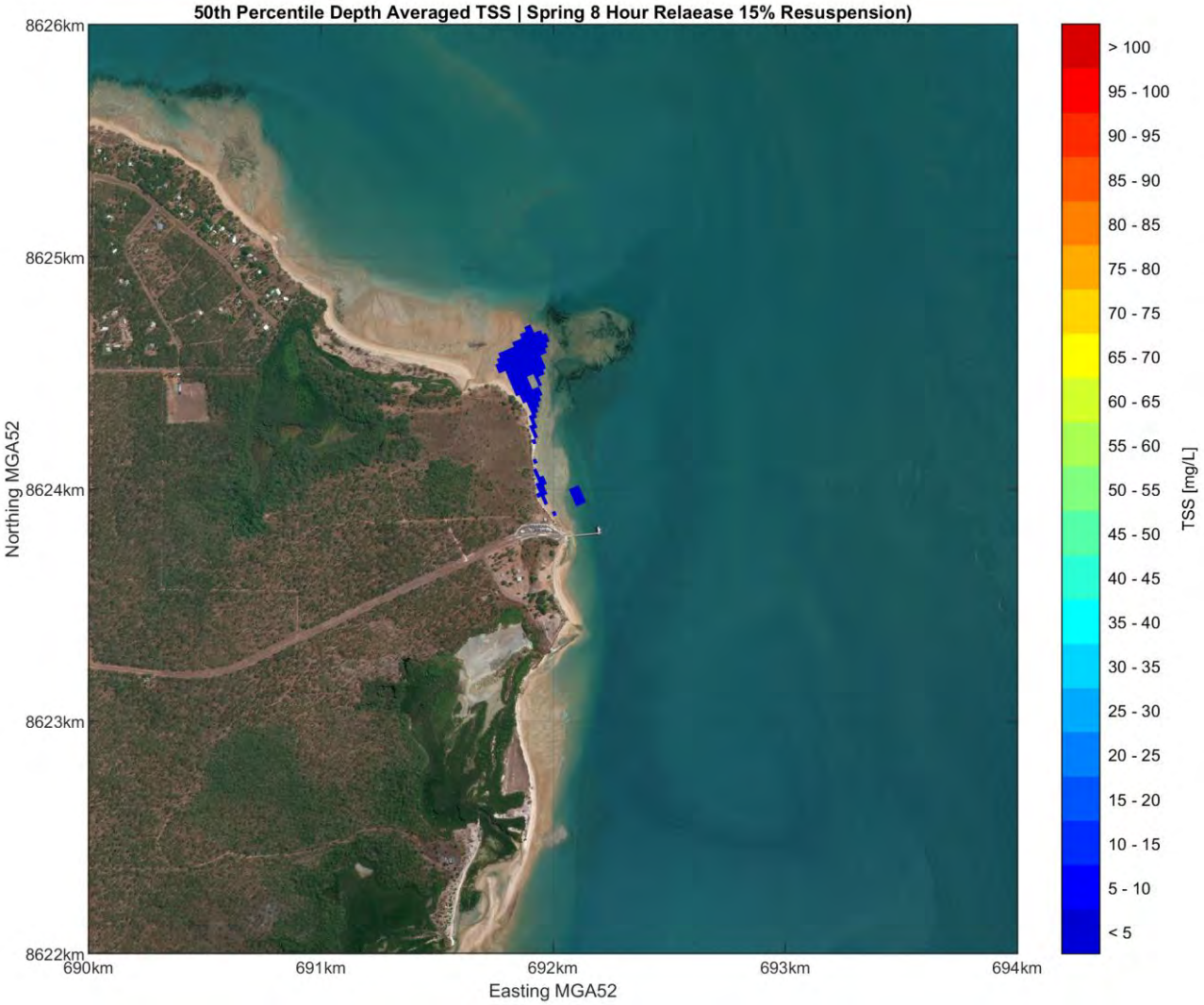
Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

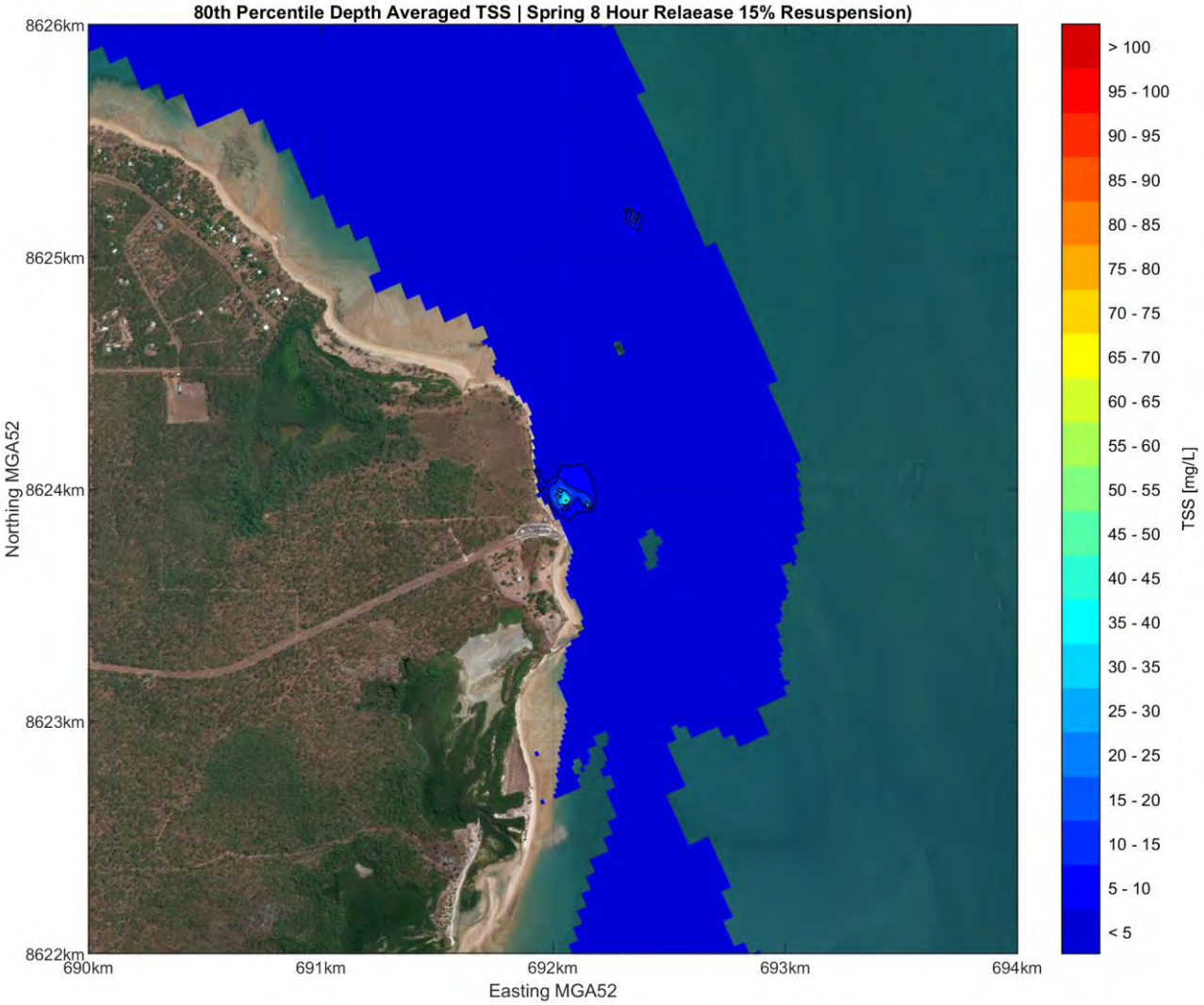
APPENDIX

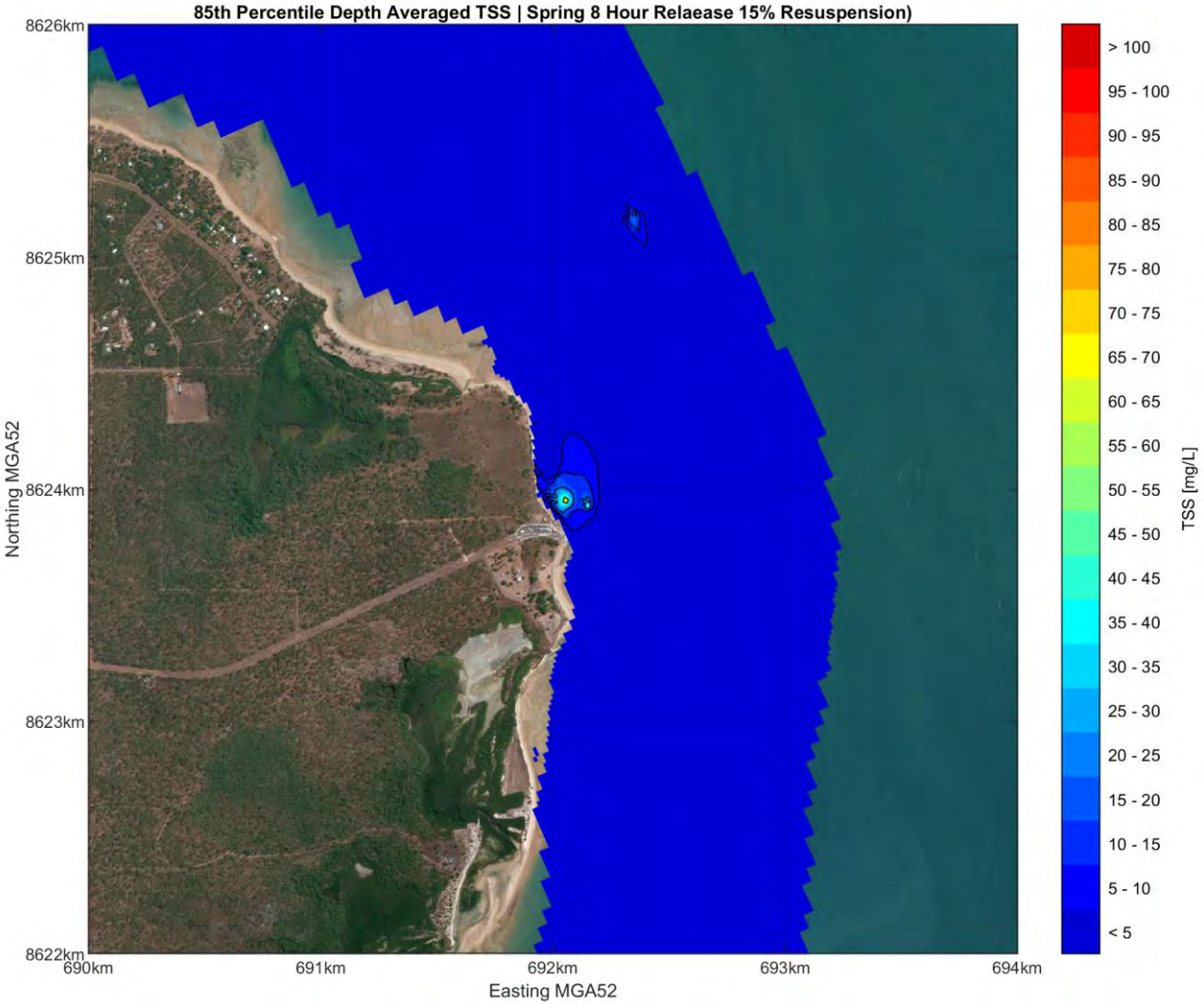
D

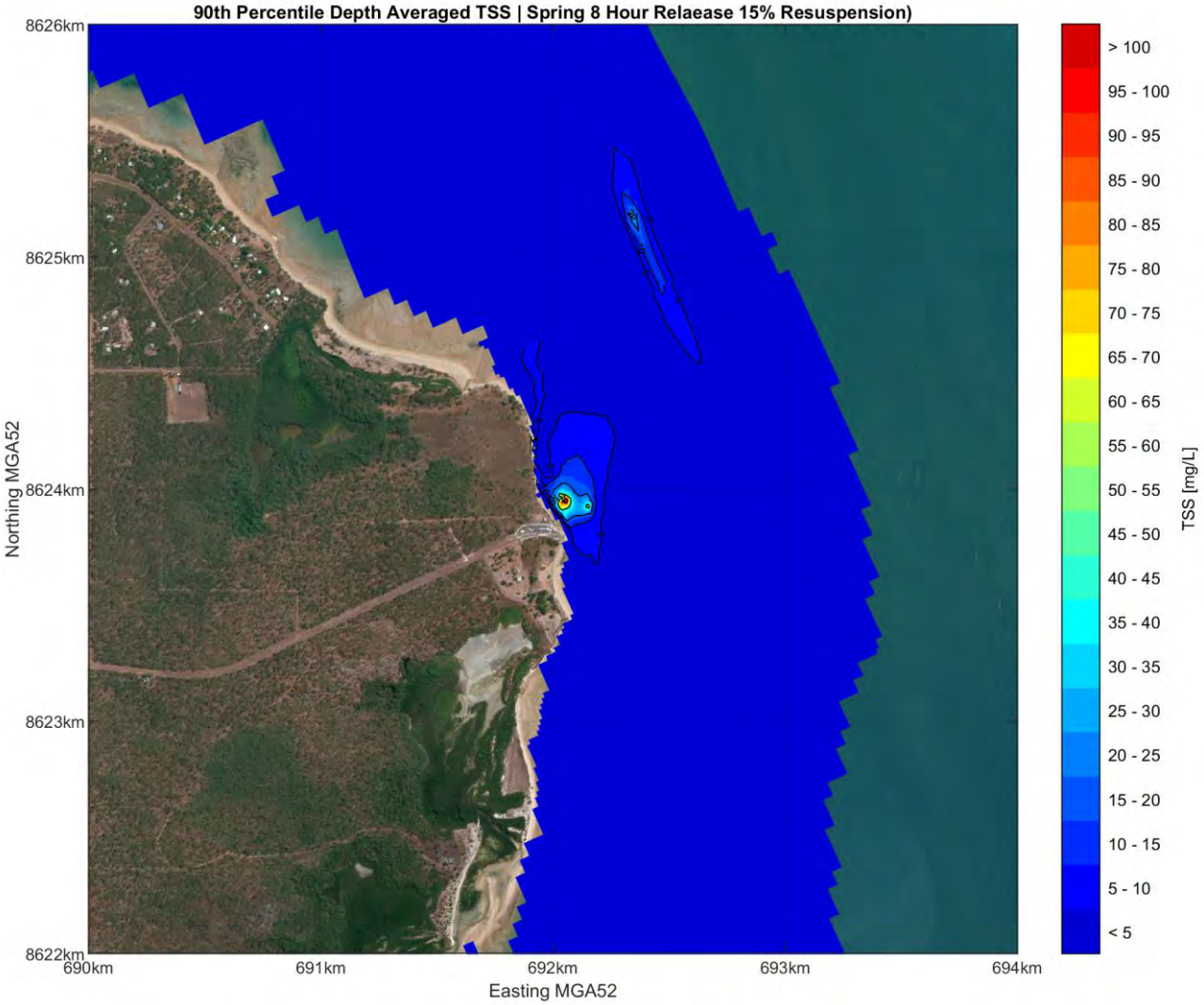
DREDGE PLUME MODELLING RESULTS

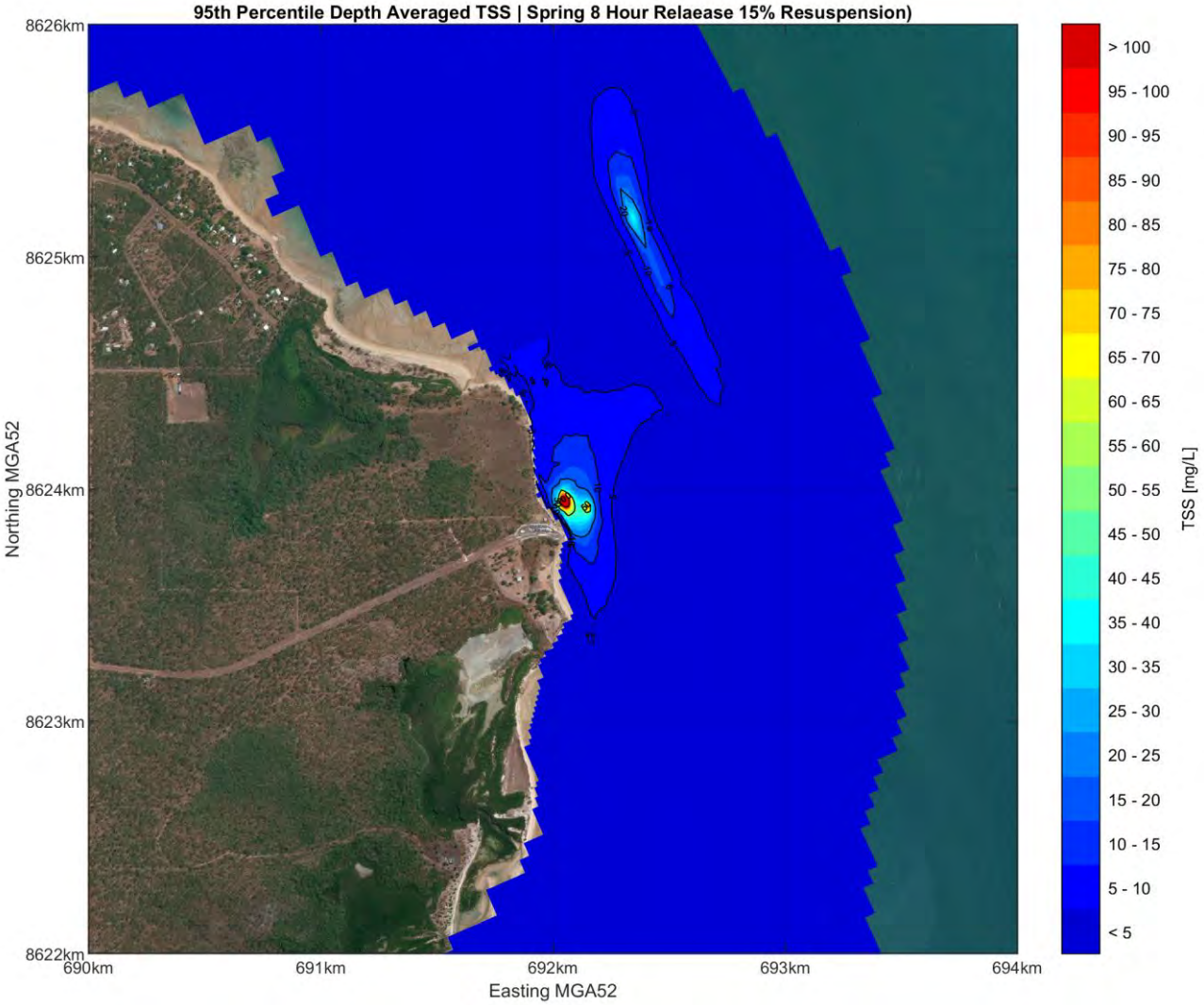

25th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

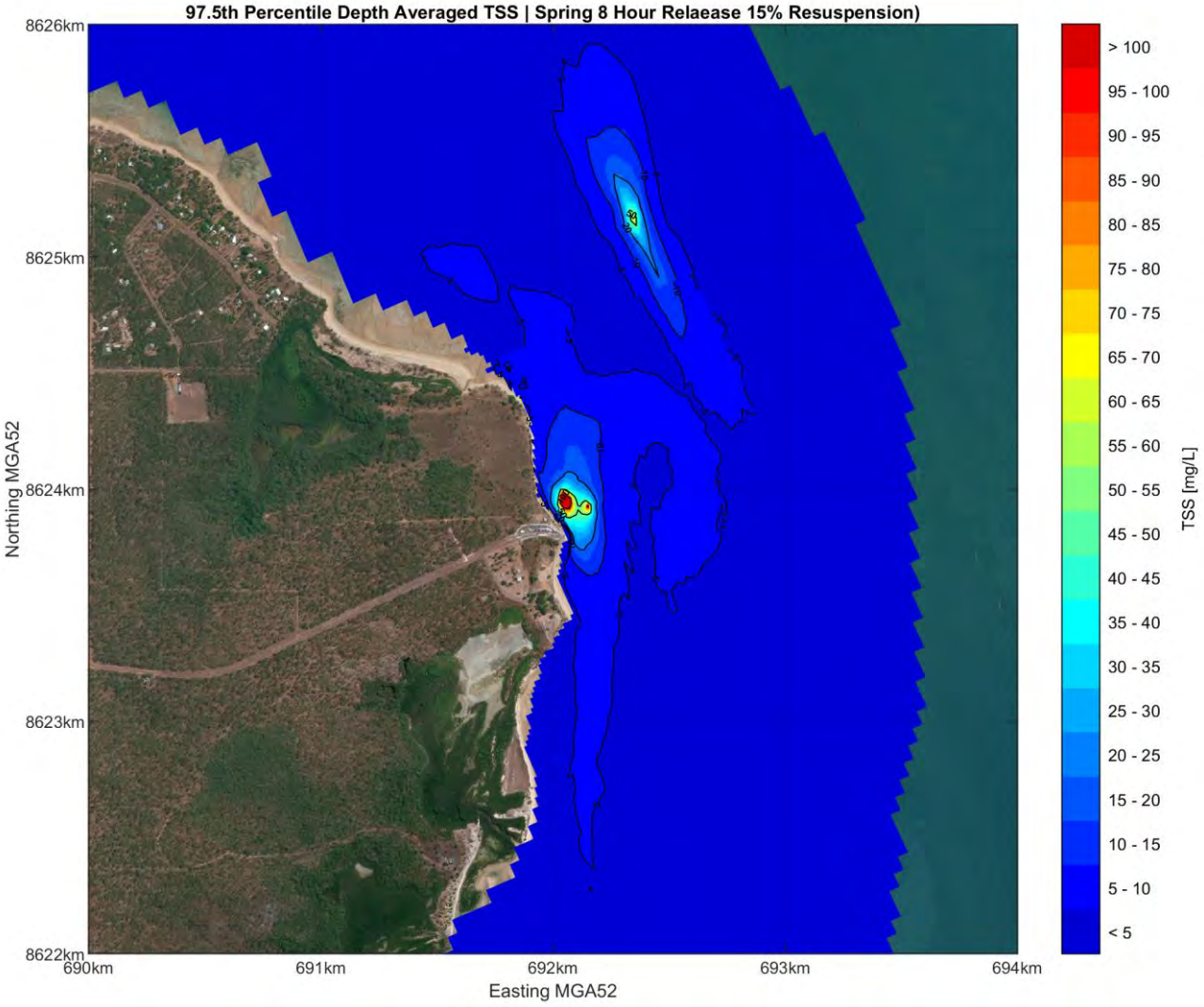

50th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

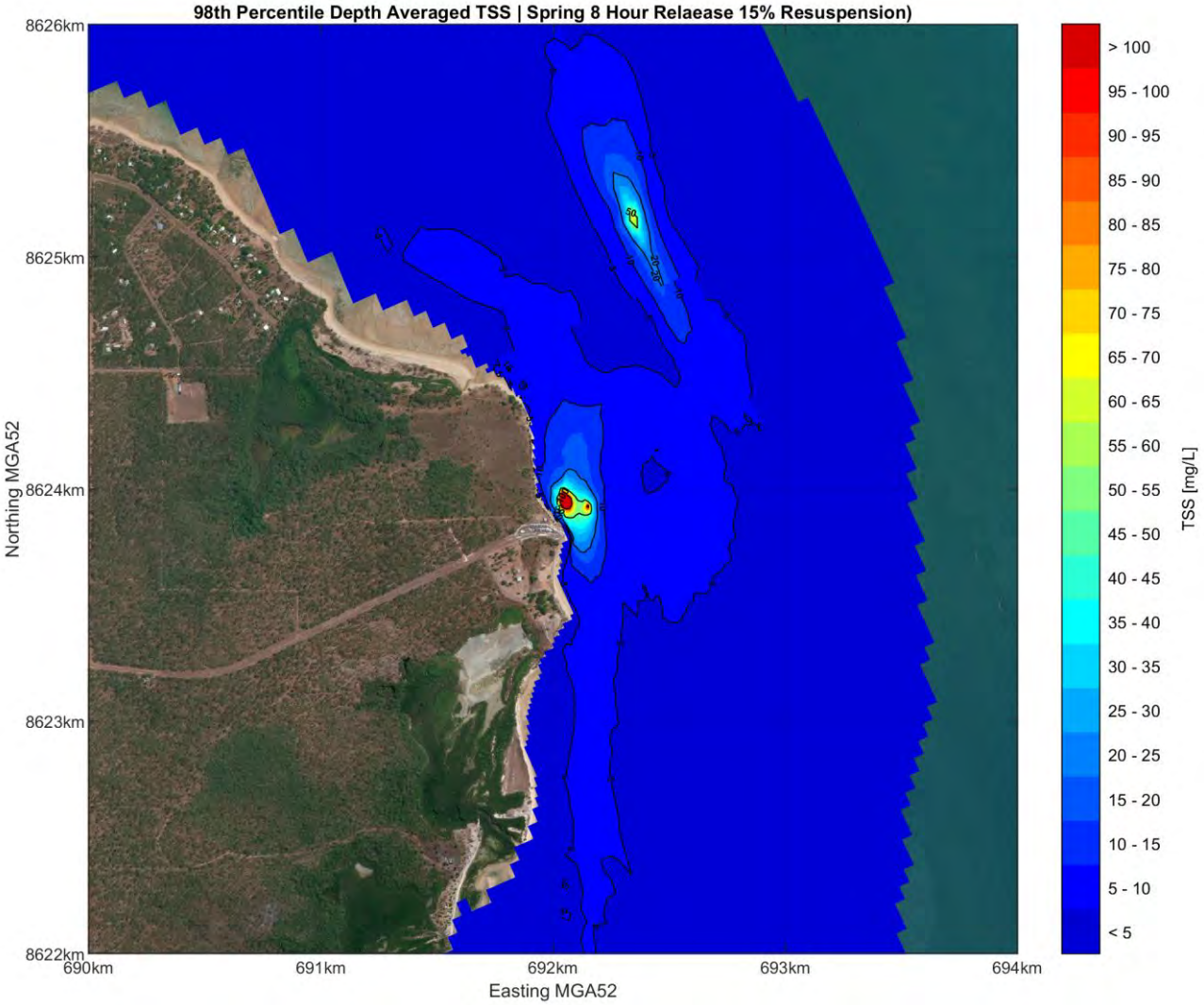

80th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

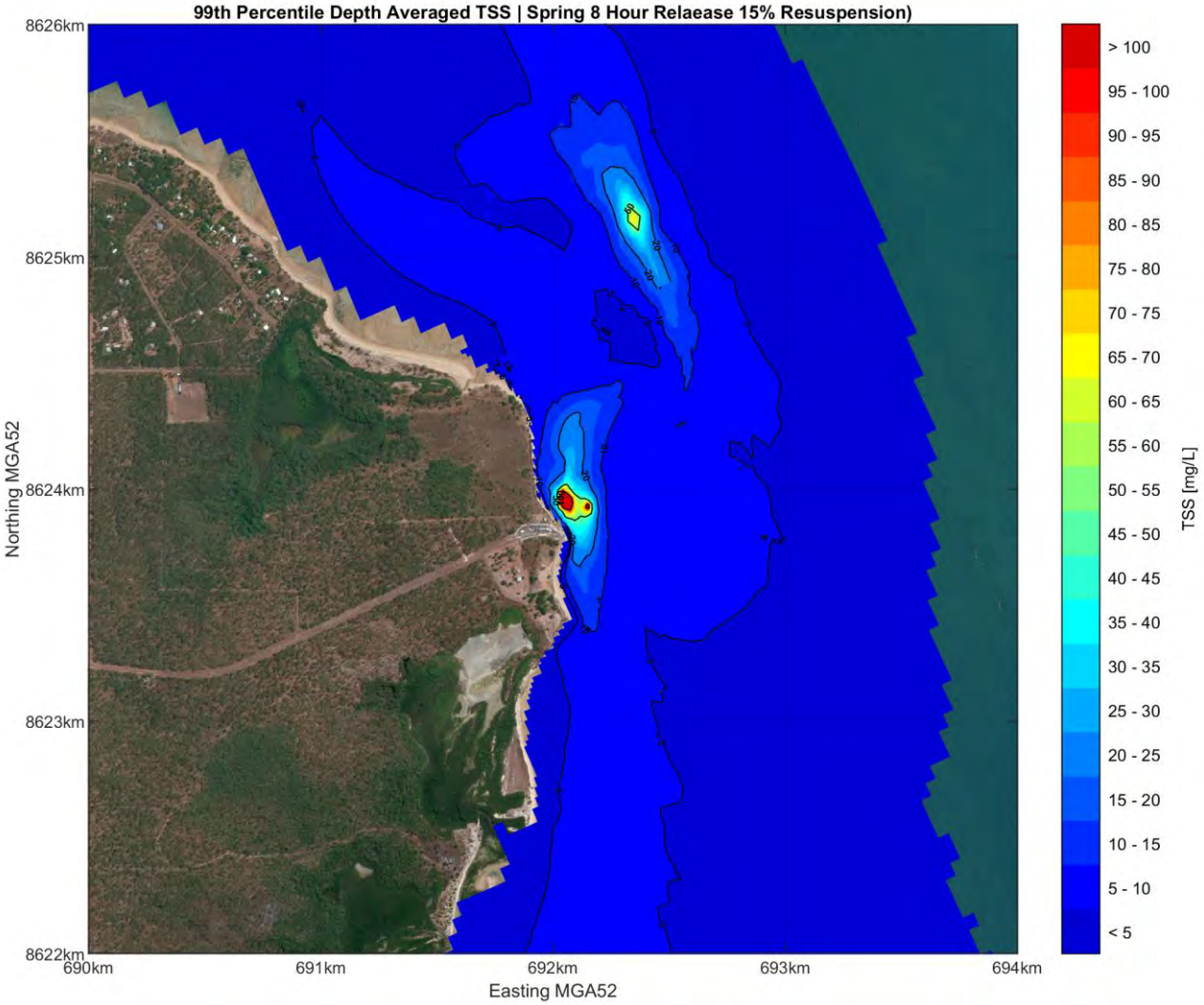

85th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

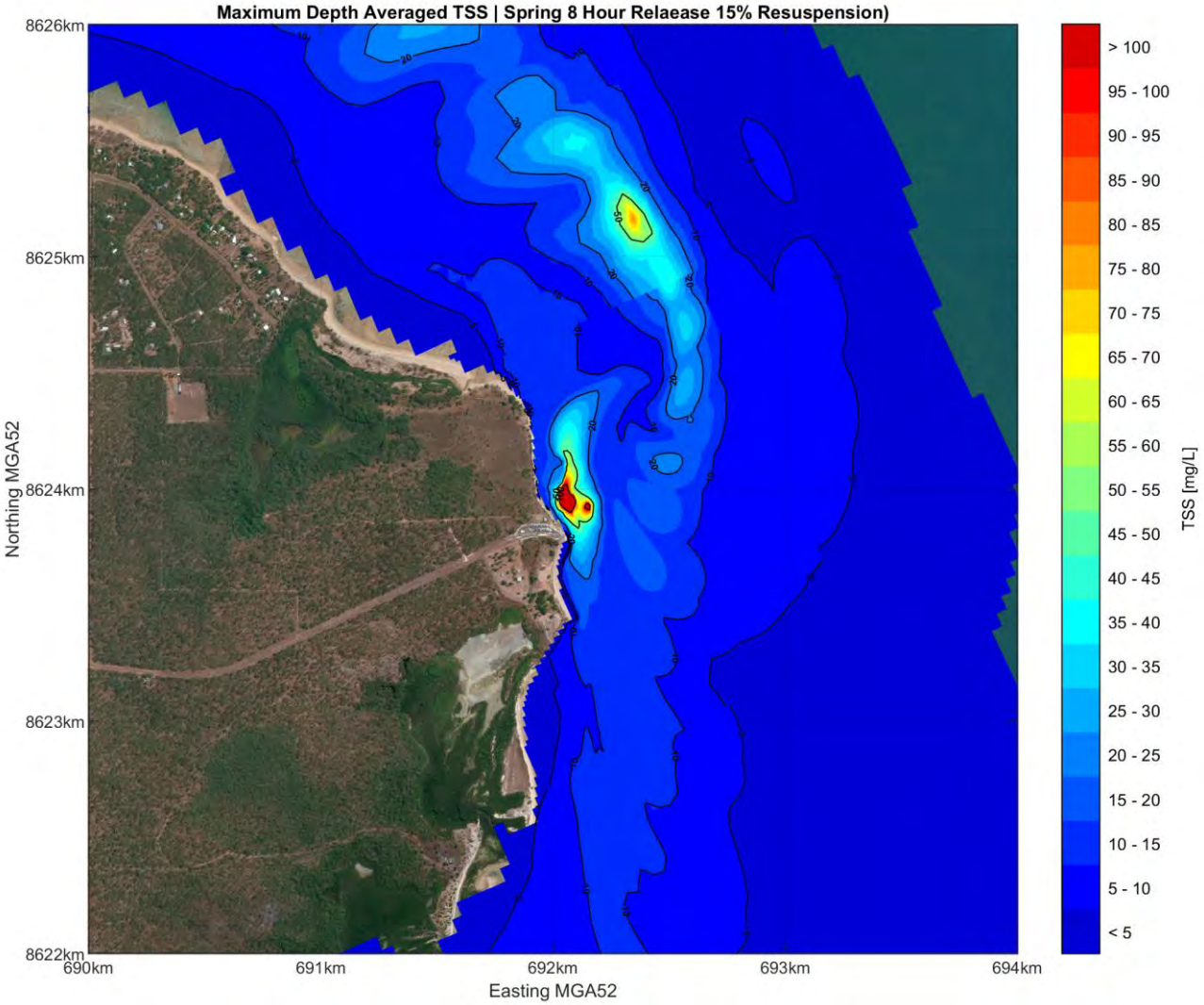

90th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

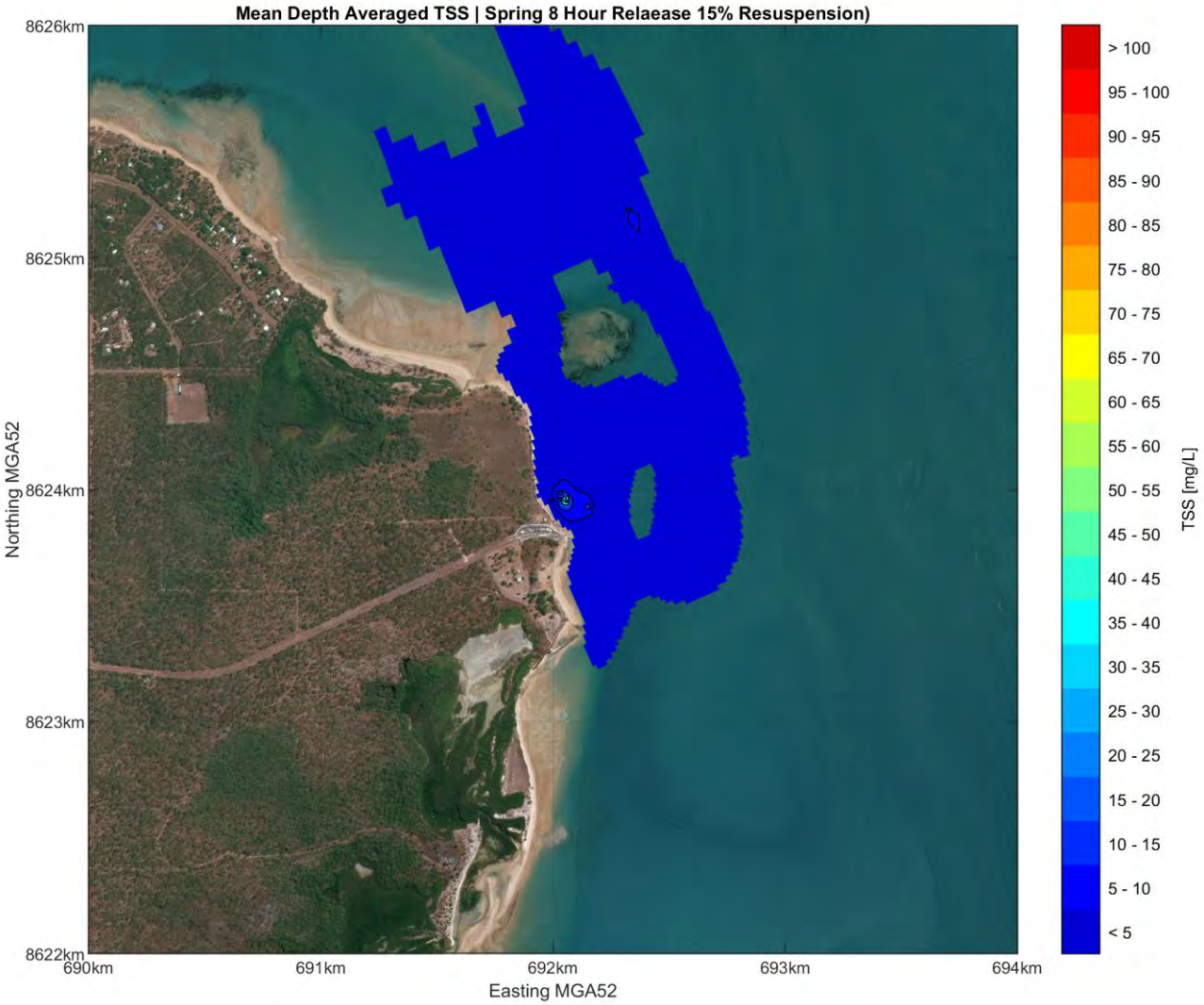

95th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

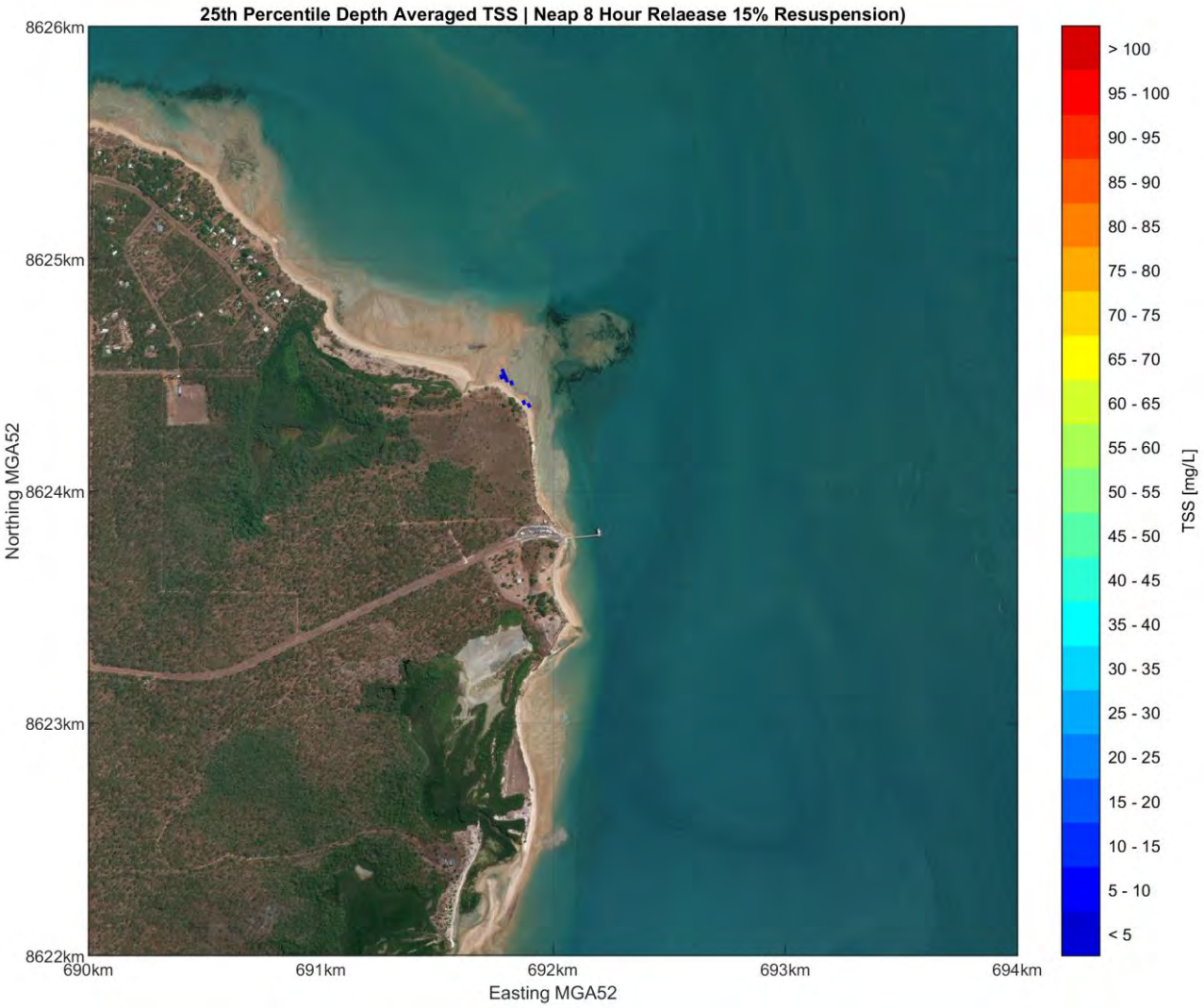

97.5th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

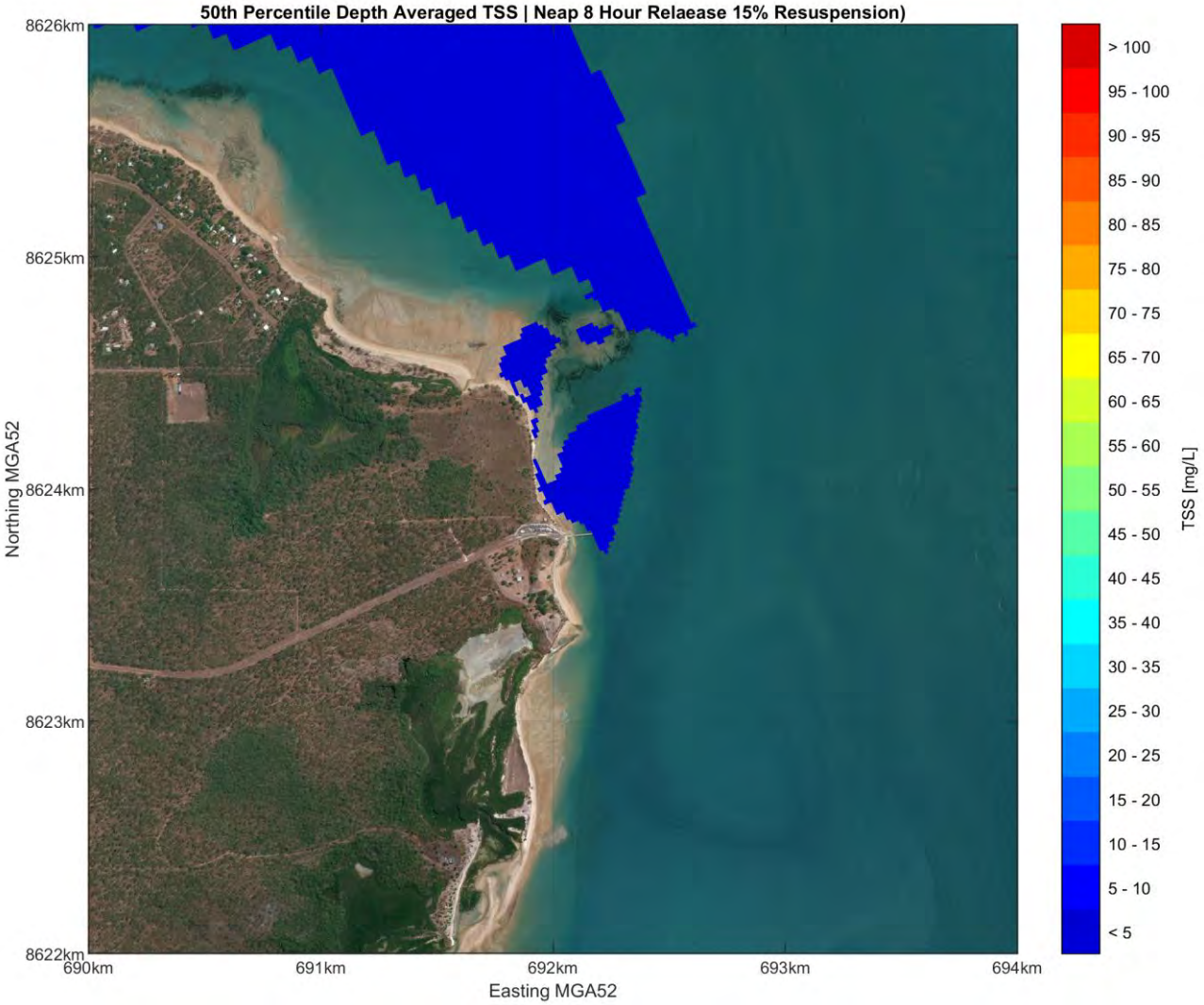

98th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

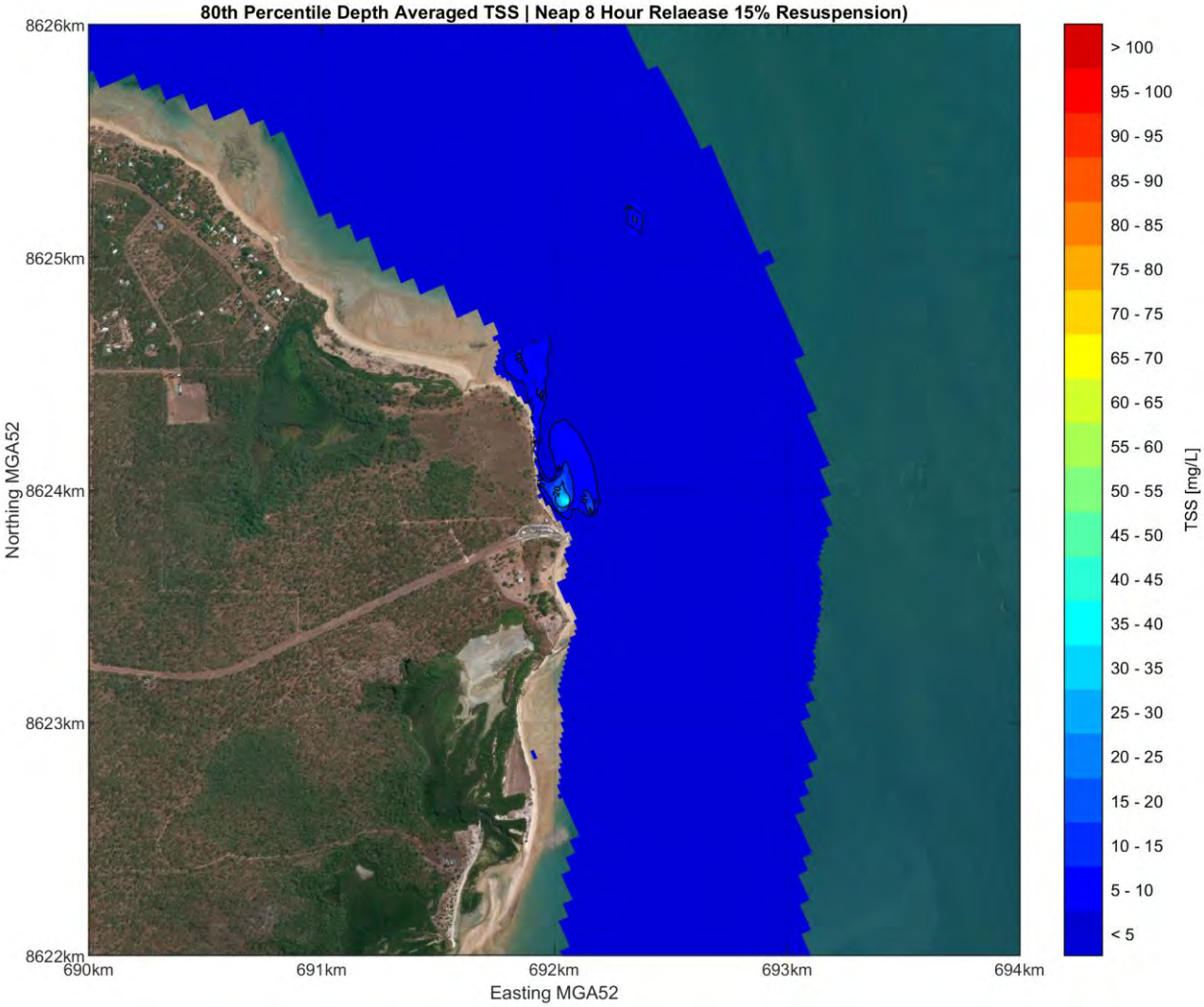

99th Percentile Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

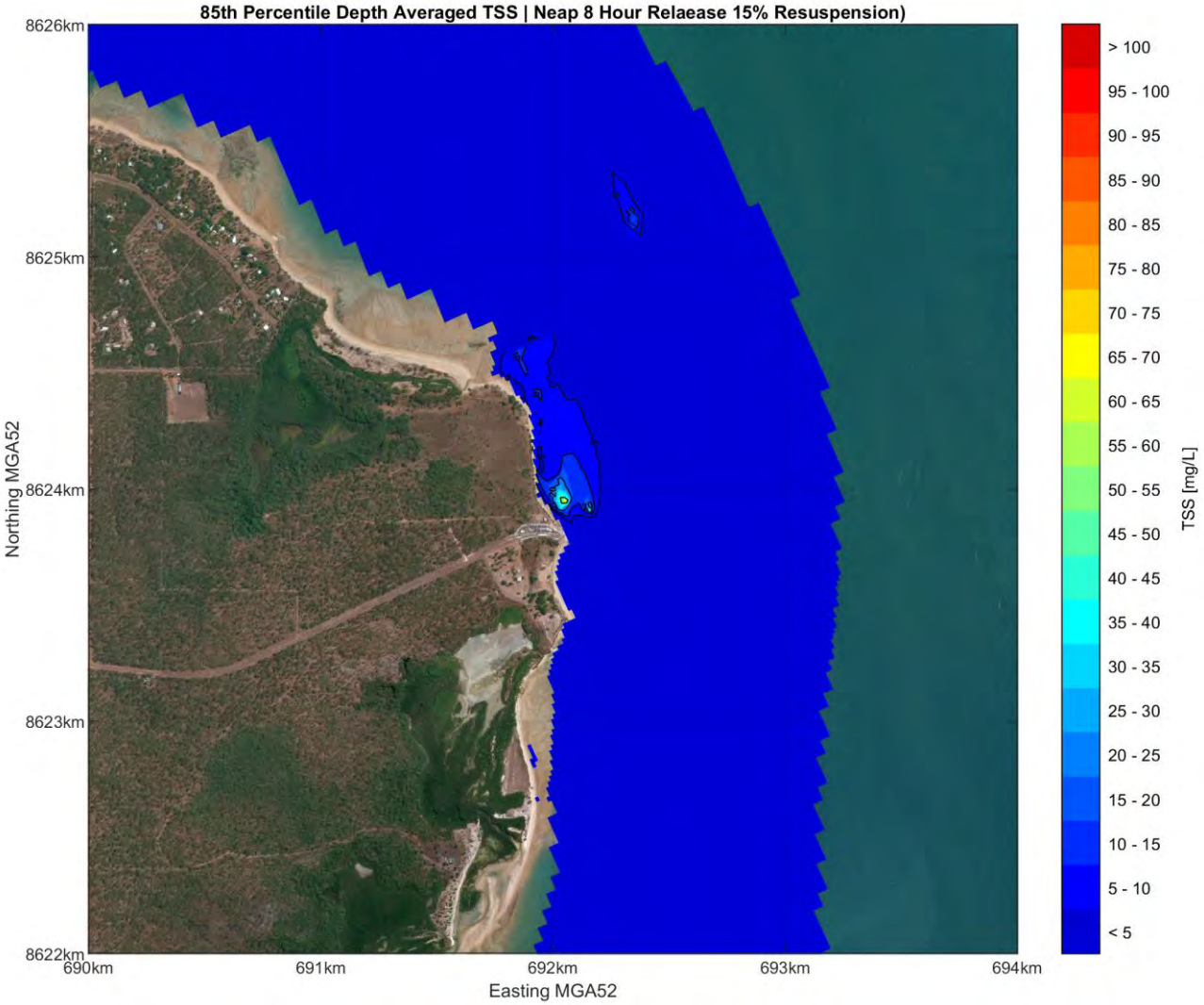

Maximum Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

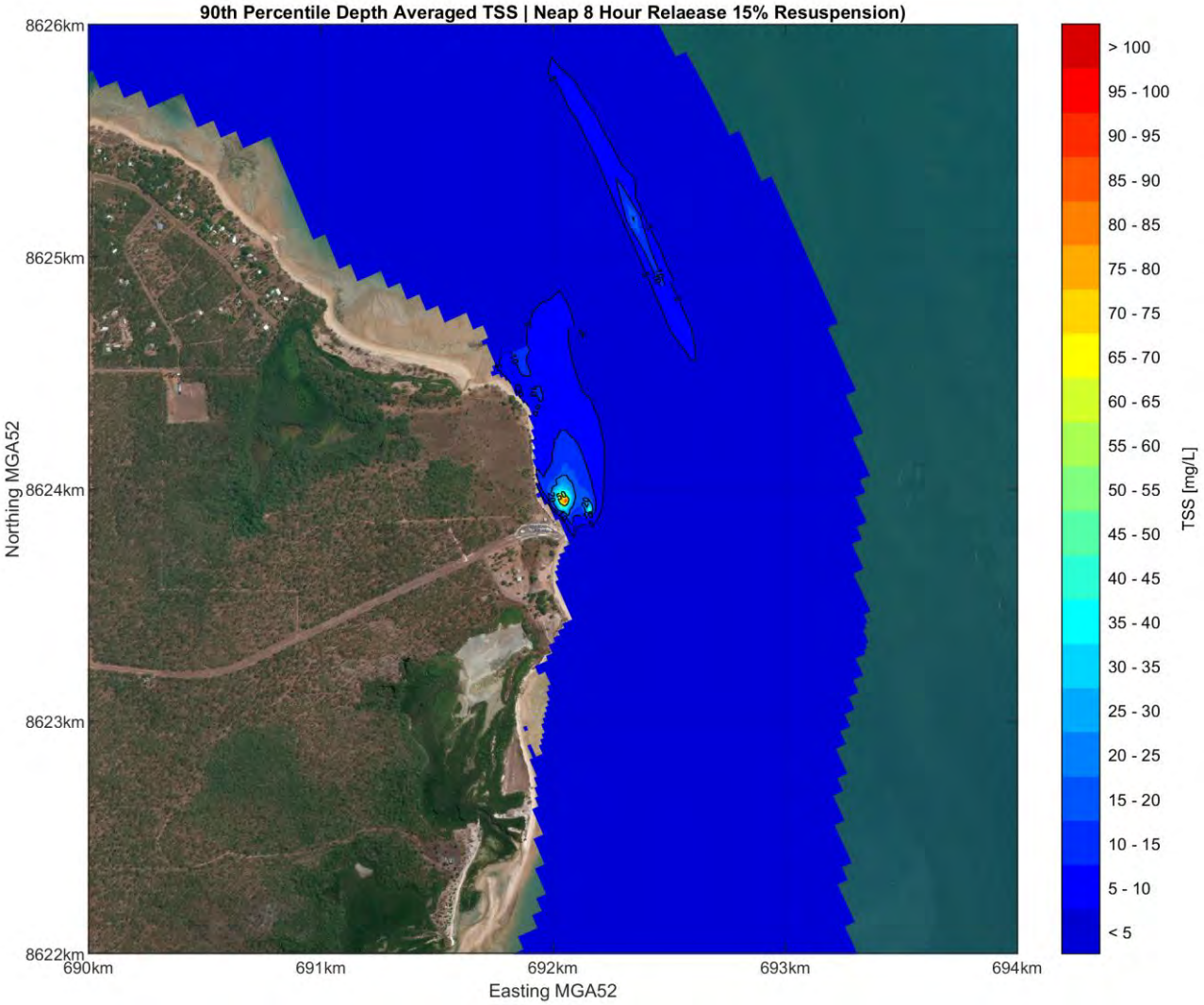

Mean Depth Averaged TSS | Spring 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

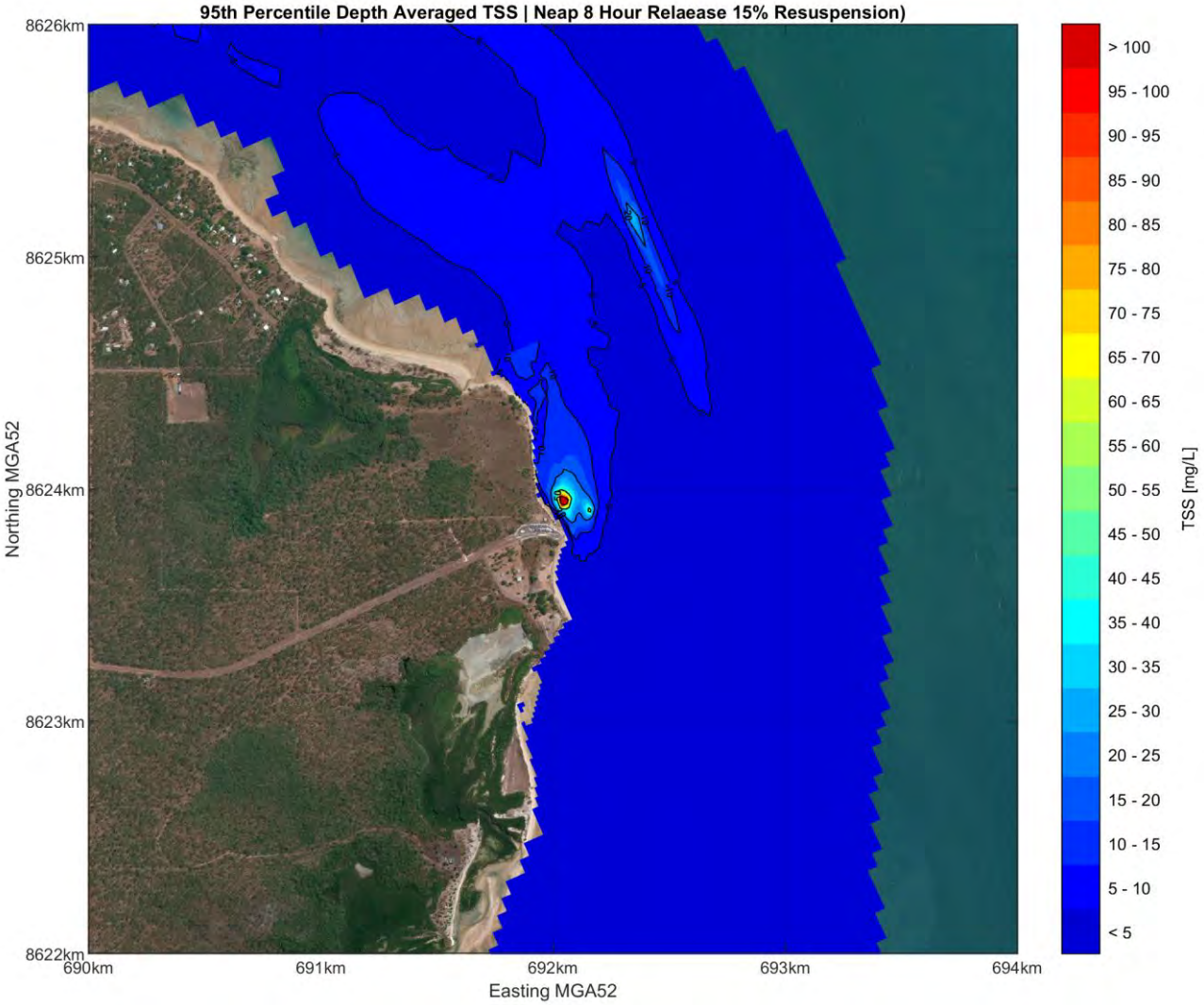

25th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

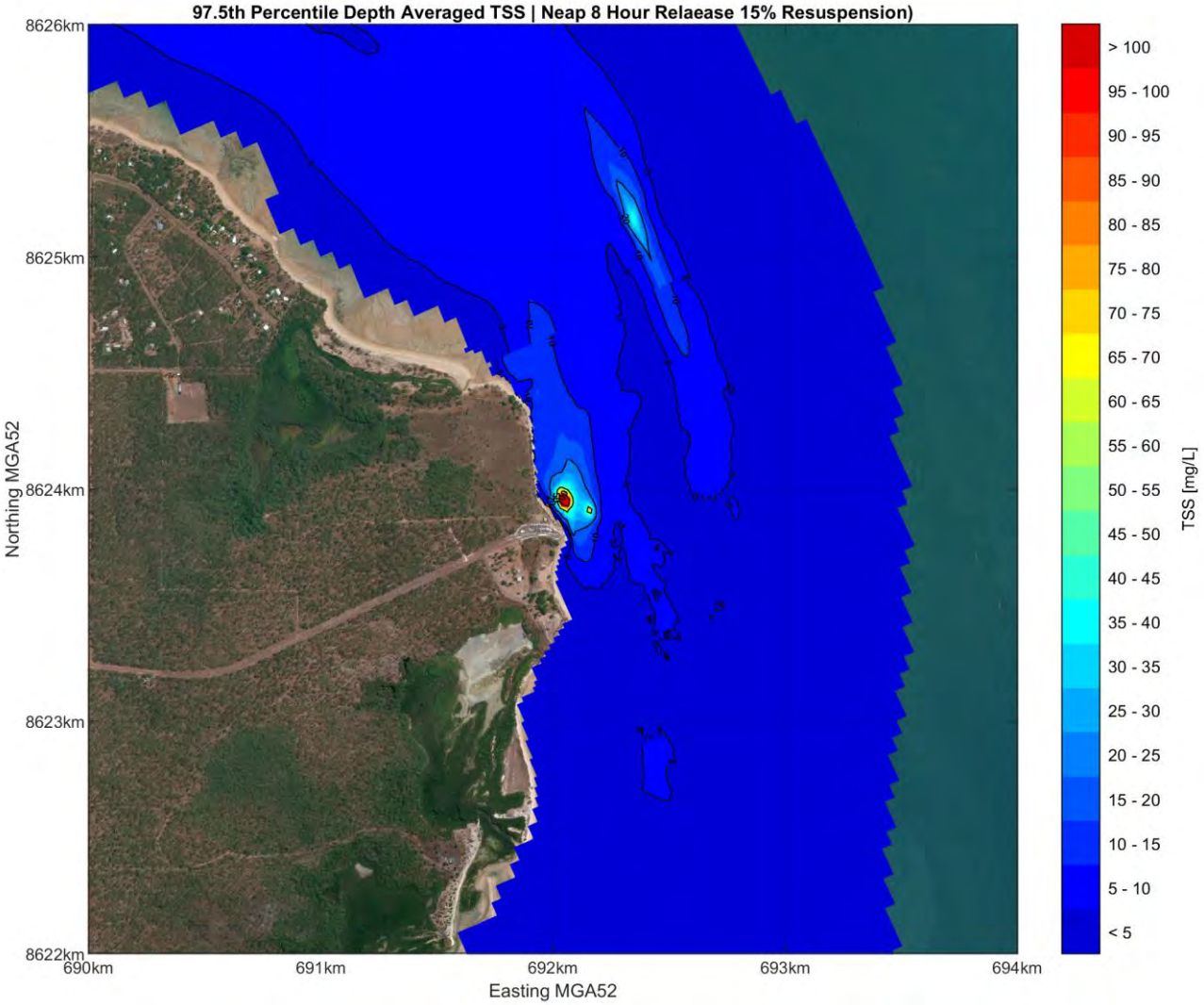

50th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

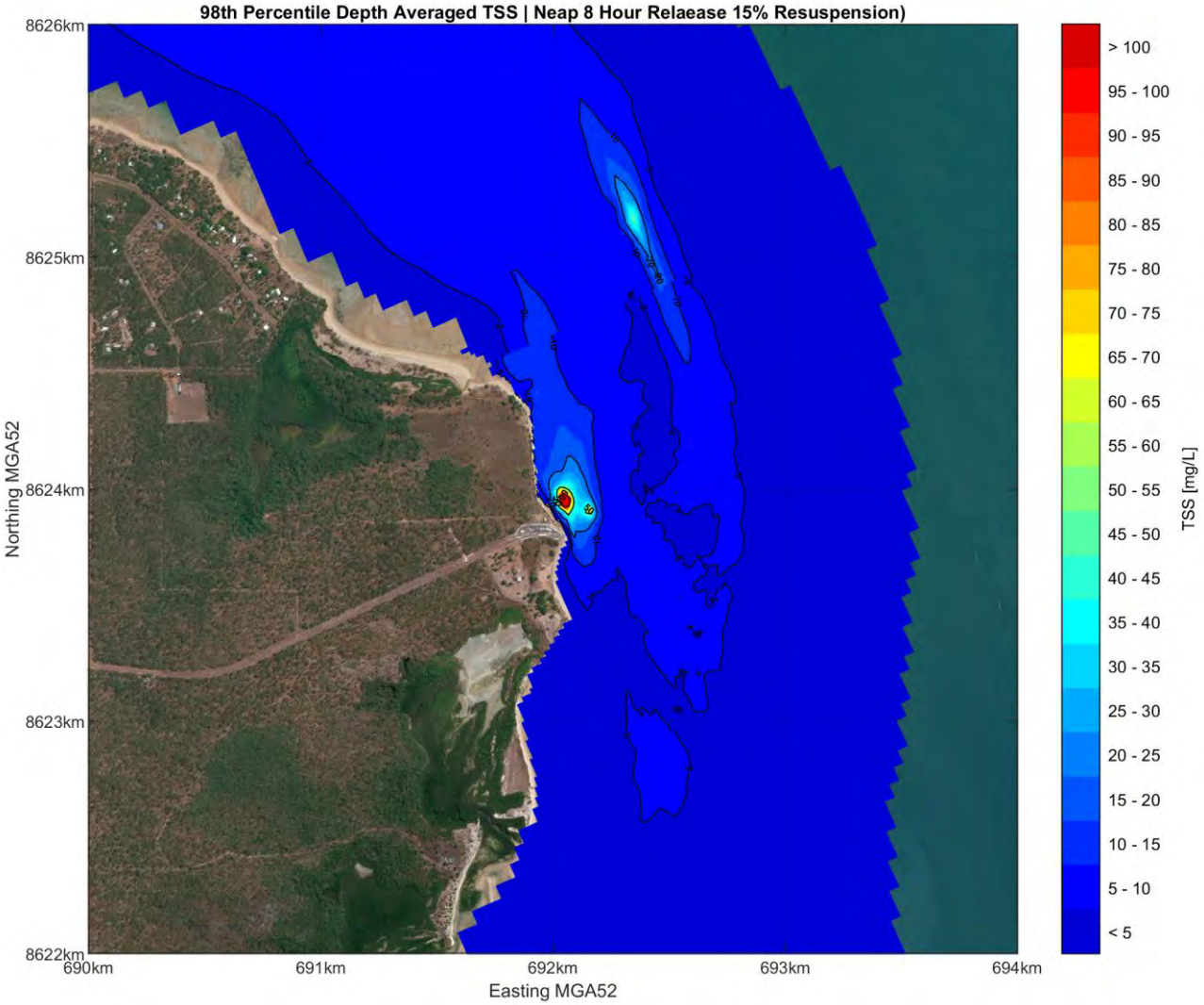

80th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

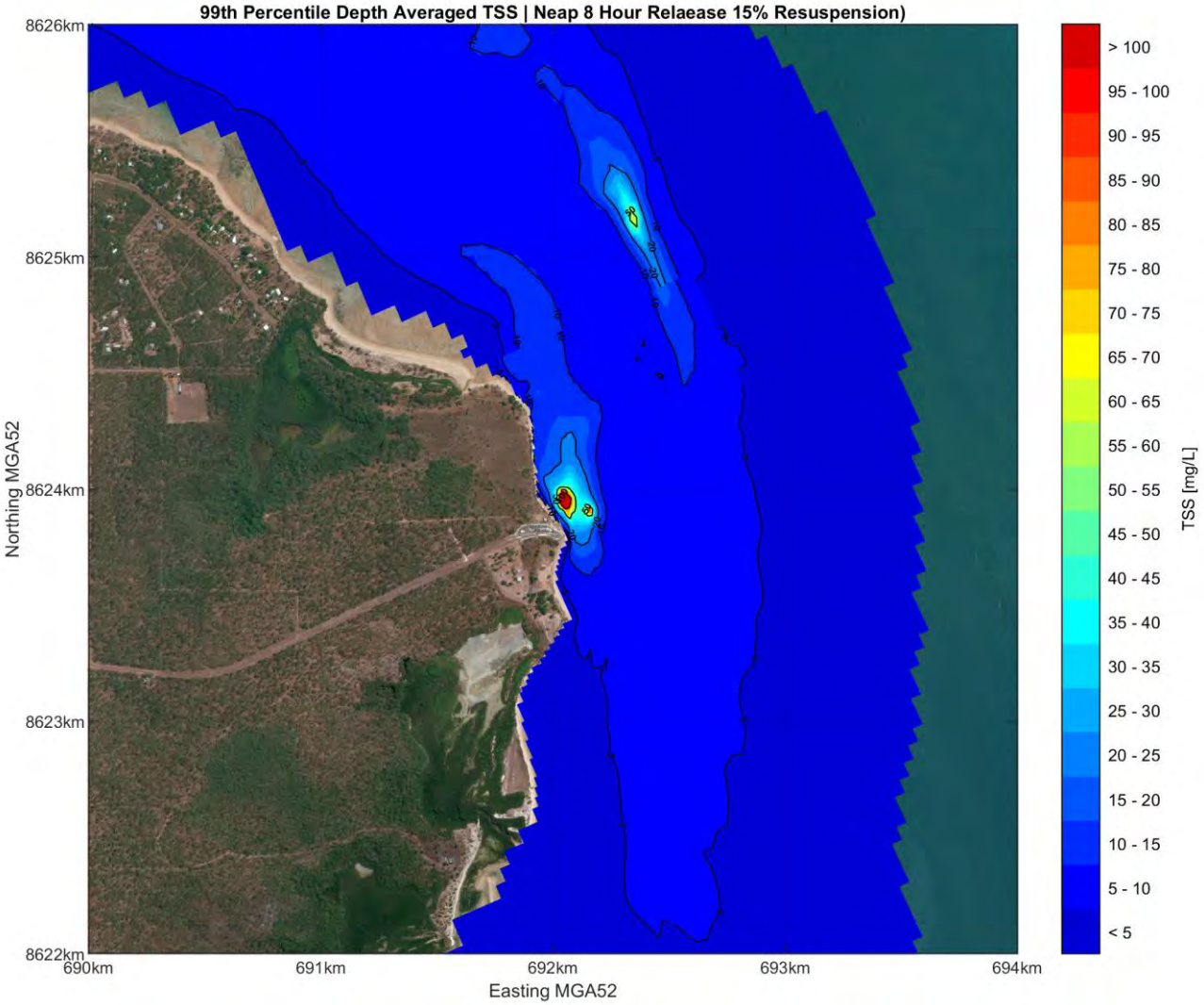

85th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

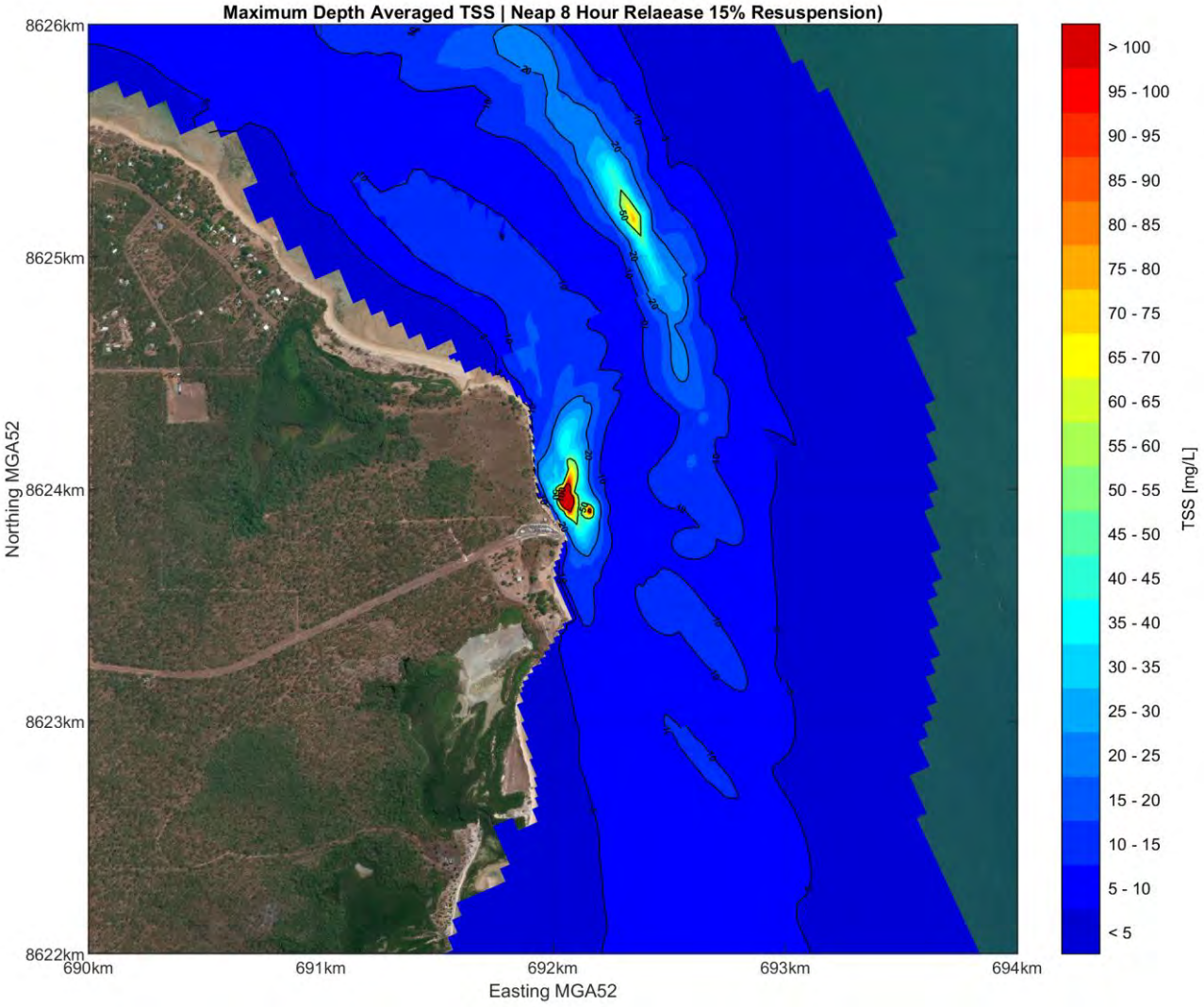

90th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]

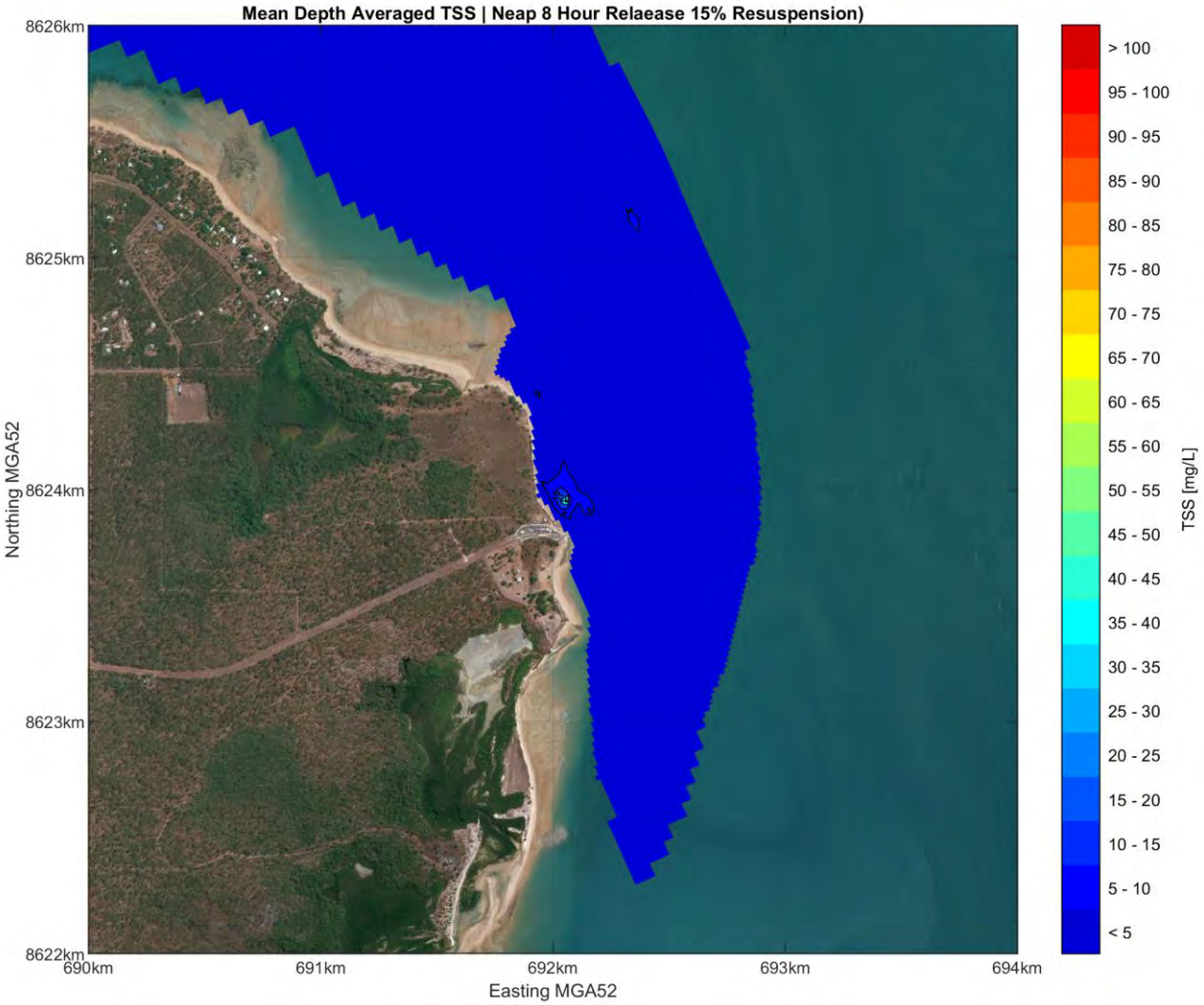

95th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]


97.5th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]


98th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]


99th Percentile Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]


Maximum Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]


Mean Depth Averaged TSS | Neap 8 Hour Relaease 15% Resuspension)
8626km
8625km
8624km
8623km
8622km
Northing MGA52
690km
691km
692km
693km
694km
Easting MGA52
> 100
95 - 100
90 - 95
85 - 90
80 - 85
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
TSS [mg/L]